



Approach Motivation, Goal Pursuit, and Reward-Related Neural Responses:
A Combined Experience-Sampling and fMRI Approach.

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Abstract

This thesis examines potential associations between trait approach motivation and related measures, the everyday experience of affect and goal pursuit, and reward-related neural responses. The Behavioural Activation System (BAS) is a core motivational system, subserved by the neural reward circuitry, eliciting approach-type behaviour and positive emotion when activated by appetitive stimuli. Deficits in BAS sensitivity are thought to underlie the lack of motivation and positive affect (PA) that characterise anhedonia, whilst hyperactivation of the BAS has been linked to the increased goal-directed behaviour and positive affectivity associated with hypomania. In order to explore relationships between BAS sensitivity, goal pursuit, and reward processing, young participants, recruited from the student population ($N = 65$), and older participants, from the community ($N = 63$), underwent a 7-day period of experience sampling (ESM) to provide a naturalistic measure of momentary affect and goal-focused motivation. Functional Magnetic Resonance Imaging (fMRI; in a subset of $n = 28$ and $n = 31$ respectively) was then used to investigate individual differences in sensitivity of brain reward-related systems to various social and non-social rewards. Limited support was found for the relationship between BAS traits and the more motivational aspects of goal pursuit and reward processing, whilst anhedonia seemed to pertain more to reward consumption, with few links to everyday goal pursuit. This would indicate that anhedonia might not be as closely related to BAS sensitivity as was initially anticipated. Finally, in order to examine real-world correlates of neural activation, the data from the naturalistic measure were correlated with reward-related activation. Everyday PA correlated with striatal activation when viewing pleasant images, but no other associations emerged. This would suggest that the basic measures of brain function in relation to the particular reward-related stimuli used might be of limited relevance to everyday affective experience and goal pursuit.

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Table of Contents.

Abstract	1
Acknowledgments	2
List of Tables	8
List of Figures	14
Chapter I: General Introduction	21
1.1. Research Overview.....	21
1.2. Reward and Motivation.....	21
1.3. Gray’s Reinforcement Sensitivity Theory.....	22
1.4. Reward Processing.....	26
1.5. BAS Sensitivity and Reward Processing.....	29
1.6. Real-World Experience and Reward Processing.....	30
1.7. Goal Pursuit.....	32
1.8. BAS Sensitivity, Positive Affect, and Goal Pursuit.....	34
1.9. Unipolar Depression.....	35
1.10. Bipolar Disorder.....	43
1.11. Older Adults.....	48
1.12. Summary of Literature.....	49
1.13. Summary of Empirical Chapters.....	49
Chapter II: The Pursuit of Everyday Goals	52
2.1. Introduction	53
2.1.1. Goal Pursuit.....	53
2.1.2. BAS Sensitivity.....	54
2.1.3. A BAS Deficiency Model of Depression.....	57
2.1.4. A BAS Dysregulation Model of Bipolar Disorder.....	59
2.1.5. Key Aims.....	62
2.1.6. Study Rationale.....	63
2.1.7. Hypotheses.....	68
2.2. Method	75
2.2.1. Study One.....	75
2.2.2. Study Two.....	80
2.2.3. Analysis Plan.....	84
2.3. Results	86
2.3.1. Study One.....	86
2.3.2. Study Two.....	93
2.3.3. Summary of Findings.....	100
2.4. Discussion	102
2.4.1. Trait Measures.....	102
2.4.2. LT Goal Pursuit.....	103
2.4.3. ST Goal Pursuit.....	106
2.4.4. BAS Sensitivity.....	107
2.4.5. Anhedonia.....	109
2.4.6. Hypomanic Personality Traits.....	111

2.4.7. Cross Level Interactions.....	112
2.4.8. Limitations.....	114
2.4.9. Conclusion.....	115
Chapter III: General Scanning Procedure.....	117
3.1. Study One.....	117
3.2. Study Two.....	119
Chapter IV: The Anticipation and Receipt of Monetary Reward.....	122
4.1. Introduction.....	123
4.1.1. Reward Processing.....	124
4.1.2. The Incentive-Saliency Model.....	125
4.1.3. Prediction Error.....	126
4.1.4. Reward Processing in Healthy Participants.....	127
4.1.5. BAS Sensitivity and Reward Processing.....	128
4.1.6. Reward Processing in Depression.....	129
4.1.7. Reward Processing in Bipolar Disorder.....	133
4.1.8. Study Rationale.....	135
4.1.9. Hypotheses.....	140
4.2. Method.....	144
4.2.1. Study One.....	144
4.2.2. Study Two.....	147
4.2.3. fMRI Processing & Analysis.....	150
4.3. Results.....	153
4.3.1. Study One.....	153
4.3.2. Region of Interest Analyses.....	156
4.3.3. Exploratory Whole Brain Analyses.....	159
4.3.4. Study Two.....	160
4.3.5. Region of Interest Analyses.....	164
4.3.6. Exploratory Whole Brain Analyses.....	168
4.3.7. Sample Differences.....	168
4.3.8. Summary of Findings.....	168
4.4. Discussion.....	170
4.4.1. BAS Sensitivity.....	171
4.4.2. Anhedonia.....	173
4.4.3. Hypomanic Personality Traits.....	176
4.4.4. ESM Measures.....	176
4.4.5. Limitations.....	179
4.4.6. Conclusion.....	180
Chapter V: Neural Responses to Social Reward.....	182
5.1. Introduction.....	183
5.1.1. Happy Facial Expressions.....	183
5.1.2. Emotion Processing in Healthy Participants.....	184
5.1.3. Emotion Processing in Depression.....	185
5.1.4. Emotion Processing in Bipolar Disorder.....	188
5.1.5. Emotion Processing and BAS Sensitivity.....	189
5.1.6. Study Rationale.....	191
5.1.7. Hypotheses.....	193
5.2. Method.....	197

5.2.1. Study One.....	197
5.2.2. Study Two.....	200
5.2.3. fMRI Processing & Analysis.....	203
5.3. Results.....	205
5.3.1. Study One.....	205
5.3.2. Region of Interest Analyses.....	206
5.3.3. Exploratory Whole Brain Analyses.....	208
5.3.4. Study Two.....	208
5.3.5. Region of Interest Analyses.....	209
5.3.6. Exploratory Whole Brain Analyses.....	211
5.3.7. Sample Differences.....	211
5.3.8. Summary of Key Findings.....	212
5.4. Discussion.....	212
5.4.1. BAS Sensitivity.....	212
5.4.2. Anhedonia.....	213
5.4.3. Hypomanic Personality Traits.....	214
5.4.4. ESM Measures.....	215
5.4.5. Limitations.....	216
5.4.6. Conclusion.....	218
Chapter VI: Neural Responses to Pleasant Images.....	219
6.1. Introduction.....	219
6.1.1. Emotion Processing in Healthy Participants.....	219
6.1.2. Emotion Processing and BAS Sensitivity.....	221
6.1.3. Emotion Processing in Depression.....	222
6.1.4. Emotion Processing in Bipolar Disorder.....	224
6.1.5. Study Rationale.....	224
6.1.6. Hypotheses.....	229
6.2. Method.....	233
6.2.1. Study One.....	233
6.2.2. Study Two.....	236
6.2.3. fMRI Processing & Analysis.....	238
6.3. Results.....	241
6.3.1. Study One.....	241
6.3.2. Region of Interest Analyses.....	241
6.3.3. Exploratory Whole Brain Analyses.....	247
6.3.4. Study Two.....	247
6.3.5. Region of Interest Analyses.....	248
6.3.6. Exploratory Whole Brain Analyses.....	254
6.3.7. Sample Differences.....	255
6.3.8. Summary of Findings.....	255
6.4. Discussion.....	256
6.4.1. BAS Sensitivity.....	257
6.4.2. Anhedonia.....	258
6.4.3. Hypomanic Personality Traits.....	260
6.4.4. ESM Measures.....	260
6.4.5. Limitations.....	262
6.4.6. Conclusion.....	263

Chapter VII: Associations Across Reward Domains.....	265
7.1. Introduction.....	265
7.1.1. Reward Specific Processing.....	265
7.1.2. Reward General Processing.....	266
7.1.3. Study Rationale.....	267
7.1.4. Study Hypotheses.....	268
7.1.5. Summary of Hypotheses.....	269
7.2. Method.....	270
7.2.1. Study One.....	270
6.2.2. Study Two.....	271
7.3. Results.....	273
7.3.1. Study One.....	273
6.3.2. Study Two.....	279
7.4. Discussion.....	286
7.4.1. Monetary Reward Anticipation and Receipt.....	286
7.4.2. Associations between Different Reward Types.....	287
7.4.4. Limitations.....	290
7.4.3. Conclusion.....	290
Chapter VIII: General Discussion.....	292
8.1. Theoretical Background.....	293
8.2. Key Research Questions.....	295
8.3. Summary of Methods.....	297
8.4. Summary of Key Findings.....	299
8.5. Integration of Findings.....	304
8.6. Limitations.....	314
8.7. Future Directions.....	316
8.8. Summary and Conclusions.....	318
References.....	321
Appendix A: Questionnaire Measures.....	408
Appendix B: ESM Documentation.....	423
Appendix C: MRI Documentation.....	439
Appendix D: MRI Task Stimuli.....	447
Appendix E: Additional Descriptive Statistics.....	455
Appendix F: Additional Measures and Analyses.....	461
Appendix G: Supplementary MRI Information.....	477

List of Tables.

Chapter II: The Pursuit of Everyday Goals.

Table 2.1. Hypothesised between-person correlations and cross-level interactions between trait measures and ESM measures of PA and goal pursuit.	74
Table 2.2. Descriptive statistics of the trait measures.	87
Table 2.3. Correlation matrix of scores on the trait measures [95% confidence intervals].	87
Table 2.4. Person-level descriptive statistics of the ESM measures.	88
Table 2.5. Correlation matrix of the ESM measures, showing between and within-person correlations [95% confidence intervals].....	89
Table 2.6. Between-person correlations between the trait measures and mean LT achievement and social goal measures [95% confidence intervals].....	90
Table 2.7. Unstandardised regression coefficients (standard errors) for cross-level interactions between trait measures and ESM measures.	91
Table 2.8. Between-person correlations between the trait measures and mean levels of PA and ST achievement goal measures [95% confidence intervals].....	92
Table 2.9. Unstandardised regression coefficients (standard errors) for cross-level interactions between trait measures and ESM measures.	92
Table 2.10. Descriptive statistics of the trait measures.	94
Table 2.11. Correlation matrix of scores on the trait measures [95% confidence intervals]. ..	95
Table 2.12. Person-level descriptive statistics of ESM measures.	96
Table 2.13. Correlation matrix of the ESM measures, showing between and within-person correlations.	97
Table 2.14. Between-person correlations between the trait measures and PA and ST achievement and social goal measures [95% confidence intervals].	98
Table 2.15. Unstandardised regression coefficients (standard errors) for cross-level interactions between the trait measures and ESM measures.	98
Table 2.16. Fate of hypotheses for correlations between trait measures and ESM measures of PA and goal pursuit, relative to a priori hypotheses.	101

Chapter IV: The Anticipation and Receipt of Monetary Reward.

Table 4.1. Hypothesised correlations between trait and ESM measures, and ROI activation associated with reward anticipation > baseline contrast.	143
---	-----

Table 4.2. Hypothesised correlations between trait and ESM measures, and ROI activation associated with reward receipt > baseline contrast.	144
Table 4.3. Descriptive statistics of the trait measures for MRI subset.	153
Table 4.4. Correlation matrix of scores on the trait measures for MRI subset [95% confidence intervals].	154
Table 4.5. Person-level descriptive statistics of ESM measures for MRI subset.	154
Table 4.6. Correlation matrix of the ESM measures for MRI subset [95% confidence intervals].	155
Table 4.7. Correlations between trait measures and ESM measures for MRI subset.	155
Table 4.8. Correlations between trait measures and ROI activation for reward anticipation > baseline contrast [95% confidence intervals].	156
Table 4.9. Correlations between trait measures and ROI activation for reward receipt > baseline contrast [95% confidence intervals].	157
Table 4.10. Correlations between ESM measures and ROI activation for reward anticipation > baseline contrast [95% confidence intervals].	159
Table 4.11. Correlations between ESM measures and ROI activation for reward receipt > baseline contrast [95% confidence intervals].	159
Table 4.12. Descriptive statistics of the trait measures for MRI subset.	161
Table 4.13. Correlation matrix of scores on the trait measures for MRI subset [95% confidence intervals].	161
Table 4.14. Person-level descriptive statistics of ESM measures for MRI subset.	162
Table 4.15. Correlation matrix of the ESM measures for MRI subset [95% confidence intervals].	163
Table 4.16. Correlations between trait measures and ESM measures for MRI subset [95% confidence intervals].	163
Table 4.17. Correlations between trait measures and ROI activation for reward anticipation > baseline contrast [95% confidence intervals].	164
Table 4.18. Correlations between trait measures and ROI activation for reward receipt > baseline contrast [95% confidence intervals].	165
Table 4.19. Correlations between ESM measures and ROI activation for reward anticipation > baseline contrast [95% confidence intervals].	166
Table 4.20. Correlations between ESM measures and ROI activation for reward receipt > baseline contrast [95% confidence intervals].	167

Table 4.21. Fate of hypotheses for correlations between trait and ESM measures, and ROI activation associated with reward anticipation > baseline contrast, relative to the a priori hypotheses.	169
Table 4.22. Fate of hypotheses for correlations between trait and ESM measures, and ROI activation associated with reward receipt > baseline contrast, relative to the a priori hypotheses.	170

Chapter V: Neural Responses to Social Reward.

Table 5.1. Hypothesised correlations between trait and ESM measures and ROI activation associated with the happy facial expressions > neutral facial expressions contrast.....	196
Table 5.2. Correlations between trait measures and ROI activation for the happy facial expressions > neutral facial expressions contrast [95% confidence intervals].	207
Table 5.3. Correlations between trait measures and ROI activation during the happy faces compared to neutral faces [95% confidence intervals].	209
Table 5.4. Correlations between ESM measures and ROI activation for the happy facial expressions > neutral facial expressions contrast [95% confidence intervals].	210

Chapter VI: Neural Responses to Pleasant Images.

Table 6.1. Hypothesised correlations between trait and ESM measures and ROI activation associated with contentment images > neutral images and excitement images > neutral images contrasts.....	232
Table 6.2. Associations between trait measures and ROI activation for the contentment images > neutral images contrast [95% confidence intervals].	242
Table 6.3. Correlations between ESM measures and ROI activation for the contentment images > neutral images contrast [95% confidence intervals].	243
Table 6.4. Correlations between trait measures and ROI activation for the excitement images > neutral images contrast [95% confidence intervals].	245
Table 6.5. Correlations between ESM measures and ROI activation for the excitement images > neutral images contrast [95% confidence intervals].	246
Table 6.6. Correlations between trait measures and ROI activation for contentment images > neutral images contrast [95% confidence intervals].	248
Table 6.7. Correlations between ESM measures and ROI activation for the contentment images > neutral images contrast [95% confidence intervals].	251

Table 6.8. Correlations between trait measures and ROI activation for the excitement images > neutral images contrast [95% confidence intervals].	252
Table 6.9. Correlations between ESM measures and ROI activation for excitement images > neutral images contrast [95% confidence intervals].	253
Table 6.10. Fate of hypotheses for correlations between trait and ESM measures and ROI activation associated with contentment images > neutral images and excitement images > neutral images contrasts, relative to the a priori hypotheses.	256

Chapter VII: Associations Across Reward Domains.

Table 7.1. Hypothesised correlations between activation associated with different rewarding stimuli.	270
Table 7.2. Correlation matrix of caudate activation associated with different reward domains [95% confidence intervals].....	274
Table 7.3. Correlation matrix of NAcc activation associated with different reward domains [95% confidence intervals].....	274
Table 7.4. Correlation matrix of amygdala activation associated with different reward domains [95% confidence intervals].	275
Table 7.5. Correlation matrix of caudate activation associated with different reward domains [95% confidence intervals].....	280
Table 7.6. Correlation matrix of NAcc activation associated with different reward domains [95% confidence intervals].....	281
Table 7.7. Correlation matrix of amygdala activation associated with different reward domains.	281

Appendix E: Additional Descriptive Statistics.

Table E1. Descriptive statistics of the trait measures in Study One Happy Faces fMRI subset.	455
Table E2. Correlation matrix of trait measures in Study One Happy Faces fMRI subset.	455
Table E3. Descriptive statistics of the trait measures in Study Two Happy Faces fMRI subset.	456
Table E4. Correlation matrix of trait measures in Study Two Happy Faces fMRI subset [95% confidence intervals].	457
Table E5. Person-level descriptive statistics of ESM measures in Study Two Happy Faces fMRI subset.....	457

Table E6. Correlations between trait measures and ESM measures for Study Two Happy Faces fMRI subset [95% confidence intervals].....	457
Table E7. Descriptive statistics for the trait measures in Study Two Positive Affect fMRI subset.....	458
Table E8. Correlation matrix of the trait measures in Study Two Positive Affect fMRI subset [95% confidence intervals].....	459
Table E9. Person-level descriptive statistics for ESM measures in Study Two Positive Affect fMRI subset.....	459
Table E10. Correlations between trait measures and ESM measures for Study Two Positive Affect MRI subset [95% confidence intervals].....	459

Appendix F: Additional Measures and Analyses.

Table F1. Descriptive statistics for additional trait measures in Study One ESM sample.....	461
Table F2. Descriptive statistics for additional trait measures in Study One fMRI subset.	462
Table F3. Descriptive statistics for additional trait measures in Study Two ESM sample....	463
Table F4. Descriptive statistics for additional trait measures in Study Two fMRI Subset. ...	464
Table F5. Correlation matrix of the trait measures in Study Two ESM sample [95% confidence intervals].	465
Table F6. Between-person correlations between the additional trait measures and PA and ST achievement and social goal measures [95% confidence intervals].	466
Table F7. Correlation matrix of the trait measures in Study Two Card-guessing MRI subset [95% confidence intervals].....	467
Table F8. Correlations between additional trait measures and ROI activation for reward anticipation > baseline contrast [95% confidence intervals].....	468
Table F9. Correlations between additional trait measures and ROI activation for reward receipt > baseline contrast [95% confidence intervals].....	468
Table F10. Correlation matrix of the trait measures in Study Two Happy Faces MRI subset [95% confidence intervals].....	469
Table F11. Correlations between additional trait measures and ROI activation for happy facial expressions > neutral facial expressions contrast [95% confidence intervals].	470
Table F12. Correlation matrix of the trait measures in Study Two MRI subset [95% confidence intervals].	472
Table F13. Correlations between additional trait measures and ROI activation for contentment images > neutral images contrast [95% confidence intervals].....	473

Table F14. Correlations between additional trait measures and ROI activation for excitement images > neutral images contrast [95% confidence intervals].	474
--	-----

Appendix G: Supplementary MRI Information.

Table G1. Coordinates for significant clusters of activation associated with monetary reward anticipation > baseline contrast.	482
Table G2. Coordinates for significant clusters of activation associated with monetary reward receipt > baseline contrast.	483
Table G3. Coordinates for significant clusters of activation associated with monetary reward anticipation > baseline contrast.	489
Table G4. Coordinates for significant clusters of activation associated with happy facial expressions > baseline contrast.	494
Table G5. Coordinates for significant clusters of activation associated with happy facial expressions > baseline contrast.	499
Table G6. Coordinates for significant clusters of activation associated with excitement images > neutral images contrast.	514

List of Figures.

Chapter II: The Pursuit of Everyday Goals.

Figure 2.1. Interaction between PA and ST achievement goal progress, for high and low BAS-D.....	93
Figure 2.2. Interaction between PA and ST achievement goal progress, for high and low BAS-FS.	99
Figure 2.3. Interaction between PA and ST achievement goal progress, for high and low MASQ-AD.	100

Chapter IV: The Anticipation and Receipt of Monetary Reward.

Figure 4.1. Example of win-trial during monetary reward card-guessing task.....	147
Figure 4.2. Left/right caudate and left/right NAcc ROIs.	152
Figure 4.3. Relationships between BAS-RR and activation of left caudate and left NAcc for reward receipt > baseline contrast.	157
Figure 4.4. Relationship between MASQ-AD and activation of right caudate for reward receipt > baseline contrast.	158
Figure 4.5. Relationship between BAS-FS and activation of left NAcc for reward anticipation > baseline contrast.	165
Figure 4.6. Relationship between Positive Affect and activation of right caudate for reward anticipation > baseline contrast.	167

Chapter V: Neural Responses to Social Reward.

Figure 5.1. An example of each condition in the facial emotion-processing task.	200
Figure 5.2. Left/right caudate (shown in pink), left/right NAcc, and left/right amygdala ROIs.	204
Figure 5.3. Relationship between BAS-RR and left amygdala activation for happy facial expressions > neutral facial expressions contrast.....	207
Figure 5.4. Relationships between ST <i>social</i> goal progress and effort and left amygdala activation for happy facial expressions > neutral facial expressions contrast.....	211

Chapter VI: Neural Responses to Pleasant Images.

Figure 6.1. Trial sequence and example images from each condition in the Positive Affect task.	236
Figure 6.2. Left/right caudate, left/right NAcc, and left/right amygdala ROIs.....	240
Figure 6.3. Relationships between Positive Affect and activation of right caudate and left NAcc for contentment images > neutral images contrast.	244
Figure 6.4. Relationships between Positive Affect and activation of right NAcc and right amygdala for excitement images > neutral images contrast.	247
Figure 6.5. Relationship between BAS-FS and activation of right caudate for contentment images > neutral images contrast.	250
Figure 6.6. Relationship between MASQ-AD and activation of left NAcc for contentment images > neutral images contrast.	250
Figure 6.7. Relationship between MASQ-AD and activation of right NAcc for excitement images > neutral images contrast.	Error! Bookmark not defined.
Figure 6.8. Relationships between ST Social Goal Pleasure and activation of left NAcc and right amygdala for excitement images > neutral images contrast.....	254

Chapter VII: Associations Across Reward Domains.

Figure 7.1. Left/right caudate, left/right NAcc, and left/right amygdala ROIs.....	273
Figure 7.2. Relationship between activation associated with reward anticipation > baseline contrast and activation associated with reward receipt > baseline contrast for the left caudate, and the left and right NAcc.	276
Figure 7.3. Relationship between activation associated with reward receipt > baseline contrast and activation associated with the contentment images > neutral images contrast for the right caudate.....	277
Figure 7.4. Relationship between activation associated with excitement images > neutral images contrast and activation associated with the contentment images > neutral images contrast for the right caudate.....	278
Figure 7.5. Relationship between activation associated with excitement images > neutral images contrast and activation associated with the contentment images > neutral images contrast for left and right NAcc, and the left and right amygdala.....	279

Figure 7.6. Relationship between activation associated with monetary reward anticipation > baseline contrast and activation associated with the monetary reward receipt > baseline contrast for the right caudate and left NAcc.	282
Figure 7.7. Relationship between activation associated with monetary reward receipt > baseline contrast and activation associated with the happy facial expressions > neutral facial expressions contrast.....	283
Figure 7.8. Relationship between activation associated with monetary reward receipt > baseline contrast and activation associated with the contentment images > neutral images contrast for the left NAcc.	284
Figure 7.9. Relationship between activation associated with excitement images > neutral images and activation associated with contentment images > neutral images for left and right caudate, and right NAcc.	Error! Bookmark not defined.
Figure 7.10. Relationship between activation associated with excitement images > neutral images and activation associated with contentment images > neutral images for left and right amygdala.	286

Chapter VIII: General Discussion.

Figure 8.1. A “nomological net” illustrating the expected associations between the “trait” measures and the outcome measures investigated in the present research.	296
Figure 8.2. A diagram illustrating the expected relationships between the ESM measures and the neural responses associated with different rewarding stimuli.	297

Appendix F: Additional Measures and Analyses.

Figure F1. Relationships between Social Anhedonia and activation of left and right caudate, and right NAcc for happy facial expressions > neutral facial expressions contrast.....	471
Figure F2. Relationship between Physical Anhedonia and activation of the left amygdala for contentment images > neutral images contrast.	475
Figure F3. Relationship between Physical Anhedonia and activation of the left amygdala for excitement images > neutral images contrast.....	475

Appendix G: Supplementary MRI Information.

Figure G1. Sum of all input masks after transformation to standard space.	477
--	-----

Figure G2. Examples of Mean Time Series Plot for the left NAcc, for the reward anticipation > reward baseline contrast.....	478
Figure G3. Examples of Mean Time Series Plot for the right NAcc, for the reward anticipation > reward baseline contrast.	472
Figure G4. Examples of Mean Time Series Plot for the left caudate, for the reward anticipation > baseline contrast.	479
Figure G5. Examples of Mean Time Series Plot for the right caudate, for the reward anticipation > baseline contrast.	479
Figure G6. Examples of Mean Time Series Plot for the left NAcc, for the reward outcome > baseline contrast.	480
Figure G7. Examples of Mean Time Series Plot for the right NAcc, for the reward outcome > baseline contrast.	480
Figure G8. Examples of Mean Time Series Plot for the left caudate, for the reward outcome > baseline contrast.	481
Figure G9. Examples of Mean Time Series Plot for the right caudate, for the reward outcome > baseline contrast.....	481
Figure G10. Group map, monetary reward anticipation > baseline contrast.	482
Figure G11. Group map, monetary reward receipt > baseline contrast.	483
Figure G12. Sum of all input masks after transformation to standard space.	484
Figure G13. Examples of Mean Time Series Plot for the left NAcc, for the reward anticipation > baseline contrast.....	485
Figure G14. Examples of Mean Time Series Plot for the right NAcc, for the reward anticipation > baseline contrast.....	485
Figure G14. Examples of Mean Time Series Plot for the left caudate, for the reward anticipation > baseline contrast.....	486
Figure G15. Examples of Mean Time Series Plot for the right caudate, for the reward anticipation > baseline contrast.....	486
Figure G16. Examples of Mean Time Series Plot for the left NAcc, for the reward outcome > baseline contrast.....	487
Figure G17. Examples of Mean Time Series Plot for the right NAcc, for the reward outcome > baseline contrast.....	487
Figure G18. Examples of Mean Time Series Plot for the left caudate, for the reward outcome > baseline contrast.....	488

Figure G19. Examples of Mean Time Series Plot for the right caudate, for the reward outcome > baseline contrast.....	488
Figure G20. Group map, monetary reward anticipation > baseline contrast.	489
Figure G21. Group map, monetary reward outcome > baseline contrast.	489
Figure G22. Sum of all input masks after transformation to standard space.	490
Figure G23. Examples of Mean Time Series Plot for the left NAcc, for the happy facial expressions > neutral facial expressions contrast.....	491
Figure G24. Examples of Mean Time Series Plot for the right NAcc, for the happy facial expressions > neutral facial expressions contrast.....	491
Figure G25. Examples of Mean Time Series Plot for the left caudate, for the happy facial expressions > neutral facial expressions contrast.....	492
Figure G26. Examples of Mean Time Series Plot for the right caudate, for the happy facial expressions > neutral facial expressions contrast.....	492
Figure G27. Examples of Mean Time Series Plot for the left amygdala, for the happy facial expressions > neutral facial expressions contrast.....	493
Figure G28. Examples of Mean Time Series Plot for the right amygdala, for the happy facial expressions > neutral facial expressions contrast.....	493
Figure G29. Group map, happy facial expressions > baseline contrast.	494
Figure G30. Sum of all input masks after transformation to standard space.	495
Figure G31. Examples of Mean Time Series Plot for the left NAcc, for the happy facial expressions > neutral facial expressions contrast.....	496
Figure G32. Examples of Mean Time Series Plot for the left NAcc, for the happy facial expressions > neutral facial expressions contrast.....	496
Figure G33. Examples of Mean Time Series Plot for the right NAcc, for the happy facial expressions > neutral facial expressions contrast.....	496
Figure G34. Examples of Mean Time Series Plot for the left caudate, for the happy facial expressions > neutral facial expressions contrast.....	497
Figure G35. Examples of Mean Time Series Plot for the right caudate, for the happy facial expressions > neutral facial expressions contrast.....	497
Figure G36. Examples of Mean Time Series Plot for the left amygdala, for the happy facial expressions > neutral facial expressions contrast.....	498

Figure G37. Examples of Mean Time Series Plot for the right amygdala, for the happy facial expressions > neutral facial expressions contrast.....	498
Figure G38. Group map, happy facial expressions > baseline contrast.	499
Figure G39. Sum of all input masks after transformation to standard space.	500
Figure G40. Examples of Mean Time Series Plot for the left NAcc for the excitement images > neutral images contrast.....	501
Figure G41. Examples of Mean Time Series Plot for the right NAcc for the excitement images > neutral images contrast.....	501
Figure G42. Examples of Mean Time Series Plot for the left caudate for the excitement images > neutral images contrast.	502
Figure G43. Examples of Mean Time Series Plot for the right caudate for the excitement images > neutral images contrast.	502
Figure G44. Examples of Mean Time Series Plot for the left amygdala for the excitement images > neutral images contrast.	503
Figure G45. Examples of Mean Time Series Plot for the right amygdala for the excitement images > neutral images contrast.	503
Figure G46. Examples of Mean Time Series Plot for the left NAcc for the contentment images > neutral images contrast.....	504
Figure G47. Examples of Mean Time Series Plot for the right NAcc for the contentment images > neutral images contrast.	504
Figure G48. Examples of Mean Time Series Plot for the left caudate for the contentment images > neutral images contrast.	505
Figure G49. Examples of Mean Time Series Plot for the right caudate for the contentment images > neutral images contrast.	505
Figure G50. Examples of Mean Time Series Plot for the left amygdala for the contentment images > neutral images contrast.	506
Figure G51. Examples of Mean Time Series Plot for the right amygdala for the contentment images > neutral images contrast.	506
Figure G52. Sum of all input masks after transformation to standard space.	507
Figure G53. Examples of Mean Time Series Plot for the left NAcc for the excitement images > neutral images contrast.....	508
Figure G54. Examples of Mean Time Series Plot for the right NAcc for the excitement images > neutral images contrast.....	508

Figure G55. Examples of Mean Time Series Plot for the left caudate for the excitement images > neutral images contrast.	509
Figure G56. Examples of Mean Time Series Plot for the right caudate for the excitement images > neutral images contrast.	509
Figure G57. Examples of Mean Time Series Plot for the left amygdala for the excitement images > neutral images contrast.	510
Figure G58. Examples of Mean Time Series Plot for the right amygdala for the excitement images > neutral images contrast.	510
Figure G59. Examples of Mean Time Series Plot for the left NAcc for the contentment images > neutral images contrast.....	511
Figure G60. Examples of Mean Time Series Plot for the right NAcc for the contentment images > neutral images contrast.	511
Figure G61. Examples of Mean Time Series Plot for the left caudate for the contentment images > neutral images contrast.	512
Figure G62. Examples of Mean Time Series Plot for the right caudate for the contentment images > neutral images contrast.	512
Figure G63. Examples of Mean Time Series Plot for the left amygdala for the contentment images > neutral images contrast.	513
Figure G64. Examples of Mean Time Series Plot for the right amygdala for the contentment images > neutral images contrast.	513
Figure G65. Group map, excitement images > neutral images contrast.	514

Chapter I: General Introduction.

1.1. Research Overview.

This thesis explores potential relationships between measures of approach motivation, anhedonic symptoms and trait hypomania, the everyday experience of positive affect (PA) and goal pursuit, and neural responses to different rewarding stimuli. First, experience sampling (ESM) was used to obtain ecologically valid measures of momentary PA and goal pursuit (Chapter Two). Functional Magnetic Resonance Imaging (fMRI) was then used to investigate potential associations between the measures of trait approach motivation, anhedonic symptoms and hypomania, and the neural responses associated with the processing of social and non-social rewards (Chapters Four – Six). Non-social rewards consisted of monetary reward and images portraying excitement, whilst social rewards comprised happy facial expressions and images depicting affiliation. In order to assess the real-world correlates of reward-related neural responses, the ESM measures of PA and goal pursuit were also correlated with the neural activation elicited by the rewarding stimuli (Chapters Four – Six). Finally, the patterns of associations between neural responses across reward paradigms were also explored (Chapter Seven). The subsequent sections in this chapter provide an overview of the relevant literature, indicating how the present research adds to this, before concluding with a brief outline of the content of each chapter in this thesis.

1.2. Reward and Motivation.

A reward may be defined as an object, event, or stimulus that has the potential to make an individual approach and consume it (Schultz, 2015). There are two key types of reward: primary rewards (e.g., food and sex) and secondary rewards (e.g. money and power). Primary rewards are innately pleasurable and represent the basic needs of an individual to ensure their own survival and reproductive success, whilst secondary rewards, which are not

directly related to survival, are learned through associations with primary rewards. Experiencing reward produces feelings of pleasure and satisfaction, and avoiding punishment produces feelings of relief, thus the desire to approach rewards and avoid negative outcomes have long been held to be fundamental motivations (Elliot & Covington, 2001; Elliot & Thrash, 2002). Motivation may be defined as the instigation, drive, and direction of behaviour, with a distinction being drawn between approach and avoidance motivation (Elliot & Covington, 2001). These motivations differ in terms of the valence of the future salient outcome: approach motivation has been described as the aspiration to attain or maintain a positive outcome, whilst avoidance motivation may be defined as the attempt to avoid any potential negative outcomes (Elliot, 1999; Sherratt & MacLeod, 2013). Abnormalities in factors pertaining to approach motivation have been implicated in the experience of both depression (Beevers & Meyer, 2002; Coplan et al., 2006; Depue, Krauss, & Spont, 1987; Jones & Day, 2008; Kimbrel et al., 2007; Meyer, Johnson, & Carver, 1999) and bipolar disorder (BD; Alloy & Abramson, 2010; Alloy, Abramson, Urosevic, Bender, & Wagner, 2009; Depue & Iacono, 1989; Depue et al., 1987; Johnson, 2005; Meyer, Johnson, & Carver, 1999; Meyer, Johnson, & Winters, 2001; Urosevic, Abramson, Harmon-Jones, & Alloy, 2008). The present research focuses on key theories of approach motivation, proposed associations with depressive and hypomanic symptoms, and the everyday experience of affect and goal pursuit. This chapter will begin by reviewing key theories of motivation, before moving on to discuss their relevance to the experience of depression and BD.

1.3. Gray's Reinforcement Sensitivity Theory.

The Reinforcement Sensitivity Theory (RST; Gray, 1970, 1973, 1982, 1987) is a bio-behavioural theory of emotion, motivation, and learning, focusing on the neurophysiological substrates of motivational systems and their contributions to personality and behaviour. The RST posits that there are three distinct systems underlying human motivation: the behavioural

activation system (BAS), the behavioural inhibition system (BIS), and the Fight/Flight system (FFS). Each system is thought to respond to different reinforcing events with a specific type of behaviour, mediated by a group of interacting brain structures. Approach and avoidance motivation map onto these systems, with an association between the BAS and approach motivation, whilst the BIS and FFS have been linked to avoidance motivation. Individual differences in these systems are thought to underlie the personality dimensions of impulsivity and anxiety respectively (Bijttebier, Beck, Claes, & Vandereycken, 2009). The research presented in this thesis concerns approach motivation, or a lack thereof, and thus there is a focus on the BAS. However, in the interest of providing a full background account, a short description of the BIS and the FFS is also included in the following section.

In the original formulation of the RST, the BIS was held to be responsible for organising behaviour in response to punishment and thus was activated by stimuli that signal conditioned aversive events, such as conditioned punishment, non-reward, and extreme novelty/high intensity of stimuli (Gray, 1972). However, later revisions attributed punishment responsivity to the FFS (renamed the Fight-Flight-Freeze system; FFFS), with the additional suggestion that the BIS is activated in response to conflict between coexisting goals, arising when a situation involves both reward and threat (Gray & McNaughton, 2000). BIS activation is thought to relieve goal conflict by inhibiting behaviour that may lead to negative or painful outcomes, particularly with regards to goal-directed behaviour. Consistent with its role in the inhibition of approach-motivated behaviour, greater BIS sensitivity is associated with lower levels of positive affect (PA) and higher levels of both negative affect (NA) and state anxiety (Campbell-Sills, Liverant, & Brown, 2004; Demaree, Robinson, & Everhart, 2005; Gable, Reis, & Elliot, 2000; Arnett & Newman, 2000). Additionally, the FFFS is thought to mediate reactions to all aversive stimuli, incorporating the fight or flight reactions, as well as the freezing reactions associated with unavoidable threat stimuli (Gray & McNaughton, 2000).

The FFFS is associated with increased arousal (so that subsequent behaviour will be carried out with additional vigour/speed), anxiety, and greater levels of selective attention, particularly to negatively valenced stimuli (Smillie, Pickering, & Jackson, 2006). As such, the FFFS is more relevant to “fear”, whilst the BIS is more closely related to anxiety (Gray & McNaughton, 2000), mapping onto the personality dimension of neuroticism (Heubeck et al., 1998; Jorm et al., 1999; Keiser & Ross, 2011; Smits & Boeck, 2006; Zelenski & Larsen, 1999).

The BAS, which is sometimes referred to as the behavioural approach or facilitation system (Fowles, 1980), is activated by appetitive stimuli, which provide signals of reward, non-punishment, and the escape from punishment. The BAS elicits approach-type behaviour, which is, in turn, linked to increased levels of PA, including feelings of hope, elation, and anticipatory pleasure (Gray, 1981). Reward relevant stimuli, which lead to BAS activation, may be internal (e.g., expectancy of a rewarding goal or outcome attainment) or external (e.g., presence of a desired outcome in the environment). Activation of the BAS is associated with increased motor behaviour, incentive reward motivation, and positive goal striving cognitions and emotions, such as hope and happiness (Depue & Collins, 1999; Gray, 1994), as well as with anger when goal striving is frustrated or blocked (Carver, 2004; Harmon-Jones & Allen, 1998; Harmon-Jones & Sigelman, 2001). It is thought that greater BAS sensitivity should be reflected in increased willingness to engage in goal-directed behaviours, and greater experience of positive feelings when exposed to cues of impending reward (Carver & White, 1994; Depue & Iacono, 1989). This is consistent with findings that greater BAS sensitivity, thought to be at least partially reflective of approach motivation, is linked to higher levels of general PA (Campbell-Sills et al., 2004; Gable et al., 2000), greater approach type responses (Corr, 2001, 2002), and the personality dimension of extraversion (Smillie et al., 2006). Extraversion itself includes facets of wellbeing and PA, achievement motivation, social

closeness, and reward seeking (Watson & Clark, 1997) and has been reliably associated with the experience of PA (Lucas, Le, & Dryenforth, 2008). BAS related concepts; such as reward sensitivity and approach motivation are at the core of extraversion, providing a partial biological basis for extraversion (Elliot & Thrash, 2002; Smillie, Cooper, Wilt, & Revelle, 2012).

The suggestion that the BIS and BAS act independently of each other has been referred to as the separable sub-system hypothesis (SSH; e.g., Gomez, Cooper, McOrmond, & Tatlow, 2004). The SSH posits that the BAS response to reward is independent of the levels of BIS and vice versa, so the resulting affective and behavioural outcomes would be decided by whichever system was dominant at a given point. However, little empirical support has been found for the SSH, leading to the proposal of the joint sub-systems hypothesis (JSH; Corr, 2001). The JSH suggests that, under most circumstances, the BIS and BAS are interdependent and thus both may have some influence over the affective and behavioural outcomes at any given time. The JSH provides a better account of everyday motivation, but there are some circumstances where the SSH may be more applicable. Examples of this include situations where a stimulus is either highly appetitive or aversive, or in the case of an individual with extreme levels of BIS/BAS sensitivity (Corr, 2002). As such, the SSH and JSH may be viewed as complementary accounts of the dual-system BIS/BAS model (Corr, 2001).

The neural underpinnings of the BAS are thought to consist of a number of cortical and sub-cortical structures, including the amygdala, caudate-putamen, and the nucleus accumbens (NAcc; Gray, 1987, 1990; Smillie, 2008). These structures have been reliably implicated in the processing of reward (e.g., Knutson, Adams, Fong, & Hommer, 2001a; Knutson, Fong, Adams, Varner, & Hommer, 2001b; Knutson, Fong, Bennett, Adams, & Hommer, 2003; O'Doherty et al., 2002), which is consistent with BAS responsivity to

rewarding cues (Gray, 1981). Consequently, neuroimaging research that focuses on the processing of rewarding and pleasant stimuli may be pertinent to the investigation of the neural structures and responses associated with activation and sensitivity of the BAS.

1.4. Reward Processing.

The incentive salience model, a leading theory of reward processing, posits that there are two distinct psychological components of reward processing: ‘wanting’ and ‘liking’¹ (Berridge, 1996, 2007, 2012). ‘Wanting’ is a term used to describe the attribution of incentive salience to reward (and its predictive cues) in order to determine the motivational value. ‘Liking’ refers to the pleasure experienced during the consumption/receipt of the reward (hedonic impact). Although these two components will often correspond to the same reward (i.e., one is often motivated to obtain what one likes), they are considered to be psychologically distinct and, as such, have separable neural substrates that might be manipulated and measured in an independent fashion (Berridge, 2007, 2009, 2012; Berridge & Robinson, 1998; Smith et al., 2011). Consistent with this dissociation, several fMRI tasks used to probe reward-related neural responses focus on two distinct stages: reward anticipation and reward consumption. Each stage is thought to represent a different psychological state (Berridge & Robinson, 1998; Pizzagalli et al., 2009), supported by partially separable neural systems (Knutson et al., 2001a; Knutson et al., 2001b; Knutson et al., 2003). Motivational processes, such as goal-directed behaviour, are thought to be more relevant to reward anticipation, whereas reward consumption is likely to be dominated by affective responses, such as the experience of pleasure (Dillon et al., 2008, 2011; Gard,

¹ Reward learning is thought to be another component of reward processing, where an individual learns predictions about the rewarding effects of a stimulus (Berridge, 2007; Blum, Gardner, Oscar-Berman, & Gold, 2012). However, learned associations carry only information about the reward and are not, in themselves, motivational (Berridge, 2012). Due to the present focus on motivation and hedonic impact, this discussion will be limited to the ‘wanting’ and ‘liking’ components of reward processing.

Germans Gard, Kring, & John, 2006). In relation to the incentive-salience model, reward anticipation is likely to be more closely related to ‘wanting’, whereas reward consumption should be more closely related to ‘liking’ (Berridge & Robinson, 2003; Wyvell & Berridge, 2000).

Although many regions of the brain are responsive to reward, the fronto-striatal neural circuit seems to be at the heart of the reward processing system (Berridge, Robinson, & Aldridge, 2009; Haber & Knutson, 2010; Hikosaka et al., 2008; Kelley & Berridge, 2002; Kringelbach & Berridge, 2009; Rolls, 2000; Schultz, 2000; Schultz, Tremblay, & Hollerman, 2000; Stefani & Moghaddam, 2006; Wise, 2002). This circuit incorporates dopaminergic projections from the ventral tegmental area (VTA) to subcortical regions, such as the striatum (Diekhof & Gruber, 2010; Diekhof, Falkai, & Gruber, 2008; Liu et al., 2012). The striatum has been implicated in the tracking of the hedonic value and tone of reward, as well as the motor effort associated with obtaining it, providing an interface between the limbic and motor regions (Berridge, 2007; Berridge & Kringelbach, 2008; Kroemer et al., 2014; O’Doherty et al., 2004). The striatum may be divided into two components: the dorsal striatum (DS; incorporating the caudate nucleus and the putamen) and the ventral striatum (VS; incorporating the NAcc and ventral regions of the caudate). The VS has been implicated in various forms of reinforcement-based learning and approach-related behaviour (Niv, 2009), whilst the DS seems to be more involved in action-contingent learning (Delgado et al., 2000, 2005, 2007; Knutson et al., 2001b; Haruno et al., 2004; O’Doherty et al., 2004; Tricomi et al., 2004). Activation of the striatal regions has been demonstrated during both monetary reward anticipation (Abler et al., 2005, 2006; Dichter, Richey, Rittenberg, Sabatino, & Bodfish, 2012; Elliott et al., 2004; Gasic et al., 2009; Knutson & Cooper, 2005; Knutson et al., 2001a, 2001b; Knutson et al., 2003; Kohls et al., 2012; O’Doherty et al., 2001; Smith et al., 2010)

and monetary reward receipt (i.e., consumption; Bjork et al., 2004; Delgado et al., 2000, 2003; Dillon et al., 2008; O’Doherty et al., 2004; Simon et al., 2010).

Previous research on the neural basis of reward has predominantly focused on the processing of monetary reward, which might not be analogous to everyday incentives that are relevant to mental wellbeing (Xie et al., 2014). An individual is likely to be exposed to different kinds of incentives and reinforcers throughout the course of their everyday life and responses to different reward types may not be equivalent. Indeed, there has been some suggestion that there may be a degree of domain specificity in reward response, with different types of reward being encoded by specific neural pathways (Naranjo et al., 2001). In support of this, domain-specific individual differences in neural activation to rewarding stimuli have been found to be predictive of real-life behaviour, e.g., greater neural responses to food, but not sexual images or monetary reward, predicts weight gain (Demos, Heatherton, & Kelley, 2012; Stice, 2016). However, whilst there may be distinct components between the processing of different rewards, there is some overlap in neural responses (Beck et al., 2010; Rizvi, Pizzagalli, Sproule, & Kennedy, 2016; Sescousse et al., 2013), suggesting that domain-based differences in reward processing should be interpreted with caution (Barta et al., 2013). Previous research investigating the neural responses to social reward, alongside monetary reward (Rademacher et al., 2010; Rademacher et al., 2014; Spreckelmeyer et al., 2009), indicated that there are both overlapping and independent components associated with the processing of different reward types. As such, further investigation is required to ascertain whether activation of the reward structures is domain-specific, or domain-general. It would also be interesting to explore any similarities and differences in relationships between reward related personality traits, such as BAS sensitivity and activation associated with different types of reward. This is examined in Chapters Four to Seven.

1.5. BAS Sensitivity and Reward Processing.

The BAS is thought to be subserved by the same neural structures that have been implicated in the processing of reward (e.g., Berridge et al., 2009; Haber and Knutson, 2010; Hikosaka et al., 2008; Kringelbach & Berridge, 2009; Smillie, 2008). In line with this, several studies have explored potential associations between BAS sensitivity and reward-related BOLD activation. BAS sensitivity is often assessed using three subscales of the BAS scale (see Appendix B; Carver & White, 1994). BAS: Fun-Seeking (BAS-FS) measures the desire to seek out new rewards, as well as the inclination to impulsively approach potentially rewarding situations (e.g., *I will often do things for no other reason than I think they might be fun*). BAS: Reward Responsiveness (BAS-RR) measures the degree of PA one tends to experience in response to reward (e.g., *When I get something that I want, I feel excited and energised*). Finally, BAS: Drive (BAS-D) measures the motivation to persistently pursue reward (e.g., *When I want something I usually go all out to get it*). Although these factors are correlated, previous studies employing factor analysis have demonstrated that they are at least partially separable (Ross et al., 2002) and so are considered independently throughout this thesis.

Research in this area is relatively limited, but there is evidence that BAS sensitivity is likely to be related to neural responses to rewarding stimuli. Caseras et al. (2013) reported a positive correlation between BAS-FS and striatal activation during monetary reward anticipation, but not receipt, in a mixed sample of healthy controls (HCs) and individuals with bipolar disorder (BD). Consistent with this, an alternative BAS measure (SPSRQ: Torrubia et al., 2001) was also found to correlate with striatal activation during the anticipation of monetary reward (Hahn et al., 2009). This association also seems to extend beyond the processing of monetary reward, with a positive correlation reported between BAS-D and activation of several reward-related structures in response to images of appetising foods

(Beaver et al., 2006).

The tendency of findings to support associations between BAS measures and activation during reward anticipation is consistent with the hypothesised role of the BAS, which engages in preparation to obtain rewards, but does not respond to the receipt of reward (Corr, Pickering, & Gray, 1995). This is also consistent with the idea that extraversion, a personality construct that is closely related to the BAS, is associated with the experience of greater levels of PA in response to situations and stimuli, where rewards are pursued, but not in response to pleasant stimuli, where no pursuit is required (Smillie et al., 2012).

However, counter to this, several studies have reported an association between an aggregate of the BAS subscales and activation of the VS during monetary reward receipt (Kim, Yoon, Kim, & Hamann, 2015; Simon et al., 2010). Due to the use of the aggregate BAS score, it is not possible to determine which trait or combination of BAS traits is driving this association, although another study reported a positive correlation between BAS-D and activation of the VS during monetary reward receipt (Costumero et al., 2015). Further research is required to explore the relevance of each of the BAS subscales to anticipatory and consummatory reward processing, as well as to explore potential relationships between BAS sensitivity and the neural responses to other types of reward, such as social reward. The research described here relates to either monetary or food reward, but no differentiation is made in the RST as to the type of reward that may lead to the activation of the BAS. This is explored in Chapters Five and Six.

1.6. Real-World Experience and Reward Processing.

It could be argued that fMRI tasks used to elicit reward-related activation lack ecological validity and so the findings may be of limited relevance to the real-world processing of reward. Several studies have sought to address this concern by gathering

ecologically valid measures of PA (collected over several days, as participants went about their everyday lives) and correlating them with reward related activation observed in the scanner. This measure of PA was found to correlate with striatal activation during monetary reward anticipation and receipt in adolescents (Forbes et al., 2009; Forbes et al., 2010; Olino et al., 2013). This was not surprising, considering the striatum is one of the key neural structures thought to subserve the BAS, the activation of which is associated with the experience of PA (Campbell-Sills et al., 2004; Gable et al., 2000). However, as adolescence is a time of great change, further research is required to determine whether these findings can be replicated in samples comprised of individuals at different stages in their lives, which would increase the external validity of the findings. This is examined in Chapters Four to Seven.

In addition to the relationship between everyday PA and monetary reward-related activation, it would also be interesting to explore potential associations between the neural response elicited by other reward processing paradigms, everyday PA, and other BAS relevant measures. These BAS relevant measures could focus on everyday goal pursuit, as the BAS is also thought to be responsive to goal-relevant stimuli, resulting in an increased willingness to engage in goal-directed behaviours, and experiencing positive feelings when exposed to cues of impending reward (Carver & White, 1994; Depue & Iacono, 1989). Consistent with this, previous research has demonstrated that approach goal priming is associated with activation of brain regions that have strong connections to areas involved in reward and emotion processing (Eddington, Dolcos, Cabeza, Krishnan, & Strauman, 2007; Eddington et al., 2009). Consequently, this thesis also examines relationships between everyday goal pursuit, BAS, and neural reward responses in Chapters Four to Seven. The following section focuses on the associations between BAS sensitivity, the experience of PA, and the pursuit of approach motivated goals.

1.7. Goal Pursuit.

A goal may be defined as the cognitive representation of a desirable end state, which serves to focus and guide short and long-term behaviour, so that the individual is not simply responding to current environmental contingencies (Austin & Vancouver, 1996; Elliot, 1997). Indeed, goals seem to serve as a mid-level construct situated between a motivational disposition, such as BAS sensitivity, and specific behaviours (Elliot & Church, 1998). As with motivation, goals are also thought to differ in terms of valence: approach goals focus on positive outcomes and function to move an individual towards or to maintain a desirable end-state (e.g. make new friends; Elliot, Sheldon, & Church, 1997), whereas avoidance goals are directed towards avoiding an undesirable outcome (e.g. do not embarrass myself in front of others; Elliot, 2006). As potentially rewarding life events activate the BAS and trigger approach goal striving (Depue, Luciana, Arbisi, Collins, & Leon, 1994; Johnson, 2005), the present review focuses on relationships between the BAS and approach goals pursuit.

Approach goal pursuit is thought to heighten sensitivity to the pursued reward (Harmon-Jones, Gable, & Price, 2012; Weinberg et al., 2014), encouraging the pursuit and attainment of desired goals (Gable, Hart, Threadgill, & Adams, 2015; Hart & Gable, 2013). This is consistent with findings that goal progress and goal attainment are associated with greater daily affective wellbeing, as well as greater psychosocial wellbeing across time (Brunstein, 1993; Emmons, 1996; Harris, Daniels, & Briner, 2003; Klug & Maier, 2015; Sheldon, Kasser, Smith, & Share, 2002). However, the idea that approach goal motivation relates solely to the experience of PA may not be adequate. Negative affects, such as sadness and anger, have been found to be associated with the approach motivation system, particularly when goal progress is perceived to be inadequate (Carver, 2004; Harmon-Jones, 2003). In an alternative formulation to the RST, Carver and Scheier's Control Theory (CT; 1990, 1998) posits that the approach system may also generate NA, which serves to control a sense of

urgency towards goals (Carver, 2001; Carver & Scheier, 2008). CT states that self-regulation during approach goal pursuit occurs as a result of discrepancy-reducing feedback loops, which are formed when an individual monitors the current state of the world and compares it to a salient reference value (e.g., the goal itself), adjusting behaviour to reduce the perceived discrepancy between their current state and the reference value (Carver, 2006). It is further suggested that a meta-monitoring feedback loop monitors rate of discrepancy reduction (i.e., progress towards the goal) and produces affect as an output. If approach goal progress exceeds the desired criterion, positive feelings and confidence results, whereas when progress falls below what the individual expects, the individual will experience negative feelings and doubt (Carver, 2004). This affect, in turn, acts as a way of modifying behavioural output in the service of self-regulation: NA leads to increased effort in the short-term and goal disengagement in the long-term, whilst PA leads to the decrease/reallocation of effort (Carver, Avivi, & Laurenceau, 2008).

Goal pursuit research has predominantly focused on achievement-based goals, which relate to competition with a standard of excellence, with little focus on social goals, which relate to the pursuit of interpersonal relationships. Achievement and social goals *are* similar in that both serve to energise behaviour and may serve basic psychological needs. However, the psychological needs that they relate to are likely to be different. Self-determination theory (Deci & Ryan, 1980, 1991, 2000) suggests that there are three basic psychological needs that may be satisfied by goal attainment: competence, relatedness, and autonomy. Social goals partly map onto the relatedness need, whereas achievement goals are more closely related to competence, so it is likely that approach motivation does vary across these broad classes of goal content (Elliot, Gable, & Mapes, 2006). Autonomy is more relevant to an individual's underlying reasons for striving towards a particular goal. As such, one could pursue an achievement or social goal that either does or does not satisfy the need for autonomy. Self-

determination theory would suggest that autonomous striving for achievement or social goal outcomes would enable one to satisfy multiple needs simultaneously. Approach-motivated social goals have been linked to greater subjective wellbeing (of which affect is a key factor; Elliot et al., 2006), greater satisfaction with one's social life (Gable, 2006), and stronger positive emotions (Impett, Gable, & Peplau, 2005; Impett et al., 2010). However, further research is required to determine the similarities and differences between achievement and social goal pursuit. This is explored in Chapter Two.

Approach goal pursuit has been linked to BAS sensitivity, with those scoring higher on BAS measures reporting more approach type goals (Jones & Day, 2007). As the BAS is theorised to be responsive to rewarding stimuli and is thought to elicit approach type behaviour, it may be of particular relevance to the investigation of approach goal pursuit.

1.8. BAS Sensitivity, Positive Affect, and Goal Pursuit.

BAS sensitivity has been related to the experience of both trait PA (Campbell-Sills, et al., 2004; Carver & White, 1994; Erdle & Rushton, 2010; Heubeck, Wilkinson, & Cologon, 1998; Hasler, Allen, Sbarra, Bootzin, & Bennett, 2010) and state PA measured in laboratory settings (Berkman, Lieberman, & Gable, 2009; Gable et al., 2000). However, the relationship between BAS sensitivity and state PA has not been consistently observed, with some studies reporting no relationship between BAS sensitivity and state PA assessed in both laboratory (Levinson, Rodebaugh, & Frye, 2011) and real life settings (Eddington, Majestic, & Silvia, 2012). Surprisingly, whilst high BAS sensitivity is associated with the reporting of more approach-type social and achievement goals (Jones & Day, 2007; Gable, 2006), few studies have investigated the direct relationship between BAS sensitivity and factors pertaining to goal pursuit, such as progress and effort. Greater BAS sensitivity has been found to be predictive of high arousal PA during laboratory based goal pursuit (Heimpel, Elliot, & Wood, 2006; Heponiemi et al., 2003), although in another study no significant associations were

observed between scores on the BAS subscales and real-world goal progress (Eddington et al., 2012). Taken together, the literature reviewed provides evidence that individual differences in trait approach motivation (BAS) have some association with individual differences in affective experience and goal pursuit. However, due to the inconsistencies in previous findings, further research, using ecologically valid measures, is necessary to assess the exact relationships between state PA and measures of real-world goal pursuit. This is investigated in Chapter Two.

It has been suggested that deficiency/dysregulation of the BAS underlies several different psychopathologies. Consequently, I will now review the literature concerning individual differences in BAS sensitivity, alterations in reward processing, and goal pursuit associated with two mood disorders relevant to the functioning of the BAS: depression and bipolar disorder (BD).

1.9. Unipolar Depression.

Major depression is thought to be the second leading cause of disability worldwide (Whiteford et al., 2013) and is one of the most common mental health disorders in the UK (National Institute for Health and Care Excellence, 2011). Indeed, in a recent NHS survey, 3.3% of respondents were identified with depression and 7.8% with mixed anxiety and depression (Stansfeld et al., 2016). A diagnosis of depression requires a distinct change of mood, characterised by feelings of sadness and/or irritability, accompanied by several psychophysiological changes, which can include (but are not limited to) sleep and appetite disturbances, a loss of pleasure associated with previously enjoyed activities (anhedonia), and suicidal thoughts (American Psychiatric Association, 2013; Belmaker & Agam, 2008).

Anhedonia may be defined as impairment in the ability to pursue and experience pleasure (Rømer Thomsen et al., 2015; Treadway & Zald, 2011). In order for depression to be

diagnosed, it is necessary for an individual to experience either anhedonia or prolonged low mood, so anhedonia is a key symptom of depression (Andreasen, 1982; Healey, Morgan, Musselman, Olino, & Forbes, 2014). Approximately 37% of depressed patients are thought to experience clinically significant anhedonia (Pelizza & Ferrari, 2009), and it has been found to precede the onset of a depressive episode (Dryman & Eaton, 1991) and to persist during remission (DiNicola et al., 2013). Anhedonia also seems to predict the course of depression (Spijker et al., 2001), even over a twenty-year period (Shankman, Nelson, Harrow, & Faull, 2010). Consequently, anhedonia has been identified as a potential endophenotype of depression, as it is relatively homogenous, easily quantified, and linked to dysfunction in the neural reward circuitry (Hasler, Drevets, Manji, & Charney, 2004; Hasler & Northoff, 2011; Pizzagalli, Deveney, & Christen, 2005; Wacker, Dillon, & Pizzagalli, 2009). As such, it may afford valuable insights into the mechanisms underlying depression, potentially allowing the early identification of at risk individuals, as well as providing information about the likely course of the disorder, and potentially inform the development of treatments.

Anhedonia is not unique to the experience of depression, with motivational and hedonic impairments being reported in other disorders, such as schizophrenia (Rado, 1953). Indeed, anhedonia is also a key symptom in the diagnosis of schizophrenia. Individuals with schizophrenia have been found to report higher levels of both social and physical anhedonia, as well as lower levels of PA (Blanchard, Mueser, & Bellack, 1998), whilst the experience of anhedonia is thought to increase the likelihood of developing the disorder (Meehl, 1962). However, whilst participants with schizophrenia have been found to report lower levels of pleasure (Horan, Kring, & Blanchard, 2006), other studies report no significant difference in levels of PA between participants with schizophrenia and HCs in response to emotionally evocative stimuli (Berenbaum & Oltmanns, 1992; Dowd & Barch, 2010; for reviews, see Cohen & Minor, 2010; Kring & Moran, 2008; Llerena et al., 2012) or to in-the-moment

pleasure experienced during the course of their everyday lives (Gard, Kring, Germans Gard, Horan, & Green, 2007; Oorschot, Lataster, Thewissen, Wichers, & Myin-Germeys, 2011), suggesting that the experience of consummatory pleasure remains intact. However, some studies do report an impaired anticipatory response in schizophrenia (Gard, Gard, Kring, & John, 2006; Gard et al., 2007; Wynn, Horan, Kring, Simons, & Green, 2010; Mote, Minzenberg, Carter, & Kring, 2014), although this has not been consistently reported (Treméau et al., 2010; Gard et al., 2014). However, the decision was made to focus on the experience of anhedonia associated with depression, as it represents the opposite pole to hypomania, thus enabling the present thesis to examine both extremes, particularly as there is evidence of differences in the underlying mechanisms of anhedonia associated with depression and schizophrenia (Barch, Pagliaccio, & Luking, 2016). As such, the focus will remain on anhedonia associated with depression and its association with PA, goal pursuit, and reward-related neural activation, which will be examined throughout this thesis (see below for more details of how anhedonia is measured).

BAS Deficiency in Depression. Depression has been linked to a hyporeactivity of the reward system, resulting in a generally lowered state of motivation towards appetitive stimuli (Depue & Iacono, 1989; Henriques & Davidson, 1991; Henriques, Glowacki, & Davidson, 1994; Tremblay, Naranjo, Cardenas, Herrmann, & Bushto, 2002). This is relevant to anhedonia, which Gray (1991) hypothesised to relate to decreased BAS sensitivity. As such, low BAS sensitivity is regarded as a crucial component for a vulnerability to depressive symptomatology (Clark, Watson, & Mineka, 1994; Fowles, 1993; Gray, 1994), particularly anhedonic-type symptoms (Beevers & Meyer, 2002; Depue & Iacono, 1989; Harmon-Jones & Allen, 1997; Kasch, Rottenberg, Arnow, & Gotlib, 2002; Pinto-Meza et al., 2006; Quilty, Macky, & Bagby, 2014). This is consistent with findings that those high in BAS sensitivity report lower levels of anhedonic depression and greater responsiveness to pleasurable

activities (Hundt et al., 2007; Spielberg et al., 2011). However, there is little research that investigates the relationship between BAS sensitivity and anhedonia specifically, instead predominantly focusing on associations between BAS sensitivity and the experience of depression/depressive symptoms in general. However, due to the high incidence of anhedonia in depressed individuals, research focusing on the general experience of depression is likely to be of relevance. This section provides a brief summary of previous findings concerning associations between BAS sensitivity with both depressive and anhedonic symptoms.

Measures of BAS sensitivity have been found to be negatively associated with concurrent depressive symptoms (Beavers & Meyer, 2002; Coplan et al., 2006; Jones & Day, 2008; Kimbrel et al., 2007), episode duration, and general functioning (Kasch et al., 2002). In depressed individuals, it has been demonstrated that BAS sensitivity is predictive of greater clinical improvement several months later (Campbell-Sills et al., 2004; Kasch et al., 2002; McFarland, Shankman, Tenke, Bruder, & Klein, 2006). Moreover, there is some indication that low BAS sensitivity may be a vulnerability marker associated with depression, rather than a concomitant of depressed mood state, as both depressed and remitted participants have been found to report lower BAS sensitivity compared to HCs, even when depressive/anxious symptoms are controlled for (Kasch et al., 2002; Pinto-Meza et al., 2006). However, the relationship between BAS sensitivity and depressive symptoms has not been consistently observed, with several studies reporting no significant associations between BAS sensitivity and depression/depressive symptoms (Johnson, Turner, & Iwata, 2003; Jorm et al., 1999; Muris et al., 2005). One possible explanation for these null findings is that, in these studies, no distinction was made between anhedonic depression and mixed-anxiety depression, which are theorised to differ in terms of BAS activity (with intact BAS sensitivity in the latter; Gray, 1991). More recent findings are in line with this, indicating that low BAS activity is predictive of symptoms associated with anhedonic depression, but not those symptoms

associated with mixed-anxiety depression (Kimbrel et al., 2007; Hundt, Nelson-Gray, Kimbrel, Mitchel, & Kwapil, 2007).

In terms of the neural basis of approach motivation, the left frontal cortical region is thought to be an important component of the circuitry (Davidson, 1984, 1987; Davidson, Ekman, Saron, Senulis, & Friesen, 1990; Kinsbourne, 1978). Increased activation in this region is thought to be associated with increased approach-related emotion and behaviour, whilst hypoactivation is thought to be reflective of deficits in the approach system (De Pascalis, Cozzuto, Caprara, & Alessandri, 2013; Henriques & Davidson, 1991).

Neurophysiological studies have reported decreased left frontal cortical activation in depressed (Allen, Iacono, Depue, & Arbisi, 1993; Henriques & Davidson, 1991), remitted (Henriques & Davidson, 1990), and subsyndromal samples (Davidson et al., 1987; Schaffer et al., 1983). Moreover, left cortical hypoactivation appears to remain stable across the different phases of depression (Hitt, Allen, & Duke, 1995), is seemingly independent of mood state (Gotlib, Ranganath, & Rosenfeld, 1998; Henriques & Davidson, 1991), and differentiates previously depressed euthymic participants from HCs (Allen et al., 1993; Henriques & Davidson, 1990).

Taken together, the evidence described here provides support for a BAS deficiency model of depression. If this were the case, depressed individuals would be expected to exhibit deficits in activation of the reward-related regions, which are also thought to underpin the BAS (Gray, 1987, 1990; Smillie, 2008). This has been consistently demonstrated. As such, the next section provides a brief review of neuroimaging evidence investigating reward-processing deficits in depression, particularly those associated with anhedonic symptoms.

Reward Processing. Depressed individuals have been found to exhibit a blunted neural response to reward, compared to HCs (Forbes et al., 2009; Heller et al., 2009; McCabe, Cowen, & Harmer, 2009), with studies reporting depression-related deficits in striatal

activation during both reward anticipation and receipt (Forbes et al., 2009; Keedwell et al., 2005; Pizzagalli et al., 2009; Smoski et al., 2011; Stoy et al., 2012; Ubl et al., 2015; Zhang et al., 2013). This is suggestive of deficits during both reward ‘wanting’ and reward ‘liking’. Surprisingly, when rating “in the moment” subjective enjoyment of certain types of stimuli, such as sweet tastes, little difference has been found between depressed participants and HCs (Barch & Dowd, 2010; Strauss & Gold, 2012; Treadway & Zald, 2011), although their prospective, retrospective, and hypothetical experiences have indicated less enjoyment than HCs (Strauss & Gold, 2012; Watson & Naragon-Gainey, 2009).

The reduced neural responses to reward associated with depression may have important implications for the neurobiological mechanisms that underlie anhedonia, which is also thought to reflect dysregulated reward processing (Heshmati & Russo, 2015; Russo & Nestler, 2013). Indeed, one study reported a negative correlation between anhedonia and striatal activation during monetary reward receipt, in a non-clinical sample, even after controlling for other symptoms of depression and anxiety (Wacker et al., 2009). Furthermore, a recent meta-analysis indicated that decreased activation of the caudate was associated with both anticipatory and consummatory anhedonia in depressed participants (Zhang et al., 2016). This is broadly consistent with findings of other studies, in which anhedonia was linked to a reduced striatal response to rewarding stimuli, such as positive facial expressions and pleasant images and words (Epstein et al., 2006; Keedwell et al., 2005; Stuhrmann et al., 2013).

As discussed previously, data gathered in the scanner may lack ecological validity, and it is unclear whether activation elicited to reward in fMRI tasks is of any relevance to the everyday experience of depressive symptoms. Several studies, using samples of depressed adolescents and adolescents at risk of depression, have attempted to address this question by correlating ecologically valid measures of PA (collected over a weekend and during the course of everyday life) with activation observed in the scanner, with mixed results (Forbes et

al., 2009; Olino et al., 2014). In depressed adolescents, caudate activation (during both reward anticipation and receipt), which differentiated them from HCs, was found to correlate with everyday PA (Forbes et al., 2009). This finding was not replicated in the at-risk adolescent sample (Olino et al., 2014). However, this does provide some indication that the reward-processing paradigm used captures brain function relevant to the experience of affect in depression. In addition to affect, it is interesting to consider whether neural responses to reward are related to everyday goal pursuit. This is explored in Chapters Four to Seven. The following section focuses on what is already known about the associations between depressive symptoms, particularly anhedonia, the experience of PA, and the pursuit of approach goals.

Positive Affect. Anhedonia has also been used to refer to a reduction in PA, as well as reduced pleasure and interest in daily activities (APA, 2013). In line with this, depressed individuals, compared to HCs, have been found to report significantly lower levels of state PA, assessed throughout the course of their daily lives (Barge-Schaapveld, Nicolson, Berkhof, & deVries, 1999; Bower, Bylsma, Morris, & Rottenberg, 2010; Bylsma, Taylor-Clift, & Rottenberg, 2011; Myin-Germeys et al., 2003; Peeters, Berkhof, Delespaul, Rottenberg, & Nicolson, 2003, 2006). PA has also been found to predict the prevention of and recovery from depression (Geschwind, Nicolson, Peeters, Van Os, & Wichers, 2010; Morris, Bylsma, & Rottenberg, 2009; Wichers et al., 2010). Reductions in PA also prospectively predict the duration of depression (Morris et al., 2009; Peeters, Berkhof, Rottenberg, & Nicolson, 2010; Rottenberg, Kasch, Gross, & Gotlib, 2002), whilst subjective well-being (a construct including PA and life satisfaction) predicted depression levels after ten years (Wood & Joseph, 2010), which is indicative of the importance of PA in the experience of depression.

Goal Pursuit. When considering goal pursuit, depressed individuals have been found to report fewer approach goals than HCs (Dickson & MacLeod, 2006; Dickson, Moberly,

O'Dea, & Field, 2016). As the BAS is thought to elicit approach motivation and behaviour, this is consistent with the BAS deficiency model of depression; if an individual has a hypoactive BAS, they are likely to experience less approach motivation and to strive for fewer desirable future outcomes. As approach goals and motives are associated with the frequency of positive events (Gable, 2006; Gable et al., 2000), it would follow that depressed individuals would participate in fewer positive and rewarding experiences (Hopko & Mullane, 2008), which may contribute to a lower expectation of future reward (Hopko, Armento, Cantu, Chambers, & Lejuez, 2003). Although it is unclear which would come first, this would provide an explanation of several core features of depression, such as anhedonia, hopelessness, and loss of energy (Trew, 2011).

In addition to this, the content of goals appears to be important, with persons reporting goals that were primarily concerned with achievement also reporting lower levels of PA than those who were chiefly concerned with interpersonal, intimacy goals (Emmons, 1991). This may be related to the limitations of achievement goals in satisfying the fundamental needs of relatedness, autonomy, and competence (SDT; Deci & Ryan, 1980, 1991). As such, it may be relatively more difficult to satisfy these fundamental needs whilst striving for an achievement goal, compared to an intimacy goal. Furthermore, it has also been suggested that depression may have some effect on goal effort, due to changes in appraised goal difficulty or by affecting perceptions of a goal's value (Brinkmann & Franzen, 2015; Gendolla, Brinkmann, & Silvestrini, 2012; Silvia, Nusbaum, Eddington, Beaty, & Kwapil, 2014). Indeed, previous research has demonstrated that dysphoric individuals appear to perceive easy tasks as harder, and hard tasks as unfeasible (Brinkmann & Gendolla, 2008), whilst anhedonia has been linked to diminished incentive value, whereby goals are perceived as less rewarding (Treadway & Zald, 2011), thus affecting goal effort by making the goal seem less appealing (Wright, 2008). However, there is little research focusing on social goal pursuit in depression

and further work is required to investigate potential differences associated with anhedonia specifically. This is examined in Chapter Two.

Depression is not the only mood disorder in which altered functioning of the BAS has been implicated. High BAS sensitivity has been linked to disorders characterized by elevated mood and impulsivity (Meyer et al., 1999; Meyer et al., 2001), such as BD (Alloy & Abramson, 2010; Alloy, Abramson, Urosevic, Bender, & Wagner, 2009; Depue & Iacono, 1989; Depue et al., 1987; Johnson, 2005; Urosevic Abramson, Harmon-Jones & Alloy, 2008). The following sections provide an account of how alterations in BAS functioning might lead to the experience of symptoms of BD, particularly hypomania.

1.10. Bipolar Disorder.

Bipolar disorder (BD) is thought to comprise a number of different sub-types, the most commonly recognised of which are bipolar I, bipolar II, and cyclothymia (Angst, 2013; APA, 2013; Bloch & Singh, 2007; Sadock & Ruiz, 2009; Semple & Smyth, 2013). The diagnosis of bipolar I requires the experience of at least one manic episode (in which a clear disruption of behaviour and an impairment of social functioning is observed) and, although not required for diagnosis, also often involves episodes of major depression (Goodwin, 2016). For a diagnosis of bipolar II, an individual is required to have experienced episodes of both major depression and hypomania. Hypomania refers to an elevation in mood, usually resulting in increased energy and confidence, but without the functional impairment resulting from a manic episode (Goodwin, 2016). Finally, cyclothymic individuals experience rapid fluctuations between manic and depressive symptoms, although these do not become intense enough to be diagnosed as either a manic or depressive episode. Lifetime prevalence reports suggest that around 1% of the U.S. population meet the criteria for bipolar I disorder, and around 5% meet it if the full spectrum is considered (Merikangas et al., 2011). The experience of BD is linked with an increased chance of premature mortality (either through suicide or accidental death)

and is associated with significant impairments in functioning (Calabrese et al., 2003; Dunner, 2003; Martinez-Aran et al., 2007; Osby et al., 2001). Although BD may also experience depressive episodes, the present review focuses on the experience of hypomania/mania, as these symptoms have been consistently associated with BAS hypersensitivity and the evidence regarding depression and the BAS is reviewed above (Alloy & Abramson, 2010; Depue & Iacono, 1989; Fowles, 1988; Gray, 1990).

BAS Dysregulation. It has been suggested that BD individuals experience a dysregulation of the BAS, with BAS hypersensitivity underlying the experience of hypomanic and manic symptoms. Consistent with this are findings that BAS sensitivity is associated with increased general positive affectivity (Davidson et al., 2000; Gable et al., 2000), anger/irritability (Carver, 2004; Harmon-Jones, & Allen, 1998; Harmon-Jones & Sigelman, 2001; Harmon-Jones et al., 2002), and an increased likelihood of aggressive behaviour (Wingrove & Bond, 1998), symptoms consistent with the experience of hypomania. Moreover, elevated scores on the BAS-FS and BAS-D subscales have been observed in BD individuals, compared to HCs (Alloy et al., 2008, 2009; Salavert et al., 2007; Van der Gucht et al., 2009). BAS sensitivity has also been found to predict increases in manic symptoms (Meyer et al., 2001; Salavert et al., 2007), whilst high BAS-FS scores are associated with an increased likelihood of progression from a less intense form of BD (bipolar II or cyclothymia) to the more severe form of mania, which characterises bipolar I disorder (Alloy et al., 2009, 2011). BAS sensitivity may also serve as a trait indicator of vulnerability to BD, with one longitudinal study reporting that BAS score, in a sample of BD participants, remained relatively constant despite fluctuations in mood state, over a period of two years (Meyer et al., 2001). Providing further support for this, high scorers on the Hypomanic Personality Scale (HPS; Eckblad & Chapman, 1986), a measure designed to assess hypomanic personality traits that might indicate an individual is at risk of developing BD, have also been found to report

elevated BAS sensitivity (Applegate et al., 2009; Bentall et al., 2010; Carver & Johnson, 2009; Fulford et al., 2008; Johnson & Carver, 2006; Jones et al., 2007; Jones & Day, 2008; Mansell et al., 2008; Meyer et al., 1999; Meyer & Hofmann, 2005).

As discussed previously, neuroimaging research focusing on the processing of rewarding and pleasant stimuli may be particularly pertinent to the investigation of the neural structures and responses relevant to the BAS. The following section provides a brief account of alterations in reward processing associated with BD.

Reward Processing. Consistent with the BAS dysregulation model, BD appears to be characterised by a hypersensitivity to reward-relevant stimuli, which could provide an explanation for the emotional lability and dysregulation that typify the disorder (Urošević et al., 2008). BD has also been linked to abnormally elevated reward-related neural activation (Berpohl et al., 2010; Nusslock et al., 2012). This has been demonstrated in several studies, with BD and at-risk participants (as assessed using the HPS) demonstrating greater activation of the NAcc, compared to HCs, during monetary reward anticipation (Caseras et al., 2013; Nusslock et al., 2012; O’Sullivan et al., 2011).

As active goal striving may be related to reward anticipation, the stage of reward processing that has been implicated in both neuroimaging and psychological investigations of BD (Nusslock et al., 2007; Urošević et al., 2010), the next section will provide a brief account of research pertaining to the experience of PA and goal pursuit in BD.

Positive Affect. An excess of positive emotionality is associated with increased risk and diagnosis of BD (Gruber, Johnson, Oveis, & Keltner, 2008; Johnson, Gruber, & Eisner, 2007; Watson & Naragon-Gainey, 2010), with both remitted and at-risk bipolar participants demonstrating elevated reactivity of PA to specific positive stimuli involving potential reward (Johnson et al., 2007). Furthermore, in a large sample of undergraduate students, a

relationship was found between high scores on the HPS and mean levels of PA and NA, which were found to be subject to a large amount of variability over time (Kwapil et al., 2011). However, the link between BD and PA has not been consistently observed, with one study reporting that euthymic BD individuals actually report lower scores on various items of a positive mood scale, relative to HCs (Gruber et al., 2009), whilst another found no significant differences in PA between cyclothymic participants and HCs (Havermans, Nicolson, Berkhof, & deVries, 2010).

Goal Pursuit. The elevated BAS sensitivity observed in bipolar individuals may translate into increased approach behaviour, with BD individuals demonstrating greater reward sensitivity and a reduced capacity for restraint in the pursuit of reward (Gruber et al., 2011; Gruber et al., 2008). Indeed, those at risk of mania, or with a history of mania, tend to endorse very high life ambitions (Johnson, 2005; Johnson et al., 2009), placing greater value on goals (Johnson, Ruggero, & Carver, 2005; Lam, Wright, & Smith, 2004; Meyer et al., 2001; Scott, Stanton, Garland, & Ferrier, 2000), particularly those relating to fame and fortune (Carver & Johnson, 2009; Gruber & Johnson, 2009; Johnson & Carver, 2006; Johnson et al., 2009). However, perhaps because of the observed emphasis on agentic strivings that distinguish the self from others, there has been little focus on the experience of social/interpersonal goals in BD. Although one study did report that scores on the HPS were more closely related to the experience of reward and achievement emotions, such as joy and pride, compared to more socially oriented emotions, such as love and compassion (Gruber & Johnson, 2009).

During hypomanic episodes, bipolar individuals tend to experience hyperhedonia, which involves excessive goal-directed and pleasure-seeking behaviour (Johnson, 2005; Leibenluft, Charney, & Pine, 2003), which they seem to be unable to inhibit, even after unexpectedly high rates of progress toward a goal (Fulford, Johnson, Llabre, & Carver, 2010).

In line with this, goal-striving/attainment life events, likely to lead to the activation of the BAS, have been found to increase the likelihood of hypomanic symptoms in BD individuals (Johnson et al., 2000; Johnson et al., 2008; Nusslock, Abramson, Harmon-Jones, Alloy, & Hogan, 2007), providing further support for the link between the BAS and hypomania. The link between BAS and hypomania is also supported by neurophysiological evidence, focusing on left frontal cortical activation, thought to act as a neurobiological index of BAS activity (Harmon-Jones & Allen, 1997; Sutton & Davidson, 1997). BD and cyclothymic individuals exhibit greater left frontal cortical activation, compared to HCs, when presented with difficult tasks that were associated with reward, although no differences in activation was observed in response to easy tasks associated with reward or difficult tasks associated with punishment (Harmon-Jones et al., 2008). This suggests that it is the potential for reward under challenging conditions that elicits this excessive activation of approach motivation, consistent with the BAS dysregulation model. However, it is important to note that the vulnerability to BD is a predisposition towards excessive BAS activation, not the actual dysregulation itself, which is considered the more direct precursor of mood symptoms (Alloy et al., 2012).

However, the external validity of previous research may be challenged on the basis of the age of the participants. This is reflected in the limited age range of samples used in previous research, particularly for the healthy control groups in clinical research, which has implications for the external validity, limiting the generalisability of the findings. As older adults have been found to report lower BAS scores (Jorm et al., 1999) and also exhibit structural atrophy of the caudate and a global decline in dopamine receptors in the striatum (Backman et al., 2000; Kaasinen et al., 2000; Volkow et al., 1998), sensitivity to potential age-related differences in this research area is important. This is examined throughout the thesis. Evidence related to this is briefly summarised in the following section.

1.11. Older Adults.

Older adults have been found to differ from younger adults in several aspects of emotional functioning: they report decreased experience of NA (Cartensen, Pasupathi, Mayr, & Nesselroade, 2000; Charles, Reynolds, & Gatz, 2001; Kunzmann, Little, & Smith, 2000; Mroczek, 2001), a less intense experience of PA, greater mood stability, and decreased sensation seeking (Lawton, Kleban, Rajagopal, & Dean, 1992). Furthermore, increased goal engagement has also been observed in older participants, who demonstrated a higher intensity of goal pursuit, doing more and investing more time into attaining the goal than younger adults (Riediger, Freund, & Baltes, 2005). Older adults have also been found to prioritise social reward more than younger adults, as the positive feelings associated with social contact appear to become more important (Cartensen & Turk-Charles, 1994; Cartensen, 1995; Kryla-Lighthall & Mather, 2008). Both social closeness (Cartensen, 1992), and social belongingness have been found to become more important with increasing age (Ojha & Pramanick, 2009). These effects may be explained by the Socioemotional Selectivity Theory (SST; Cartensen, 1992, 1999), which posits that as time horizons shrink with advancing age, people prioritise positive affective experience and invest more in emotionally meaningful goals and activities. In line with this, older adults are less likely to attend to negative facial expressions than to positive or neutral expressions (Mather & Cartensen, 2003), suggesting that there might be some age-related changes in emotion processing/bias. One previous study demonstrated decreased activation in limbic areas in response to emotional facial expressions (particularly the amygdala) in older compared to younger adults (Gunning-Dixon et al., 2003), although in another study increases in amygdala activation were observed in response to positively valenced images in older adults (Mather et al., 2004).

As a result of these observed differences, research into reward processing and affective experience needs to be attentive towards differences in sample characteristics that contextualise the findings.

1.12. Summary of Literature.

In summary, sensitivity of the BAS, an appetitive motivation system that is thought to elicit PA and approach motivated behaviour (Fowles, 1980; Gray, 1981), is associated with greater activation of reward-related neural circuitry (e.g., Beaver et al., 2006; Caseras et al., 2013). Furthermore, alterations in BAS sensitivity are thought to underlie the experience of several psychopathologies, including depression and bipolar disorder. Hypoactivation of the BAS has been associated with the experience of depression, and with anhedonic symptoms in particular (e.g., Pinto-Meza et al., 2006; Kasch et al., 2002). This is consistent with the reduced levels of PA (e.g., Barge-Schaapveld et al., 1999; Bower et al., 2010; Bylsma et al., 2011), lack of motivation (Trew, 2011), and deficits in neural responses to rewarding stimuli (e.g., Forbes et al., 2009; Heller et al., 2009; McCabe et al., 2009) that are associated with depression. Conversely, dysregulation of the BAS is thought to underlie the experience of bipolar disorder, with hypomanic symptoms being associated with greater BAS sensitivity (e.g., Meyer et al., 2001; Salavert et al., 2007), leading to higher levels of PA (Kwapil et al., 2011), greater emphasis on approach goal pursuit (Johnson, 2005; Leibenluft et al., 2003), and increased activation of the neural reward circuitry in response to rewarding stimuli (Berpohl et al., 2010; Nusslock et al., 2012).

1.13. Summary of Empirical Chapters.

The present research aims to add to the literature reviewed above by focusing on potential associations between trait measures of approach motivation, trait vulnerability for

hypomania, anhedonic symptoms,² and neural responses associated with the processing of different types of rewarding stimuli. Each of the studies described in the following chapters was conducted in two non-clinical samples, distinct in terms of age.

Chapter Two: The Pursuit of Everyday Goals. The focus of Chapter Two is on the everyday experience of PA and characteristics relating to the pursuit of long and short-term, social and achievement goals, using a method of data collection high in ecological validity (ESM). Potential associations were then investigated between measures of these constructs and trait measures of approach motivation and hypomania, as well as with anhedonic symptoms. The chapter concludes with an exploratory analysis of whether these trait measures serve to moderate the relationship between particular momentary associations among aspects of achievement and social goal pursuit and PA.

Chapter Three: General Scanning Procedure. Chapter Three provides an outline of the MRI scanning procedure followed in Study One and Two.

Chapter Four: Neural Responses to the Anticipation and Receipt of Monetary Reward. Chapter Four concerns neural activation associated with the (more motivational) anticipatory and the (more hedonic) consummatory processing of monetary reward. In a more tightly controlled functional MRI study, potential links are explored between neural responses to reward and the trait measures described above (approach motivation and hypomania) and anhedonic symptoms. Also examined are associations between neural responses to reward and the ecologically valid measures of PA and achievement goal pursuit gathered in the studies described in Chapter Two.

² The measure of anhedonia used in the present study, the MASQ-AD lies somewhere between a state and trait measure, as it focuses on the experience of anhedonic symptoms in the preceding two weeks. However, it has been reported that less than 25% of the variance in MASQ-AD score is attributable to state fluctuations in anhedonic symptoms (Kendall et al., 2016). As a result of this, the present research will treat the MASQ-AD scale as equivalent to a trait measure, whilst also being mindful that anhedonic symptoms fluctuate somewhat.

Chapter Five: Neural Responses to Social Reward. Chapter Five extends the focus from monetary reward to stimuli relevant to social reward. This chapter explores potential associations between neural activation in response to happy facial expressions, thought to serve as a social reward, and the aforementioned trait (approach motivation and hypomania) measures, anhedonic symptoms, and measures of everyday PA and social goal pursuit.

Chapter Six: Neural Responses to Pleasant Images. Chapter Six builds on the work outlined in Chapter Four by distinguishing between responses to rewarding stimuli representing distinct types of PA. This chapter therefore focuses on neural responses to affiliation-related “contentment” images, expected to be more socially rewarding, and “excitement” images, expected to be more generally rewarding. Associations were examined between these neural responses and the trait measures (approach motivation and hypomania), anhedonic symptoms, as well as with the measures of everyday PA and both social and achievement goal pursuit.

Chapter Seven: Associations Across Reward Domains. Chapter Seven examines patterns of associations between neural responses across reward paradigms and domains, as assessed in Chapters Four – Six. This allows the investigation of whether there is some overlap in the activation of reward-related brain structures in response to different rewarding stimuli.

Chapter Eight: General Discussion. Chapter Eight integrates the findings reported in the previous chapters, providing a discussion of the potential theoretical and clinical implications of the present research, what they contribute to the literature described above, a review of key limitations, and concludes with ideas for future research.

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Chapter II: The Pursuit of Everyday Goals.

2.1. Introduction.

2.1.1. Goal Pursuit.

A goal can be defined as a cognitive representation of a desirable end state, used to focus and guide behaviour (Austin & Vancouver, 1996; Elliot, 1997). Goals are hierarchically organized in networks that include broad, abstract goals (e.g., “Be a sassy woman”) and specific, concrete goals (e.g., “Write 500 words every day”); Carver & Scheier, 1998). Personal goals constitute the meaningful pursuits that individuals construe for themselves during everyday life (Brunstein, 1993), serving as a mid-level construct situated between motivational disposition and specific behaviours (Elliot & Church, 1998). In this way, goals provide a more concrete representation of an individual’s abstract motivational disposition (Cattell, 1957; Emmons, 1989; McClelland, 1951; Nuttin, 1984). As such, goals are thought to directly regulate behaviour, whereas motivational disposition exerts more of an indirect influence (Carver & Scheier, 1981; Powers, 1973). Whether consciously or not, individuals are constantly engaged in the pursuit of personal goals (Chartrand, Dalton, & Cheng, 2008) and, as a result of this are engaged in a continuous process of self-regulation in order to increase the chances of attaining their goals (Carver & Scheier, 1998).

Achievement goals relate to competition with a standard of excellence (Atkinson, 1957; McClelland, Atkinson, Clark, & Lowell, 1953), whereas social goals are more concerned with the pursuit of interpersonal relationships (Gable, 2006). Social goals can refer to a specific relationship (e.g., spend more time with a partner), or they can be more general (e.g., make new friends; Gable & Berkman, 2008). Across both achievement and social domains, there are held to be two types of goals: approach goals and avoidance goals (Elliot

& Thrash, 2002). Approach goals focus on positive outcomes and serve to move the person towards or to maintain a desirable end state, whilst avoidance goals focus on negative outcomes and moving the person away from undesirable end states (Elliot et al., 1997). With regards to social goals, approach goals are motivated by the need for affiliation and social avoidance goals are motivated by a fear of rejection (Gable, 2006; Mehrabian, & Ksionzky, 1974; Russell & Mehrabian, 1978). Approach goal pursuit is thought to heighten sensitivity to the pursued reward (Harmon-Jones et al., 2012; Weinberg et al., 2014) and is associated with the experience of PA (Carver & Scheier, 1998; Gable & Harmon-Jones, 2011), which encourages the pursuit and attainment of desired goals (Gable et al., 2015; Hart & Gable, 2013). Furthermore, individuals who report more approach goals also tend to report lower levels of depression and NA and higher levels of psychological wellbeing (Coats et al., 1996; Sideris, 2005). This also seems to extend to the social domain, with research demonstrating that, compared to avoidance social goal pursuit, approach motivated social (friendship) goal pursuit is a positive predictor of subjective wellbeing (Elliot et al., 2006), less loneliness and greater satisfaction with one's social life (Gable, 2006), and stronger positive emotions (Impett, Gable, & Peplau, 2005). Furthermore, one study demonstrated that those partners who reported a greater number of approach-type relationship goals, were rated as being more satisfied, as well as demonstrating the tendency to experience greater positive emotion, in comparison to those partners who reported fewer approach type goals (Impett et al., 2010).

Achievement and social goals may both be defined in terms that are consistent with the BAS in Gray's RST (i.e., approach/avoidance; Gray, 1982). The present research focuses on relationships between trait approach motivation and hypomania, as well as anhedonic symptoms and the pursuit of achievement and social approach goals in everyday life.

2.1.2. BAS Sensitivity.

The RST (Gray, 1973, 1991), an influential model of motivation, suggests that there

are three motivational systems: the BAS, the BIS, and the FFFS (see Chapter One for a more detailed description). The BAS, activated by signals of reward is an approach-related, positive reinforcement motivational system, associated with the experience of PA (Gray, 1981).

Consistent with this, higher BAS sensitivity has been linked to both trait PA (Campbell-Sills, et al., 2004; Carver & White, 1994; Erdle & Rushton, 2010; Heubeck et al., 1998; Hasler et al., 2010) and state PA, measured in a laboratory setting (Berkman et al., 2009; Gable et al., 2000; Heimpel et al., 2006). However, the association between BAS sensitivity and state PA has not been consistently reported (Eddington et al., 2012; Levinson et al., 2011).

The circumplex model of affect, a leading model of emotion, posits that all affective states arise from a linear combination of valence and arousal (Posner et al., 2005; Russell, 1980; Russell, Weiss, & Mendelsohn, 1989). In this context, valence refers to the hedonic tone of the subjectively experienced emotion (e.g., pleasant or unpleasant; Colombetti, 2005; Russell, 2003), whilst arousal relates to the emotional intensity (Malhi, Lagopoulos, Sachdev, Ivanovski, & Shnier, 2005). As such, emotions and emotional stimuli should be differentiable in terms of both valence and arousal. For example, happiness and fear differ in valence, but are both high in arousal, whereas happiness and calmness differ in terms of arousal, but are both positively valenced (Spielberg et al., 2010). This is particularly relevant because many studies in this research area focus on the experience of high arousal PA, using high arousal adjectives, such as alert and inspired in order to assess links between BAS sensitivity and PA (e.g. Campbell-Sills et al., 2004; Gable et al., 2000). The BAS is also thought to regulate appetitive motivation and goal directed behaviour, with an association being found between greater BAS sensitivity and the number of approach type goals set (Jones & Day, 2007), as well as greater valuation of these goals (Alloy et al., 2009). Consistent with this, BAS sensitivity has been found to predict affective responses to cues of impending reward (in this case, extra experimental points; Carver & White, 1994), and the receipt of reward (De

Pascalis et al., 2010; Germans & Kring, 2000). Furthermore, BAS sensitivity, assessed using the BAS scales (Carver & White, 1994) has also been linked with greater levels of state PA during a lab-based goal pursuit task, with an association emerging between a measure of high arousal PA (consisting of ratings in response to adjectives such as vigorous, peppy, and lively) and appetitive goal pursuit (Heponiemi et al., 2003). BAS sensitivity is also relevant to social goals; a moderate association has been observed between the number of approach motivated social goals reported by individuals and BAS score (Gable, 2006).

There has been debate as to whether the BAS is exclusively linked to the experience of PA, as NA has also been linked to the functioning of the approach system. BAS sensitivity and left frontal cortical activation (thought to serve as a neurobiological index of approach motivation) have both been linked to measures of state and trait anger (Harmon-Jones, 2003; Harmon-Jones & Allen, 1998; Harmon-Jones & Sigelman, 2001; Harmon-Jones et al., 2002). Furthermore, significant associations have also been reported between the BAS-FS subscale and sadness following frustrative non-reward, as well as between BAS-RR and anger in response to a scenario to which an anger response would be plausible (Carver, 2004). This is consistent with the Control Theory model of motivation (see Chapter One for description; Carver & Scheier, 1990), which states that the experience of emotion is contingent upon ongoing feedback about goal progress.

As reviewed in Chapter One, converging evidence suggests that depression is characterised by a specific pattern of deficits in approach related behaviour (Arnett et al., 1997; Rosenbaum et al., 2000), whilst the experience of hypomania and mania is typified by dysregulation in both trait and state approach motivation (Alloy & Abramson, 2010; Alloy et al., 2009; Johnson, 2005; Urosevic et al., 2008). As such, a brief review of the evidence pertaining to BAS-related constructs, such as PA and goal pursuit, and the experience of depression and BD will be provided in the following sections.

2.1.3. A BAS Deficiency Model of Depression.

BAS hyporeactivity has been linked to disorders in which an individual might experience low mood, withdrawal, and decreased goal striving/pursuit (Campbell-Sills et al., 2004). Depression is often characterised by a lack of motivation and interest in daily activities, leading to the suggestion that symptoms stem from a lack of engagement in goal-directed and positively reinforcing behaviours (Jacobson, Martell, & Dimidjian, 2001; Lewinsohn & Graf, 1973). Low BAS sensitivity is regarded as a crucial component for a vulnerability to depressive symptomatology (Clark et al., 1994; Fowles, 1993; Gray, 1994), particularly anhedonia (Beevers & Meyer, 2002; Depue & Iacono, 1989; Harmon-Jones & Allen, 1997; Kasch et al., 2002; Pinto-Meza et al., 2006; Quilty et al., 2014), which is a defining symptom of depression (Andreasen, 1982; Healey et al., 2014; see Chapter One, for a more detailed discussion of depression-related anhedonia). Consistent with this, low BAS sensitivity has been reliably found to be cross-sectionally associated with depressive symptoms (Beevers & Meyer, 2002; Coplan et al., 2006; Depue et al., 1987; Jones & Day, 2008; Kimbrel et al., 2007; Meyer et al., 1999), as well as being prospectively predictive of both the severity and course of depression (Kasch et al., 2002; McFarland et al., 2006). However, whilst the literature is predominantly consistent, several studies have found no significant association between BAS sensitivity and depression/depressive symptoms (Johnson et al., 2003; Jorm et al., 1999; Muris et al., 2005), although these studies made no distinction between anhedonic and mixed-anxiety depression. This distinction is important because, according to the RST, mixed-anxiety, or anxious depression, differs from anhedonic depression in terms of BAS activity, with anhedonic depression thought to relate more to low BAS activity, whilst anxiety is more closely related to high BIS activity (Gray, 1991). This is supported by the findings that low BAS sensitivity is predictive of anhedonia, but is not related to mixed anxiety symptoms of depression (Hundt et al., 2007; Kimbrel et al., 2007).

BAS sensitivity has also been demonstrated to be predictive of the intensity of the positive emotional reaction to an incentive, along with the degree of effort exerted to obtain this reward (Carver & White, 1994; Gray, 1994). This lack of response to rewarding stimuli may lead to both reduced enjoyment and limited exposure to positive experiences (Beevers & Meyer, 2002), due to difficulties in becoming active and decreased motivation to engage in such experiences (Carver & White, 1994). Indeed, the limited exposure to pleasant events is considered a key risk factor for depression (Beevers & Meyer, 2010), with depressed individuals also being found to report lower pleasure levels during pleasant events (Bylsma et al., 2011; Peeters et al., 2003). Furthermore, depression severity has been linked to recall of fewer positive experiences (MacLeod, Tata, Kentish, & Jacobsen, 1997) and attenuated anticipation of future positive events (Abramson, Metalsky, & Alloy, 1989; MacLeod et al., 1997; MacLeod, Pankhania, Lee, & Mitchell, 1997). In addition to this, consistent with the association between approach goals and the reported frequency of positive events (Gable, 2006; Gable et al., 2000), it has been found that individuals who report a greater number of approach goals tend to have lower levels of self-reported depressive symptoms (Coats, Janoff-Bulman, & Alpert, 1996; Sideridis, 2005), whereas dysphoric and depressed individuals have been found to report fewer approach-type goals than non-depressed individuals (Dickson & MacLeod, 2006; Dickson et al., 2016). This is in line with the finding that depressed participants who reported fewer approach goals demonstrated greater symptomatic improvement than those with a greater number of approach type goals, following a period of self-system therapy (SST; Vieth et al., 2003) that aims to identify and correct approach goal deficits (Eddington, Silvia, Foxworth, Hoet, & Kwapil, 2015; Strauman et al., 2006).

Neurophysiological evidence also provides support for a BAS deficiency model of depression. A pattern of decreased left frontal cortical activation (a neurobiological marker of approach motivation) has been reported in depressed, subsyndromal, and remitted individuals,

relative to HCs (Allen et al., 1993; Davidson et al., 1987; Henriques & Davidson, 1990, 1991; Schaffer et al., 1983). This pattern of hypoactivation seems to be a stable characteristic, remaining unchanged across the different phases of depression (Hitt et al., 1995), seemingly independent of mood state (Gotlib et al., 1998; Henriques & Davidson, 1991), and enabling the differentiation of previously depressed euthymic participants from those with no history of depression (Allen et al., 1993; Henriques & Davidson, 1990), although it does not seem to be predictive of the course of depression (Allen et al., 2004; McFarland et al., 2006).

2.1.4. A BAS Dysregulation Model of Bipolar Disorder.

As described previously, the BAS, activated by goal or reward relevant stimuli, is implicated in the regulation of appetitive motivation and goal-directed behaviour and is associated with increased effortful approach goal pursuit (Davidson, 1999; Depue & Iacono, 1989). Consequently, greater BAS sensitivity has been linked to disorders that are characterised by elevated mood and impulsivity (Meyer et al., 1999; Meyer et al., 2001), such as BD (Alloy & Abramson, 2010; Alloy et al., 2009; Depue & Iacono, 1989; Depue et al., 1987; Johnson, 2005; Urosevic et al., 2008). This forms the basis of the BAS dysregulation model of BD, which posits that bipolar individuals have a hypersensitive BAS that becomes dysregulated easily, resulting in high levels of variability in state levels of BAS activation over time and across situations (Alloy et al., 2009; Depue & Iacono, 1989; Depue et al., 1987; Johnson, 2005; Urosevic et al., 2008). Consistent with this model, elevated scores on the BAS-FS and BAS-D subscales have been observed in BD individuals (Alloy et al., 2008, 2009; Meyer et al., 2001), with BAS score being found to be predictive of increases in manic symptoms (Meyer et al., 2001), even when controlling for mood symptoms (Salavert et al., 2007). Furthermore, BAS sensitivity was also found to predict a shorter time to the onset of hypomanic/manic symptoms in BD participants (Alloy et al., 2008a), whilst high scores on the BAS-FS subscale predicted an increased likelihood of participants with a less intense form

of BD (bipolar II or cyclothymia) developing the more severe bipolar I disorder (Alloy et al., 2012). High BAS sensitivity has also been identified as a potential marker of trait vulnerability marker for BD, with at-risk individuals reporting greater BAS sensitivity (Applegate et al., 2009; Carver & Johnson, 2009; Fulford et al., 2008; Johnson & Carver, 2006; Jones et al., 2007; Jones & Day, 2008; Mansell et al., 2008). This is consistent with the findings of several longitudinal studies, which found that high BAS individuals were significantly more likely to meet the diagnostic criteria for BD than moderate BAS individuals (Alloy et al., 2006), as well as being more likely to receive a diagnosis of BD in the future (Alloy & Abramson, 2009).

During a hypomanic episode, an individual experiences hyperhedonia, which involves excessive goal-directed and pleasure-seeking behaviour (Johnson, 2005; Leibenluft et al., 2003). Individuals with bipolar disorder exhibit more ambitious goal setting than controls, particularly for goals involving popular fame and financial success (Carver & Johnson, 2009; Gruber & Johnson, 2009; Johnson & Carver, 2006; Johnson et al., 2009; Johnson et al., 2005; Meyer & Krumm-Merabet, 2003), as well as more positive appraisal of major personal goals (Meyer, Beevers, & Johnson, 2004). Additionally, those with BD have also been found to exhibit greater increases in confidence as a result of small successes (Eisner, Johnson, & Carver, 2008), interpreting their moods as a sign that they are able to accomplish more (Jones et al., 2006). Furthermore, BD individuals have been found to be less likely than controls to decrease their goal-striving efforts after unexpectedly high progress toward a goal (Fulford et al., 2010). Indeed, high achievement striving predicted increases in manic symptoms over six months (Lozano & Johnson, 2001), patterns that are consistent with BAS hyperactivity (Depue et al., 1987; Depue & Iacono, 1989; Fowles, 1988; Gray, 1994). Greater valuation also appears to be placed on goal attainment, which is viewed as being central to the self-worth of the individual with BD (Alloy et al., 2009; Fulford et al., 2009; Lam et al., 2001,

2004; Scott et al., 2005). This increased goal valuation has not been found to be affected by mood inductions in remitted bipolar participants (Wright, Lam, & Newsom-Davis, 2005) and is also observed in sub-syndromal participants (Morrison et al., 2003), which would suggest that this is a stable trait and not the consequence of a hypomanic episode, although it is possible that this could be a “scar” from previous hypomanic episodes. Considering the implication of the BAS in goal-directed behaviour, this research is consistent with a BAS dysregulation model of bipolar disorder.

Life events that involve goal-striving and goal-attainment, likely to lead to the activation of the BAS, have also been found to significantly increase the likelihood of manic symptoms in bipolar I participants (Johnson et al., 2000; Johnson et al., 2008) and bipolar II/cyclothymic participants (Nusslock et al., 2007). The experience of new hypomanic symptoms in BD participants, but not HCs, was found to be significantly associated with a goal striving event (Nusslock et al., 2007). The same pattern was not observed for depressive symptoms, which suggests that the activation associated with a goal-striving event might be what pushes a vulnerable individual into a hypomanic or manic episode (Johnson et al., 2000, 2008; Nusslock et al., 2007). The idea that experiencing a goal striving event would be the trigger for a hypomanic or manic episode is consistent with the neurobiological research in this area. As described previously, left frontal cortical activity seems to be a neurobiological index of BAS activity (Harmon-Jones & Allen, 1997; Sutton & Davidson, 1997), and the experience of mania is associated with increased activity in this area (Harmon-Jones et al., 2002; Kano, Nakamura, Matsuoka, Iida, & Nakajima, 1992). Furthermore, it appears to be particularly challenging and rewarding events that activate the reward circuitry in bipolar II and cyclothymic participants (Harmon-Jones et al., 2008). BD participants exhibited similar levels of left frontal cortical activation as HCs in response to easy tasks or difficult tasks associated with punishment, but when presented with difficult tasks that were associated with

reward, BD participants demonstrated greater left frontal cortical activation than HCs, which is in line with the BAS dysregulation model.

2.1.5. Key Aims.

As discussed in the literature review, BAS sensitivity has been associated with the experience of both anhedonic and hypomanic symptoms, particularly when considered in relation to goal striving and motivation. However, to the best of my knowledge, no study has focused on potential associations between BAS sensitivity, anhedonic and hypomanic symptoms, and the everyday experience of PA and goal pursuit in achievement and social domains. Considering the disparity in findings relating to the relationship between BAS sensitivity and PA, as well as the limited focus on active goal pursuit in the literature, the present investigation is likely to add a valuable contribution to the literature. The present research had three key aims:

1. The investigation of correlations between trait measures of approach motivation (BAS sensitivity), hypomania, and anhedonic symptoms, with real-world PA and measures of long-term (LT) and short-term (ST) social/achievement goal pursuit.
2. The investigation of how these trait measures may moderate the relationship between the everyday experience of PA and social and achievement goal progress.
3. The investigation of the previously described associations in two non-clinical³ samples, distinct in terms of age.

³ Details of clinical diagnoses were not collected from the participants, so some participants may have had a clinical diagnosis. The MASQ-AD subscale, the measure of anhedonia in the present research, has been demonstrated to have good predictive utility for depression (Buckby, Yung, Cosgrave, & Killackey, 2007). In accordance with their suggested cut-off, six participants (10%) in each sample reported scores higher than 76 on the MASQ-AD. Additionally, the community sample also completed the Patient Health Questionnaire (PHQ-9; Kroenke, Spitzer, & Williams, 2001), for which a cut-off of 10 has been suggested for the diagnosis of depression, with a recent meta-analysis reporting that cut-off scores of 8-11 had acceptable diagnostic properties for the detection of depression (Manea, Gilbody, & McMillan, 2012). In the community sample, seven (11.67%) participants scored 10 or more on the PHQ-9, which is in line with predictions using the MASQ-AD, whilst a further eleven (18.3%) reported scores between 5-9, which would be indicative of mild depression.

2.1.6. Study Rationale.

Positive Affect and Goal Pursuit. As previously discussed, personal goals are a key concept in providing a bridge between general motivational dispositions and behaviour (Emmons, 1986; Sherratt & MacLeod, 2013). Additionally, the experience of affect plays a key role in motivated behaviour (Carver & Scheier, 1998), conveying information about goal progress (Carver, 2001), and controlling a sense of urgency towards goals (Carver & Scheier, 2008). Taken together, it is not surprising that affect appears to be closely associated with goal pursuit, with perceived progress towards goals being found to be predictive of SWB (Brunstein, 1993), although PA is only one component of wellbeing. In addition to this, one study reported that daily reports of progress towards a personally relevant goal were associated with increased PA, regardless of levels of pain and fatigue, in a sample of fibromyalgia patients (Affleck et al., 1998). This is consistent with the findings of a similar study that reported an association between PA and the attainment of work goals, with the relationship being stronger for more important goals (Harris, Daniels, & Briner, 2003). Due to this association between the experience of PA and goal pursuit in everyday life, it is interesting not only to assess the relationships between these constructs, but also potential associations with measures of BAS sensitivity, anhedonia, and trait hypomania. As such, the present research investigated the associations between constructs relating to approach motivation (BAS-FS, BAS-RR, and BAS-D) and anhedonia (MASQ-AD). Furthermore, anhedonia and hypomania are thought to represent opposite poles in terms of PA and approach motivation, the decision was made to introduce a measure of trait hypomania (HPS) in Study Two. Thus, an attempt was made to increase understanding of the motivational facets of anhedonia and trait hypomania by examining associations with the everyday pursuit of personally relevant, achievement and social goals, rather than responsivity to rewarding stimuli, or progress associated with experimenter-set goals.

The present research also aimed to extend the literature in terms of the types of goal investigated, as well as the measures used to investigate them. First, the investigation included both social and achievement based goals, whereas previous research (e.g. Eddington et al., 2012; Dickson et al., 2016) has not explicitly focused on social goal pursuit. Although social and achievement goals are similar in that they both may fulfil basic psychological needs for relatedness and competence, which serve to energise the behaviour of an individual (Deci & Ryan, 2000; Elliott et al., 2002), research should consider whether characteristics of these goals have similar associations with individual difference variables. Little research has focused on the pursuit of social goals, and, to the best of my knowledge, no investigation has been conducted into potential associations between the pursuit of social goals and measures of anhedonia and hypomanic traits, despite the finding that social relationship difficulties have been linked to a range of psychopathologies, including depression, anxiety, and substance abuse (Davila, Bradbury, Cohan, & Tochluk, 1997; Whisman, 2001; Whisman, Uebelacker, & Settles, 2010).

The present investigation also focused on goals that require different amounts of time to attain and thus varying degrees of sustained effort to achieve them. In this case, a long-term (LT) goal was considered to be anything that would take longer than seven days to achieve, whereas a short-term (ST) goal was considered to be something that could be attained within one day. Although previous research (e.g., Affleck et al., 2008) has investigated the pursuit of daily goals, little has been made of this distinction, which is surprising as the achievement of ST goals are likely to be a more regular source of positive reinforcement. Also, more ST goals may have more concrete action steps associated with them such that they are easier to self-regulate towards (Carver & Scheier, 1998). LT goals are also more central to the self-concept (Powers, 1973) and are more aligned with a sense of meaning and enduring purpose. Goals have previously been investigated as more dispositional personal strivings (Emmons, 1986) or

more low-level personal projects (Little, 1983), so it is useful to investigate goals at different levels of abstraction. In addition to this, the measures of goal pursuit used in the present research are also likely to provide a greater understanding of goal pursuit, as instead of just focusing on the progress one makes towards achieving a goal, the degree of effort exerted in order to achieve the goal was also considered, taking into account the possibility that one might be striving towards completion of the goal, but actually making very little headway in terms of progress. There is some evidence that whilst depressed participants felt like they were exerting more effort, during a handgrip task, objectively they did not exert any more effort than HCs (Cléry-Melin et al., 2011). Furthermore, the reduced anticipation of positive future events has also been associated with a lower willingness to expend effort (Treadway et al., 2012), a finding that was also replicated in a sub-syndromal population, in whom the willingness to expend effort was found to correlate with self-reported anhedonia (Yang et al., 2012). Taken together, this would suggest that depression might be related to both a decreased willingness to expend effort, and an exaggeration of how much effort is expended during goal pursuit. Conversely, those with BD, or are at risk of BD tend to demonstrate greater sustained effort towards goals after an initial success (Johnson, Edge, Holmes, & Carver, 2012). BD individuals have also been found to expend more effort in conditions involving reward (Johnson et al., 2012), although this seems unique to conditions involving reward. For example, BD participants completed a card-sorting task faster than HCs when a reward was at stake, but no faster in the non-reward conditions (Hayden et al., 2008). BD individuals also appear to experience increases in energy and effort after success compared to others (Fulford et al., 2010), responding to a thwarting of goals with an increase in approach engagement (Harmon-Jones et al., 2008; Wright, Lam, & Brown, 2008). Finally, as participants were not asked to consider goal progress when rating their levels of PA, I also

included a measure designed to directly assess the positive feelings (pleasure) associated with making progress.

As previous research concerning the trait measures (BAS sensitivity, anhedonia, and hypomania) has been predominantly assessed in a laboratory setting. The present research aims to increase ecological validity and reduce retrospective recall bias by using Experience Sampling Methodology (ESM).

Experience Sampling. ESM is used to explore subjective experiences as they occur during the course of an individual's everyday life (Telford, McCarthy-Jones, Corcoran, & Rowse, 2011; de Vries, 2006), providing ecologically valid accounts of real-life affect and behaviour (Hurlbert, 1997). The resulting rich data allow the researcher to investigate everyday experiences, potentially providing a way to explore spontaneously occurring thoughts and feelings, which would not otherwise be detected by retrospective self-report measures (Telford et al., 2011). This is particularly useful as many symptoms of psychopathology are dynamic (Ebner-Priemer & Trull, 2009). ESM has been consistently demonstrated to be more reliable than retrospective self-report (Ben Zeev et al., 2009; Csikszentmihalyi & Larson, 1987, 2006; Stone et al., 1998), with key advantages including a reduction in memory bias (Bolger, Davis, & Rafaeli, 2003) and enabling the researcher to obtain measures of life as it is lived in the "real world". This is particularly important when focusing on the investigation of psychopathology, as there is considerable evidence that individuals with mental health difficulties, particularly depression, are more likely to recall negative, rather than positive experiences, and therefore may give biased accounts of their everyday experience (Fritsche et al., 2010; Lepage, Sergerie, Pelletier & Harvey, 2007; Ben Zeev et al., 2009; Barge-Schaapveld et al., 1999; Myin-Germeys et al., 2003; Peeters et al., 2003, 2006; Bower et al., 2010).

In the present research, ESM was used to provide a naturalistic measure of momentary affect and goal-focused cognitions/behaviour of participants as they pursued personally relevant goals in everyday life. This provided greater insight into the everyday experience of pursuit of both short and longer-term goals (which require more of a sustained effort), levels of PA, and potential relationships with BAS sensitivity, anhedonia, and trait hypomania, which, to the best of my knowledge, has not been examined in previous research.

Distinct Samples. The majority of research focusing on anhedonic and hypomanic symptoms has focused on clinical samples, recruiting from treatment or institutional settings. Difficulties with personality may increase the likelihood of treatment seeking and so clinical samples might over-represent participants with maladaptive traits (Cohen & Cohen, 1984). The present research addresses this by focusing on the measurement of individual differences in two distinct samples, younger adults recruited from the student body (Study One) and older adults recruited from the wider community (Study Two). The samples recruited were distinct in terms of age, as there is considerable evidence that older and younger adults may differ in terms of their experience of affect, emotion regulation, and goal pursuit. For example, there is some evidence suggesting that older individuals might be more engaged in goal pursuit than younger adults, demonstrating a higher intensity of goal pursuit (Riediger et al., 2004), although BAS score has been found to decline with age (Jorm et al., 1999). Additionally, emotional experience has been found to be more positive with age (Cartensen et al., 2000; Cartensen et al., 2011; Ross & Mirrowsky, 2008). Older adults experience significantly greater levels of low arousal PA (e.g., calm, peaceful), but no differences in high arousal PA (Scheibe, English, Tsai, & Cartensen, 2013), whilst their focus seems to be maintaining PA, but not enhancing it (Riediger, Schmiedek, Wagner, & Lindenberger, 2009). A widely accepted explanation for this is the Socioemotional Selectivity Theory (SST; Cartensen, 1992, 1999), which posits that as people get older and perceive their lifetime as being more limited,

they become more motivated to experience positive and meaningful emotional states in the current moment, as well as being more likely to prioritise hedonic goals that satisfy psychological needs for relatedness, focusing their goals on more intrinsic values, such as community involvement (Sheldon & Kasser, 2001). Finally, when considering the experience of depressive symptoms, it has been observed that older individuals tend to report lower levels of dysphoria and worthlessness/guilt (Gallo et al., 1994), but there is a higher incidence of the experience of hopelessness, fatigue, and a loss of interest (Christensen et al., 1999), symptoms consistent with the experience of anhedonia. Furthermore, students are likely to be in a more restricted 'life-space' (both institutionally and in terms of life stage), which may homogenise the goals that they report in studies where they are asked about individual strivings. Taken together, the disparities in the experience of affect and goal pursuit between older and younger adults would suggest that there may be differences in the relationships expected between measures of BAS sensitivity, anhedonia, and hypomania and the everyday experience of affect and goal pursuit. As such it is important to assess whether the associations observed in younger adults remain stable across age groups and expanding to wider community may provide external validity in terms of establishing relationships for the more diverse goals reported by this population.

2.1.7. Hypotheses.

Trait Measures. It was predicted that the BAS subscales (BAS-FS, BAS-RR, and BAS-D) would strongly positively intercorrelate. Previous findings, using Confirmatory Factor Analysis (CFA), demonstrated that the subscales are closely related, despite representing distinct constructs (Heubeck et al., 1998; Leone, Perugini, Bagozzi, Pierro, & Mannetti, 2001; Ross, Millis, Bonebright, & Bailley, 2002). A negative correlation was expected between MASQ-AD and each of the BAS subscales, as, conceptually, BAS should be inversely related to anhedonia, and BAS sensitivity has been found to negatively predict

depressive symptoms (e.g., Coplan et al., 2006; Jones & Day, 2008; Kimbrel et al., 2007). These associations were expected in both the student and community samples. Additionally, positive correlations were expected between HPS (which was only completed by the community sample) and the BAS subscales because high levels of BAS sensitivity are thought to underlie hypomania (e.g., Applegate et al., 2009; Carver & Johnson, 2009; Fulford et al., 2008). Conversely, a negative correlation was expected between HPS and MASQ-AD, because anhedonia and mania represent opposite poles in terms of PA and approach motivation.

Trait Measures and ESM Measures: Between-Person Associations. It was predicted that mean levels of state PA would correlate positively with each of the BAS subscales, as BAS strength was originally defined as the degree of PA experienced in response to reward (Carver & White, 1994; Campbell-Sills et al., 2004), with significant associations being demonstrated between BAS sensitivity and state PA (Berkman et al., 2009; Gable et al., 2000). A positive correlation was also expected between HPS and PA as significant associations have previously been reported between the HPS and PA (Kirkland, Gruber, & Cunningham, 2015; Meyer & Hofmann, 2005), with high levels of PA being associated with hypomania (Gruber et al., 2008; Hofmann & Meyer, 2006). Furthermore, conceptually, the HPS was designed to identify those individuals who were optimistic, self-confident, and energetic (Eckblad & Chapman, 1986), which are traits consistent with high PA. A negative correlation was expected between mean reported PA and MASQ-AD, as the experience of anhedonia is generally associated with a low level of PA (Germans & Kring, 2000).

The measures of goal progress and effort (LT/ST and *achievement/social*) were expected to positively correlate with BAS-D, which assesses the motivation to pursue goals or to obtain rewards, whilst pleasure associated with goal progress was expected to correlate

positively with BAS-RR, which measures the responsiveness to any feedback about progress towards goals. The same relationships were expected to emerge for both the ST and LT goal measures, as it is likely that both reflect broader social and achievement motivation (McClelland, 1985). However, no significant associations were expected to emerge between the goal pursuit measures and BAS-FS, which was designed to measure the tendency to seek out and impulsively approach potentially rewarding activities (Beck et al., 2009; Johnson et al., 2005) and thus is not likely to be conducive to (and may even distract from) goal pursuit.

HPS was expected to correlate positively with ST and LT *achievement* goal progress, effort, and associated pleasure, as hypomania is associated with excessive goal pursuit (Johnson, 2005; Leibenluft et al., 2003), whilst goal-striving events have been associated with hypomanic symptoms (Johnson et al., 2000, 2008; Nusslock et al., 2007). However, no associations were predicted between HPS and the measures of LT/ST *social* goal pursuit. This was based on the preoccupation with achievement-based goals concerning fame⁴ and fortune associated with BD, as well as the finding that HPS is more closely related achievement emotions (e.g., joy and pride) than to prosocial emotions (e.g., love and compassion; Gruber & Johnson, 2009).

Finally, negative correlations were expected between MASQ-AD and the goal pursuit measures (LT/ST and *achievement/social*) of progress, effort, and pleasure associated with progress, due to associations between the experience of anhedonia, blunted reward responsivity, and diminished motivation to seek out and pursue rewarding stimuli (Germans & Kring, 1998; Treadway, Buckholtz, Schwartzman, Lambert, & Zald, 2009). As such, higher scorers on the MASQ-AD subscale are less likely to be motivated to exert effort on goals and therefore less likely to make progress. Furthermore, as anhedonia is also associated

⁴ Although fame might superficially seem to be a social goal, this is not necessarily the case, as it concerns the elevation of an individual from the masses and thus is agentic, rather than communal.

with a diminished responsivity to reward (Germans & Kring, 1998), it is likely that participants high in anhedonic symptoms would not experience as much pleasure from favourable, and thus rewarding, progress. Finally, due to a lack of previous research about whether associations between the BAS subscales, MASQ-AD, and the LT and ST *social* goal pursuit measures would differ from the LT and ST *achievement* goal pursuit, the associations for social goals were expected to be similar to those detailed above.

ESM Measures: Within-Person Correlations. A positive within-person correlation was expected between PA and the measures of LT and ST *achievement* and *social* goal progress, effort, and pleasure associated with progress. This is based on the suggestion that the successful accomplishment of, daily, goal-directed activities is fundamental to emotional wellbeing, of which PA is an element (Carver & Scheier, 1990; Deci & Ryan, 2000; Emmons, 1986), with strong links being observed between goal progress and the experience of subjective wellbeing (of which PA is a key component; Emmons, 1986). Furthermore, for each goal type (e.g., LT *achievement*, ST *social*), the goal pursuit measures of progress, effort, and pleasure associated with progress were expected to positively intercorrelate. Whilst there has been little research that focuses on measuring effort directly (Blau, 1993; Brown & Peterson, 1994), there has been some indication of an association between self-report measures of effort intensity (a measure of how hard a person tries to carry out a chosen behaviour, similar to the measure used in the present research; Kanfer, 1990; Porter & Lawler, 1968; Vroom, 1964) and task performance, at the between-person level (Brown & Leigh, 1996; Rasch & Tosi, 1992; Terborg & Miller, 1978). Furthermore, momentary measures of LT *achievement* goal pursuit were expected to correlate with the corresponding momentary measures of ST *achievement* goal pursuit, as although they were not required to

be associated, it is likely that they both reflect broader achievement motivation (McClelland, 1985).⁵

Sample Differences. When comparing the two samples, it was expected that the student sample would report significantly higher scores on the BAS subscales than the community sample, as BAS scores have been found to be lower in older age groups (Jorm et al., 1999). However, no sample differences were expected in reported PA, as the present research focuses on high-arousal PA, in which age-related differences have not previously been found (Scheibe et al., 2013). In addition to this, the community sample were expected to report significantly greater levels of both *achievement* and *social* (LT and ST) goal progress and effort, compared to the student sample, as previous findings indicate that older adults exhibit a greater intensity of goal pursuit (Riediger et al., 2004).

Cross Level Interactions. Previous findings have demonstrated that the within-person relationship between effort and performance may be moderated by an individual difference variable (Schmitz & Skinner, 1993). Due to the conceptual overlap between this previous study and the present research, as well as the multi-level nature of the dataset, I conducted an exploratory analysis to assess whether the strength of the within-person relationships between momentary PA and the measures of LT and ST *achievement* and *social* goal progress could be predicted by BAS sensitivity and anhedonia. For these cross-level interactions, the hypotheses were somewhat speculative. However, it was tentatively predicted that the within-person relationships between (i) LT *achievement* and *social* goal progress and PA, and (ii) ST *achievement* and *social* goal progress and PA would change as a function of BAS-RR and MASQ-AD. BAS-RR is designed to measure the degree of energy and enthusiasm in response to reward. As progress towards a goal is likely to be rewarding to

⁵This prediction relates only to the sample of younger adults, as LT goal pursuit was not assessed in the sample of older adults.

an individual, it would follow that those high in BAS-RR would experience greater PA during goal progress. The reverse was predicted for MASQ-AD, with high scorers being expected to report less PA when making more goal progress, due to the conceptual nature of anhedonia, which relates to reduced enjoyment and motivation.

Summary of Hypotheses. Table 2.1 presents a summary of the hypothesised between-person correlations between the trait measures of approach motivation, trait hypomania, anhedonic symptoms, and ESM measures of PA and everyday goal pursuit. Details of the expected cross-level interactions are also included. It should also be noted that there were several differences in the variables assessed in the student and community samples. LT *social* and *achievement* goal pursuit was assessed in the student sample, but only ST *achievement* goal pursuit. However, in the community sample, both ST *social* and *achievement* goal pursuit were assessed, but no ratings were collected with regards to LT goal pursuit, in order to minimise burden to participants. Furthermore, as hypomania is linked to greater BAS sensitivity and increased focus on goal pursuit, the HPS was introduced as a measure of trait hypomania, in the community sample.

Table 2.1.

Hypothesised between-person correlations and cross-level interactions between trait measures and ESM measures of PA and goal pursuit.

	BAS-FS	BAS-RR	BAS-D	MASQ-AD	HPS (Study Two)
LT Achieve Progress (Study One)			✓+	✓-	✓+
LT Achieve Pleasure (Study One)		✓+		✓-	✓+
LT Achieve Effort (Study One)			✓+	✓-	✓+
LT Social Progress (Study One)			✓+	✓-	
LT Social Pleasure (Study One)		✓+		✓-	
LT Social Effort (Study One)			✓+	✓-	
Positive Affect	✓+	✓+	✓+	✓-	✓+
ST Achieve Progress			✓+	✓-	✓+
ST Achieve Pleasure		✓+	✓+	✓-	✓+
ST Achieve Effort			✓+	✓-	✓+
ST Social Progress (Study Two)			✓+	✓-	
ST Social Pleasure (Study Two)		✓+	✓+	✓-	
ST Social Effort (Study Two)			✓+	✓-	
PA & LT Achieve Progress* (Study Two)		✓		✓	
PA & ST Achieve Progress*		✓		✓	
PA & LT Social Progress* (Study One)		✓		✓	
PA & ST Social Progress* (Study Two)		✓		✓	

Note. MASQ-AD = Mood and Anxiety Symptom Questionnaire Anhedonic Depression subscale, BAS = Behavioural Activation Scale, FS = Fun-Seeking, D = Drive, RR = Reward Responsiveness, HPS = Hypomanic Personality Score, PA = Positive Affect, ST = Short-term, LT = Long-term. “+” denotes a positive correlation, whilst “-“ indicates a negative correlation. * indicates a within-person association that is moderated by the trait variable (cross-level interaction).

2.2. Method.

2.2.1. Study One.

Sample Size. Sample size was calculated to provide adequate power (.80) to detect two-tailed medium-sized ($r = .20$; Cohen, 1992) associations between experience-sampling (ESM) ratings. Calculations using G*Power software (Faul, Erdfelder, Lang, & Buchner, 2007) revealed that this would require 193 ratings. However, clustering of ratings within persons for ESM requires multiplying this number of ratings by the design effect (Kish, 1965), which equals $1 + (\text{ICC} * (\text{ratings per person} - 1))$. I estimated 70% completion of ratings, equating to $7 \text{ ratings} \times 7 \text{ days} \times 70\% = 34.3 \text{ ratings per person}$, and an intraclass correlation of 0.3. The design effect is therefore calculated as 10.99 and the required sample of ratings is therefore $193 \times 10.99 = 2121.1$. Dividing this number by the average number of ratings per person (34.3) produces a required sample for ESM of 62 persons.

Participants. Participants were recruited from the University of Exeter undergraduate participation pool. In total, 65 individuals (45 female) consented to participate (age range = 19-55, $M = 22.85$ years old, $SD = 7.23$). There were no exclusions (e.g. age/gender) on who could participate in the ESM study. Depending on their preference, participants were either paid £15 or given course credits to participate in the study.

Trait Measures.

i) Mood and Anxiety Symptom Questionnaire – Anhedonic Depression Subscale (MASQ-AD; Clark & Watson, 1991). The MASQ (Appendix A) is a 62-item questionnaire, designed to measure different symptoms relating to depression and anxiety. These symptoms may be divided into four distinct categories: General Distress – Anxiety (GDA), General Distress – Depression (GDD), Anxious Arousal (AA), and Anhedonic Depression (AD). The AD scale consists of 22 items that are each rated on a scale of 1 to 5 ($1 = \text{Not at all}$, $5 = \text{Extremely}$).

Fourteen items are reverse-scored and reflect high positive emotion (e.g., *Felt cheerful*), whereas a further eight items focus on low positive emotion (e.g., *Felt bored*). These items are typically combined to form a unidimensional scale (e.g., Light, Heller, Johnstone, & Kolden, 2011; Wacker et al., 2009). The MASQ, particularly the AD scale, has been found to have excellent convergent validity (Watson et al., 1995). Cronbach's alpha for the MASQ-AD scale in the present sample was .83.

ii) *BAS Scales* (Carver & White, 1994). The BAS scale (Appendix A) consists of three subscales designed to assess different facets of behavioural activation and approach motivation: Fun-Seeking (BAS-FS; four items), Reward Responsiveness (BAS-RR; five items), and Drive (BAS-D; four items). For all scales, each item is rated between 1 and 4 (*1 = very true for me, 4 = very false for me*). Several items are reverse scored so that higher scores are indicative of greater BAS sensitivity. Although previous research has indicated that the three subscales load onto the same factor (Caseras et al., 2002), implying one dimension, it is widely advised that they should be considered as separate constructs (Carver & White, 1994; Ross et al., 2002). When evaluated as distinct subscales, Jorm et al. (1998) concluded that they were correlated, but nonetheless measured distinct types of reward sensitivity. Cronbach's alpha for the present sample are as follows: BAS-FS = .74, BAS-RR = .89, BAS-D = .71. The BAS subscales have been found to have good convergent validity, with positive correlations found between the subscales and measures of extraversion, positive affectivity, and novelty-seeking (Carver & White, 1994; Jorm et al., 1998; Vandeweghe et al., 2016).

Goal Elicitation. (Dickson & MacLeod, 2004). As there is evidence that the way a goal is framed can have some effect on how an individual monitors their progress (Coats et al., 1996), all goals were constrained to being approach goals, due to the focus on the approach motivation system (BAS) in the present research. Participants were asked to generate two long-term (LT) goals that they wished to achieve in the future, but could not

realistically attain within the next seven days (see Appendix B for full instructions and examples). The first was required to an approach, achievement based goal, i.e., involving competition with a standard of excellence (LT *achievement*; e.g., *I will train for a marathon*), whilst the second was required to be an approach social goal (LT *social*; e.g., *I will make more of an effort with my partner*). Secondly, at the beginning of each of the seven days that they participated in the study, participants were required to think of an approach achievement-based goal that they wished to achieve that day (ST *achievement*; e.g., *I will work on my report*), but that they would anticipate working on for a good proportion (at least half) of the day. Participants were asked to note these goals in the booklet provided (Appendix B).

The ST *achievement* goal was not required to be associated with the LT achievement goal in any way. See Appendix B for examples of both LT and ST goals.

Experience Sampling (Larson & Csikszentmihalyi, 1983). ESM was used to assess momentary PA, LT/ST *achievement* and *social* goal progress and effort, as well as pleasure associated with goal progress. A signal contingent methodology was used, which involved participants providing ratings when signalled by an alarm from a wrist-worn Actiwatch (Cambridge Neurotechnology Ltd, Cambridge, UK). Each participant was asked to select a twelve-hour time window (e.g., 10am to 10pm) that would suit his or her sleep-wake schedule (actual range: 6am – 11.59pm). This twelve-hour window was divided into six equal time periods. An alert, reminding participants to think of a ST *achievement* goal, occurred both at the start of the first two-hour period, and at the end of the last period, when participants were asked to provide ratings on the LT *achievement* and *social* goal measures. Participants also received an alert at a random time during each of the six time periods (e.g., 12.00pm to 1.30pm), prompting them to complete measures concerning their “in the moment” experience of momentary PA and ST *achievement* goal pursuit. A restriction was imposed such that no two alerts could occur within thirty minutes of each other, in order to ensure that the ratings

were distributed throughout the day. At each alert, the individual questions were displayed on the LED screen of the Actiwatch, prompting participants to enter a rating for the moment before the alert, by using a small track pad to cycle through ratings. After each rating was entered, the next question was displayed and the participant would continue through until all ratings were complete. In order to minimise burden, participants were able to silence the watch if they needed to and were able to “snooze” the watch for up to fifteen minutes if they were temporarily unable to answer the questions.

Momentary Affect Measures. Levels of momentary PA were assessed by asking participants to rate on a 7 point Likert scale (*1 = not at all, 7 = a great deal*) how much they felt each of the adjectives listed on the short form of the International Positive and Negative Affect Schedule (I-PANAS-SF; Thompson, 2007). The I-PANAS-SF was designed to contain only cross-culturally, easily understandable emotion words. PA is measured using the adjectives: active, alert, determined, attentive, and inspired, whereas NA is measured using the adjectives: afraid, ashamed, hostile, nervous, and upset. Composite scores were generated separately for PA by calculating the mean score across all of the adjectives. NA was not analysed in this thesis. Previous research has indicated that the I-PANAS-SF is a valid and reliable scale to measure levels of affect, particularly using ESM (Meimann, 2016).

Momentary ST Achievement Goal Measures. During each period, participants were asked the following questions regarding their ST *achievement* goal:

- To measure ST *achievement* goal progress, participants were asked: *How much progress have you made towards your daily achievement goal, since the last set of questions?*
- To measure pleasure associated with ST *achievement* goal progress, participants were asked: *How pleasurable has this progress towards your daily achievement goal felt?*
- To measure effort on the ST *achievement* goal, participants were asked: *How much effort have you put into achieving your daily achievement goal, since the last set of questions?*

Participants were asked to provide these ratings on a seven point Likert scale (*1 = not at all, 7 = a great deal*). These measures are quick to administer via ESM, have face validity, and are similar to those that have been used in similar studies of this nature (e.g., Fulford et al., 2010; Moberly & Watkins, 2010).

Daily LT Achievement Goal Measures. During the last alert of each day, participants were asked to provide ratings to the following questions, regarding their LT *achievement* goals:

- To measure LT *achievement* goal progress, participants were asked: *How much progress have you made towards your long-term achievement goal today?*
- To measure pleasure associated with LT *achievement* goal progress, participants were asked: *How much pleasure did you get from progress towards this long-term achievement goal?*
- To measure effort on the LT *achievement* goal, participants were asked: *How much effort have you put into working towards your long-term achievement goal today?*

Participants were asked to provide these ratings on a seven point Likert scale (*1 = not at all, 7 = a great deal*). These measures are quick to administer via ESM, had face validity, and are similar to those that have been used in similar studies of this nature (e.g., Fulford et al., 2010; Moberly & Watkins, 2010).

Daily LT Social Goal Measures. During the last alert of each day, participants were asked to provide ratings to the following questions, regarding their LT *social* goals:

- To measure LT *social* goal progress, participants were asked: *How much progress have you made towards your long-term social goal today?*
- To measure pleasure associated with LT *social* goal progress, participants were asked: *How much pleasure did you get from progress towards this long-term social goal?*
- To measure effort on the LT *social* goal, participants were asked: *How much effort have you put into working towards your long-term social goal today?*

Participants were asked to provide ratings on a seven point Likert scale ($1 = not\ at\ all$, $7 = a\ great\ deal$). These measures are quick to administer via ESM, had face validity and are similar to those that have been used in similar studies of this nature (e.g., Moberly & Watkins, 2010).

Procedure. Ethical approval was granted by the University of Exeter ethics committee. During an initial meeting with the researcher, participants were shown the Actiwatch and the ESM measures described above were explained to them. Participants were informed that they would be asked questions about their momentary experience of PA and ST *achievement* goals six times daily and that they would be asked about their LT *achievement* and *social* goals at the end of their chosen 12-hour time period (e.g., 10pm). After being invited to ask questions about the procedure, participants provided informed consent and completed the BIS/BAS subscales and the MASQ. After seven full days of experience sampling, participants returned the Actiwatch and booklet to the researcher and were paid £15 or given course credit, and fully debriefed.

2.2.2. Study Two.

Sample Size. Sample size was calculated to provide adequate power (.80) to detect two-tailed medium-sized ($r = .20$; Cohen, 1992) associations between experience-sampling (ESM) ratings. Calculations using G*Power software (Faul et al., 2007) revealed that this would require 193 ratings. However, clustering of ratings within persons for ESM requires multiplying this number of ratings by the design effect (Kish, 1965), which equals $1 + (ICC * (ratings\ per\ person - 1))$. I estimated 70% completion of ratings, equating to $7\ ratings \times 7\ days \times 70\% = 34.3\ ratings\ per\ person$, and an intraclass correlation of 0.3. The design effect is therefore calculated as 10.99 and the required sample of ratings is therefore $193 \times 10.99 =$

2121.1. Dividing this number by the average number of ratings per person (34.3) produces a required sample for ESM of 62 persons.

Participants. Participants were recruited from the Exeter 10,000, a database set up for members of the local community to volunteer to participate in research. Invitations were sent to those individuals who had previously taken part in another researcher's online behavioural study focusing on the assessment of responses to positive stimuli, reward and punishment, and the willingness to expend effort to obtain a reward. There were no other exclusions (e.g. age/gender) on who could participate in the ESM study. Sixty-three individuals (43 female) consented to participate (age range = 38-91 years; $M = 59.56$; $SD = 10.22$). Participants volunteered their time and did not receive any monetary reimbursement/incentive for their participation, consistent with the guidelines of the steering committee of the Exeter 10, 000.

Trait Measures.

i) Mood and Anxiety Symptom Questionnaire – Anhedonic Depression Subscale (MASQ; Clark & Watson, 1991). Refer to section 2.1.1. for full description. Cronbach's alpha for the MASQ-AD scale in this sample was .92.

ii) BAS Scales (Carver & White, 1994). Refer to section 2.1.1. for full description. Cronbach's alpha for the subscales are as follows: BAS-FS = .71, BAS-RR = .68, BAS-D = .79.

iii) Hypomanic Personality Scale (HPS; Eckblad & Chapman, 1986). The HPS (Appendix B) measures a personality style associated with vulnerability to bipolar disorder. It is a 48 item, True-False scale measuring hyperactive, ambitious, and exhibitionistic behaviour, as well as euphoric feelings. The predictive (Eckblad & Chapman, 1986; Kwapil et al., 2000), concurrent (Eckblad & Chapman, 1986), and divergent (Petzel & Rado, 1990) validity of the HPS has been found to be very good. Cronbach's alpha for in the present sample was .84.

Participants were also asked to complete various other related measures (Appendix A), including the Revised Physical Anhedonia Scale (Chapman, Chapman, & Raulin, 1976), the Revised Social Anhedonia scale (Eckblad, Chapman, Chapman, & Mishlove, 1982), the Patient Health Questionnaire (PHQ-9; Kroenke, Spitzer, & Williams, 2001). However, these measures were not included in the present analysis.

Goal Elicitation. Replicating Study One (see section 2.2.1.), on each day that they participated in the study, participants were asked to specify an approach, achievement goal that they wished to achieve that day (*ST achievement*; e.g., *I will complete my To Do list*). In addition to this, they were also asked to specify a social approach goal that might be achieved in the course of one day (*ST social goal*; e.g., *I will make an effort to talk to colleagues*). Participants were asked to specify ST goals that they would anticipate working towards for a good proportion (at least half) of the day (see Appendix B for examples).

In Study One, participants had also been asked to think of a *LT achievement* and *LT social* goal, which they were asked to complete ratings about at the end of each day. However, the decision was made to simplify the protocol for Study Two, which meant jettisoning the LT goal measures, leaving the more frequent ST measures for greater sensitivity.

Experience Sampling. The ESM protocol was very similar to the one followed in Study One (see section 2.2.1.), although there were a few differences. First, because there was no investigation of LT goal pursuit, participants were only alerted seven times (instead of eight) throughout the day: once at the beginning of the day as a reminder to think of their ST goals, and six times to provide ratings pertaining to the momentary experience of affect and goal pursuit. Furthermore, during all six alerts (instead of six out of seven in Study One), participants were asked to provide ratings of affect. To minimise burden, the ST goal

measures were only administered on three of these occasions (instead of six in Study One): the second occasion and then alternating occasions from then on.

Momentary Affect Measures. Replicating Study One, levels of momentary affect were assessed by asking participants to rate on a seven point Likert scale (*1 = not at all, 7 = a great deal*) how much they felt each of the adjectives listed on the I-PANAS-SF (see section 2.2.1. for a more detailed description, Thompson, 2007), six times daily. Composite scores were generated for PA by calculating the mean score across all of the adjectives.

Momentary ST Achievement Goal Measures. Following Study One (see section 2.2.1.), participants were asked various questions regarding their ST *achievement* goal, three times daily, on alternate occasions.

Momentary ST Social Goal Measures. Participants were asked the following questions regarding their ST *social* goal:

- To measure ST *social* goal progress, participants were asked: *How much progress have you made towards your short-term social goal today?*
- To measure pleasure associated with ST *social* goal progress, participants were asked: *How much pleasure did you get from progress towards this short-term social goal?*
- To measure effort on the ST *social* goal, participants were asked: *How much effort have you put into working towards your short-term social goal today?*

Participants were asked to provide ratings on a seven point Likert scale (*1 = not at all, 7 = a great deal*). These measures are easy to administer via ESM, have face validity and are similar to those that have been used in similar studies of this nature (e.g. Fulford et al., 2010; Moberly & Watkins, 2010).

Procedure. Ethical approval was granted by the University of Exeter ethics committee. Invitations were sent to Exeter 10,000 volunteers who had previously participated in an online behavioural study run by another researcher. This research had included tasks

designed to assess responses to positive stimuli, reward and punishment, and the willingness to expend effort to obtain a reward. Volunteers who returned the correspondence indicating their interest were contacted with further information, and an appointment was arranged with the researcher. During this initial meeting, participants were shown the Actiwatch and the ESM measures were explained to them, before providing informed consent. Participants were also asked to provide an email address, to which a link to an online questionnaire was sent. This questionnaire included the trait measures (BAS subscales, MASQ-AD, and HPS). Participants were asked to complete these at some point over the following seven days of the study period. After seven complete days of experience sampling, participants returned the Actiwatch and booklet to the researcher and were fully debriefed.

2.2.3. Analysis Plan.

Data Cleaning. For both Study One and Two, the raw data were processed using SPSS Version 21 for Mac (IBM Corp., 2012) in order to prepare it for analysis. Scores for each of the trait measures were calculated as per instruction and scatter plots were inspected for outliers. Furthermore, the percentage of missing ESM data was also calculated for each participant in order to determine whether any participants had completed less than one third of the time-point measures. This exclusion was put in place to ensure that participants had completed enough of the occasions that their data provided a reliable measure of each variable and was in accordance with standard guidelines (Delespaul, 1995).

Statistical Model. The dataset comprised three levels: occasions (Level 1), nested within days (Level 2), which were nested within persons (Level 3), so multi-level modelling (MLM) was used for the analysis. Multilevel models were used instead of linear regression models, as they enable the estimation of variation at each level, thus accounting for the violation of independence between occasions nested within days, and days nested within participants (Palmier-Claus et al., 2011). A further advantage of the use of MLM was that

within- and between-subjects random effects can be estimated and it was possible to explain within-subject processes in terms of individual differences (Bolger & Laurenceau, 2013).

The software MLwiN Version 2.1 (Rasbash, Charlton, Browne, Healy, & Cameron, 2009) was used to analyse the data. Each model was built in accordance with a priori hypotheses and the intercepts of the model were allowed to vary randomly at each level, to reflect variation between and within days and between individual participants, so that it was possible to see how much variance is at each level, whilst also controlling for the explanatory variable. The decision to specify fixed slopes in the multilevel models was a pragmatic one. It would have been possible to test whether the model fit was improved by allowing the slopes to vary randomly across persons, but due to the relatively limited sample size at the person-level, which may result in model convergence problems, it was decided that there was unlikely to be enough variability at the person-level to warrant doing so. The participant level (between person) hypotheses focused on the associations between trait measures of approach motivation (BAS subscales), anhedonia (MASQ-AD), and trait hypomania (HPS), and mean levels of the outcome measures collected during the ESM period (PA, LT & ST *achievement* and *social* goal progress, pleasure, and effort).

In order to analyse these associations, person-level variables (i.e., trait measures and person-level aggregates of the momentary variables used for between-person correlations) were grand-mean centred across participants. To grand mean centre a variable, the grand mean (i.e., the mean of all the values across all individuals for that particular variable) is subtracted from each of the individual's scores. The mean of each variable across participants is then 0, although the standard deviation remains unchanged. This provides an estimate (or intercept) of the outcome variable when the predictor variables are at their mean values (Bolger & Laurenceau, 2013) and tends to reduce the correlation between intercept and slope estimates across groups, which can reduce multicollinearity. Additionally, within-person

associations between the day (e.g., LT *achievement* goal progress) and occasion (e.g., ST *achievement* goal progress) levels were assessed. In order to do this, within-person measures were person-mean centred, which involves subtracting the mean value of an individual's scores for a particular variable from the score on each day or occasion. This has the advantage that it results in 'pure' estimates of within-person effects that are uncontaminated by between-person variance (Enders & Tofighi, 2007).

Finally, the use of MLM allows the investigation of cross-level interactions (Aguinis, Gottfredson, & Culpepper, 2013), providing information as to whether the within-person relationship between (person-mean centred) lower level variables (e.g., PA and ST *achievement* goal progress) change as a function of (grand-mean centred) person-level, moderator variables (e.g., BAS-RR).

2.3. Results.

2.3.1. Study One.

Data Processing. In total, data were collected from 65 participants. Five participants were excluded from the analysis because they completed less than one third of the ESM time point measures (Delespaul, 1995). For the 60 participants that were included in the analysis, the mean completion rate of the ESM time-point measures was 79.48% ($SD = 13.51\%$). In total the data from 1973 time-points were analysed. Age and gender were not associated with any of the trait measures and so were not included in the analyses. Of the four trait measures, BAS-RR was negatively skewed and so was reverse scored before it was lg10 transformed. These transformed data were then reverse scored again so that higher values reflected higher scores on the original BAS-RR sub-scale.

Descriptive Data. The untransformed means and standard deviations of scores of the trait measures are summarised in Table 2.2. The mean score for the BAS subscales are also in

line with previous findings from non-clinical populations (Carver & White, 1994), as were MASQ-AD scores (e.g., Bredemeier et al., 2010).

Table 2.2.

Descriptive statistics of the trait measures.

	Mean	<i>SD</i>	Min	Max
BAS-FS	12.51	2.65	6.00	16.00
BAS-RR	16.95	3.24	6.00	20.00
BAS-D	11.60	2.27	5.00	16.00
MASQ-AD	55.75	12.51	31.00	95.00

Note. MASQ-AD = Mood and Anxiety Symptom Questionnaire Anhedonic Depression subscale, BAS = Behavioural Activation Scale. FS = Fun-Seeking, D = Drive, RR = Reward Responsiveness.

Table 2.3 presents a correlation matrix among the trait measures, reporting Pearson's correlation coefficients. As expected, the BAS subscales positively correlated with each other. A negative correlation was predicted between MASQ-AD and each of the BAS subscales, but no significant association was found.

Table 2.3.

Correlation matrix of scores on the trait measures [95% confidence intervals].

	BAS-FS	BAS-RR	BAS-D
BAS-RR	.54** [.32, .70]		
BAS-D	.45** [.21, .64]	.36** [.11, .57]	
MASQ-AD	-.02 [-.28, .24]	.02 [-.24, .28]	.09 [-.18, .34]

Note. BAS = Behavioural Activation Scale. MASQ-AD = Mood and Anxiety Symptom Questionnaire - Anhedonic Depression. FS = Fun-Seeking, D = Drive, RR = Reward Responsiveness. ** $p < .001$ (two tailed).

The momentary variables reported at each time-point were also explored and person-level descriptive statistics for these are summarised in Table 2.4.

Table 2.4.

Person-level descriptive statistics of the ESM measures.

	Mean	<i>SD</i>	Min	Max
Positive Affect	4.15	1.17	1.00	7.00
ST Achieve Progress	3.41	2.04	1.00	7.00
ST Achieve Pleasure	3.53	1.93	1.00	7.00
ST Achieve Effort	3.51	2.01	1.00	7.00
LT Achieve Progress	3.73	1.82	1.00	7.00
LT Achieve Pleasure	3.80	1.77	1.00	7.00
LT Achieve Effort	3.81	1.82	1.00	7.00
LT Social Progress	4.03	1.79	1.00	7.00
LT Social Pleasure	4.15	1.75	1.00	7.00
LT Social Effort	4.87	1.58	1.00	7.00

Note. Positive Affect is a composite score (range = 1-7). The mean value reflects the mean of the individual person means. *SD* refers to the between person standard deviation. ST = Short-term, LT = Long-term.

Correlations among the variables at the between-person and within-person levels are presented in Table 2.5. Contrary to hypotheses, no significant associations were found between PA and measures of ST *achievement* goal pursuit, or with measures of LT and ST *social* goal pursuit. In partial support of the predictions, there was a general pattern for the goal measures to intercorrelate within the same goal. However, no associations were found across the different types of goal (e.g., between LT and ST *achievement* goal measures). The pattern of relationships is generally the same for the within-subject and between-subject correlations.

Table 2.5.

Correlation matrix of the ESM measures, showing between and within-person correlations [95% confidence intervals].

	Positive Affect	ST Achieve Progress	ST Achieve Pleasure	ST Achieve Effort	LT Achieve Progress	LT Achieve Pleasure	LT Achieve Effort	LT Social Progress	LT Social Pleasure	LT Social Effort
Positive Affect		.05 [-.21, .31]	.04 [-.22, .30]	.05 [-.21, .31]	.06 [-.20, .32]	-.01 [-.27, .25]	.04 [-.22, .30]	.05 [-.21, .31]	.04 [-.22, .30]	.04 [-.22, .30]
ST Achieve Progress	.20 [-.06, .44]		.73** [.58, .83]	.80** [.68, .88]	-.02 [-.28, .24]	-.02 [-.28, .24]	-.01 [-.27, .25]	-.01 [-.27, .25]	.05 [-.21, .31]	-.02 [-.28, .24]
ST Achieve Pleasure	.30 [.04, .52]	.73** [.58, .83]		.70** [.54, .81]	.01 [-.25, .27]	-.01 [-.27, .25]	.03 [-.23, .29]	-.01 [-.27, .25]	.02 [-.24, .28]	-.01 [-.27, .25]
ST Achieve Effort	.23 [-.03, .46]	.79** [.67, .87]	.64** [.45, .77]		-.01 [-.27, .25]	-.01 [-.27, .25]	.00 [-.26, .26]	.06 [-.20, .32]	.09 [-.18, .34]	.02 [-.24, .28]
LT Achieve Progress	-.14 [-.39, .13]	-.18 [-.42, .09]	.01 [-.25, .27]	-.02 [-.28, .24]		.76** [.62, .85]	.62** [.43, .76]	.09 [-.18, .34]	.09 [-.18, .34]	.09 [-.18, .34]
LT Achieve Pleasure	-.10 [-.35, .17]	.00 [-.26, .26]	.08 [-.18, .33]	-.06 [-.32, .20]	.68** [.51, .80]		.37* [.12, .58]	.04 [-.22, .30]	.06 [-.20, .32]	.02 [-.24, .28]
LT Achieve Effort	-.04 [-.30, .22]	.02 [-.24, .28]	.11 [-.16, .36]	.00 [-.26, .26]	.81** [.70, .88]	.65** [.47, .78]		.14 [-.13, .39]	.05 [-.21, .31]	.11 [-.16, .36]
LT Social Progress	.08 [-.18, .33]	.01 [-.25, .27]	.02 [-.24, .28]	.04 [-.22, .30]	.15 [-.12, .40]	.10 [-.17, .35]	.10 [-.17, .35]		.54** [.32, .70]	.25* [-.01, .48]
LT Social Pleasure	.15 [-.12, .40]	.15 [-.12, .40]	.04 [-.22, .30]	.06 [-.20, .32]	.05 [-.21, .31]	.17 [-.10, .41]	.08 [-.18, .33]	.66** [.48, .79]		.16 [-.11, .40]
LT Social Effort	.16 [-.11, .40]	.16 [-.11, .40]	.01 [-.25, .27]	-.02 [-.28, .24]	.04 [-.22, .30]	.11 [-.16, .36]	.02 [-.24, .28]	.38** [.13, .58]	.33** [.08, .54]	

Note. Between-person correlations are shown below the diagonal and within-person correlations are shown (**in bold**) above the diagonal. ST = Short-term, LT = Long-term.

** $p < .001$ (two tailed). * $p < .05$ (two tailed).

Trait Measures and LT Goal Pursuit. During the study, participants provided ratings concerning their LT *achievement* and *social* goals at the end of each day. Between-person correlations among the trait measures (collected at baseline), and the mean LT *achievement* and *social* goal measures were explored and are displayed in Table 2.6. Contrary to predictions, LT *achievement* goal progress and effort did not positively correlate with BAS-D, nor was a significant association found between LT *achievement* pleasure and BAS-RR. However, in line with predictions, LT *social* goal pleasure was found to positively correlate with BAS-RR. Furthermore, although not anticipated, a positive correlation was found between LT *social* goal pleasure and BAS-FS, as well as between LT *social* goal progress and BAS-RR. Finally, it was predicted that the measures of LT *achievement* and *social* goal pursuit would negatively correlate with MASQ-AD, but this hypothesis was not supported.

Table 2.6.

Between-person correlations between the trait measures and mean LT achievement and social goal measures [95% confidence intervals].

	BAS-FS	BAS-RR	BAS-D	MASQ-AD
LT Achieve Progress	.17 [-.10, .41]	.14 [-.13, .39]	.23 [-.03, .46]	-.18 [-.42, .09]
LT Achieve Pleasure	.23 [-.03, .46]	.19 [-.07, .43]	.18 [-.09, .42]	-.16 [-.40, .11]
LT Achieve Effort	.11 [-.16, .36]	.15 [-.12, .40]	.16 [-.11, .40]	-.18 [-.42, .09]
LT Social Progress	.16 [-.11, .40]	.26* [.00, .49]	.08 [-.18, .33]	-.16 [-.40, .11]
LT Social Pleasure	.25* [-.01, .48]	.26* [.00, .49]	.06 [-.20, .32]	.14 [-.13, .39]
LT Social Effort	.06 [-.20, .32]	.16 [-.11, .40]	-.02 [-.28, .24]	-.08 [-.33, .18]

Note. MASQ-AD = Mood and Anxiety Symptom Questionnaire - Anhedonic Depression, BAS = Behavioural Activation Scale. FS = Fun-Seeking, D = Drive, RR = Reward Responsiveness, LT = Long-term. * $p < .05$ (two tailed).

Cross Level Interactions. The data were analysed to see whether the within-person relationship between PA and LT *achievement* and *social* goal progress changed as a function of the trait measures, the results of which are displayed in Table 2.7. Contrary to predictions, the relationships between PA and LT achievement and social goal progress were not found to change as a function of BAS-FS, BAS-RR, BAS-D, or MASQ-AD.

Table 2.7.

Unstandardised regression coefficients (standard errors) for cross-level interactions between trait measures and ESM measures.

	BAS-FS	BAS-RR	BAS-D	MASQ-AD
PA & LT Achieve Progress	0.0139 (0.0157)	0.4436 (0.2761)	0.0054 (0.0172)	-0.0027 (0.0033)
PA & LT Social Progress	-0.0120 (0.0167)	0.0252 (0.2807)	-0.0228 (0.0192)	-0.0022 (0.0035)

Note. MASQ-AD = Mood and Anxiety Symptom Questionnaire - Anhedonic Depression, BAS = Behavioural Activation Scale, FS = Fun-Seeking, D = Drive, RR = Reward Responsiveness, PA = Positive Affect, LT = Long-term.

Trait Measures, Positive Affect, and ST Goal Pursuit. Between-person correlations were computed to investigate whether scores on the BAS subscales and the MASQ-AD predicted participants' mean ratings of PA and ST *achievement* goal pursuit (see Table 2.8). As hypothesised, a positive correlation was found between mean levels of PA and both BAS-D and BAS-FS. However, contrary to predictions, neither mean levels of ST *achievement* goal progress nor mean levels of effort correlated with BAS-D. Mean levels of ST *achievement* goal pleasure also did not correlate with BAS-RR. Furthermore, no support was provided for the hypothesis that the mean levels of ST *achievement* goal measures would negatively correlate with MASQ-AD. Finally, although not predicted, mean levels of ST *achievement* goal progress positively correlated with BAS-FS.

Table 2.8.

Between-person correlations between the trait measures and mean levels of PA and ST achievement goal measures [95% confidence intervals].

	BAS-FS	BAS-RR	BAS-D	MASQ-AD
Positive Affect	.27* [.01, .50]	.02 [-.24, .28]	.34** [.09, .55]	-.13 [-.38, .14]
ST Achieve Progress	.28* [.02, .50]	.04 [-.22, .30]	.04 [-.22, .30]	.18 [-.09, .42]
ST Achieve Pleasure	.23 [-.03, .46]	.07 [-.19, .33]	.04 [-.22, .30]	.05 [-.21, .31]
ST Achieve Effort	.00 [-.26, .26]	-.03 [-.29, .23]	.04 [-.22, .30]	.05 [-.21, .31]

Note. MASQ-AD = Mood and Anxiety Symptom Questionnaire - Anhedonic Depression, BAS = Behavioural Activation Scale, FS = Fun-Seeking, D = Drive, RR = Reward Responsiveness, ST = Short-term. ** $p < .001$ (two tailed). * $p < .05$ (two tailed).

Cross Level Interactions. The data were analysed to see whether the within-person relationships between PA and ST *achievement* goal effort changed as a function of BAS-RR or MASQ-AD. The results of this analysis are displayed in Table 2.9.

Table 2.9.

Unstandardised regression coefficients (standard errors) for cross-level interactions between trait measures and ESM measures.

	BAS-FS	BAS-RR	BAS-D	MASQ-AD
PA & ST Achieve Progress	0.0090 (0.0047)	0.1549 (0.0969)	0.0142* (0.0057)	-0.0002 (0.0010)

Note. MASQ-AD = Mood and Anxiety Symptom Questionnaire - Anhedonic Depression, BAS = Behavioural Activation Scale, FS = Fun-Seeking, D = Drive, RR = Reward Responsiveness, PA = Positive Affect, ST = Short-term. * $p < .05$ (two tailed).

BAS: Drive. Although not hypothesised, BAS-D significantly predicted the within-person association between PA and ST *achievement* goal progress. This interaction was plotted (Figure 2.1) and it revealed that the positive association between PA and ST

achievement goal progress on a particular occasion was stronger for persons with lower levels of BAS-D, although this effect was modest.

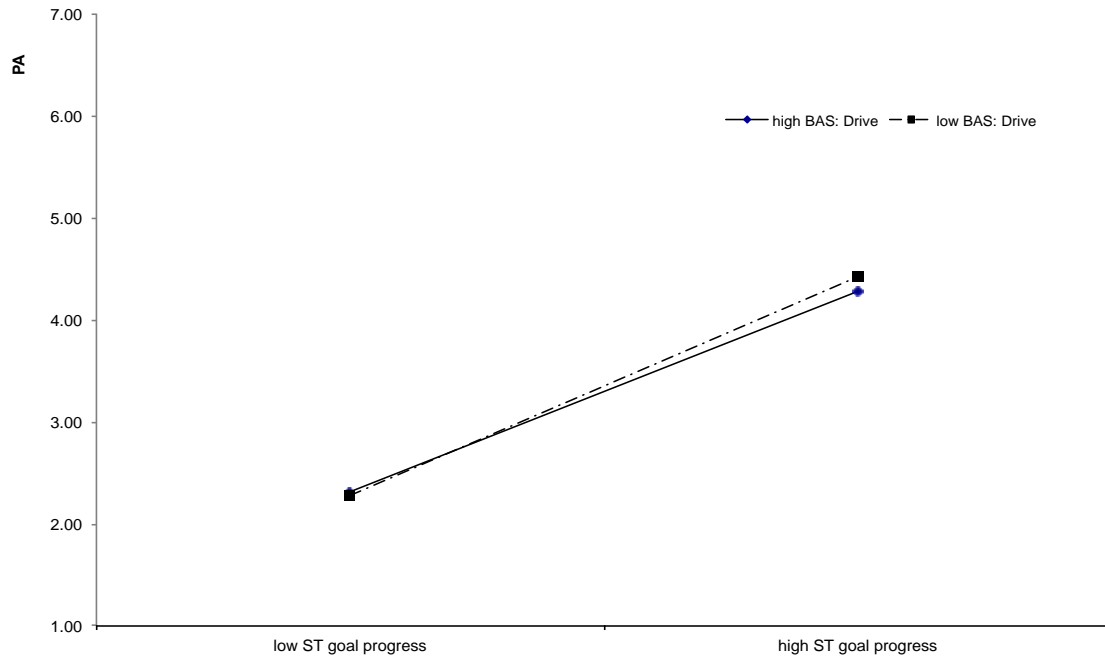


Figure 2.1.

Interaction between PA and ST achievement goal progress, for high and low (+/- one SD) BAS-D.

2.3.2. Study Two.

Data Processing. In total, data were collected from 63 participants. Three participants were excluded from the analysis as they completed less than one third of the ESM time point measures (Delespaul, 1995). For the 60 participants (43 female) that were included in the final analysis, the mean completion rate of the ESM time-point measures was 81.94% (SD = 10.23%). In total the data from 2591 time-points for PA and 1259 time points for the ST goal measures were analysed. Of the five trait measures, both BAS-D and HPS were positively skewed and so were lg10 transformed before the analysis.

Descriptive Data. The untransformed means and standard deviations of scores on the trait measures are summarised in Table 2.10.

The community sample (Study Two) was found to be significantly older than the student sample ($t = 21.49, p < .001$). Consistent with predictions, the community sample reported significantly lower scores for BAS-FS ($t = -5.32, p < .001$), BAS-RR ($t = -4.81, p < .001$), and BAS-D ($t = -7.28, p < .001$). Scores on the MASQ-AD were not significantly different ($t = -.85, p = .399$). Finally, HPS score in the present sample was also found to be approximately one standard deviation lower than has been previously reported in non-clinical samples (e.g., Bentall et al., 2011), although it should be noted that the participants in the present sample were markedly older than those in previous non-clinical samples.

Table 2.10.

Descriptive statistics of the trait measures.

	Mean	<i>SD</i>	Min	Max
BAS-FS	9.70	2.67	5.00	16.00
BAS-RR	14.52	2.96	7.00	20.00
BAS-D	7.77	3.00	4.00	16.00
MASQ-AD	53.97	15.52	23.00	91.00
HPS	9.67	6.64	0.00	32.00

Note. MASQ-AD = Mood and Anxiety Symptom Questionnaire - Anhedonic Depression, BAS = Behavioural Activation Scale, FS = Fun-Seeking, D = Drive, RR = Reward Responsiveness, HPS = Hypomanic Personality scale.

Table 2.11 depicts a correlation matrix of scores on the trait measures, reporting Pearson's correlation coefficients. As predicted, the BAS subscales were positively intercorrelated. Partial support was provided for the prediction that MASQ-AD would

negatively correlate with the BAS subscales, with a negative correlation being found between MASQ-AD and the BAS-FS and BAS-D subscales. Finally, in partial support of the hypotheses, HPS positively correlated with BAS-FS although not with the other BAS subscales.

Table 2.11.

Correlation matrix of scores on the trait measures [95% confidence intervals].

	BAS-FS	BAS-RR	BAS-D	MASQ-AD
BAS-RR	.51** [.29, .68]			
BAS-D	.47** [.24, .65]	.63** [.44, .77]		
MASQ-AD	-.40** [-.60, -.16]	-.21 [-.45, .05]	-.27* [-.50, -.01]	
HPS	.36** [.11, .57]	.21 [-.05, .45]	.14 [-.13, .39]	-.02 [-.28, .24]

Note. MASQ-AD = Mood and Anxiety Symptom Questionnaire - Anhedonic Depression, BAS = Behavioural Activation Scale, FS = Fun-Seeking, D = Drive, RR = Reward Responsiveness, HPS = Hypomanic Personality scale. ** $p < .001$ (two tailed). * $p < .05$ (two tailed).

The ESM measures were also explored and person-level descriptive statistics are summarised in Table 2.12. The community sample reported significantly higher PA ($t = 6.21$, $p < .001$), ST *achievement* goal progress ($t = 4.64$, $p < .001$), ST *achievement* goal pleasure ($t = 4.08$, $p < .001$), and ST *achievement* goal effort ($t = 3.18$, $p < .001$) than the younger student sample in Study One.

Table 2.12.

Person-level descriptive statistics of ESM measures.

	Mean	<i>SD</i>	Min	Max
Positive Affect	5.07	1.14	1.00	7.00
ST Achieve Progress	4.18	2.22	1.00	7.00
ST Achieve Pleasure	4.21	1.99	1.00	7.00
ST Achieve Effort	4.12	2.09	1.00	7.00
ST Social Progress	4.25	2.09	1.00	7.00
ST Social Pleasure	4.21	1.94	1.00	7.00
ST Social Effort	4.04	2.00	1.00	7.00

Note. Positive Affect is a composite score (range = 1-7). The mean value reflects the mean of the individual person means. *SD* refers to the between person standard deviation. ST = Short-term.

Between-person and within-person correlations among PA and the ST *achievement* and *social* goal variables are presented in Table 2.13. Contrary to predictions, no significant associations were found between PA and the measures of ST goal pursuit, at either the within or the between person level. This is consistent with the findings in the student sample. However, as predicted, there was a strong positive intercorrelation among the ST *achievement* goal measures and ST *social* goal measures respectively. These measures were also found to correlate across goals, i.e., ST *achievement* goal measures positively correlated with ST *social* goal measures.

Table 2.13.

Correlation matrix of the ESM measures, showing between and within-person correlations.

	Positive Affect	ST Achieve Progress	ST Achieve Pleasure	ST Achieve Effort	ST Social Progress	ST Social Pleasure	ST Social Effort
Positive Affect		.01 [-.25, .27]	.01 [-.25, .27]	.03 [-.23, .29]	.09 [-.18, .34]	.11 [-.16, .36]	.09 [-.18, .34]
ST Achieve Progress	.06 [-.20, .32]		.80** [.68, .88]	.81** [.70, .88]	.22* [-.04, .45]	.19* [-.07, .43]	.21* [-.05, .45]
ST Achieve Pleasure	.10 [-.17, .35]	.82** [.71, .89]		.76** [.62, .85]	.23* [-.03, .46]	.26* [.00, .49]	.23* [-.03, .46]
ST Achieve Effort	.10 [-.17, .35]	.82** [.71, .89]	.78** [.65, .86]		.21* [-.05, .45]	.19* [-.07, .43]	.20* [-.06, .44]
ST Social Progress	.17 [-.10, .41]	.29* [.03, .51]	.30* [.04, .52]	.27* [.01, .50]		.90** [.84, .94]	.88** [.80, .93]
ST Social Pleasure	.19 [-.07, .43]	.29* [.03, .51]	.39** [.14, .59]	.29* [.03, .51]	.91** [.85, .95]		.72** [.57, .83]
ST Social Effort	.18 [-.09, .42]	.28* [.02, .50]	.30* [.04, .52]	.29* [.03, .51]	.88** [.80, .93]	.84** [.74, .90]	

Note. Between-person correlations are shown below the diagonal and within-person correlations are shown (in **bold**) above the diagonal. ST = Short-term. ** $p < .001$ (two tailed). * $p < .05$ (two tailed).

Trait Measures, Positive Affect, and ST Goal Pursuit. The data were analysed to investigate potential associations between the trait measures and the mean ratings of PA and the ST *achievement* and *social* goal measures, displayed in Table 2.14. Providing partial support for the hypotheses, PA positively correlated with BAS-FS and negatively correlated with MASQ-AD. ST *achievement* goal effort was also negatively correlated with BAS-FS and MASQ-AD. ST social goal effort was positively associated with BAS-FS and BAS-RR.

Table 2.14.

Between-person correlations between the trait measures and PA and ST achievement and social goal measures [95% confidence intervals].

	BAS-FS	BAS-RR	BAS-D	MASQ-AD	HPS
Positive Affect	.27** [.01, .50]	.19 [-.07, .43]	.00 [-.26, .26]	-.33** [-.54, -.08]	.11 [-.16, .36]
ST Achieve Progress	.18 [-.09, .42]	.16 [-.11, .40]	.06 [-.20, .32]	-.16 [-.40, .11]	.02 [-.24, .28]
ST Achieve Pleasure	.05 [-.21, .31]	.18 [-.09, .42]	.02 [-.24, .28]	-.12 [-.37, .15]	.01 [-.25, .27]
ST Achieve Effort	.31** [.05, .53]	.21 [-.05, .45]	.13 [-.14, .38]	-.24** [-.47, .02]	.13 [-.14, .38]
ST Social Progress	.18 [-.09, .42]	.22 [-.04, .45]	.03 [-.23, .29]	-.04 [-.30, .22]	.08 [-.18, .33]
ST Social Pleasure	.10 [-.17, .35]	.16 [-.11, .40]	.00 [-.26, .26]	-.07 [-.33, .19]	-.00 [-.26, .26]
ST Social Effort	.39* [.14, .59]	.34* [.09, .55]	.14 [-.13, .39]	-.21 [-.45, .05]	.17 [-.10, .41]

Note. MASQ-AD = Mood and Anxiety Symptom Questionnaire - Anhedonic Depression, BAS = Behavioural Activation Scale, FS = Fun-Seeking, D = Drive, RR = Reward Responsiveness, HPS = Hypomanic Personality scale, ST = Short-term. ** $p < .001$ (two tailed). * $p < .05$ (two tailed).

Cross Level Interactions. The data were analysed to investigate whether the within-person relationship between PA and ST *achievement* and *social* goal progress changes as a function of BAS-RR or MASQ-AD. The results of these analyses are displayed in Table 2.15.

Table 2.15.

Unstandardised regression coefficients (standard errors) for cross-level interactions between the trait measures and ESM measures.

	BAS-FS	BAS-RR	BAS-D	MASQ-AD	HPS
PA & ST Achieve Progress	-0.0040* (0.0018)	0.0021 (0.0017)	0.0194 (0.0306)	0.0006* (0.0003)	0.0099 (0.0158)
PA & ST Social Progress	-0.0048 (0.0046)	-0.0003 (0.0042)	-0.0621 (0.0704)	0.0004 (0.0008)	0.0514 (0.0389)

Note. MASQ-AD = Mood and Anxiety Symptom Questionnaire - Anhedonic Depression, BAS = Behavioural Activation Scale, FS = Fun-Seeking, D = Drive, RR = Reward Responsiveness, HPS = Hypomanic Personality scale, PA = Positive Affect, ST = Short-term. * $p < .05$ (two tailed).

BAS-FS. Although not predicted, the relationship between PA and ST *achievement* goal progress changed as a function of BAS-FS. The interaction plot (Figure 2.2) demonstrated that the positive association between PA and ST *achievement* goal progress on a particular occasion was stronger for persons with lower levels of BAS-FS, although this effect was modest.

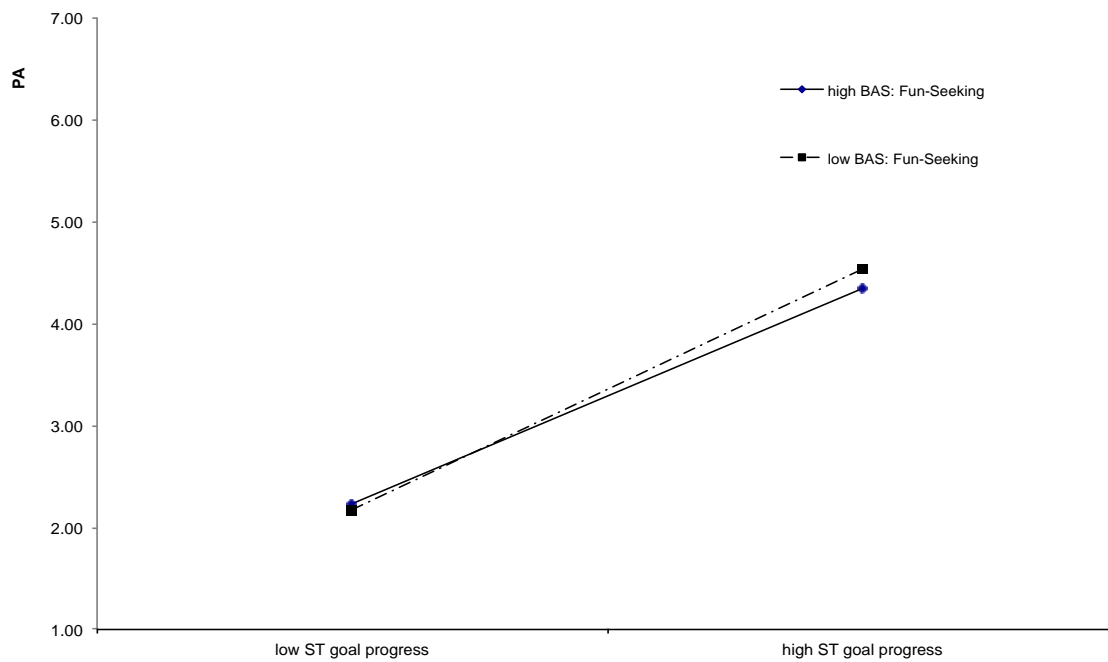


Figure 2.2.

Interaction between PA and ST achievement goal progress, for high and low (+/- one SD) BAS-FS.

MASQ-AD. Consistent with predictions, MASQ-AD significantly predicted the within-person associations between PA and ST *achievement* goal progress. This interaction was plotted (Figure 2.3). However, it was found that the positive association between PA and ST *achievement* goal progress on any given occasion was stronger for persons lower in MASQ-AD.

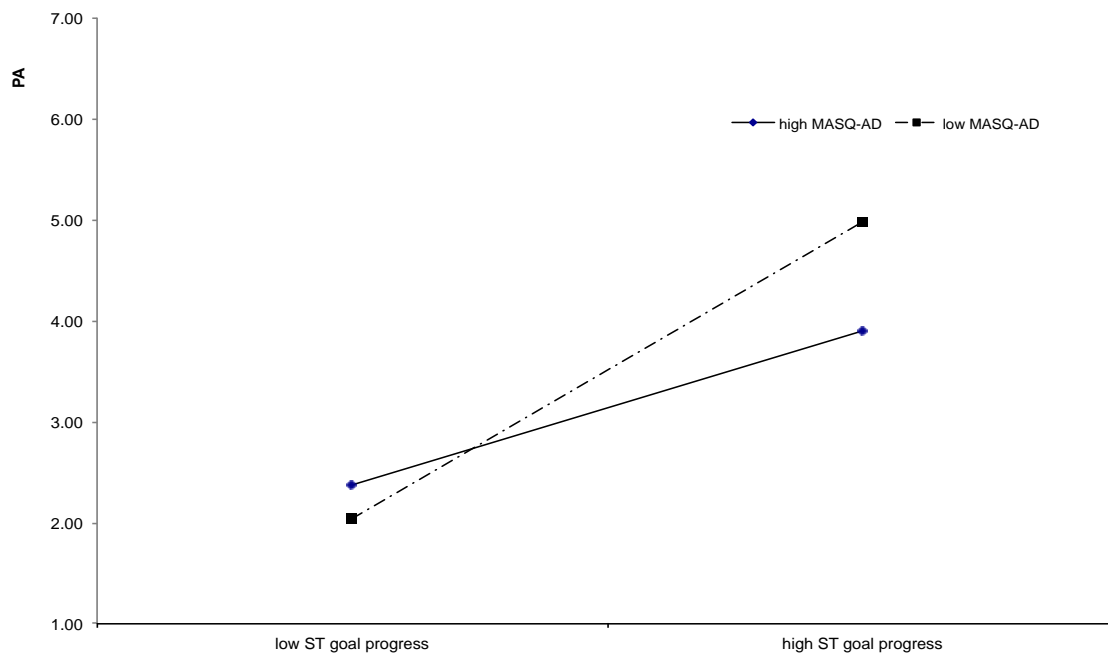


Figure 2.3.

Interaction between PA and ST achievement goal progress, for high and low (+/- one SD) MASQ-AD.

2.3.3. Summary of Findings.

Table 2.16 provides a summary of the observed relationships between the trait measures of approach motivation and hypomania, anhedonic symptoms, and the ESM measures of PA and everyday goal pursuit, relative to the a priori predictions.

Table 2.16.

Fate of hypotheses for correlations between trait measures and ESM measures of PA and goal pursuit, relative to a priori hypotheses.

	BAS-FS	BAS-RR	BAS-D	MASQ-AD	HPS (Study Two)
LT Achieve Progress (Study One)			×	×	×
LT Achieve Pleasure (Study One)		×		×	×
LT Achieve Effort (Study One)			×	×	×
LT Social Progress (Study One)		✓+1	×	×	
LT Social Pleasure (Study One)	✓+1	✓+1		×	
LT Social Effort (Study One)			×	×	
Positive Affect	✓+1, 2	×	✓+1	✓-2	×
ST Achieve Progress	✓+1		×	×	×
ST Achieve Pleasure		×		×	×
ST Achieve Effort	✓+2		×	✓-2	×
ST Social Progress (Study Two)			×	×	
ST Social Pleasure (Study Two)		×		×	
ST Social Effort (Study Two)	✓+2	✓+2	×	×	
PA & LT Achieve Progress* (Study One)		×	×	×	
PA & ST Achieve Progress*	✓2	×	✓1	✓2	
PA & LT Social Progress* (Study One)		×	×	×	
PA & ST Social Progress* (Study Two)		×	×	×	

Note. MASQ-AD = Mood and Anxiety Symptom Questionnaire Anhedonic Depression subscale, BAS = Behavioural Activation Scale, FS = Fun-Seeking, D = Drive, RR = Reward Responsiveness, HPS = Hypomanic Personality Score, PA = Positive Affect, ST = Short-term, LT = Long-term. “+” denotes a positive correlation, whilst “-“ indicates a negative correlation. * indicates a within-person association that is moderated by the trait variable (cross-level interaction). 1 or 2 refers to sample observed in (1 = student sample, 2 = community sample). Observations marked in red indicate findings outside of a priori hypotheses.

2.4. Discussion.

The aim of the present research was to investigate the associations between measures of approach motivation, trait hypomania, anhedonic symptoms, and factors pertaining to the everyday experience of affect and the pursuit of personally relevant achievement and social goals. The two studies focused on distinct populations: the first, a sample of undergraduate students and the second, a community sample of older adults. As such, it was possible to explore whether the aforementioned associations are similar across different life stages. Whilst many of the a priori hypotheses were not supported by the data, several interesting associations did emerge between measures of BAS sensitivity, MASQ-AD, and the experience of PA and goal pursuit.

2.4.1. Trait Measures.

As predicted, the BAS sub-scales were positively intercorrelated in both samples, consistent with previous findings demonstrating that the BAS sub-scales loaded onto the same factor (Caseras et al., 2002). Additionally, BAS-FS was correlated with HPS in Study Two, which is in line with the hypothesised links between hypomania and greater BAS sensitivity (e.g., Alloy et al., 2008; Salavert et al., 2007; Van der Gucht et al., 2009). It is interesting that this correlation emerged with BAS-FS, a measure of the tendency to impulsively seek out and pursue reward, as this subscale was previously found to correlate with manic symptoms in a sample of BD individuals (Quilty et al., 2014). This would indicate that trait hypomania might be more related to greater levels of impulsivity, rather than excessive incentive motivation. It was also hypothesised that MASQ-AD would negatively correlate with the BAS subscales and HPS (in Study Two). This was not found to be the case in the student sample, although a negative correlation did emerge between MASQ-AD and both the BAS-FS and BAS-D subscales in the community sample. This may provide some indication that low BAS

sensitivity might be more relevant to anhedonic symptoms in older adults, with post-hoc tests indicating that the correlation was statistically significantly different between samples ($t = 2.19, p = .03$). However, the null findings in the student sample could be reflective of the fact that the BAS subscales (and the HPS) are considered to be true trait measures, whereas the MASQ-AD focuses on experiences in the preceding two weeks. It may be that the MASQ-AD and BAS subscales fluctuate more in students, as a result of random shocks, life events, etc., so that less of a correlation may be observed between them. This is particularly relevant to the student sample as many of the participants were in their first term at university, and so were likely to be undergoing a period of transition.

2.4.2. LT Goal Pursuit.

It was predicted that the measures of LT *achievement* goal pursuit would correlate with the measures of LT *social* goal pursuit.⁶ These measures were also expected to correlate with the momentary measures of PA and ST *achievement* goal pursuit. However, no support was found for these hypotheses at either the between or the within-person level. The null finding with PA was unexpected, as general goal progress has been linked to the experience of PA (Affleck et al., 1998; Emmons, 1986; Harris et al., 2003), whilst social goal progress has been linked with a greater level of positive emotions (Impett et al., 2010). However, it was specified that the LT goals should require a period of sustained effort to attain and, as such, it is possible that progress towards these goals did not occur often enough to manifest an association with state PA. Furthermore, these null findings may also be due to limitations in the measurement of the LT goals, for which the measures were only completed once per day. As a result of this fewer occasions were included in the analysis, which is likely to have reduced the sensitivity required to pick up fluctuations on the measures of LT *achievement*

⁶ The LT *achievement* and *social* goal measures were only assessed in the student sample, and not the community sample of older adults.

and *social* goal pursuit that were linked to fluctuations in PA. An alternative explanation may be that the LT *achievement* and *social* goals were unlikely to have been a participant's only goal in each domain during the ESM period, and therefore might not have a strong association with PA. This is particularly relevant as they were also asked to specify ST *achievement* goals each day, which were not required to be linked to their LT *achievement* goal. It is also likely that they would have had additional, unspecified LT goals. The pursuit of the LT *achievement* and *social* goals that were specified may have been in conflict with other goals, in such a way that the pursuit of one goal might interfere with the pursuit of another (Segerstrom & Solberg Nes, 2006), leading to psychological distress (Emmons, 1986; Emmons & King, 1988; Palys & Little, 1983; Riediger & Freund, 2004). Furthermore, intrinsic motivation has been linked with greater levels of PA (Higgins & Trope, 1990; Kaplan & Maehr, 1999; Ryan & Deci, 2000; Schiefele, 1991), so it could be that the LT goals specified in the present study were not intrinsically motivating, which would be of particular relevance to the LT *achievement* goal. Moreover, as discussed previously, so-called negative affects, such as anger and sadness have also been linked to the approach motivation system, particularly when goal striving is frustrated or blocked, or at least viewed as being inadequate (Carver, 2004; Harmon-Jones, 2003; Harmon-Jones & Allen, 1998; Harmon-Jones & Sigelman, 2001). This is in accordance with the control theory account (see Chapter One for more detail; Carver & Scheier, 1990, 1998), which posits that self-regulation during approach goal pursuit occurs as a result of discrepancy-reducing feedback loops, which are formed when an individual monitors the current state of the world and compares it to a salient reference value (e.g., the goal itself), adjusting behaviour to reduce the perceived discrepancy between their current state and the reference value (Carver, 2006). It is further suggested that a meta-monitoring feedback loop monitors rate of discrepancy reduction (i.e., progress towards the goal) and produces affect as an output. If approach goal progress exceeds the desired criterion, positive feelings and

confidence results, whereas when progress falls below what the individual expects, the individual will experience negative feelings and doubt (Carver, 2004). This affect, in turn, acts as a way of modifying behavioural output in the service of self-regulation: NA leads to increased effort in the short-term and goal disengagement in the long-term, whilst PA leads to the decrease/reallocation of effort (Carver et al., 2008). Thus it is possible that the lack of relationship between PA and the LT goal measures may have been the result of the participants experiencing some frustration during the pursuit of their LT goals, despite high levels of progress and effort, which may have led to a decrease in the experience of PA and an increase in feelings of NA. It is beyond the scope of the present research to assess this, but it would be an interesting avenue of future research to assess the relationship between PA and the discrepancy between expected goal progress/effort and perceived goal progress/effort.

It was less surprising that no significant associations were found between the daily LT *achievement* goal measures and the momentary ST *achievement* goal measures as, although they were both expected to reflect broader achievement motivation (McClelland, 1985). However, the LT *achievement* goal was quite different in nature to the ST *achievement* goal, requiring more sustained effort and organisation of behaviour over an extended period of time. Furthermore, there was no requirement for the LT and ST *achievement* goals to be hierarchically related (Carver & Scheier, 1998), such that progress towards the ST *achievement* goal facilitated progress towards the LT *achievement* goal. It may be that, due to limited resources, the pursuit of one of the goals precluded pursuit of the other; there might even have been conflict between the goals (Emmons & King, 1992). In conclusion, the null findings observed here do not support the notion that effort, progress, and pleasure associated with the pursuit of the LT *achievement* goal are associated with the same variables in relation to ST *achievement* goal pursuit.

2.4.3. ST Goal Pursuit.

The *ST achievement* and *social* goal pursuit measures were expected to correlate positively with state PA at the within-person level. This was not supported by the data in either sample. Alongside the null findings concerning the relationship between PA and LT *achievement* and *social* goal pursuit, this would indicate that goal pursuit is of limited relevance to the experience of transient PA. However, as discussed previously, the goals specified in the present research may have been less intrinsically motivating and thus less related to PA. The content of the *ST achievement* goals is particularly consistent with this (see Appendix B for examples), as they predominantly focused on the completion of mundane tasks that may not have been particularly rewarding. An alternative explanation would be that the particular goal that a participant chose for the purposes of the study may have conflicted with other goals, blunting their experience of PA. In addition, participants could instead have been engaging in another enjoyable activity, such as socializing with friends etc., which would be likely to be associated with higher levels of PA, despite no goal progress. Furthermore, not all goal progress has been demonstrated to be associated with PA and subjective wellbeing, particularly if a given goal is not aligned with an individual's implicit motives, or does not satisfy more fundamental needs (Brunstein, Schultheiss, & Grassman, 1998; Sheldon & Kasser, 1998). Finally, as also discussed in the context of the null relationships between PA and the LT goal pursuit measures, it is also possible that, despite providing relatively high ratings of ST goal progress/effort, participants may have experienced some frustration in the pursuit of their goals. In line with a control theory account of goal pursuit (Carver & Scheier, 1990, 1998), this frustration, or at least a discrepancy between expected/desired goal progress/effort and perceived goal progress/effort may have led to a reduction in PA. However, it is beyond the scope of the present research to assess this.

In the community sample, both ST *achievement* and ST *social* goal pursuit were assessed. These measures were found to correlate positively, suggesting that there is some relationship between variables relating to *social* and *achievement* goal pursuit at the ST level. This is in contrast to the null findings regarding the LT *achievement* and *social* goal pursuit in the student sample. This could be an issue of statistical power, as there more observations for ST goals than for LT goals, therefore the likelihood of finding an effect is greater. Another possibility is that variables relating to *achievement* and *social* goal pursuit are associated for goals that are relatively easy to attain (ST goals), but not for goals that require more sustained effort (LT goals). Alternatively, variables relating to *achievement* and *social* goal pursuit may be more closely related in the community sample, which may indicate that older adults' pursuits are more coherent and integrated, even across social and achievement domains. However, as LT goal pursuit was not assessed in the community sample, and the ST *social* goal was not assessed in the student sample, it is beyond the scope of the present research to provide an answer to this question.

2.4.4. BAS Sensitivity.

The ESM measure of PA was expected to correlate with each of the BAS subscales. Limited support was provided for this prediction, with significant associations emerging between mean levels of PA and the BAS-FS and BAS-D subscales, in the student sample. The association between PA and BAS-FS was particularly compelling as it was replicated in the community sample, which would suggest that it remains stable across different life stages, and is in line with the idea that BAS sensitivity is associated with state PA (Berkman et al., 2009; Gable et al., 2000). As previous work predominantly focuses on associations between the BAS subscales and trait measures of PA, the present research extended this by demonstrating an association with a state measure of PA throughout everyday life. It is

interesting that this association emerged consistently with BAS-FS, which measures the tendency to seek out and impulsively approach potentially rewarding activities (Beck et al., 2009; Johnson et al., 2005), making it particularly relevant to the experience of the more transient state PA assessed in the present research. Furthermore, PA was measured randomly and not in relation to particular incentives, which could explain why it is related particularly to BAS-FS, if the latter reflects a generalised tendency to find fun across situations, rather than just goal-oriented contexts. In its original formulation, the BAS was proposed to correspond to an impulsivity personality dimension, with those high in impulsivity being more sensitive to the signals of reward, as well as being more susceptible to the experience of PA than those low in impulsivity (Gray, 1981).

It was also hypothesised that the measures of goal progress and effort (for all goal types) would correlate with BAS-D, whilst the measures of associated pleasure for all goal types would correlate with the BAS-RR subscale. Very limited support for these hypotheses was provided, with LT *social* goal progress and pleasure (in the student sample), as well as ST social goal effort (in the community sample) being found to positively correlate with BAS-RR. As no associations were observed with *achievement* goal pursuit, this may provide a very tentative indication that BAS-RR may be of greater relevance to *social* goal pursuit. Considering the conceptual nature of BAS-RR, which measures the tendency to respond to positive stimuli, this would follow, as it could be that the *social* goals may have been more hedonic and intrinsically motivated, which would be consistent with self-determination theory, as the social goals are likely to address the fundamental need of relatedness (Deci & Ryan, 1985; Ryan & Deci, 2002). However, contrary to predictions, no significant associations were found between BAS-D and the measures of goal pursuit. This was surprising as BAS-D is thought to measure the tendency to pursue appetitive goals (Beck et

al., 2009; Johnson et al., 2005), so it would follow that higher scorers would make more goal progress and effort. However, it could be that the goals selected were not sufficiently appetitive or intrinsically motivating, representing a ‘colder’, less directly rewarding construct (particularly relevant for the *achievement* goals), whilst BAS-D may capture the response to more directly or immediately rewarding incentives. Additionally, participants may not have assigned a great deal of importance to their goals, but this is unlikely to explain the null result because they were asked to select goals that were important to them and reported relatively high levels of goal effort.

Finally, although not predicted, positive correlations were found between BAS-FS, ST *achievement* goal progress in the student sample, and ST *achievement* goal effort in the community sample. This was somewhat surprising, as the impulsive pursuit of rewarding experiences, as measured by BAS-FS was not expected to be conducive to goal pursuit, even hindering it due to the greater likelihood of distraction. BAS-FS was also related to *social* goal pursuit, with significant associations found with LT *social* goal pleasure (in the student sample) and ST *social* goal effort (in the community sample), which would suggest that, surprisingly, BAS-FS might be the BAS component most relevant to *achievement* and *social* goal pursuit.

2.4.5. Anhedonia.

Negative correlations were expected between MASQ-AD and the ESM measures of PA and goal pursuit (for all goal types). The negative associations between PA, ST *achievement* goal effort, and MASQ-AD in the community sample provided limited support for these predictions. This is consistent with the literature, which has linked the experience of depressive symptoms, such as anhedonia (thought to be associated with a lack of approach motivated behaviour) with lower levels of PA (Harris et al., 2003; Tellegen, 1985; Watson et

al., 1988), and a decreased willingness to expend effort to gain reward (Treadway et al., 2009; Yang et al., 2012), which, in this context, would be successfully completing their goal (assuming that goals are sufficiently rewarding). However, neither PA, nor any of the goal variables were associated with MASQ-AD in the student sample. This would indicate that the experience of anhedonic symptoms might be more closely associated with low PA and goal effort in older adults, although post-hoc tests indicated that the difference in correlations were not statistically significant between samples (MASQ-AD & PA: $t = 1.23, p = .27$; MASQ-AD & ST achievement goal effort: $t = 1.59, p = .12$) Interestingly, when further analyses were conducted in order to explore potential associations with trait measures of anhedonia (see Appendix F for details of these analyses), no significant associations emerged between PA and the trait measures of physical anhedonia (Chapman et al., 1976), or social anhedonia (Eckblad, Chapman et al., 1982), which would suggest that the association between PA and anhedonia in the community sample is more related to state components of anhedonic symptoms.

MASQ-AD scores were not found to be significantly different in the two samples, so the magnitude of anhedonic symptoms is unlikely to be the cause of the disparity in findings. However, it could be that high scorers on the MASQ-AD drove the associations with PA and ST *achievement* effort in the community sample. This is consistent with the greater range and variability of MASQ-AD score in the community sample. However, the lack of associations between MASQ-AD, goal progress, and associated pleasure was rather surprising. One possible explanation for this is perhaps anhedonia is more related to baseline levels of affect and less related to goal progress. Further research in different populations is required to elucidate the mechanisms and explanations underlying the relationship between anhedonia, affect, and goal pursuit across different life stages.

No significant associations were found between the measures of *social* goal pursuit and MASQ-AD, in either sample. This was somewhat surprising, as dysfunctional social behaviour has been implicated in the experience of depression, with depressed participants being found to report more negative social interactions overall, as well as lower levels of subjective wellbeing on the days that they reported more negative social interactions (Steger & Kashdan, 2009). However, the MASQ-AD focuses more on the physical aspects of anhedonia (e.g. *Felt really slowed down*); it is possible that a measure of social anhedonia may have been more appropriate to the measures of *social* goal pursuit. However, this does not seem to be the case, as no significant associations were found between social goal pursuit and a measure of trait social anhedonia in the community sample (Eckblad et al., 1982; see Appendix F for these additional analyses). Furthermore, another potential complication in the interpretation of the present findings, which relates to both *achievement* and *social* goal pursuit, is that the types of goals that those high in MASQ-AD select may differ from those chosen by someone low in MASQ-AD.

2.4.6. Hypomanic Personality Traits.

Contrary to predictions, no significant associations were found between HPS and ESM measures of PA and ST *achievement* goal pursuit in Study Two. This is in contrast to the idea that hypomania is linked to general positive affectivity (Davidson et al., 2000; Gable et al., 2000) and previous findings reporting a positive correlation between HPS and the PA scale of the PANAS (Kirkland et al., 2015; Meyer & Hofmann, 2005). Hypomania is also associated with greater goal-directed behaviour, so it was also surprising that no associations were found between the measures of ST *achievement* goal pursuit and HPS score. It is possible that the ST *achievement* goals selected by participants were less relevant to the HPS; those high in HPS may need to be “triggered” by particular kinds of goal-relevant life events to

demonstrate the increased levels of PA previously observed. It is unlikely that the ST *achievement* goal would be grandiose enough to trigger this, particularly due to the observation that goals concerning fame and financial success are particularly salient for people with bipolar disorder (Carver & Johnson, 2009; Gruber & Johnson, 2009; Johnson & Carver, 2006; Johnson et al., 2009). Although the content of the goals were not formally analysed, the ST *achievement* goals tended to focus on more mundane and trivial, task-based goals (see Appendix B). However, the consistently null findings related to the HPS could also be a result of the very low sample mean on this scale, which was around one standard deviation lower and less variable than that observed in other non-clinical samples (e.g., Bentall et al., 2011); it could be that a more diverse range of scores (including greater representation at the higher end of the scale) are required to observe any relationships between HPS score, and measures of PA and goal pursuit.

In conclusion, the two studies reported here present some evidence for the association between several of the trait measures, most notably BAS-FS and MASQ-AD, and the everyday experience of PA. There was a more ambiguous pattern of correlations between the trait and goal pursuit measures, such that only a few of the predicted results were statistically significant.

2.4.7. Cross Level Interactions.

Following the initial analysis, which focused on the between and within-person correlations, a more exploratory analysis was conducted, investigating how the relationships between the measures of PA and goal progress may have been moderated by the trait measures. However, relatively few of the a priori hypotheses were supported and for those that were, the interactions were small in magnitude (see section 2.3. for interaction plots) and were not replicated across the student and community samples. Although future research

should examine their replicability, the individually significant interactions will now be briefly discussed.

BAS-FS. Although not predicted, BAS-FS was found to moderate the relationship between PA and ST *achievement* goal progress, in the community sample. The positive association between PA and ST *achievement* goal progress on a particular occasion was stronger for persons with lower levels of BAS-FS. Considering BAS-FS measures the tendency to impulsively pursue reward, the direction of the effect was not surprising, as those participants high in BAS-FS could be more prone to focus on hedonic experiences than on *achievement* goals. It would follow that more impulsive people might find the progress and effort associated with a mundane, ST *achievement* goal to be rather dull such that effort and progress on *achievement* goals are less tightly coupled with PA (see Appendix B for examples). Limited support for this explanation is provided by the findings that the same relationship was not observed for the ST *social* goal progress.

Anhedonia. MASQ-AD was found to moderate the relationship between PA and ST *achievement* goal progress, in the community sample. A stronger positive association between ST *achievement* goal progress and PA was found for persons lower in MASQ-AD than for persons higher in MASQ-AD, indicating that less anhedonic participants experienced more PA when they were making more progress, as expected. Conceptually, anhedonia is related to a lack of motivation and enjoyment, so it would follow that high scorers for anhedonic symptoms would experience less PA as a result of progress. It is worth considering that people with lower mood, including anhedonic symptoms, tend to hold themselves to higher standards of performance (Cervone, Kopp, Schaumann & Scott, 1994), and might be more demanding about what constitutes a good rate of progress. Although goal progress was person-centred in this analysis, such that this does not directly threaten the above

interpretation, it would be beneficial for future research to focus on more objective measures of goal progress, such as goal attainment scaling (Kirusek & Sherman, 1968).

2.4.8. Limitations.

The present research offered many novel advantages: the ability to investigate both the between and within person relationships of PA, as well as the pursuit of different types of personally relevant goals, in two distinct samples. The methodology used was also more reliable and ecologically valid than retrospective self-report. However, it is important to acknowledge the limitations of the present research. The first is the relatively homogenous nature of the two samples. The first sample consisted solely of undergraduate students, whilst the second consisted of participants from an older age range, who were predominantly retired. Although these two samples are likely to be quite distinct from each other, there was very little variance in scores on the trait measures, although these were in line with data in non-clinical populations for the BAS subscales and MASQ-AD (Carver & White, 1994; Watson et al., 1995). This is particularly relevant to the MASQ-AD and HPS measures, for which the higher end of the scale might be under-represented in the present samples. It may be that one needs to see more extreme levels of anhedonia and trait hypomania for the associations with affect and goal pursuit to emerge, so future research could be conducted in clinical samples, where this is likely to be the case.

A general limitation of the use of ESM is the use of the signal-contingent method, which means that participants only provided ratings when they were alerted. Participants may not have been experiencing strong levels of affect when they completed the ratings and so this method may not have accurately captured the true range or extent of an individual's affective experience. Furthermore, participants were asked to complete the goal pursuit measures after they had completed ratings of affect, which could result in altered goal appraisals, due to the

prior focus on the experience of affect. For example, if a participant provided high ratings of PA, they might have appraised goal pursuit more positively (e.g., Cervone et al., 1994). As such, it may be that mood state and the act of responding to a mood item influenced goal appraisal. In addition to this, it is also possible that the use of ESM exaggerated the correlations for certain measures (e.g., the relationship between goal progress and effort), as increased self-focus, brought about by the regular ratings, is thought to increase the salience of discrepancies between desired and perceived progress (Carver & Scheier, 1998). This is particularly relevant due to the very high intercorrelation between the measures of *ST achievement* goal pursuit, particularly in the community sample, suggesting that participants might have simply been providing very similar ratings across the measures, although measures such as goal progress and pleasure associated with progress were expected to be very highly correlated as there is an inherent overlap between them.

Finally, although statistical power was high for the investigation of within-person relationships due to the large number of observations, it was only moderate for the investigation of the between-person relationships and the cross-level interactions, which were of more central interest here. As such, there was only power of .80 to detect medium-sized between-person associations (Cohen, 1992), thus, some of the null findings in the present research could have been Type II errors.

2.4.9. Conclusion.

In conclusion, it seems that relationships between measures of trait approach motivation, anhedonic symptoms, trait hypomania, PA, and goal pursuit are not as straightforward as initially expected. In particular, the everyday experience of PA was not related to progress, pleasure or effort associated with the achievement and social goals investigated, whilst the trait measures of approach motivation, hypomanic traits and

anhedonic symptoms were also found to be mostly uncorrelated with these measures of goal pursuit.

Previous research has reported associations between BAS sensitivity and neural activation associated with reward anticipation and consumption (e.g., Caseras et al., 2013; Simon et al., 2010), which has also been found to correlate with a real-world measure of PA (Forbes et al., 2009; Forbes et al., 2010; Olino et al., 2014). In order to further examine these associations and their links to goal pursuit, the following chapters (Chapters Four – Seven) sought to probe the neural responses associated with different aspects of reward processing, using diverse positive stimuli. This research also aimed to demonstrate the relevance of both individual difference (trait) measures and differences in the experience of everyday PA and goal pursuit to neural responses to reward. Chapter Three provides an overview of the general scanning procedure.

Chapter III: General Scanning Procedure.

3.1. Study One.

Sample Size. In terms of calculating required sample size for associations between fMRI activations and individual difference variables, I assumed large ($r = .5$) effect sizes on the basis of prior research. G*Power calculations revealed a required sample size of 29 persons for fMRI. Based on prior experience, I assumed that approximately 10% of participants would not complete the study, so I aimed to recruit 32 participants for fMRI scanning such that adequate power would be attained after attrition.

Inclusion/Exclusion Criteria. In order to be invited to participate in the MRI study, participants were required to have completed at least 60% of the ratings in the ESM study to ensure representative data. For safety reasons, participants were also excluded if they had any MRI contraindications (e.g., metal implants) in accordance with the MRI scanning centre safety policy. Medication status and the presence of mental and physical health conditions were not explicitly measured, so no exclusions were made on this basis, beyond the MRI contraindications described above. No further exclusions were in place.

Trait Measures.

i) Mood and Anxiety Symptom Questionnaire – Anhedonic Depression Subscale (MASQ-AD; Clark & Watson, 1991). Refer to Chapter Two for full description (section 2.2.1.).

ii) BAS Scales (Carver & White, 1994). Refer to Chapter Two for full description (section 2.2.1.).

Experience Sampling. All participants had previously undergone a period of ESM in order to gain ecologically valid measures of everyday PA and ST *achievement* goal pursuit.

See Chapter Two (section 2.2.1) for a full description. Participants would commence the ESM study on the day after their initial briefing and the delay between this briefing and participation in the MRI study ranged from ten to twenty-three days.

fMRI Task. E-Prime software (Psychology Software Tools, Inc.) was used to deliver and record responses. Stimuli were presented during scanning using an Epson EMP-74 digital projector system projected onto a screen at the foot of the scanner, and viewed via an angled mirror, which was attached to the head coil. Participants responded using their right index and middle fingers, via a fibre-optic response button-box.

Procedure. Ethical approval was granted by the University of Exeter ethics committee. Following the completion of the ESM study, a follow up appointment was arranged at Exeter MR Research Centre at the earliest convenience. The researcher then described the general procedure of the scanning session, as well as a description of tasks that they would complete as part of the scanning session. After being invited to ask questions about the procedure, participants provided their informed consent and completed and signed the MR centre safety checklist to ensure that there were no MRI contraindications and it was safe for them to undergo an MRI scan. The participant was then placed in the scanner and completed three tasks in a set order. First, the Card-Guessing task (see Chapter Four), followed by the Happy Faces task (see Chapter Five), and ending with the Positive Affect Task (see Chapter Six). Participants were provided with a reminder of the instructions at the start of each task and were offered the opportunity to ask the researcher any questions. Although participants remained in the scanner for the duration of the session, they were offered short breaks between each task, the duration of which they decided upon.

3.2. Study Two.

Sample Size. In terms of calculating required sample size for associations between fMRI activations and individual difference variables, I assumed large ($r = .5$) effect sizes on the basis of prior research. G*Power calculations revealed a required sample size of 29 persons for fMRI. Based on prior experience, I assumed that approximately 10% of participants would not complete the study, so I aimed to recruit 32 participants for fMRI scanning such that adequate power would be attained after attrition.

Inclusion/Exclusion Criteria. In order to be invited to participate in the MRI study, participants were required to have completed at least 60% of the ratings in the ESM study to ensure representative data. For safety reasons, participants were also excluded if they had any MRI contraindications (e.g., metal implants) in accordance with the MRI scanning centre safety policy. Additionally, due to possible age-related degradation in the brain (e.g., Peters, 2006; Scahill et al., 2003), participants over the age of 70 years were excluded from the MRI study. Medication status and the presence of mental and physical health conditions were not explicitly measured, so no exclusions were made on this basis, beyond the MRI contraindications described above. No further exclusions were in place.

Trait Measures.

i) Mood and Anxiety Symptom Questionnaire – Anhedonic Depression Subscale (MASQ-AD; Clark & Watson, 1991). Refer to Chapter Two for full description (section 2.2.1.).

ii) BAS Scales (Carver & White, 1994). Refer to Chapter Two for full description (section 2.2.1.).

iii) Hypomanic Personality Scale (HPS; Eckblad & Chapman, 1986). Refer to Chapter Two, section 2.2.1., for full description.

Participants were also asked to complete various other related measures (Appendix A), including the Revised Physical Anhedonia Scale (Chapman et al., 1976), the Revised Social Anhedonia scale (Eckblad et al., 1982), the Patient Health Questionnaire (PHQ-9; Kroenke et al., 2001). However, these measures were not included in the present analysis.

Experience Sampling. All participants had previously undergone a period of ESM in order to gain ecologically valid measures of everyday PA and ST *achievement* and ST *social* goal pursuit. See Chapter Two (section 2.2.1) for a full description. Participants would commence the ESM study on the day after their initial briefing and the delay between this briefing and participation in the MRI study ranged from nine to thirty-one days.

fMRI Task. E-Prime software (Psychology Software Tools, Inc.) was used to deliver and record responses. Stimuli were presented during scanning using an Epson EMP-74 digital projector system projected onto a screen at the foot of the scanner, and viewed via an angled mirror, which was attached to the head coil. Participants responded using their right index and middle fingers, via a fibre-optic response button-box.

Procedure. Ethical approval was granted by the University of Exeter ethics committee. Following the completion of the ESM study, a follow up appointment was arranged at Exeter MR Research Centre at the earliest convenience. The researcher then described the general procedure of the scanning session, as well as a description of tasks that they would complete as part of the scanning session. After being invited to ask questions about the procedure, participants provided their informed consent and completed and signed the MR centre safety checklist to ensure that there were no MRI contraindications and it was safe for them to undergo an MRI scan. The participant was then placed in the scanner and completed three tasks in a set order. First, the Card-Guessing task (see Chapter Four), followed by the Happy Faces task (see Chapter Five), and ending with the Positive Affect

Task (see Chapter Six). Participants were provided with a reminder of the instructions at the start of each task and were offered the opportunity to ask the researcher any questions. Although participants remained in the scanner for the duration of the session, they were offered short breaks between each task, the duration of which they decided upon.

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Chapter IV: The Anticipation and Receipt of Monetary Reward.

4.1. Introduction.

As the majority of everyday behaviour is motivated by the anticipated outcome of our actions, many activities are performed to either obtain a reward or avoid punishment. For example, I sit down to write everyday so that I will eventually finish my thesis and earn my PhD (reward), but also to avoid failing in this endeavour (punishment). Due to the link between approach motivated behaviour and rewarding stimuli, the present chapter focuses on the neural responses related to the processing of reward.

A reward may be defined as a desirable outcome that serves to influence behaviour (Delgado, 2007), leading to positive emotional experiences, such as the subjective feeling of pleasure (Wise, 2002), and eliciting approach behaviour (Schultz, 2000). Reward is a central component that drives incentive based learning and the development of goal-directed behaviours (Haber & Knutson, 2010). Therefore, a necessary step in understanding goal-directed behaviour is also to understand how rewards are represented in the brain and how such knowledge leads to learning of new associations that guide goal-directed behaviour (Delgado, 2007). The primary focus of the present chapter was to assess potential relationships between trait approach motivation, as well as constructs pertaining to either high or low trait approach motivation (trait hypomania and anhedonic symptoms respectively) and neural responses associated with monetary reward anticipation and receipt, within a card game of chance. A secondary focus was to explore potential associations between this reward-related activation and measures of everyday affective experience and goal pursuit.

4.1.1. Reward Processing.

The processing of reward is a key focus in neuroimaging research, which has provided a relatively clear idea of the neural substrates likely to be involved (Bjork et al., 2004; Knutson et al., 2001). Several subcortical regions, such as the basal ganglia, and its cortical targets are thought to be central to reward processing (Fareri, Martin, & Delgado, 2008). A key structure of the basal ganglia is the striatum, which has been implicated in the processing of reward in both animal (Ikemoto & Panksepp, 1999; Robinson & Berridge, 2003; Schultz, 1998) and human (Ablner et al., 2005, 2006; Knutson & Cooper, 2005; Knutson et al., 2001) studies, with striatal activation in response to monetary reward being consistently demonstrated (e.g. Knutson et al., 2001a; Knutson et al., 2001b).

The striatum can be divided into two components: the ventral striatum (VS) and the dorsal striatum (DS; Fareri et al., 2008; Haber & Knutson, 2010). The VS is comprised of the NAcc and ventral portions of the caudate nucleus and the putamen (Fudge & Haber, 2002; Voorn, Vanderschuren, Groenewegen, Robbins, & Pennartz, 2004). Particular emphasis has been placed on the role of the NAcc in reward processing, with preclinical research indicating that the dopaminergic neurons of the NAcc initially respond during consumption of unexpected rewards, but then begin to fire in response to reward-predicting cues (Ikemoto et al., 1999; Schultz, 1998). Consequently, the NAcc is believed to be involved in various forms of reinforcement-based learning and approach-related behaviour (Niv, 2009) and is held to be integral to both motivational and consummatory aspects of reward processing (Belin, Jonkman, Dickinson, Robbins, & Everitt, 2009). The DS, incorporating the caudate nucleus and the putamen, has been implicated in action-contingent learning (Delgado et al., 2000, 2005, 2007; Knutson et al., 2001; Haruno et al., 2004; O'Doherty et al., 2004; Tricomi et al., 2004), which involves the learning of an association between an action and outcome before processing the value associated with different goal directed actions (Delgado, 2007). This

suggestion is supported by both human (O'Doherty et al., 2004; Tricomi et al., 2004) and animal (Ito et al., 2002; Yin et al., 2005) studies.

There is some suggestion that the VS and the DS are functionally distinct sub-regions. Indeed, several rodent studies have demonstrated that lesions of the VS were associated with deficits in approach behaviour (Robbins & Everitt, 1992), whilst lesions in the DS were linked to deficits in consummatory response and stimulus response learning (Robbins et al., 1989). As such, it has been suggested that the VS is involved in affective and motivational processing, whilst the DS plays a role in more cognitive and sensorimotor functions (Graybiel et al., 2004; Packard & Knowlton, 2002; White & McDonald, 2002). This is consistent with their respective connections to the prefrontal cortex (PFC), as the DS is connected to the motor/cognitive regions of the PFC, whilst the VS is connected to the more ventral regions that are thought to be involved in emotion and motivation (Groenewegen & Uylings, 2000).

4.1.2. The Incentive-Saliency Model.

The incentive salience model (Berridge, 1996, 2007, 2012) posits that there are two distinct psychological components of reward processing and learning: wanting and liking. 'Wanting', or incentive salience, is the motivation for reward, elicited by reward-related cues, which makes both the reward and its cue more attractive, sought after, and, therefore more likely to be consumed (Berridge, 2009; Berridge et al., 2010). 'Liking' refers to the pleasure experienced during the consumption/receipt of the reward (hedonic impact). Although these two components often correspond to the same reward (i.e., one is often motivated to obtain what one likes), they are thought to have separable neural substrates that can be manipulated/measured in an independent fashion (Berridge, 2007; Berridge & Robinson, 1998; Smith et al., 2011). Consistent with this psychological dissociation, many tasks used to assess neural responses during reward processing are divided into two distinct stages: reward anticipation (i.e., the response to a reward-predicting cue) and reward consumption/receipt

(i.e. the response to the reward itself). This dissociation is of particular importance as each phase is thought to represent a very different psychological state (Berridge & Robinson, 1998; Pizzagalli et al., 2009). Reward anticipation is likely to be associated with motivational processes, such as the willingness to work during goal-directed behaviour, whereas the outcome phase is likely to be dominated by affective responses (Dillon et al., 2008, 2011), such as the experience of pleasure (Gard et al., 2006). When relating this to the incentive salience model of reward processing, reward anticipation is likely to be more closely related to ‘wanting’, whilst reward consumption/receipt should relate more to ‘liking’ (Berridge & Robinson, 2003; Wyvell & Berridge, 2000).

4.1.3. Prediction Error.

Prediction error serves as an index that brings together reward anticipation and consumption (Schultz et al., 1997) and is a fundamental concept to understanding how learning and decision-making occur in the brain. When presented with a stimulus, the brain predicts what will happen, based on prior experience and patterns of response. If the outcome matches this expectation, no prediction error occurs. However, when there is a difference between expectation and outcome, a prediction error is generated. A positive prediction error occurs when the outcome exceeds the expectation, whilst a negative prediction occurs if the outcome falls short of the expectation. The concept of prediction error is based on research in non-human primates, which demonstrated that midbrain dopamine neurons exhibit greater firing rates during the receipt of a more valuable reward than expected, but decreased during the presentation of a less valuable reward than expected (Schultz, 2000). Human research has demonstrated that the encoding of prediction errors occurs in dopamine-rich brain areas, such as the striatum (Glascher et al., 2009; O’Doherty et al., 2003, 2004; Pessiglione et al., 2006), with a positive prediction error following unexpected rewards (Berns et al., 2001) and a negative prediction error following the omission of expected rewards (Ablner et al., 2005;

Knutson et al., 2001b). Furthermore, the VS appears to code prediction error signals for reward, and less dominantly for punishment (Abler et al., 2006; Garrison et al., 2013; Schultz, 2010; Yacubian et al., 2006), which further implicates the VS in reward processing.

4.1.4. Reward Processing in Healthy Participants.

Activation of the VS, and of the NAcc in particular, has been consistently associated with reward anticipation (Abler et al., 2005, 2006; Dichter et al., 2012; Elliott et al., 2004; Gasic et al., 2009; Knutson & Cooper, 2005; Knutson et al., 2001a; Knutson et al., 2003; Kohls et al., 2012; O'Doherty et al., 2001; Smith et al., 2010), with activation being found to increase proportionally to magnitude of anticipated reward (Knutson et al., 2001a; Yacubian et al., 2006). Consequently, NAcc activation is thought to sustain appetitive motivation for obtaining reward (Delgado et al., 2000; Der-Avakian and Markou, 2012; Kumar et al., 2014; Warner-Schmidt et al., 2012), which is consistent with its association with approach-related behaviour (Niv, 2009). Furthermore, activation of the NAcc has also been reported during reward receipt (Bjork et al., 2004; Dillon et al., 2008; Simon et al., 2010), although this has not been consistently observed (Knutson et al., 2003). Taken together, these findings are consistent with the suggestion that the VS mediates reward-based drive and motivation (Haber & McFarland, 1999; Heimer, 2003; McGinty, 1999), representing a limbic-motor interface, responsible for the attribution of incentive salience to cues of potential reward ('wanting': Berridge, 2007) and translating them into goal-directed action.

Although there has been less of a focus on the DS, caudate activation has also been reported during reward anticipation (Knutson et al., 2001; O'Doherty et al., 2002). DS activation at this stage is thought to reflect action-contingent learning (Delgado et al., 2000, 2005; Haruno et al., 2004; Knutson et al., 2001a; O'Doherty, 2004; Tricomi et al., 2004), specifically the coding of prediction error during goal directed behaviour (Davidson et al., 2004; Delgado et al., 2005; Haruno & Kawato, 2006; O'Doherty et al., 2004). Furthermore,

caudate activation has also been observed during reward receipt (Delgado et al., 2000, 2003), particularly when feedback informs subsequent actions (O'Doherty et al., 2004). This suggests that the caudate is involved in strategic action planning, with increased caudate activation promoting the choice of the best action (Haber & Knutson, 2010).

4.1.5. BAS Sensitivity and Reward Processing.

Personality traits are likely to account for a substantial proportion of variance in behaviour (e.g., Fleeson & Noftle, 2009; Hogan, 2009), so due consideration of the potential impact that individual differences may have on reward-related neural responses is valuable. A potential avenue for investigation concerns the RST (Gray, 1970), a prominent, biologically based personality model. The RST concerns individual differences in appetitive functioning, postulating two behavioural systems implicated in reward-related responses (see Chapter One for a more detailed description; Pickering & Gray, 2001). The BAS, an approach-based motivational system, is thought primarily to respond to rewarding stimuli leading to the activation of reward-seeking behaviour. Activation of the BAS results in an approach to reward despite any associated costs or risks, which would map onto the more motivational reward 'wanting'. The BAS is thought to be subserved by the same neural circuitry that underlies reward processing, including the mesolimbic (incorporating the striatum) and the mesocortical systems (Smillie, 2008). This is supported by the findings of a longitudinal study, which reported a positive association between changes in NAcc volume and changes in BAS-D (a self-report measure used to assess individual differences in BAS; Carver & White, 1994) in adolescents, whilst NAcc volume at baseline was predictive of changes in BAS-RR over a two-year period (Urošević, Collins, Muetzel, Lim, & Luciana, 2012). Taken together, these findings provide a compelling argument for the investigation of BAS sensitivity as a potential source of individual differences in striatal reward processing.

As the BAS engages in preparation to obtain, but not to receive reward (Corr,

Pickering, & Gray, 1995), it is likely that BAS sensitivity would be closely related to neural responses associated with the more motivational reward anticipation. In support of this, Caseras et al. (2013) reported a significant association between the BAS-FS subscale and striatal activation during reward anticipation, but not reward receipt, in a mixed sample of individuals with bipolar disorder and HCs. Consistent with this, another study reported a positive correlation between an alternative BAS measure (SPSRQ: Torrubia et al., 2001) and striatal activation during reward anticipation (Hahn et al., 2009). This association also seems to extend across domains of reward, with a significant association being found between BAS-D and striatal activation associated with viewing images of appetising foods, in contrast to images of bland foods (Beaver et al., 2006).

The specific association between the BAS and reward anticipation has not been consistently observed. A positive correlation between an aggregate score of the BAS subscales (Carver & White, 1994) and VS activation during monetary reward receipt has been reported in several studies (Kim et al., 2015; Simon et al., 2010). Moreover, no relationship was found between the aggregate BAS score and VS activation during reward anticipation in either study, suggesting that those high in BAS demonstrate greater hedonic reactivity. As this research focused on the aggregate BAS score, it is not possible to determine which trait/combination of BAS-related traits drove the association with VS activation. However, another study reported a significant association between BAS-FS and VS activation during reward receipt, in a sample of non-clinical adolescents (Duijenvoorde et al., 2014), whilst another study reported a positive correlation between BAS-D and VS activation during monetary reward receipt (Costumero et al., 2015).

4.1.6. Reward Processing in Depression.

Considerable emphasis has been placed on examining reward-related neural circuitry in depression (Eshel & Roiser, 2010; Kupfer, Frank, & Phillips, 2012; Martin-Soelch, 2009),

with depressed participants found to exhibit a blunted neural response to reward (e.g., Forbes et al., 2009; Heller et al., 2009; McCabe et al., 2009). This reduction in reward responsiveness has been attributed to diminished neural responses and structural changes in the basal ganglia, particularly the striatal regions (Drevets, Videen, Price, Preskorn, Carmichael, & Raichle, 1992; Elliott, Sahakian, Michael, Paykel, & Dolan, 1998; Epstein et al., 2006; Keedwell et al., 2005; Kumar et al., 2009; Steele, Kumar, & Ebmeier, 2007).

During reward anticipation, several studies have reported diminished NAcc activation in depressed participants (Forbes et al., 2009; Smoski et al., 2011; Stoy et al., 2012; Ubl et al., 2015). The NAcc is believed to be responsible for sustaining appetitive motivation to obtain rewards during the anticipatory stage (Delgado et al., 2000; Der-Avakian & Markou, 2012; Kumar et al., 2012; Warner-Schmidt et al., 2012). As such, depression-related deficits in VS activation may reflect a reduced ability to compute the value of stimuli and initiate goal directed behaviour (Ubl et al., 2015). These deficits are consistent with anhedonic symptoms, such as the lack of motivation to work for rewards. However, there is considerable inconsistency in the literature, with some studies finding no differences between depressed participants and HCs in striatal activation during reward anticipation (Knutson et al., 2008; Pizzagalli et al., 2009). The cause of this disparity is unclear, but may relate to symptom pattern, symptom severity, or even the use of different experimental designs resulting in the activation associated with reward receipt being carried over into the anticipation stage of the subsequent trial (Knutson et al., 2008; Kumar et al., 2008, Wacker et al., 2009).

Reduced striatal activity during reward receipt has also been associated with depression (Forbes et al., 2009; Keedwell et al., 2005; Pizzagalli et al., 2009). Depressed participants, relative to HCs, have been found to exhibit attenuated NAcc and caudate responses during reward receipt (Pizzagalli et al., 2009; Redlich et al., 2015; Satterthwaite et al., 2015; Zhang et al., 2013). As the NAcc is also posited to track the hedonic value of

outcomes, it has been suggested that diminished activation during reward receipt might indicate deficits in hedonic coding, whilst reduced caudate activation may be reflective of depression-related deficits in expressing goal-directed behaviours (Pizzagalli et al., 2009). However, as with findings concerning reward anticipation, there is some inconsistency, with several studies reporting no observable differences in striatal activity between depressed individuals and HCs during reward receipt (Stoy et al., 2012; Ubl et al., 2015).

Diminished reward responsivity seems to be a key element of depression, as it has been demonstrated to persist after remission (Pechtel, Dutra, Goetz, & Pizzagalli, 2013), is predictive of chronicity despite pharmacological treatments (Vrieze et al., 2013), and worsens with disease burden (as assessed by the number of depressive episodes experienced; Hall, Milne, & MacQueen, 2014). However, there is still some question as to whether the abnormal reward function observed in depression is a consequence of symptoms or due to an underlying neural vulnerability (Marchand, 2010). A recent meta-analysis provides some evidence for the latter, reporting that deficits in reward-related striatal activation in depressed participants do not seem to alter with treatment (Graham et al., 2013). The authors suggested that this attenuated activation might serve as a trait vulnerability marker, or at least provide a neural marker of treatment resistance. This is supported by two studies that demonstrated attenuated activation of the striatum during both reward anticipation and receipt, in never depressed adolescents at risk of depression based on family history, compared to matched low risk participants (Gotlib et al., 2010; Olino et al., 2014). Furthermore, deficits in striatal activation during reward anticipation were found to predict increases in depressive symptoms over two years, in a sample of never-depressed adolescents (Morgan et al., 2013). Taken together, these findings suggest that deficits in striatal activation during reward processing, particularly during the anticipatory stage, may provide a possible neurobiological marker for the development of depression, as well as informing the likely course of the disorder.

The activation patterns observed in depressed participants may have important implications for the neurobiological mechanisms that underlie anhedonia, which is also thought to reflect dysregulated reward processing (Heshmati & Russo, 2015; Russo & Nestler, 2013). Anhedonia may be defined as impairment in the ability to pursue and experience pleasure (Rømer Thomsen et al., 2015; Treadway & Zald, 2011) and is a cardinal symptom of depression (Andreasen, 1982; Healey et al., 2014),

One study focusing on reward processing in a healthy sample reported a significant association between anhedonia (measured using the MASQ-AD) and reduced striatal activation during reward receipt, even after controlling for other symptoms of depression and anxiety, suggesting that this association was specific to anhedonic symptoms (Wacker et al., 2009). This was consistent with previous findings that anhedonia is associated with reduced striatal responses when viewing positive stimuli (Epstein et al., 2006; Keedwell et al., 2005; Stuhmann et al., 2013). However, associations have also been reported between anhedonia and striatal activation during reward anticipation (Stoy et al., 2012; Ubl et al., 2015), which suggests that anhedonia may relate to striatal deficits during both stages of reward processing. This is in line with the findings of a recent meta-analysis, which indicated that decreased caudate activation was associated with both anticipatory and consummatory anhedonia (Zhang et al., 2016).

Furthermore, a negative correlation has been found between anhedonia and caudate volume, in both depressed and sub-clinical participants (Harvey et al., 2007; Pizzagalli et al., 2009) and with NAcc volume in HCs (Wacker et al., 2009). This is interesting as the striatum is thought to encode and track prediction errors (Glascher et al., 2009; O'Doherty et al., 2003, 2004; Pessiglione et al., 2006; Rohe, Weber, & Fliessbach, 2012) and disruption in the processing of prediction errors may lead to anhedonia through reduced reward learning or blunted response to reward (Gradin et al., 2011; Greenberg et al., 2015; Kumar et al., 2008).

Furthermore, using EEG, Bress and colleagues (2013) found that the onset of MDD in never-depressed adolescent girls could be predicted by the reduced amplitude of feedback-related negativity, which is believed to originate from reward prediction error related activity in the striatal regions.

In conclusion, the decreased striatal response observed in MDD may indicate difficulties with several aspects of reward processing (Forbes et al., 2009). For example, it has been suggested that a lack of caudate activation could be indicative of difficulties in responding to rewarding cues with appropriate behaviour (Balleine, Delgado, & Hikosaka, 2007), which is consistent with other behavioural findings that those low in approach motivation, as in depression, are less likely to respond to reward cues with appropriate behaviour to maximize the chances of a positive outcome (Corr, 2002). Furthermore, reduced NAcc activation may signify a reduced ability to compute the value of stimuli and initiate goal directed behaviour (Ubl et al., 2015), which would be in line with other markers of reduced approach motivation in MDD and subclinical depression, such as decreased left frontal cortical activation (Davidson et al., 1987; Henriques & Davidson, 1991; Schaffer et al., 1983), thought to be indicative of deficits in the approach system (Henriques & Davidson, 1991).

4.1.7. Reward Processing in Bipolar Disorder.

Bipolar disorder appears to be characterised by a hypersensitivity to reward-relevant stimuli, which may be a key component of the emotional lability and dysregulation that typify the disorder (Urošević et al., 2008). This is consistent with previous behavioural findings that indicate greater self-reported reward sensitivity in BD individuals (Meyer et al., 1999; Meyer et al., 2001; Rich et al., 2005), which, in turn, is associated with a more severe course of the disorder (Alloy et al., 2008). It is thought that this hypersensitivity to reward may lead to an excessive increase in approach/goal-directed behaviour in BD individuals, which is consistent

with the association between the experience of hypomania and abnormal goal regulation, including unrealistic goal setting and inflated success expectancy (Johnson, 2005). Consequently, BD is thought to be the result of a dysregulation of the neural networks responsible for the mediation of motivation and goal-directed behaviour (Johnson, 2005; Miller, 1993), with greater BAS sensitivity underlying hypomania and mania (see Alloy & Abramson, 2010, for a review). This is supported by findings that both manic and remitted BD participants score higher than matched controls on the BAS subscales, whilst in non-clinical populations those with greater levels of hypomania also score higher than those with lower levels of hypomania (Bentall et al., 2010; Meyer et al., 1999).

In accordance with these findings, BD has been linked with abnormally elevated reward-related neural activation (Berpohl et al., 2010; Nusslock et al., 2012). Several neuroimaging studies have reported the increased activation of the striatal regions, particularly the NAcc, in BD participants compared to HCs (Caseras et al., 2013; Nusslock et al., 2012; O'Sullivan et al., 2011). As BD individuals seem to be particularly affected by anticipatory/goal striving events and stimuli (Nusslock et al., 2007; Urošević et al., 2010) and NAcc activation has been reliably demonstrated during reward anticipation (Breiter et al., 2001; Knutson et al., 2003), it would follow that any potential dysregulation is likely to occur during the anticipatory period (Caseras et al., 2013; Nusslock et al., 2012). This is supported by findings that both euthymic bipolar and hypomanic participants, as measured by the Hypomanic Personality Scale (HPS; Eckblad & Chapman, 1986), exhibit increased striatal activation relative to healthy controls during reward anticipation, but do not differ during reward receipt (Caseras et al., 2013; Nusslock et al., 2012; O'Sullivan et al., 2011). This is consistent with the greater difference in FRN amplitude (thought to originate from reward prediction error related activity in the striatal regions) observed in response to immediate and delayed rewards in hypomania-prone individuals, suggesting prediction error abnormalities in

hypomania (Mason et al., 2012). However, in contrast to this, one study reported reduced striatal response during reward anticipation in unmedicated BD participants (Yip, Worhunsky, Rogers, & Goodwin, 2015), although this has yet to be replicated. The authors suggested that increased striatal activation observed in previous research may have been the result of the ameliorative effects of medication on neural activity in the limbic system, which has previously been demonstrated (Haldane et al., 2008; Passarotti et al., 2011; Phillips et al., 2008).

Elevated striatal activation during reward anticipation has been observed in both euthymic BD (Nusslock et al., 2012) and sub-clinical samples (Harada et al., 2013; O'Sullivan et al., 2011) suggesting that the altered activation is not likely to be mood state-dependent (Nusslock, Young, & Damme, 2014) and may serve as a potential marker for the vulnerability to bipolar disorder. This is further supported by the observation of grey matter deficits in the striatum in individuals at genetic risk for the development of BD (McDonald et al., 2004). However there is some evidence that mood state can influence neural reward responses in BD: reduced striatal responses were seen in depressed bipolar participants, relative to healthy controls (Troost et al., 2014) Another study, using a depressed bipolar sample, also reported reduced activation of the NAcc to reward outcomes relative to healthy controls (Redlich et al., 2015). Thus there is some evidence that mood state might play a contributory role, at least in terms of depressive symptoms.

4.1.8. Study Rationale.

The present research served three key purposes:

1. The investigation of potential associations between reward-related neural activation and trait measures of BAS and hypomania, and anhedonic symptoms.

2. The investigation of potential associations between reward-related neural activation and ecologically valid measures of everyday PA and goal pursuit.
3. The investigation of the previously described associations in two non-clinical samples,⁷ distinct in terms of age.

Trait Measures and Reward-Related Activation. The present research focused on the relationship between measures of BAS sensitivity and reward related neural activation. There has been some investigation of this association, using an aggregate score of the BAS subscales as a measure of BAS sensitivity (Kim et al., 2015; Simon et al., 2010), which did not allow the examination of the role of different BAS-related traits. Two previous studies did focus on the individual subscales, one did so in a partially clinical sample, consisting of both BD participants and HCs (Caseras et al., 2013), whilst the other focused on the neural activation associated with viewing appetising foods (Beaver et al., 2006). The present research sought to extend this by investigating associations between each of the BAS subscales (BAS-FS, BAS-RR, and BAS-D), and neural activation associated with monetary reward anticipation and receipt. The investigation of potential associations with the separate BAS subscales is particularly relevant as there are substantive conceptual differences in the aspects of reward sensitivity measured by each of the BAS subscales, with BAS-D focusing on general motivation to pursue reward, BAS-FS focusing on the tendency to pursue reward impulsively, whilst BAS-RR was designed to measure the enthusiasm with which one responds to having obtained reward.

⁷ Details of clinical diagnoses were not collected from the participants, nor were any participants excluded on this basis. As a result of this, it is possible that some participants in the present sample may have had a clinical diagnosis. As discussed previously, the MASQ-AD has relatively good predictive utility (Buckby et al., 2007), at a suggested cut-off of 76. 2 (7.4%) participants from the student sample and 3 (10.3%) participants from the community sample reported MASQ-AD scores of 76 or greater. Moreover, a cut-off score of 10 on the PHQ-9 (Kroenke et al., 2001) has been suggested for the diagnosis of depression. In community sample, four (13.8%) participants reported PHQ-9 scores of 10 or greater, whilst a further four (13.8%) participants reported scores between 5-9, which would indicate mild depression.

Additionally, due to reported reward-processing deficits in depressed participants and the association with BAS hypoactivation, potential associations between anhedonic symptoms and neural responses to reward anticipation and receipt were examined. Whilst there have been a number of studies that have investigated reward processing in depressed participants, few have focused on the experience of anhedonia and only one study has examined anhedonic symptoms in sub-syndromal samples. The present research aimed to explore the association between anhedonic symptoms in two non-clinical samples, recruited from the student body or the community, and reward-related neural responses, as elicited by a card-guessing paradigm designed to dissociate reward anticipation and receipt.

Finally, the present research also sought to replicate findings of altered anticipatory reward processing that have been demonstrated in those high in hypomanic personality traits, as the experience of BD is associated with a dysregulation of the BAS, with hypomanic symptoms held to be the result of BAS hyperactivation.

Taken together, I aimed to investigate potential associations between anticipatory and consummatory reward processing and traits that either reflect BAS sensitivity directly, or are conceptually related to BAS sensitivity.

Positive Affect, Goal Pursuit, and Reward-Related Activation. This research also explored potential associations between measures of everyday affective experience, goal pursuit, and reward-related neural activation. Previous research has demonstrated a positive association between ratings of everyday PA and striatal activation associated with both reward anticipation and receipt (Forbes et al., 2009; Forbes et al., 2010; Olino et al., 2014), which would indicate the relevance of basic measures of brain function to the everyday experience of affect. During these studies, ratings of PA were completed via the telephone three times a day, over four days at the weekend, because participants were adolescents and so

were not able to complete measures during the school day. As a result of this, whilst the ecological validity of this is greater than collecting this information at one time-point, there were limitations of this measure in terms of capturing representative experience. As adolescents have been found to report relatively low levels of momentary PA (Larson, Moneta, Richards, & Wilson, 2002), and also exhibit altered striatal response to reward, compared to both children and adults (Bjork et al., 2004; Ernst et al., 2005; Forbes et al., 2010; Galvan et al., 2006), it is also important that these results are replicated in adult samples. Consequently, in order to build upon this research, I aimed to replicate the aforementioned relationship, in two distinct adult samples, using a more intensive period of experience sampling (ESM; see Chapter Two for a detailed description, as well as a discussion of its strengths and limitations) to gather a measure of real-world PA. I also investigated possible links between everyday goal pursuit, measured using ESM, and reward processing. The data from the naturalistic measure (ESM) were correlated with neural activation associated with reward anticipation and receipt in order to explore potential relationships. This combined the two methodologies in order to examine the links between individual differences in everyday levels of affect, goal pursuit, and brain activation in response to reward, bringing together two separate literatures and examining whether basic measures of brain function are of relevance to everyday aspects of depressive and hypomanic symptoms.

Reward-Related Activation in Distinct Samples. The distinction in age between samples is particularly relevant, as an age-related decrease in dopamine concentration and receptor density, particularly in the striatum has previously been reported (Bäckman & Farde, 2005; Bäckman et al., 2010). Furthermore, the basal ganglia has also been found to be susceptible to age-related decreases in volume (Raz, 2000; Raz & Rodrigue, 2006), with structural atrophy of the caudate, as well as global decline in dopamine receptors in the

striatum being found in older adults (Bäckman et al., 2000; Kaasinen et al., 2000; Volkow et al., 1998). Initially, deficits in reward learning were attributed to these alterations in frontostriatal circuitry (Eppinger, Hämmerer, & Li, 2011; Hämmerer & Eppinger, 2012; Samanez-Larkin & Knutson, 2014; Samanez-Larkin et al., 2014). However, older adults do appear to exhibit intact frontostriatal responses to reward outcomes (Cox, Aizenstein, & Fiez, 2008; Samanez-Larkin et al., 2007; Schott et al., 2007; Spaniol, Bowen, Wegier, & Grady, 2015), which contradict previous suggestions that differences in reward related decision-making in older adults are not the result of a motivational deficit (Eppinger, Nystrom, & Cohen, 2012). Indeed, it has been suggested that there are few differences between younger and older adults for reward-related tasks that do not have a learning component (Mata, Josef, Samanez-Larkin, & Hertwig, 2011), which would indicate dissociation between cognition and motivation in older adults (Samanez-Larkin et al., 2014). As such, it is important to explore potential associations in diverse samples in order to assess whether any associations observed are similar at different life stages.

Finally, previous research has predominantly focused on clinical samples. Whilst more is known about the deficits in neural function in depressed and BD populations, relatively little is known about the individuals who exhibit sub-clinical symptoms, but may not meet the criteria for diagnosis at that point in time. The investigation of these sub-clinical symptoms may yield several potential insights: for example, it may allow the detection of potential neurobiological markers for at risk individuals (Brown, Bifulco, Harris, & Bridge, 1986; Cuijpers & Smit, 2008).⁸ Moreover, due to the nature of clinical samples, the majority of participants in previous research are likely to be taking some form of medication for the treatment of their disorder, which might interact with the variables and the relationships

⁸ This may be less relevant to the sample of older adults, as it is probable that they would have developed depression by their age, so are less likely to be at-risk.

among them. This is particularly the case in the investigation of BD, as it has previously been demonstrated that anti-psychotics and mood stabilisers have an ameliorative effect on neural activity within limbic circuits, making the accurate interpretation of data from medicated individuals difficult (Haldane et al., 2008; Phillips et al., 2008; Passarotti et al., 2011). The present study therefore focused on individual differences of participants recruited from a non-clinical student (Study One) and a community (Study Two) population, distinct in terms of age.

4.1.9. Hypotheses.

The analysis focused on two key contrasts: i) the anticipation of reward compared to baseline, and ii) the receipt of reward compared to baseline. By contrasting the activation associated with reward anticipation/receipt with baseline activation, as opposed to activation associated with the anticipation/outcome of loss, it is possible to be confident that the results reported are the result of reward processing and are not driven by the processing of loss. The following hypotheses focus on two key brain regions of interest (ROIs): the caudate and the NAcc, regions that have been reliably implicated in both reward anticipation and outcome (e.g., Abler et al., 2005, 2006; Knutson & Cooper, 2005; Knutson et al., 2001a; Knutson et al., 2001b).

The analysis was undertaken using FSL (FMRIB Software Library, version 5.0; e.g., Jenkinson, Beckmann, Behrens, Woolrich, & Smith, 2012), with a focus on anatomically defined striatal ROIs defined using the Harvard-Oxford Subcortical Atlas. This atlas separates subcortical regions into distinct left and right areas. The left and right areas were analysed separately⁹ due to the suggestion that approach motivation is characterised by cortical asymmetry. This model suggests that left frontal cortical activity acts as a neurobiological

⁹ As reported in the results, although the present hypotheses refer to both left and right portions of the ROI, unless stated otherwise.

index of approach motivation (Harmon-Jones & Allen, 1997; Sutton & Davidson, 1997), with hypoactivation in the left regions reflecting a vulnerability to emotion and behaviour associated with approach deficits, as in depression (Coan & Allen, 2004; De Raedt, Franck, Fannes, & Verstraeten, 2008; Henriques & Davidson, 1991). Conversely, a link between manic symptoms and increased activity in this area has also been observed (Harmon-Jones et al., 2002; Kano et al., 1992). Although it is unclear whether this asymmetry extends to the subcortical level, considering the numerous connections between the prefrontal cortex and the mesolimbic system, this is likely (Posner et al., 2005). This suggestion is supported by findings that participants with greater activation in the left NAcc, compared to the right NAcc, demonstrated better approach learning (Aberg, Doell, & Schwartz, 2015).

BAS Sensitivity. It was predicted that ROI activation during reward anticipation would correlate with BAS-FS, as has previously been reported (Caseras et al., 2013). A similar association was expected with BAS-D, as a high score on the BAS-D subscale is thought to indicate greater motivation to pursue goals, and reward anticipation has been postulated to reflect a more motivational psychological state (Pizzagalli et al., 2009). Finally, ROI activation during reward receipt was expected to correlate with BAS-RR, based on the conceptual description of BAS-RR as the tendency to respond to rewarding outcomes with energy and enthusiasm (Johnson, 2005).

Anhedonia. ROI activation during both reward anticipation and receipt was expected to correlate negatively with MASQ-AD, as anhedonic symptoms are thought to reflect a lack of pleasure and motivation, which are key steps in the normal processing of reward (Der Avakian & Markou, 2012). This is in line with previous findings, which have reported a negative correlation between anhedonia and striatal activation during reward anticipation (Stoy et al., 2012; Ubl et al., 2015) and reward receipt (Wacker et al., 2009).

Hypomanic Personality Traits. A significant association was expected between HPS and ROI activation during reward anticipation, but not with activation associated with reward receipt. Conceptually, trait hypomania is likely to be more closely related to anticipatory and goal striving events, so it would follow that any potential dysregulation is likely to occur during the anticipatory period (Caseras et al., 2013; Nusslock et al., 2012). This is in line with the findings of O' Sullivan et al. (2011), who demonstrated that those high in HPS score exhibited greater striatal activation during the anticipation, but not the receipt of reward.

ESM Measures. In order to investigate the ecological validity of the neural measures of reward, data collected from two earlier ESM studies, concerning the everyday experience of PA and achievement goal pursuit (see Chapter Two for a full description) were correlated with ROI activation in response to reward anticipation and receipt. PA was expected to correlate with ROI activation during both reward anticipation and receipt. Conceptually, increased responses during reward anticipation and receipt should be linked to greater PA in everyday life. This is consistent with the findings of previous research that related measures of real world PA in adolescents to striatal activation associated with both anticipatory and consummatory reward processing (Forbes et al., 2009; Forbes et al., 2010; Olino et al., 2014).

Measures of ST *achievement* goal progress and effort were expected to correlate with ROI activation during reward anticipation. As discussed previously, reward is a central component in the development of goal directed behaviour (Haber & Knutson, 2010) and so ST *achievement* goal progress and effort may be related to activation associated with the more motivational stage of reward anticipation i.e. reward anticipation leads to effort, which then translates into progress. Additionally, a significant association between ST *achievement* goal pleasure and ROI activation during reward receipt was expected. ST *achievement* goal pleasure was designed to assess the feelings of pleasure associated with moving closer to achieving a goal, thus relating more to consummatory reward processing.

Summary of Hypotheses. Tables 3.1 and 3.2 provide a summary of the expected relationships between the trait measures of BAS sensitivity and hypomania, anhedonic symptoms, and ROI activation associated with anticipatory and consummatory reward processing. A summary of the hypothesised correlations between the ESM measures of PA and goal pursuit, and ROI activation associated with reward anticipation and receipt is also provided.

Table 4.1.

Hypothesised correlations between trait and ESM measures, and ROI activation associated with reward anticipation > baseline contrast.

	Left Caudate	Right Caudate	Left NAcc	Right NAcc
BAS-FS	✓+	✓+	✓+	✓+
BAS-RR				
BAS-D	✓+	✓+	✓+	✓+
MASQ-AD	✓-	✓-	✓-	✓-
HPS (Study Two)	✓+	✓+	✓+	✓+
Positive Affect	✓+	✓+	✓+	✓+
ST Achieve Progress	✓+	✓+	✓+	✓+
ST Achieve Effort	✓+	✓+	✓+	✓+

Note. MASQ-AD = Mood and Anxiety Symptom Questionnaire Anhedonic Depression subscale, BAS = Behavioural Activation Scale, FS = Fun-Seeking, D = Drive, RR = Reward Responsiveness, HPS = Hypomanic Personality Score, ST = Short-term. “+” denotes expectation of a positive correlation, whilst “-“ indicates the expectation of a negative correlation.

Table 4.2.

Hypothesised correlations between trait and ESM measures, and ROI activation associated with reward receipt > baseline contrast.

	Left Caudate	Right Caudate	Left NAcc	Right NAcc
BAS-FS				
BAS-RR	✓+	✓+	✓+	✓+
BAS-D				
MASQ-AD	✓-	✓-	✓-	✓-
HPS (Study Two)				
Positive Affect	✓+	✓+	✓+	✓+
ST Achieve Pleasure	✓+	✓+	✓+	✓+

Note. MASQ-AD = Mood and Anxiety Symptom Questionnaire Anhedonic Depression subscale, BAS = Behavioural Activation Scale, FS = Fun-Seeking, D = Drive, RR = Reward Responsiveness, HPS = Hypomanic Personality Score, ST = Short-term. “+” denotes expectation of a positive correlation, whilst “-“ indicates the expectation of a negative correlation.

4.2. Method.

4.2.1. Study One.

Sample Size. In terms of calculating required sample size for associations between fMRI activations and individual difference variables, I assumed large ($r = .5$) effect sizes on the basis of prior research. G*Power calculations revealed a required sample size of 29 persons for fMRI. Based on prior experience, I assumed that approximately 10% of participants would not complete the study, so I aimed to recruit 32 participants for fMRI scanning such that adequate power would be attained after attrition.

Inclusion/Exclusion Criteria. In order to be invited to participate in the MRI study, participants were required to have completed at least 60% of the ratings in the ESM study to

ensure representative data. For safety reasons, participants were also excluded if they had any MRI contraindications (e.g., metal implants) in accordance with the MRI scanning centre safety policy. Medication status and the presence of mental and physical health conditions were not explicitly measured.

Participants. A subset of 28 participants was recruited from the 65 participants who had previously completed the ESM Study One (see Chapter Two) participated in the MRI study. The final sample consisted of 28 (16 female) participants (range = 19-55 years, $M = 25.04$ years old, $SD = 8.82$). Depending on their preference, participants were either paid £15 or given course credits for completing the fMRI study.

Trait Measures.

i) Mood and Anxiety Symptom Questionnaire – Anhedonic Depression Subscale (MASQ-AD; Clark & Watson, 1991). Refer to Chapter Two for full description (section 2.2.1.). Cronbach's alpha for the AD subscale in the present sample was .68.

ii) BAS Scales (Carver & White, 1994). Refer to Chapter Two for full description (section 2.2.1.). Cronbach's alpha for the subscales were as follows: BAS-FS = .68, BAS-RR = .87, BAS-D = .74.

Experience Sampling. All participants had previously undergone a period of ESM in order to gain ecologically valid measures of everyday PA and ST *achievement* goal pursuit. See Chapter Two (section 2.2.1) for a full description. Participants would commence the ESM study on the day after their initial briefing and the delay between this briefing and participation in the MRI study ranged from ten to twenty-three days.

fMRI Task. E-Prime software (Psychology Software Tools, Inc.) was used to deliver and record responses. Stimuli were presented during scanning using an Epson EMP-74 digital projector system projected onto a screen at the foot of the scanner, and viewed via an angled

mirror, which was attached to the head coil. Participants responded using their right index and middle fingers, via a fibre-optic response button-box.

Card-Guessing Task. A card-guessing task that has been shown to reliably elicit striatal activation (Caseras et al., 2013; Delgado et al., 2000; Forbes et al., 2009) and to be associated with real-world PA (Forbes et al., 2009; Olino et al., 2014) was used to probe BOLD responses to reward anticipation and receipt. It consisted of a slow event-related paradigm, during which participants were required to guess whether a card, with a possible value of 1 to 9, was higher or lower than 5. Each trial included an anticipation phase, during which participants were informed of the trial type: potential reward or potential loss. This was followed by the outcome phase, during which participants were informed whether the actual number was higher or lower than 5, before being provided with feedback about this outcome. Depending on the trial type and their guess, participants could win £1, lose 50p, or the balance would remain the same.

An example trial is presented in Figure 4.1. Each trial consisted of a guessing time (4 seconds), after which the trial type was revealed (start of anticipation period), which is either potential win (reward) or potential loss (punishment). This anticipation period lasted 8, 10 or 12 seconds and was followed by the presentation of the actual numeric value of the card (500msec), then a feedback screen (500msec), which indicated the outcome of the trial: reward, loss, or no change. The entire trial duration was fixed at 24 seconds (e.g., an 8 second anticipation period was followed by an 11 second fixation cross period).

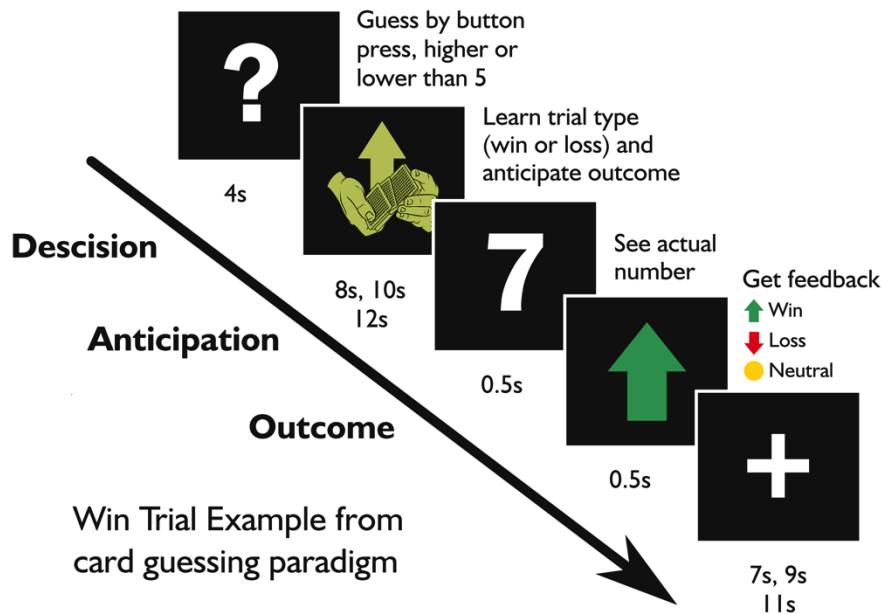


Figure 4.1.

Example of win-trial during monetary reward card-guessing task.

Trials were presented in a pseudorandom order with predetermined outcomes, ensuring that there were equal numbers of each outcome across all participants. The task lasted for nine minutes and included a total of 24 trials: 12 reward anticipation trials (leading to six actual reward and six non-reward trials) and 12 loss anticipation trials (leading to six actual loss and six non-loss trials). Although this is a low number of trials, this slow event-related task has previously been demonstrated to have sufficient sensitivity to detect striatal activation (e.g., Caseras et al., 2013; Forbes et al., 2009), and a greater number of trials resulted in habituation suggesting no gain in sensitivity (Forbes et al., 2009). In order to make the task more motivating and rewarding, participants were told that they would be paid an additional £5 bonus if they reached a high enough score. All participants were paid this £5 bonus, although they were not aware of the fixed outcome probabilities.

4.2.2. Study Two.

Sample Size. In terms of calculating required sample size for associations between fMRI activations and individual difference variables, I assumed large ($r = .5$) effect sizes on

the basis of prior research. G*Power calculations revealed a required sample size of 29 persons for fMRI. Based on prior experience, I assumed that approximately 10% of participants would not complete the study, so I aimed to recruit 32 participants for fMRI scanning such that adequate power would be attained after attrition.

Inclusion/Exclusion Criteria. In order to be invited to participate in the MRI study, participants were required to have completed at least 60% of the ratings in the ESM study to ensure representative data. For safety reasons, participants were also excluded if they had any MRI contraindications (e.g., metal implants) in accordance with the MRI scanning centre safety policy. Additionally, due to possible age-related degradation in the brain (e.g., Peters, 2006; Scahill et al., 2003), participants over the age of 70 years were excluded from the MRI study. Medication status and the presence of mental and physical health conditions were not explicitly measured, so no exclusions were made on this basis, beyond the MRI contraindications described above. No further exclusions were in place.

Participants. A subset of 31 participants was recruited from the 65 participants who had previously completed the ESM Study Two. Due to technical issues with the fMRI files, data from two participants were excluded from the final analysis. The final sample consisted of 29 (14 female) participants (range = 38-67 years, $M = 55.17$ years old, $SD = 8.74$).

Trait Measures.

i) Mood and Anxiety Symptom Questionnaire – Anhedonic Depression Subscale (MASQ-AD; Clark & Watson, 1991). Refer to Chapter Two, section 2.2.1., for full description. Cronbach's alpha for the subscale was .94.

ii) BAS Scales (Carver & White, 1994). Refer to Chapter Two, section 2.2.1., for full description. Cronbach's alpha for the subscales were as follows: BAS-FS = .72, BAS-RR = .86, BAS-D = .86.

iii) *Hypomanic Personality Scale (HPS; Eckblad & Chapman, 1986)*. Refer to Chapter Two, section 2.2.1., for full description. Cronbach's alpha for the HPS scale in the present sample was .82.

Participants were also asked to complete various other related measures (Appendix A), including the Revised Physical Anhedonia Scale (Chapman et al., 1976), the Revised Social Anhedonia scale (Eckblad et al., 1982), the Patient Health Questionnaire (PHQ-9; Kroenke et al., 2001). However, these measures were not included in the present analysis.

Experience Sampling. All participants had previously undergone a period of ESM in order to gain ecologically valid measures of everyday PA and ST *achievement* and *social* goal pursuit. See Chapter Two for a full description. Participants commenced the period of ESM the day after the initial briefing with the researcher. The delay between the initial briefing for the ESM study and participation in the MRI study ranged from nine to thirty-one days.

fMRI Task. E-Prime software (Psychology Software Tools, Inc.) was used to deliver and record responses. Stimuli were presented during scanning using an Epson EMP-74 digital projector system projected onto a screen at the foot of the scanner, and viewed via an angled mirror, which was attached to the head coil. Participants responded using their right index and middle fingers via a fibre-optic response button-box.

Card-Guessing Task. A card-guessing task that has been shown to reliably elicit striatal activation (Delgado et al., 2000; Caseras et al., 2013; Forbes et al., 2009), which is associated with real-world PA (Forbes et al., 2009; Olino et al., 2014) was used to probe BOLD responses reward anticipation and receipt. See section 3.2.1. for a full description. In accordance with the policies of the Exeter 10,000, it was not possible to offer payment for participation in this study.

4.2.3. fMRI Processing & Analysis.

MR Image Acquisition. Activation during the fMRI tasks was measured using a 1.5-T Philips Gyroscan MRI scanner fitted with a quadrature head coil. During each task, brain volumes of 26 slices (3.5 mm thick and ACPC [anterior commissure-posterior commissure] orientated) were acquired interleaved using a gradient echoplanar imaging sequence (TR = 2s; TE = 45msec; voxel size = 3.5mm isotropic; FOV=270mm; flip angle = 90 degrees). For the card-guessing task, 270 volumes were acquired (9 minutes). For each participant, functional data were overlaid on a high-resolution T1-weighted anatomical image for registration into standard space and functional localisation (3D T1 FFE, TR = 252 ms, TE = 4.2 ms, Voxel size = 0.9mm³, Number of Slices = 160, FOV = 230 mm, Flip angle = 30 degrees).

Data Processing. fMRI data pre-processing and statistical analyses were carried out using FEAT (fMRI Expert Analysis Tool), version 5.98, as part of FSL (FMRIB's Software Library). For each participant, standard pre-processing steps were performed. These consisted of motion correction (Jenkinson, Bannister, Brady, & Smith, 2002), non-brain removal (Smith, 2002), spatial smoothing (using a Gaussian kernel of FWHM 5mm). This was followed by normalisation based on grand-mean intensity and high-pass temporal filtering (Gaussian-weighted least-squares straight line fitting, $\sigma = 50.0s$). Registration of the participant's functional data to high-resolution T1 structural images was achieved using FLIRT (FMRIB's Linear Image Registration Tool; Jenkinson et al., 2002; Jenkinson & Smith, 2001). Participants' data were inspected visually for artefacts and excessive head motion (greater than 3 mm; average = 0.68 mm). None were found, so no participants were excluded from the analysis on these grounds.

Analysis of the Card-Guessing Task. The task was modelled within the general linear modelling framework, using the crosshair periods as baseline stimuli (as described in Caseras et al., 2013). The anticipation periods were divided into independent events,

representing the initial two seconds and the remaining anticipation time (4, 6 or 8 seconds), in order to avoid potential issues with habituation effects. It was assumed that the effect of reward anticipation would be most prominent at the start of the anticipation period. As a result of this, all analyses concerning reward anticipation refer to the initial two seconds of the anticipation phase (as in Caseras et al., 2013). The four second guessing window (during which time participants made their guess) was also included in the model, as was the onset of the outcome phase (total duration: one second), which started when participants were presented with the “actual number” and extended to the presentation of feedback as to whether they had won money, lost money or there had been no change.

Region of Interest Analyses. Due to a priori hypotheses regarding activation in striatal brain regions reviewed previously, the anatomical ROI analyses focused on extracting the mean % BOLD signal change in two specific anatomical regions of interest (Figure 4.2): the caudate and the NAcc. This ROI analysis was implemented in FSL's Featquery tool using the Harvard–Oxford subcortical atlas with separate ROIs for the left and right caudate and NAcc. As discussed previously (see section 4.1.), these hemisphere regions were not combined for the analysis due to potential asymmetry of activation. For the monetary reward card-guessing task, the mean % BOLD signal change was extracted from each participant for the contrasts (i) reward anticipation > baseline and (ii) reward receipt > baseline.

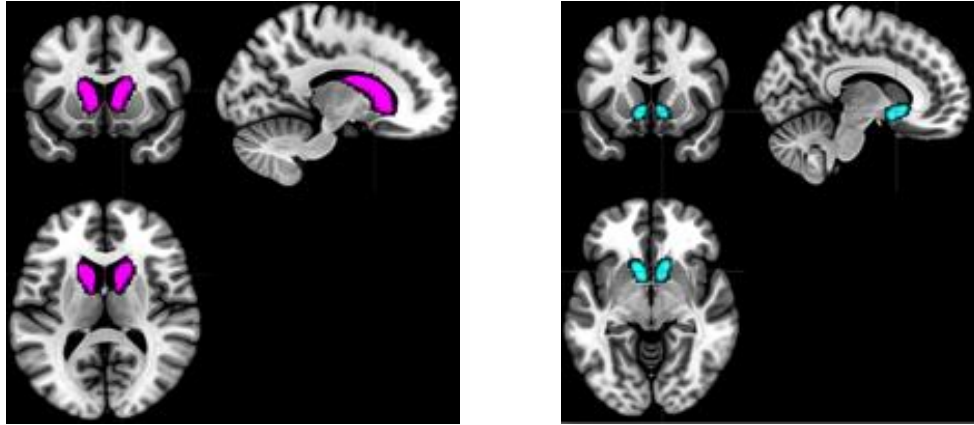


Figure 4.2.

Left/right caudate (shown in pink) and left/right NAcc (shown in blue) ROIs.

Exploratory Whole Brain Analyses. Supplementary whole-brain regression analyses provided additional information about regions of activation, outside the a priori ROIs (detailed above), that were correlated with the trait questionnaire measures (BAS, MASQ-AD, and HPS in Study Two). Individual statistical maps for each contrast of interest were entered into a whole-brain group-level mixed effects model. The grand-mean centred trait measure scores for each participant were entered as additional regressors (one for each of the measures of interest) at this group level. Contrasts were defined to examine positive and negative associations between activation across the whole brain and measure scores. Group activation maps were constructed using FLAME (FMRIB's Local Analysis of Fixed Effects; Beckman et al., 2003; Woolrich et al., 2004) and Z (Gaussian transformed) statistical maps thresholded using clusters determined by $Z > 2.3$ and a whole brain corrected cluster significance threshold of $p < .05$ (Worsley, 1992). These maps indicated regions showing significant correlations (corrected for whole-brain analyses) between trait measure scores and brain activity for the contrasts of interest.

Statistical Analyses. Analysis of data was conducted using SPSS for Mac, version 21 (IBM Corp., 2012). Potential relationships between trait measures, ESM measures, and ROI

activation (mean % BOLD signal change) associated with the reward anticipation > baseline and reward receipt > baseline contrasts were examined using correlation analyses. Given the non-normal distributions of BOLD activation in several of the ROIs, non-parametric Spearman's rho analyses were conducted.

4.3. Results.

4.3.1. Study One.

Preliminary Analyses. In total, the data from 28 participants (16 female) were included in the fMRI analysis. These participants consisted of a subset of those who completed the previous ESM study (see Chapter Two). The untransformed means and standard deviations of scores on the trait measures are summarised in Table 3.3. Both the MASQ-AD scores and scores on each of the BAS subscales were in line with scores previously reported in non-clinical populations (e.g., Bredemeier et al., 2010; Carver & White, 1994), as well as in the full ESM sample (see Chapter Two, Table 2.2).

Table 4.3.

Descriptive statistics of the trait measures for MRI subset.

	Mean	<i>SD</i>	Min	Max
BAS-FS	12.04	2.95	6.00	16.00
BAS-RR	15.79	4.03	6.00	20.00
BAS-D	11.82	2.07	7.00	15.00
MASQ-AD	54.32	13.83	31.00	81.00

Note. MASQ-AD = Mood and Anxiety Symptom Questionnaire - Anhedonic Depression, BAS = Behavioural Activation Scale, FS = Fun-Seeking, D = Drive, RR = Reward Responsiveness.

Table 4.4 depicts a correlation matrix of the trait measure scores. Consistent with the full ESM sample (see Chapter Two), there were no significant correlations between MASQ-

AD and the BAS subscales. In the full ESM sample, the BAS subscales were found to intercorrelate, but only BAS-FS and BAS-RR were found to correlate in the MRI subset.

Table 4.4.

Correlation matrix of scores on the trait measures for MRI subset [95% confidence intervals].

	BAS-FS	BAS-RR	BAS-D
BAS-RR	.53** [.18, .76]		
BAS-D	-.08 [-.45, .31]	-.03 [-.41, .36]	
MASQ-AD	-.00 [-.38, .38]	.15 [-.25, .50]	.17 [-.23, .52]

Note. MASQ-AD = Mood and Anxiety Symptom Questionnaire - Anhedonic Depression, BAS = Behavioural Activation Scale, FS = Fun-Seeking, D = Drive, RR = Reward Responsiveness. ** $p < .001$ (two tailed).

A summary of the person-level descriptive statistics for the ESM measures of PA and ST *achievement* goal pursuit for the MRI subset is presented in Table 4.5. In order to calculate the mean, an average was taken for the ratings provided by each participant and the mean value displayed in Table 4.5 is the average of these scores. These scores were slightly lower than those observed in the full ESM sample (see Chapter Two, Table 2.4).

Table 4.5.

Person-level descriptive statistics of ESM measures for MRI subset.

	Mean	SD	Min	Max
Positive Affect	4.12	0.69	2.69	5.65
ST Achieve Progress	3.24	0.62	2.08	4.68
ST Achieve Pleasure	3.37	0.84	1.81	5.68
ST Achieve Effort	3.29	0.60	1.85	4.31

Note. Positive affect is a composite score (Range = 1 – 7), ST = Short-term.

A correlation matrix among the ESM measures, reporting Pearson's correlation coefficient, is displayed in Table 4.6. Consistent with the full ESM sample, the measures of

ST achievement goal pursuit were positively intercorrelated. However, PA was found to correlate positively with ST achievement pleasure, an association not observed in the full ESM sample.

Table 4.6.

Correlation matrix of the ESM measures for MRI subset [95% confidence intervals].

	Positive Affect	ST Achieve Progress	ST Achieve Pleasure
ST Achieve Progress	.25 [-.15, .58]		
ST Achieve Pleasure	.58** [.25, .79]	.69** [.42, .85]	
ST Achieve Effort	.30 [-.09, .61]	.84** [.67, .93]	.74** [.50, .88]

Note. ST = Short-term. ** $p < .001$ (two tailed).

Correlations between the trait measures and the ESM measures are displayed in Table 4.7. BAS-FS positively correlated with PA, which is broadly in line with the full ESM sample, although BAS-D had been found to correlate with PA in the larger sample.

Table 4.7.

Correlations between trait measures and ESM measures for MRI subset.

	BAS-FS	BAS-RR	BAS-D	MASQ-AD
Positive Affect	.47*	.24	.22	-.22
ST Achieve Progress	.17	-.19	-.01	-.33
ST Achieve Pleasure	.35	.15	-.09	-.35
ST Achieve Effort	.20	-.04	.02	-.31

Note. MASQ-AD = Mood and Anxiety Symptom Questionnaire - Anhedonic Depression, BAS = Behavioural Activation Scale, FS = Fun-Seeking, D = Drive, RR = Reward Responsiveness, ST = Short-term. * $p < .05$ (two tailed).

4.3.2. Region of Interest Analyses.

Reward Anticipation. ROI activation during reward anticipation was correlated with the trait measures, the results of which are displayed in Table 4.8. ROI activation during reward anticipation was expected to correlate with BAS-FS and BAS-D, and to be negatively correlated with MASQ-AD. No support was provided for these hypotheses and no significant associations were found.

Table 4.8.

Correlations between trait measures and ROI activation for reward anticipation > baseline contrast [95% confidence intervals].

	BAS-FS	BAS-RR	BAS-D	MASQ-AD
Left Caudate	.17 [-.22, .52]	.02 [-.37, .40]	-.23 [-.56, .17]	.17 [-.22, .52]
Right Caudate	.32 [-.07, .63]	.22 [-.18, .56]	-.00 [-.38, .38]	.20 [-.20, .54]
Left NAcc	-.02 [-.40, .37]	-.00 [-.38, .38]	-.07 [-.44, .32]	.00 [-.38, .38]
Right NAcc	.23 [-.17, .56]	.03 [-.36, .41]	.04 [-.35, .42]	.15 [-.25, .50]

Note. MASQ-AD = Mood and Anxiety Symptom Questionnaire - Anhedonic Depression, BAS = Behavioural Activation Scale, FS = Fun-Seeking, D = Drive, RR = Reward Responsiveness.

Reward Receipt. ROI activation associated with reward receipt compared to baseline was correlated with the trait measures, the results of which are displayed in Table 4.9. ROI activation was expected to correlate with BAS-RR. This prediction was supported, with a significant positive association observed between BAS-RR and activation of the left caudate and NAcc. Additionally, ROI activation during reward receipt was expected to correlate negatively with MASQ-AD. This was partially supported in that right caudate activation was significantly associated with MASQ-AD, whilst the relationship with activation of the right NAcc approached significance ($p = .057$).

Table 4.9.

Correlations between trait measures and ROI activation for reward receipt > baseline contrast [95% confidence intervals].¹⁰

	BAS-FS	BAS-RR	BAS-D	MASQ-AD
Left Caudate	.17 [-.22, .52]	.40* [.02, .68]	.18 [-.22, .53]	-.32 [-.63, .07]
Right Caudate	-.04 [-.42, .35]	.20 [-.20, .54]	-.25 [-.58, .15]	-.48* [-.73, -.12]
Left NAcc	.09 [-.30, .46]	.39* [.01, .67]	.13 [-.27, .49]	-.11 [-.47, .29]
Right NAcc	-.19 [-.53, .21]	.14 [-.26, .50]	-.08 [-.45, .31]	-.36 [-.65, .03]

Note. MASQ-AD = Mood and Anxiety Symptom Questionnaire - Anhedonic Depression, BAS = Behavioural Activation Scale, FS = Fun-Seeking, D = Drive, RR = Reward Responsiveness. * $p < .05$ (two tailed).

Scatter plots were generated to investigate the relationship between BAS-RR and activation in the left caudate and the left NAcc (Figure 4.3), as well as between MASQ-AD and activation in the right caudate (Figure 4.4).

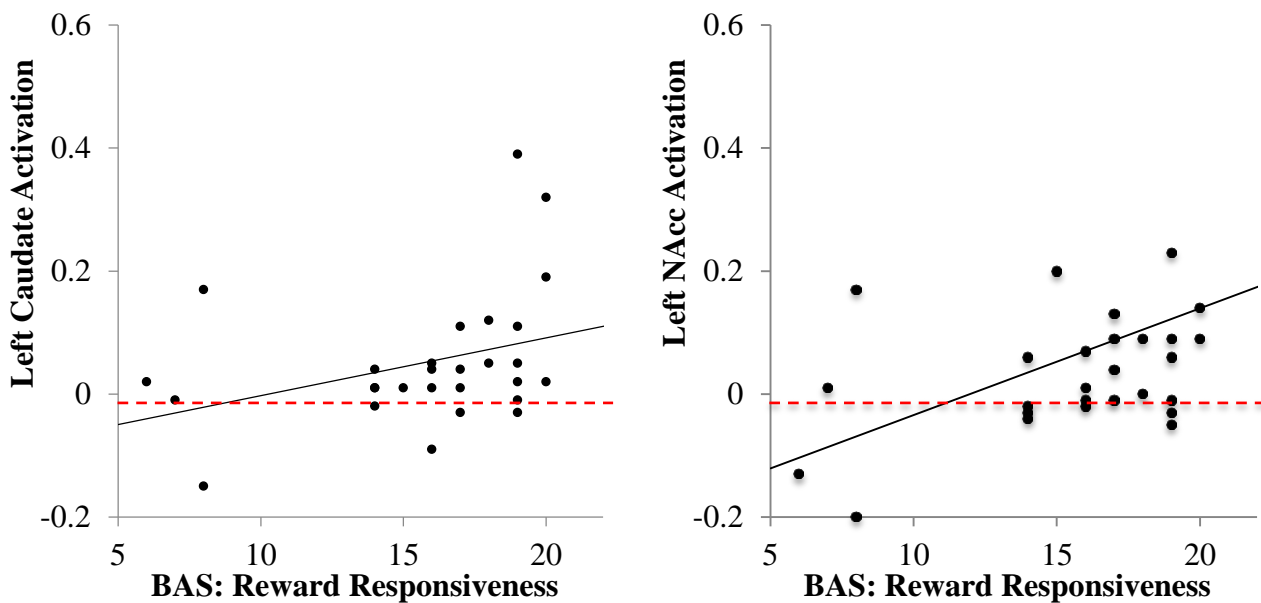


Figure 3.3.

Relationships between BAS-RR and activation of left caudate and left NAcc for reward receipt > baseline contrast.

¹⁰ However, the significant relationships observed would not have survived Bonferroni correction for multiple comparisons, at an alpha level of .003.

The relationships between BAS-RR and both left caudate and NAcc activation were similar (Figure 4.3): they were predominantly driven by those individuals who scored higher for BAS-RR demonstrating greater activation during reward receipt but with a few low scorers showing relative deactivation.

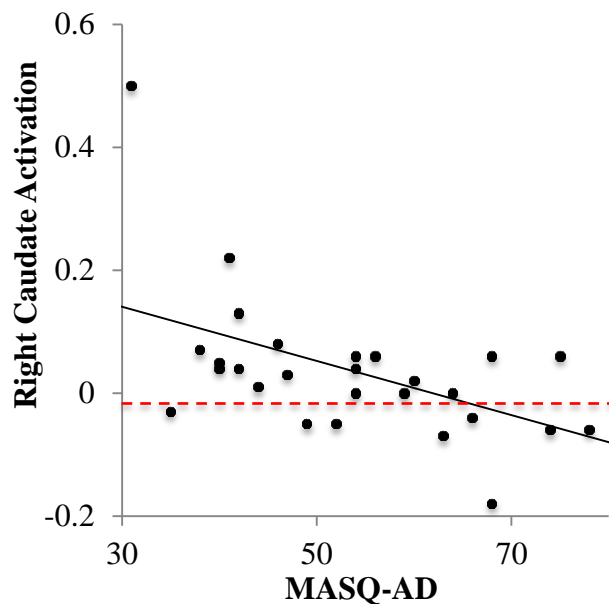


Figure 4.4.

Relationship between MASQ-AD and activation of right caudate for reward receipt > baseline contrast.

The negative correlation between MASQ-AD and right caudate activation (Figure 4.4) appeared to be driven by low scorers exhibiting greater activation during reward receipt compared to baseline.

Reward Anticipation and ESM Measures. Correlations between ROI activation associated with the reward anticipation > baseline contrast and means of the ESM measures were explored and are presented in Table 4.10. It was predicted that ROI activation during reward anticipation would correlate with PA and ST *achievement* progress and effort. However, no support was found for these predictions and no significant associations were found.

Table 4.10.

Correlations between ESM measures and ROI activation for reward anticipation > baseline contrast [95% confidence intervals].

	Positive Affect	ST Achieve Progress	ST Achieve Effort
Left Caudate	-.05 [-.42, .34]	-.23 [-.56, .17]	-.16 [-.51, .24]
Right Caudate	.12 [-.28, .48]	-.05 [-.42, .34]	.09 [-.30, .46]
Left NAcc	.10 [-.29, .47]	-.05 [-.42, .34]	.24 [-.16, .57]
Right NAcc	-.00 [-.38, .38]	.08 [-.31, .45]	.14 [-.26, .50]

Reward Receipt and ESM Measures. Correlations between ROI activation during reward receipt and the ESM measures of PA and ST *achievement* pleasure were investigated and the results are presented in Table 4.11. It was predicted that ROI activation during reward receipt would positively correlate with PA and ST *achievement* pleasure, but this was not found to be the case and no significant associations were observed.

Table 4.11.

Correlations between ESM measures and ROI activation for reward receipt > baseline contrast [95% confidence intervals].

	Positive Affect	ST Achieve Pleasure
Left Caudate	.22 [-.18, .56]	.16 [-.24, .51]
Right Caudate	-.10 [-.47, .29]	-.12 [-.48, .28]
Left NAcc	.01 [-.37, .39]	-.06 [-.43, .34]
Right NAcc	-.05 [-.42, .34]	-.16 [-.52, .24]

4.3.3. Exploratory Whole Brain Analyses.

Supplementary whole-brain regression analyses examined regions of activation outside the a priori ROIs that were associated with the trait questionnaire measures (BAS

subscales and MASQ-AD). At the whole-brain, second level (thresholded group map) clusters of activation were observed in the lateral occipital cortex for the reward anticipation contrast, and in the occipital pole for the reward receipt contrast, but these areas were not significantly correlated with the trait measures (see Appendix F).

4.3.4. Study Two.

Preliminary Analyses. In total, the data from 29 participants (14 female) were included in the fMRI analysis. These participants consisted of a subset of those who completed the previous ESM study (see Chapter Two). The untransformed means and standard deviations of scores on the trait measures are summarised in Table 3.12. The scores on the BAS subscales and MASQ-AD were in line with those previously reported in non-clinical samples (Bredemeier et al., 2010; Carver & White, 1994). However, scores on the HPS were very low, and the mean score was approximately one standard deviation below that reported in a previous non-clinical sample (e.g., Bentall et al., 2011). The scores for the present subset were also in line with those in the full ESM sample (see Chapter Two, Table 2.10).

As with the full ESM sample, the fMRI community subset was significantly older than the student sample ($t = 13.62, p < .001$). The community sample also reported lower scores for BAS-FS ($t = -2.90, p = .007$) and BAS-D ($t = -2.72, p < .001$), but not for BAS-RR ($t = -2.48, p = .479$) or MASQ-AD ($t = -.335, p = .740$). This is consistent with the larger ESM sample, with one exception: BAS-RR was also found to be significantly higher in the student sample.

Table 4.12.

Descriptive statistics of the trait measures for MRI subset.

	Mean	SD	Min	Max
BAS-FS	9.97	2.85	5.00	16.00
BAS-RR	14.97	2.81	10.00	20.00
BAS-D	8.17	3.41	4.00	16.00
MASQ-AD	55.48	15.75	26.00	87.00
HPS	10.17	7.40	0.00	32.00

Note. MASQ-AD = Mood and Anxiety Symptom Questionnaire - Anhedonic Depression, BAS = Behavioural Activation Scale, FS = Fun-Seeking, D = Drive, RR = Reward Responsiveness, HPS = Hypomanic Personality scale.

Table 4.13 displays a correlation matrix among the trait measures. BAS-RR was positively correlated with BAS-FS and BAS-D, whilst a negative correlation was found between MASQ-AD and BAS-FS and BAS-D. This is broadly in line with the correlations observed in the full ESM sample, although in the full sample all BAS subscales were found to correlate and HPS correlated with BAS-FS.

Table 4.13.

Correlation matrix of scores on the trait measures for MRI subset [95% confidence intervals].

	BAS-FS	BAS-RR	BAS-D	MASQ-AD
BAS-RR	.43* [.06, .70]			
BAS-D	.36 [-.03, .65]	.63** [.33, .82]		
MASQ-AD	-.42* [-.69, -.04]	-.26 [-.58, .14]	-.37* [-.66, .02]	
HPS	.18 [-.22, .53]	-.09 [-.46, .30]	-.12 [-.48, .28]	-.04 [-.42, .35]

Note. MASQ-AD = Mood and Anxiety Symptom Questionnaire - Anhedonic Depression, BAS = Behavioural Activation Scale, FS = Fun-Seeking, D = Drive, RR = Reward Responsiveness, HPS = Hypomanic Personality scale. * $p < .05$ (two tailed). ** $p < .001$ (two tailed).

Table 4.14 presents the descriptive statistics of the ESM measures for participants from the MRI subset. In order to calculate the mean, an average was taken for the ratings provided by each participant and the mean displayed in Table 12 is the average value of these scores. The average ratings for the present subset were markedly lower than those observed in the full ESM sample (see Chapter Two, Table 2.12).

Table 4.14.

Person-level descriptive statistics of ESM measures for MRI subset.

	Mean	<i>SD</i>	Min	Max
Positive Affect	3.88	1.01	1.40	6.43
ST Achieve Progress	3.35	1.14	1.41	6.71
ST Achieve Pleasure	3.35	1.00	1.46	6.71
ST Achieve Effort	3.22	1.15	1.36	6.86

Note: Positive affect is a composite score (range = 1 – 7), ST = Short-term.

A correlation matrix among the ESM measures, reporting Pearson’s correlation coefficient, is displayed in Table 4.15. Consistent with the full ESM sample, the measures of *ST achievement* goal pursuit were positively intercorrelated. However, PA was found to correlate positively with the *ST achievement* goal measures, which was not observed in the full ESM sample.

Table 4.15.

Correlation matrix of the ESM measures for MRI subset [95% confidence intervals].

	Positive Affect	ST Achieve Progress	ST Achieve Pleasure
ST Achieve Progress	.44** [.07, .70]		
ST Achieve Pleasure	.60** [.28, .80]	.80** [.60, .91]	
ST Achieve Effort	.53** [.18, .76]	.87** [.73, .94]	.83** [.66, .92]

Note. ST = Short-term. ** $p < .001$ (two tailed).

The correlations between the trait and ESM measures are displayed in Table 4.16.

BAS-FS was positively correlated with mean levels of PA and ST *achievement* goal effort, whilst MASQ-AD was negatively correlated with PA. This is predominantly consistent with the full ESM sample, with one exception: MASQ-AD was negatively correlated with ST *achievement* goal effort in the full ESM sample.

Table 4.16.

Correlations between trait measures and ESM measures for MRI subset [95% confidence intervals].

	BAS-FS	BAS-RR	BAS-D	MASQ-AD	HPS
Positive Affect	.37* [-.02, .66]	-.02 [-.40, .37]	.12 [-.28, .48]	-.58** [-.79, -.25]	.19 [-.21, .53]
ST Achieve Progress	.27 [-.13, .59]	-.14 [-.50, .26]	.06 [-.33, .43]	-.19 [-.53, .21]	.24 [-.16, .57]
ST Achieve Pleasure	.15 [-.25, .50]	-.08 [-.45, .31]	.08 [-.31, .45]	-.21 [-.55, .19]	.24 [-.16, .57]
ST Achieve Effort	.39* [.01, .67]	-.06 [-.43, .33]	.14 [-.26, .50]	-.17 [-.52, .23]	.23 [-.17, .56]

Note. MASQ-AD = Mood and Anxiety Symptom Questionnaire - Anhedonic Depression, BAS = Behavioural Activation Scale, FS = Fun-Seeking, D = Drive, RR = Reward Responsiveness, HPS = Hypomanic Personality scale, ST = Short-term. ** $p < .001$ (two tailed). * $p < .05$ (two tailed).

4.3.5. Region of Interest Analyses.

Reward Anticipation. ROI activation associated with the reward anticipation > baseline contrast was correlated with the trait measures, the results of which are displayed in Table 4.17. It was predicted that ROI activation during reward anticipation would positively correlate with BAS-FS, BAS-D, and HPS, as well as negatively correlate with MASQ-AD. Little support was provided for these predictions with only one significant association found between left NAcc activation and BAS-FS.

Table 4.17.

Correlations between trait measures and ROI activation for reward anticipation > baseline contrast [95% confidence intervals].¹¹

	BAS-FS	BAS-RR	BAS-D	MASQ-AD	HPS
Left Caudate	-.10 [-.47, .29]	.01 [-.37, .39]	-.13 [-.49, .27]	.10 [-.29, .47]	.10 [-.29, .47]
Right Caudate	.03 [-.36, .41]	.17 [-.23, .52]	.05 [-.34, .42]	.10 [-.29, .47]	.10 [-.29, .47]
Left NAcc	.44* [.07, .70]	.14 [-.26, .50]	-.08 [-.45, .31]	-.03 [-.41, .36]	-.03 [-.41, .36]
Right NAcc	.17 [-.23, .52]	.16 [-.24, .51]	.07 [-.32, .44]	.13 [-.27, .49]	.13 [-.27, .49]

Note. MASQ-AD = Mood and Anxiety Symptom Questionnaire - Anhedonic Depression, BAS = Behavioural Activation Scale, FS = Fun-Seeking, D = Drive, RR = Reward Responsiveness, HPS = Hypomanic Personality scale. * $p < .05$ (two tailed).

A scatter plot was generated to investigate the relationship between BAS-FS and activation in the left NAcc during reward anticipation (Figure 3.5). It was found that the association was driven by a combination of those higher in BAS: Fun-Seeking exhibiting greater activation, whilst low scorers demonstrated greater deactivation in response to the anticipation of reward, compared to baseline.

¹¹ However, the significant relationship observed would not have survived Bonferroni correction for multiple comparisons, at an alpha level of .003.

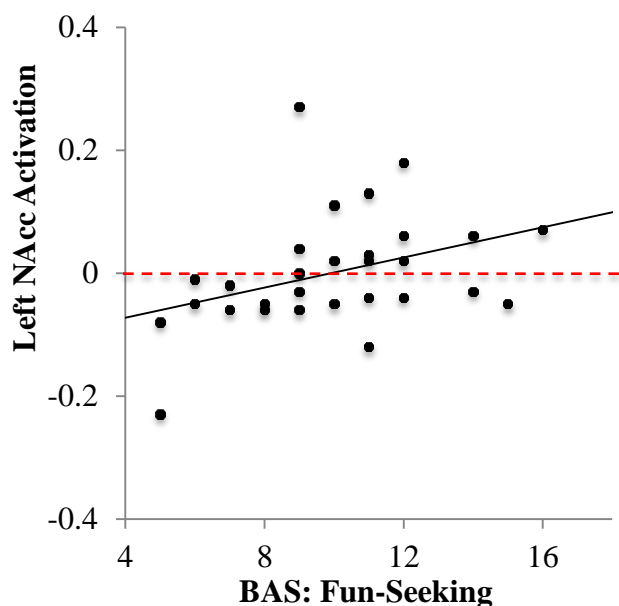


Figure 4.5.

Relationship between BAS-FS and activation of left NAcc for reward anticipation > baseline contrast.

Reward Receipt. ROI activation associated with the reward receipt > baseline contrast was correlated with the trait measures, the results of which are displayed in Table 4.18. ROI activation during reward receipt was expected to correlate positively with BAS-RR and negatively with MASQ-AD. These hypotheses were not supported and no significant associations were found.

Table 4.18.

Correlations between trait measures and ROI activation for reward receipt > baseline contrast [95% confidence intervals].

	BAS-FS	BAS-RR	BAS-D	MASQ-AD	HPS
Left Caudate	.11 [-.29, .47]	.05 [-.34, .42]	.03 [-.36, .41]	-.11 [-.47, .29]	-.06 [-.43, .33]
Right Caudate	.14 [-.26, .50]	.12 [-.28, .48]	.19 [-.21, .53]	-.18 [-.53, .22]	-.03 [-.41, .36]
Left NAcc	.09 [-.30, .46]	-.08 [-.45, .31]	-.06 [-.43, .33]	.18 [-.22, .53]	-.14 [-.50, .26]
Right NAcc	.09 [-.30, .46]	-.02 [-.40, .37]	-.08 [-.45, .31]	.29 [-.10, .61]	-.11 [-.47, .29]

Note. MASQ-AD = Mood and Anxiety Symptom Questionnaire - Anhedonic Depression, BAS = Behavioural Activation Scale, FS = Fun-Seeking, D = Drive, RR = Reward Responsiveness, HPS = Hypomanic Personality scale.

Reward Anticipation and ESM Measures. Correlations between ROI activation during reward anticipation and the ESM measures of PA and ST *achievement* progress and effort were explored, the results of which are presented in Table 4.19. It was predicted that ROI activation during reward anticipation would correlate with PA and ST *achievement* progress and effort. No support was provided for these hypotheses. One significant association was found: right caudate activation was negatively correlated with PA, which was in the opposite direction to that expected.

Table 4.19.

Correlations between ESM measures and ROI activation for reward anticipation > baseline contrast [95% confidence intervals].¹²

	Positive Affect	ST Achieve Progress	ST Achieve Effort
Left Caudate	-.17 [-.52, .23]	.14 [-.26, .50]	.14 [-.26, .50]
Right Caudate	-.42* [-.69, -.04]	-.18 [-.53, .22]	-.08 [-.45, .31]
Left NAcc	-.16 [-.51, .24]	-.08 [-.45, .31]	-.08 [-.45, .31]
Right NAcc	-.01 [-.39, .37]	.24 [-.16, .57]	.31 [-.08, .62]

Note. ST = Short-term. * $p < .05$ (two tailed).

In order to examine this relationship, a scatter plot was generated for the association between PA and right caudate activation (Figure 3.6) In this case, the association appears to be driven by those low in PA exhibiting relatively more activation when anticipating reward compared to baseline than those high in PA.

¹² However, the significant relationships observed would not have survived Bonferroni correction for multiple comparisons, at an alpha level of .004.

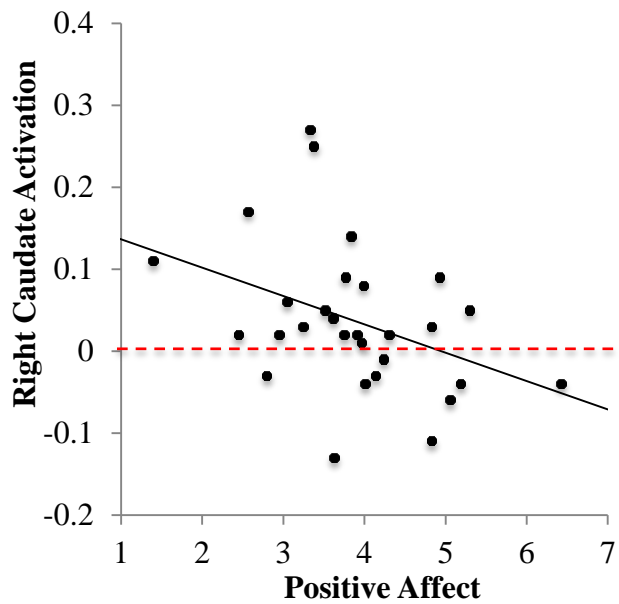


Figure 4.6.

Relationship between Positive Affect and activation of right caudate for reward anticipation > baseline contrast.

Reward Receipt and ESM Measures. Correlations between ROI activation during reward receipt and the ESM measures were investigated, the results of which are presented in Table 4.20. ROI activation during reward receipt was expected to correlate with PA and ST *achievement* pleasure. However, the data did not support these predictions and no significant associations were found.

Table 4.20.

Correlations between ESM measures and ROI activation for reward receipt > baseline contrast [95% confidence intervals].

	Positive Affect	ST Achieve Pleasure
Left Caudate	-.02 [-.40, .37]	.29 [-.10, .61]
Right Caudate	.16 [-.24, .51]	.26 [-.14, .58]
Left NAcc	-.14 [-.50, .26]	-.20 [-.54, .20]
Right NAcc	-.18 [-.53, .22]	-.13 [-.49, .27]

Note. ST = Short-term.

4.3.6. Exploratory Whole Brain Analyses.

Supplementary whole-brain regression analyses examined regions of activation outside the a priori ROIs that were associated with the trait questionnaire measures (BAS subscales, MASQ-AD, and HPS). At the whole-brain, second level (group map) one cluster of activation, which extended into the Occipital Fusiform Gyrus survived thresholding for the reward anticipation contrast, but this area was not significantly correlated with the trait measures (see Appendix F). No clusters survived thresholding for the reward receipt contrast.

4.3.7. Sample Differences.

Given the non-normal distributions of BOLD activation in several of the ROIs, non-parametric Mann-Whitney U analyses were conducted to assess differences in ROI activation in the student and community samples. Compared to the community sample, the student sample exhibited significantly less BOLD activation during reward anticipation in both the left ($U = 172, Z = -3.47, p < .001$) and right ($U = 196, Z = -3.35, p < .001$) caudate. No significant differences were found between the groups for activation of the left ($U = 298, Z = -1.72, p = .086$) or right NAcc ($U = 398, Z = -.128, p = .905$) during reward anticipation. However, the student sample exhibited significantly greater BOLD activation during reward receipt in the left ($U = 240, Z = -2.65, p = .007$) and right ($U = 243, Z = -2.60, p = .009$) caudate, compared to the community sample. No significant differences were found between the two samples for activation of the left ($U = 383, Z = -.367, p = .722$) or right ($U = 350, Z = -.894, p = .378$) NAcc during reward receipt.

4.3.8. Summary of Findings.

Tables 4.21 and 4.22 provide a summary of the observed relationships between the trait measures of BAS sensitivity and hypomania, anhedonic symptoms, and ROI activation during reward anticipation and receipt, relative to the a priori predictions. Details of the

observed correlations between the ESM measures of PA and goal pursuit, and reward related ROI activation are also provided.

Table 4.21.

Fate of hypotheses for correlations between trait and ESM measures, and ROI activation associated with reward anticipation > baseline contrast, relative to the a priori hypotheses.

	Left Caudate	Right Caudate	Left NAcc	Right NAcc
BAS-FS	x	x	√+ 2	x
BAS-RR				
BAS-D	x	x	x	x
MASQ-AD	x	x	x	x
HPS (Study Two)	x	x	x	x
Positive Affect	x	√- 2	x	x
ST Achieve Progress	x	x	x	x
ST Achieve Effort	x	x	x	x

Note. MASQ-AD = Mood and Anxiety Symptom Questionnaire - Anhedonic Depression, BAS = Behavioural Activation Scale, FS = Fun-Seeking, D = Drive, RR = Reward Responsiveness, HPS = Hypomanic Personality scale, PA = Positive Affect, ST = Short-term. “+” denotes a positive correlation, whilst “-“ indicates a negative correlation. 1 or 2 refers to sample observed in (1 = student sample, 2 = community sample). Significant associations marked in red indicate that they were unexpected/in the opposite direction as to what was expected.

Table 4.22.

Fate of hypotheses for correlations between trait and ESM measures, and ROI activation associated with reward receipt > baseline contrast, relative to the a priori hypotheses.

	Left Caudate	Right Caudate	Left NAcc	Right NAcc
BAS-FS				
BAS-RR	✓+ 1	✗	✓+ 1	✗
BAS-D				
MASQ-AD	✗	✓- 1	✗	✓- 1 (<i>p</i> = .057)
HPS (Study Two)				
Positive Affect	✗	✗	✗	✗
ST Achieve Pleasure	✗	✗	✗	✗

Note. MASQ-AD = Mood and Anxiety Symptom Questionnaire - Anhedonic Depression, BAS = Behavioural Activation Scale, FS = Fun-Seeking, D = Drive, RR = Reward Responsiveness, HPS = Hypomanic Personality scale, PA = Positive Affect, ST = Short-term. “+” denotes a positive correlation, whilst “-“ indicates a negative correlation. 1 or 2 refers to sample observed in (1 = student sample, 2 = community sample). Significant associations marked in red indicate that they were unexpected/in the opposite direction as to what was expected.

4.4. Discussion.

The present research investigated the relationships between trait approach motivation and hypomania, anhedonic symptoms, and neural responses associated with both anticipatory and consummatory reward processing. Potential links between everyday affective experience and goal pursuit and the aforementioned reward-related neural responses were also explored. These investigations were conducted in two samples, distinct in terms of age, providing some insight as to whether the predicted associations are similar across different stages of life.

4.4.1. BAS Sensitivity.

ROI activation during reward anticipation was expected to correlate with BAS-FS and BAS-D. This hypothesis was partially supported by the data, with a significant correlation emerging between BAS-FS and left NAcc activation in the community sample of older adults, although this association was not found in the student sample. However, post-hoc tests indicated that these correlations were not statistically significant different between the two samples ($t = -1.75, p = .08$). This is consistent with the findings of Caseras et al. (2013), who had previously reported a similar association in a mixed sample of BD individuals and HCs. Interestingly, the sample in this previous study also consisted of older (middle aged) participants, who are likely to be more similar to the community sample in the present research. Upon further investigation, it was observed that the correlation was driven by participants high in BAS-FS demonstrating greater left NAcc activation during reward anticipation, whilst low scorers exhibited greater deactivation. This relationship is in line with the conceptual nature of BAS-FS, in that those individuals who are more likely to impulsively seek out more rewarding experiences are more likely to be more responsive to potential reward.

Contrary to predictions, BAS-D was not found to correlate significantly with ROI activation during reward anticipation, in either sample. This was somewhat surprising as BAS-D is posited to measure the motivation to pursue goals, which was expected to be relevant to the more motivational stage of reward anticipation. Moreover, previous research (Beaver et al., 2006) reported a significant association between BAS-D and striatal activation (as well as several other reward-related areas that were not investigated here) associated with viewing images of appetizing food. One reason for this disparity in findings could be a result of the type of incentive offered. Money is a secondary reward (Schultz, 2000), whereas food is a primary reward (Kelley & Berridge, 2002), so it may be that the food images were more

motivating, particularly due to the relatively small amounts (or lack) of monetary incentive offered in the present research.

It was also predicted that ROI activation during reward receipt would correlate with BAS-RR. The data provided some support for this hypothesis, with activation of the left caudate and left NAcc during reward receipt being found to correlate with BAS-RR, in the student sample only. Post hoc tests revealed that the correlations were not statistically significantly different between samples (left caudate: $t = 1.33$, $p = .18$; left NAcc: $t = 1.76$, $p = .08$). As the BAS is thought to be engaged in preparation to obtain, but not to receive reward, it had previously been suggested that there should be no link between BAS sensitivity and striatal activation during reward receipt (Caseras et al., 2013). However, the BAS-RR subscale specifically focuses on measuring an individual's responsiveness to reward, with questions such as "*When good things happen to me, it affects me strongly*", which suggests that it might be more related to the hedonic ('liking') reward receipt, rather than the more motivational ('wanting') reward anticipation. Furthermore, this is broadly consistent with the findings of two previous studies, which reported significant associations between an aggregate BAS score and striatal activation during reward receipt (Kim et al., 2015; Simon et al., 2010). However, as these studies used the aggregate score of the BAS subscales, it is not possible to determine whether this is truly consistent with the present findings as it is not possible to determine which subscale(s) drove the association. The current association was found to be predominantly driven by those individuals who scored higher for BAS-RR demonstrating greater activation during reward receipt compared to baseline. However, the associations between left caudate and NAcc activation during reward receipt and BAS-RR was not replicated in the community sample. This may have been a result of the sample, as the levels of BOLD activation in the caudate during reward receipt were significantly lower in the community sample. A likely explanation for the null finding in the community sample, is

a key methodological difference between the studies: the student sample was promised a £5 bonus, which they believed was contingent on their performance during the task, but the community sample were aware that they would receive no payment (in line with organisational policies). As the student sample believed that the more times they received a reward, the greater the chance of “winning” the bonus payment, it would follow that activation during the outcome of reward would be greater in the student sample, compared to the community sample.

It is also interesting that the associations with BAS-FS and BAS-RR were observed in the left portions of the NAcc and caudate, as a left asymmetry in activation might indicate greater approach motivation (Harmon-Jones & Allen, 1997; Sutton & Davidson, 1997), with high BAS scores specifically being linked to greater left cortical activity (Harmon-Jones & Allen, 1997; Sutton & Davidson, 1997). The present findings suggest that this asymmetry may indeed extend to the subcortical level, supporting other observations of greater left striatal responses to rewarding stimuli being associated with stronger approach responses (e.g., Knutson & Greer, 2008; Lawrence et al., 2012).

4.4.2. Anhedonia.

It was predicted that ROI activation during both reward anticipation and receipt would negatively correlate with MASQ-AD. However, no significant associations emerged between MASQ-AD and activation associated with reward anticipation. This is in contrast to previous findings that NAcc activation during reward anticipation was negatively correlated with anhedonia (Stoy et al., 2012) and positively correlated with hedonic capacity (Ubl et al., 2015). However, these associations emerged in clinical samples of depressed participants, so the null findings may be the result of the differences in samples. As such, it is likely that the higher end of the MASQ-AD is under-represented in the present samples and it could be that

these higher scores, as well as a greater variance, is required for associations to manifest between MASQ-AD and activation associated with reward anticipation.

Some support was provided for the hypothesis that activation during reward receipt would negatively correlate with MASQ-AD, with a significant (negative) association emerging with right caudate activation in the student sample only (the association with right NAcc activation also approached significance), although post-hoc tests revealed that the correlation did not differ significantly between samples ($t = -1.21, p = .22$). This association was chiefly driven by those low in MASQ-AD demonstrating greater activation, whilst those higher in MASQ-AD exhibited greater deactivation in response to the receipt of reward, which would provide some evidence for reduced hedonic reactivity in those higher in anhedonic symptoms. This is in line with the findings of an earlier study, which reported a significant negative correlation between striatal activation and MASQ-AD score in a non-clinical sample (Wacker et al., 2009). This suggests that anhedonia may predict striatal function in non-clinical participants, as well as in depressed individuals, as has previously been reported (Epstein et al., 2006; Keedwell et al., 2005). It is also in line with previous research that has observed diminished striatal activation during consummatory reward processing in MDD patients (Forbes et al., 2009; Pizzagalli et al., 2009), but has also extended it to demonstrate a direct association between striatal activation and a measure of anhedonia. However, this previous study (Wacker et al., 2009) did control for other symptoms of depression and anxiety, which was not done in the present research, due to concerns about limited power. As such, in the present research, it is not possible to be sure that this relationship is unique to the experience of anhedonic symptoms, or to depressive symptoms in general.

The finding of an association between deficits in caudate activation and levels of anhedonia, is especially interesting, due to the structure's implication in the processing of

reward related information (Delgado et al., 2000; Delgado et al., 2005; Tricomi et al., 2004). Caudate activation has been demonstrated to be greatest when reward is unpredictable (e.g., when participants receive reward on a limited number of trials, as in the present research), as well as when an individual believes that the outcome of the trial is contingent on their own response (as is the case here; Tricomi et al., 2004). The negative correlation between caudate activation during reward receipt and MASQ-AD, observed in the present research, may be indicative of a weaker perceived action-outcome relationship and/or weaker responses to unpredictable rewards.

Taken together, this association between MASQ-AD and striatal activation during consummatory, but not anticipatory reward processing indicates that anhedonia-related deficits in striatal activation during reward processing might be more closely associated with the more hedonic ('liking') consummatory period, rather than the anticipatory ('wanting') phase of reward processing. These findings underlie the importance of assessing the stages of reward processing separately, which is reinforced by the negative correlation between responses during reward anticipation and receipt (see Chapter Six).

However, it should be noted that the negative correlation between MASQ-AD and activation during reward receipt was not replicated in the community sample, which was surprising as MASQ-AD score was not found to be significantly different in the two samples, and the range of scores were similar. However, the student sample did exhibit significantly greater caudate activation during reward receipt. As discussed previously, this is likely to reflect methodological differences as the community sample were aware that they would not receive any payment as a result of "winning" during the task. Additionally, it could be that the older adults in the community sample may have been more financially stable and thus the receipt of hypothetical monetary reward may be less salient.

4.4.3. Hypomanic Personality Traits.

ROI activation during reward anticipation was expected to correlate with HPS, but the data did not support this hypothesis and no significant associations emerged. However, this was not entirely surprising for several reasons. First, the HPS is not designed as a direct measure of BD/hypomania, but as a measure of personality traits that might indicate a predisposition to the development of BD (Eckblad & Chapman, 1986). Therefore a participant might score highly on this measure without experiencing any hypomanic symptoms. To my knowledge, only one study has reported a significant correlation between HPS score and striatal activation during reward anticipation in a sub-clinical sample (O’Sullivan et al., 2011). These participants were recruited based on their high HPS score, which would suggest that higher scores than those reported in the community sample (which were unusually low) might be required for these associations to emerge.

4.4.4. ESM Measures.

Positive correlations were expected between the ESM measure of PA and ROI activation associated with reward anticipation and receipt. These hypotheses were not supported, with only one significant association emerging between mean levels of PA and reward-related activation: in the community sample, PA was negatively correlated with right caudate activation during reward anticipation. This is somewhat inconsistent with previous findings that clusters of left caudate activation associated with both reward anticipation and receipt were positively correlated with everyday PA in depressed, at-risk, and healthy adolescents (Forbes et al., 2009; Olino et al., 2014). However, the assessment of PA in the present research was far more intensive than in the previous studies, collecting more than twice the number of ratings. Furthermore, as participants completed these measures themselves on a wrist-worn diary, they were able to complete the measures during the course of their everyday lives, whereas previous research (Forbes et al., 2009; Forbes et al., 2010;

Olino et al., 2014) collected this data via a phone call with a researcher, which would have been more intrusive than the method used in the present research. Previous studies also only examined PA during the weekend, rather than over a more representative sample of occasions, as in the present research. As such, the data gathered using the present method should provide a more ecologically valid representation of everyday PA. However, it could be that the ESM measure of PA may relate to more tonic levels of affect, whereas PA elicited by the card-guessing paradigm is based on response to incentives, which may be more akin to responses to “positive life events”. As such, a measure of PA that captured reactions to real world positive events may be more highly correlated with activation associated with the present task. Finally, it should be noted that for some participants, there may have been a lengthy (more than two weeks) delay between completing the ESM measures and undertaking the scan, and so they might not provide a true representation of the participants’ level of PA at the time of the scan. Although ESM reports of PA were sometimes collected quite far in advance of the scan, there is some evidence that PA remains relatively stable (Charles, Reynolds, & Gatz, 2001; Costa et al., 1987), so this may not clearly explain the null findings.

An alternative explanation for the disparity in findings could relate to the clear differences in samples. Previous research (Forbes et al., 2009; Olino et al., 2014) focused on adolescents and it has been observed that adolescence may be the developmental period during which reward function is most disrupted (Forbes et al., 2012). There also appears to be a tendency for healthy adolescents to experience rewards more intensely than adults (Ernst et al., 2005; Steinberg, 2008), whilst there has been some suggestion that adulthood may involve decreases in reward function, including greater difficulty in learning reward associations (Mell et al., 2005), decreased total earnings in reward decision-making (Brown & Ridderinkhof, 2009), and lower levels of subjective PA (Kunzmann, 2008). This may provide

some indication that there is a tighter correlation between reward responsivity and everyday PA in adolescents, compared to adults.

The ESM measures of ST *achievement* progress and effort were expected to correlate with activation during reward anticipation, whilst ST *achievement* pleasure was expected to correlate with activation during reward receipt. However, this hypothesis was not supported and no significant associations were found. The predictions were based on the conceptual relationship between the anticipation of reward and effortful goal pursuit, which generally leads to progress, as well as previous findings suggesting that approach goal pursuit heightens sensitivity to the pursued reward (Harmon-Jones et al., 2012; Weinberg et al., 2014). In this way, different phases of goal pursuit could be viewed in terms of the dissociation between reward anticipation and consumption: goal striving is likely to be more closely related to the more motivational stage of reward anticipation, whilst goal attainment would be more relevant to the more hedonic reward receipt. However, the ESM study required that participants provide short-term, achievement-focused goals, which may not have been as intrinsically motivating as other goals (Ryan & Deci, 2000; Sheldon & Elliot, 1998), therefore, having little association with the processing of reward. Furthermore, particularly for the student sample, these goals may have even been pursued largely for avoidant reasons (e.g. “*I must finish this essay, or I will fail*”; Sheldon & Elliot, 1998) such that the motivation for goal pursuit may have been more related to the BIS than the BAS. Additionally, achievement motivation is considered to be an individual difference (McClelland, 1985), so some individuals may find achievement goals to be more motivating than others, which may have served to attenuate relationships between striatal activation during reward processing and the ESM measures of everyday goal pursuit.

4.4.5. Limitations.

First and foremost, a substantial limitation of this research was the use of a relatively low powered (1.5T) scanner, which may not have been sensitive enough to differentiate BOLD activation for different contrasts. However, when viewing the uncorrected whole brain maps (see Appendix F), limited activation was observed for the reward anticipation/receipt > baseline contrasts. As fewer clusters of activation were observed at the whole brain level compared to previous research, this would suggest reduced power to detect activation compared to those studies conducted in a more powerful scanner or in clinical samples. A further limitation of the present studies is the small sample size in both studies, such that the findings must be interpreted with caution and significant findings require replication. Moreover, statistical power was adequate only to detect large-sized ($r > .5$) associations between variables, so the possibility of Type II errors should be considered. Furthermore, although a priori predictions were made, predominantly based on previous research, a relatively large number of statistical tests were conducted in the absence of correction for multiple comparisons. However, alpha level was not made more conservative in this case as it would have further reduced the already limited statistical power of the present research. It should also be noted that for some participants, there may have been a lengthy (more than two weeks) delay between completing the ESM measures and undertaking the scan, and so they might not provide a true representation of the participants' level of PA at the time of the scan.

Furthermore, although the card-guessing task employed has previously been demonstrated to engage striatal reward areas reliably (e.g., Caseras et al., 2013), it consisted of only 12 reward anticipation trials and 6 reward outcome trials. Arguably, so few trials from which to measure participants' neural activation would be less sensitive than similar monetary reward tasks used elsewhere. Moreover, the degree of effort expenditure required to make a choice is minimal, so it is likely to require less motivation to complete than other tasks, which

require, for example, a speeded button press (e.g., Monetary Incentive Delay, MID: Knutson et al., 2000). However, activation in the ROIs was associated with several of the trait measures, indicating some sensitivity to detect individual differences in trait measures.

Additionally, the present research focuses solely on the anticipation and outcome phases of the processing of simple monetary reward and so only examined responses to one type of reward and not across domains. Several studies have emerged, using a task that has been designed to assess neural responses to both social and monetary reward (e.g., Kohls et al., 2011, 2012; Rademacher et al., 2010; Spreckelmeyer et al., 2009), which have suggested that the neural mechanisms underlying the outcome of reward may be more modality specific than the anticipation of reward (Spreckelmeyer et al., 2009).

4.4.6. Conclusion.

In conclusion, the present research sought to investigate links between the activation of reward-related brain regions and various measures linked to trait BAS and hypomania, as well as anhedonic symptoms. Whilst partial support was provided for some of the hypotheses, in particular the associations between BAS-RR and MASQ-AD and activation associated with consummatory reward processing, these findings were not found to replicate across both samples. This lack of consistency between studies is suggestive of possible differences in reward processing between older and younger populations, although the low sample sizes in the present study and slight methodological differences (e.g., participant payment in student sample, but not community sample) makes comparison somewhat more challenging. However, due to this limited power and slight methodological difference, I did not conduct a statistical comparison of the magnitude of associations between the student and community samples. This makes it difficult to draw definitive conclusions about potential differences between the two samples.

Whilst previous research has indicated that anticipatory reward processing of both monetary and social rewards is associated with activation of the same neural regions, a difference was found during consummatory reward processing (Rademacher et al., 2010). This is consistent with the suggestion that different types of reward may be encoded by different neural pathways (Naranjo et al., 2001), so it is important that the focus is not limited to one specific type of reward. The following chapter (Chapter Five) aimed to address this by probing the neural responses associated with viewing positive facial expressions, which are thought to function as a social reward (Chakrabarti, Kent, Suckling, Bullmore, & Baron-Cohen, 2006)

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Chapter V: Neural Responses to Social Reward.

5.1. Introduction.

fMRI tasks used to investigate the neural substrates associated with reward processing tend to fall into two categories: those that focus on the response to monetary reward (e.g., Forbes et al., 2009; Knutson et al., 2001a, 2001b; Pizzagalli et al., 2009) and those that investigate the neural processing of emotional stimuli (Zhang et al., 2013), such as facial expressions (Fusar-Poli et al., 2009; Murphy et al., 2003; Phan et al., 2002; Vytal & Hamman, 2010). Different types of reward may be encoded by specific, but overlapping neural pathways (Naranjo et al., 2001; Sescousse et al., 2013), so consideration of the brain activation patterns associated with both monetary reward and emotional stimuli is important, particularly as neural activation associated with consummatory reward processing has been found to be different for social and monetary rewards (Rademacher et al., 2010).

5.1.1. Happy Facial Expressions.

The perception of emotion portrayed by facial expressions is vital to the regulation of social interactions (Gosselin et al., 1995; van Rheezen & Rossell, 2013). As such, to a social species such as humans, positive facial expressions are a fundamental reward (King-Casas et al., 2005; Kringelbach et al., 2008; Frith & Frith, 2010; Chelnokova et al., 2014). Happy facial expressions can be seen as a representation of social approval (Lawrence et al., 2004) and thus can be perceived to function as a social reward (Chakrabarti et al., 2006), which has been demonstrated to be as gratifying as more sensory pleasures (Kringelbach & Rolls, 2003; Rømer Thomsen et al., 2011). Assessing the neural responses associated with viewing happy facial expressions (compared to viewing neutral or negative facial expressions, such as sadness and disgust) should enable the identification of specific brain regions that might be related to the experience of more socially oriented reward. The incentive salience model of reward processing postulates distinct ‘wanting’ and ‘liking’ components of reward (Berridge,

1996, 2007, 2012). As discussed in Chapter 3 (section 3.1.2.), ‘wanting’ includes the motivational components, whereas ‘liking’ refers to the pleasure obtained from the reward (the hedonic impact). It is beyond the scope of the present research to determine in detail which stage is more relevant to viewing happy facial expressions, but it is likely that this is more closely related to the consummatory ‘liking’ stage of reward processing as a happy facial expression is likely to be rewarding in its own right.

5.1.2. Emotion Processing in Healthy Participants.

Consistent with the idea that happy facial expressions function as rewards, viewing them has been associated with activation in the basal ganglia, including areas such as the VS, the caudate, and the putamen (Lawrence et al., 2004; Monk et al., 2008; Morris et al., 1996, 1998; Phillips et al., 1998; Whalen et al., 1998). These areas have also been implicated in both anticipatory and consummatory processing of money and food rewards (Ablner et al., 2005, 2006; Berridge, 1996; Ikemoto & Panksepp, 1999; Knutson & Cooper, 2005; Knutson et al., 2001; O’Doherty et al., 1998; Small et al., 2001). Amygdala activation has also been reliably demonstrated in response to viewing happy facial expressions, which, due to its association with the processing of the emotional intensity of stimuli (as opposed to valence), may be indicative of positive arousal (Breiter et al., 1996; Canli et al 2002; Fitzgerald et al., 2006; Killgore & Yurgelun-Todd, 2001; Pessoa et al., 2002; Whalen et al., 1998; Yang et al., 2002). Striatal regions, particularly the NAcc, have been implicated in tracking the hedonic value of reward, providing an interface between the limbic and motor regions (Berridge, 2007; Berridge & Kringelbach, 2008; O’Doherty et al., 2004). The amygdala is thought to respond to meaningful stimuli in general (Costafreda et al., 2008; Morris et al., 1998; Phan et al., 2002; Sergerie, Chochol, & Armony, 2008; Zald, 2003), acting as a rapid detector of cues that might have some impact on well-being (Whalen et al., 1998), which may provide an explanation as to why it is responsive to both positively and negatively valenced stimuli

(Hariri et al., 2000; Monk et al., 2003; Phelps et al., 2001; Whalen et al., 1998; Yang, Menon, Reid, Gotlib, & Reiss, 2003). Taken together, the NAcc and the amygdala are thought to mediate the detection of and reaction to motivating and reinforcing stimuli (Monk et al., 2008).

5.1.3. Emotion Processing in Depression.

Abnormalities in facial emotion processing have been reliably demonstrated in both depressed and remitted individuals (Dalili, Penton-Voak, Harmer, & Munafò, 2015; Leppänen, 2006; Phillips et al., 2003; Stuhrmann, Suslow, & Dannlowski, 2011), with consistent reports of a clear mood-congruent perceptual bias towards negative and away from positive emotional stimuli (Anderson et al., 2011; Bhagwagar, Cohen, Goodwin, & Harmer, 2004; David & Cutting, 1990; Gur et al., 1992; Surguladze et al., 2005; Suslow et al., 2001). These deficits in emotion processing appears to be particularly prominent for the identification of emotional faces to which depressed individuals tend to exhibit a clear mood congruent bias (Stuhrmann et al., 2011), interpreting neutral faces as sad, as well as under-identifying positive emotion and interpreting happy faces as neutral (Bourke, Douglas, & Porter, 2010; Elliott, Zahn, Deakin, & Anderson, 2011). Depressed participants, compared to HCs, also require the facial expression to have greater emotional intensity in order to be able to correctly identify an emotion as positive (Joorman & Gotlib, 2006; Surguladze et al., 2004; Yoon, Joormann, & Gotlib, 2009). This would suggest that a key feature of depression might be impairment in the processing of positive emotion, which is consistent with reports of blunted facial reactivity to positive facial expressions in depressed individuals, who maintained a frown, whilst HCs smiled in response to the positive facial expressions (Sloan, Bradley, Dimoulas, & Lang, 2002). Further support is provided by the results of a recent meta-analysis, which indicated that depression is associated with a general deficit in emotion recognition, both positive and negative, although recognition seemed to remain intact for

expressions of sadness (Dalili et al., 2015). As positive emotional expressions are rewarding, this is consistent with the idea that depressed individuals display a reduced sensitivity to reward in general (Pizzagalli et al., 2009), i.e. during the processing of monetary and social rewards, suggesting that this represents a trait-like abnormality that generalises across contexts (Pechtel et al., 2013). As a result of these apparent deficits in emotion processing, the investigation of biased processing of emotional facial expressions may provide a significant contribution to the understanding of depression (Gotlib & Hammen, 1992), as a depressed individual's failure to correctly identify and respond to facial expressions is likely to have negative real-world consequences (Persad & Polivy, 1993). For example, the inability to detect positive facial expressions may lead to a reduction in approach behaviour, due to a perceived lack of reinforcement (Gotlib & Hammen, 1992; Yoon, Joorman, & Gotlib, 2009). As the processing of emotional facial expressions, both positive and negative, is a fundamental step in social functioning, serving to guide social interaction (Blair, 2003), impaired emotion processing may also contribute to the various interpersonal issues associated with the experience of depression, such as social withdrawal and feelings of rejection (Suslow & Dannlowski, 2005).

Neuroimaging research is consistent with the findings described above, reporting several functional abnormalities during the processing of emotional facial expressions in depressed individuals, particularly in the frontal and limbic neural circuits (see Stuhmann et al., 2011 for a review). Depressed participants have been found to exhibit greater activation of the striatum, particularly the caudate and the putamen, in response to negative facial expressions, as well as hypoactivation in response to positive facial expressions (Lawrence et al., 2004; Fu et al., 2004; Fu et al., 2007; Scheuerecker et al., 2010). With regards to positive facial expressions in particular, depressed individuals were found to exhibit relatively less striatal activation in response to viewing happy facial expressions (Surguladze et al., 2005),

whilst children and adolescents at risk of developing MDD evidenced less NAcc activation (Monk et al., 2008). Furthermore, consistent with its hypothesised role in rapidly processing salient stimuli (Fitzgerald et al., 2006; Gerber et al., 2008; Murray, 2007; Santos, Mier, Kirsch, & Meyer-Lindenberg, 2011; Scharpf, Wendt, Lotze, & Hamm, 2010; Sander, Grafman, & Zalla, 2003), abnormal activation of the amygdala has also been observed during facial emotion processing in depression. Several studies report increased amygdala activation in response to negative facial expressions (Fu et al., 2004; Fu et al., 2008; Peluso et al., 2009; Sheline et al., 2001; Surguladze et al., 2005; Suslow et al., 2010; Victor, Furey, Fromm, Ohman, & Drevets, 2010; Zhong et al., 2011), although this has not been consistently found (Lawrence et al., 2004). With regards to viewing happy facial expressions specifically, depressed participants have been found to demonstrate a hypoactivation of the amygdala, relative to HCs (Suslow et al., 2010; Etkin & Schatzberg, 2011; Liao et al., 2012; Matthews, Strigo, Simmons, Yang, & Paulus, 2008; Victor et al., 2010; Yang et al., 2011). However, this has not been consistently reported, with depressed adolescents being found to exhibit greater amygdala activation and connectivity (Henje Blom et al., 2015; Yang et al., 2010), whilst others report no differences in neural responses (Barch et al., 2012; Hall, Milne, & MacQueen, 2014). The hypoactivation of the amygdala in depression has also been directly related to anhedonia, with a negative correlation being reported between anhedonic symptoms and activation of the amygdala in response to positive facial expressions (Stuhrmann et al., 2013). The negative association between anhedonia and amygdala activation is thought to be the consequence of inappropriate or reduced salience attribution to positive stimuli during the early stages of emotion processing (Disner, Beevers, Haigh, & Beck, 2011; Dowd & Barch, 2010).

5.1.4. Emotion Processing in Bipolar Disorder.

As the perception of emotion from facial expressions is important to successful social functioning, it is thought that abnormalities in the processing of facial expressions may be a contributing factor to the reduced social functioning observed in BD individuals (Martino, Strojilevich, Fassi, Marengo, & Igoa, 2011; van Rheenen & Rossell, 2013). Findings in this area are inconsistent. Some studies report intact recognition of most emotions and even enhanced recognition for disgust (Harmer, Grayson, & Goodwin, 2002; Summers, Papadopoulou, Bruno, Cipolotti, & Ron, 2006), whilst others suggest impairments in the recognition and discrimination of facial emotions, an impairment which has been observed in symptomatic, euthymic, and at risk samples (Bozikas, Tonia, Fokas, Karavatos, & Kosmidis, 2006; Brotman et al., 2008; Getz, Shear, & Strakowski, 2003; Lembke & Ketter, 2002; Vederman et al., 2012). These impairments do not appear to be state-related, as they have been found to persist even when an individual is in a euthymic state. This would indicate that disturbances in emotion processing are either a factor in the development of BD (Yurgelun-Todd et al., 2000), or a “scar” resulting from the experience of the disorder itself. As a consequence of these abnormalities in emotion processing, those with BD are more likely to experience difficulty in emotional discrimination, which may lead to inappropriate and incongruent affective responses (Addington & Addington, 1998; Walker, McGuire, & Bettes, 1984). Furthermore, there is some disagreement as to whether emotion recognition is associated with symptom severity, with some studies reporting negative correlations between manic symptoms and the recognition of negative emotions (Harmer et al., 2002) and between depressive symptoms and the recognition of positive emotions (Gray et al., 2006), whilst others report no relationship between symptoms and emotion recognition (Bozikas et al., 2006; Venn et al., 2004).

BD individuals demonstrate increased emotional reactivity to positive stimuli in general (Johnson et al., 2007), with neuroimaging research indicating greater activation of reward-related striatal areas, such as the caudate, in response to positively valenced stimuli (Delvecchio et al., 2012; Hassell et al., 2008). As activation of the reward circuitry has been found to correlate positively with valence (Gerdes et al., 2010), the increased caudate activation observed in BD participants may indicate that happy facial expressions hold greater reward value for them (Delvecchio et al., 2012). However, increased activation of the reward-related circuitry in response to the appraisal of positive emotional stimuli may lead to the generation of inappropriate and/or extreme emotional responses that are difficult to regulate (Chen et al., 2006). Additionally, greater amygdala activation has also been observed in BD individuals when viewing positive facial expressions (Blumberg et al., 2005; Lawrence et al., 2004), although this has not been consistently reported (Hassell et al., 2008). This activation was not found to correlate with levels of either mania or depression, so it is unlikely to be symptom related (Lawrence et al., 2004). As the amygdala has been implicated in the attribution of salience to a stimulus (Costafreda et al., 2008; Morris et al., 1998; Phan et al., 2002; Sergerie et al., 2008; Zald, 2003), this increased activation might be indicative of greater perceived salience of positive emotional stimuli, which may provide an explanation for the increased lability in mood associated with the experience of bipolar disorder.

5.1.5. Emotion Processing and BAS Sensitivity.

An individual might use facial expressions to glean information about the internal emotional state and intentions of others. As observed changes in another person's facial expression may serve to inform an individual's behaviour, it would follow that these signals have a deep impact on motivational systems (Muhlberger et al., 2011). However, to date there has been little neuroimaging research focusing on individual differences in personality and motivational disposition on the processing of positive facial expression stimuli. One such

study focused on extraversion, a measure conceptually related to reward responsivity (Smillie, 2013), particularly in relation to social stimuli. A positive correlation was reported between extraversion and amygdala activation in response to happy facial expressions (compared to neutral expressions; Canli et al., 2002). This activation was left lateralized, which is consistent with the proposed left lateralization of positive emotions and approach related behaviour (Davidson et al., 1990). Canli et al. (2002) suggested that the inconsistent amygdala activation in response to happy facial expressions described in the literature (Breiter et al., 1996; Morris et al., 1996; Whalen et al., 1998) might reflect individual differences in extraversion. Extraversion has been related to sensitivity of the BAS (Smillie et al., 2006), a key motivational system, which is thought to regulate appetitive motivation and is associated with greater PA (see Chapter One for a more detailed description; Gray, 1981).

Low BAS sensitivity is regarded as a crucial component for a vulnerability to depressive symptomatology (Clark et al., 1994; Fowles, 1993; Gray, 1994), particularly anhedonic symptoms (Beevers & Meyer, 2002; Depue & Iacono, 1989; Harmon-Jones & Allen, 1997; Pinto-Meza et al., 2006; Kasch et al., 2002). Conversely, high BAS sensitivity has been linked to disorders that are characterized by elevated mood and impulsivity, such as the experience of manic symptoms in BD (Johnson et al., 2000; Meyer et al., 2001). Both depression and BD have been associated with deficits in emotion processing (e.g. Blumberg et al., 2005; Lawrence et al., 2004) and yet, to the best of my knowledge, only one study has investigated associations between BAS sensitivity and facial emotion processing. This study reported that BAS score significantly predicted an individual's electrophysiological (EEG) response in anterior frontal sites to facial expressions (Balconi & Mazza, 2009), with scores on the BAS-RR subscale being predictive of greater responses within the left hemisphere to happy facial expressions.

5.1.6. Study Rationale.

The present research had three key aims:

1. The investigation of potential associations between trait measures relating to reward responsivity and neural activation associated with viewing happy facial expressions.
2. The investigation of potential associations between ecologically valid measures of PA, social goal pursuit, and neural activation associated with viewing happy facial expressions.
3. The investigation of these associations in two populations, distinct in terms of age.

Facial expressions are well-validated, socially salient emotional stimuli (Phillips, Drevets, Rauch, & Lane, 2003b), with happy facial expressions thought to represent a social reward through the portrayal of social approval (Lawrence et al., 2004), thus allowing the investigation of social reward processing. The present research focused on activation of reward-associated brain regions in response to happy facial expressions, compared to neutral facial expressions, rather than compared to a fixation cross baseline or negative facial expressions, in line with previous research. This was in order to determine that observed differences in activation were due to the processing of happy facial expressions rather than due to altered responses to faces in general or activation associated with negatively valenced stimuli (Somerville, Kim, Johnstone, Alexander, & Whalen, 2004).

The present research also explored potential associations between the activation associated with viewing happy facial expressions and BAS sensitivity, anhedonic symptoms, and trait hypomania. As discussed earlier, deficits in emotion processing have been observed in both depression and BD (Blumberg et al., 2005; Lawrence et al., 2004), whilst a measure of

extraversion, closely related to BAS sensitivity, has been found to correlate with amygdala activation associated with viewing happy facial expressions (Canli et al., 2002). Furthermore, anhedonia has been linked to reduced amygdala response to happy facial expressions in depressed participants (Stuhrmann et al., 2013), whilst BD participants exhibit greater striatal and amygdala responses (Blumberg et al., 2001; Delvecchio et al., 2012; Hassell et al., 2008; Lawrence et al., 2004). However, this has only been assessed in clinical samples. The present research focuses on potential associations between BAS sensitivity, anhedonic symptoms, and trait hypomania, in two non-clinical samples.¹³

Furthermore, despite some indication that the abnormal processing of facial expressions in depression and BD has real-world consequences for social interactions and behaviours (e.g. Persad & Polivy, 1993; Martino et al., 2011; van Rheeën & Rossell, 201), to my knowledge, no study has attempted to link this to related real-world constructs, such as measures of everyday affect and motivation. In order to address this, the present study explored potential associations between neural responses to happy facial expressions and ecologically valid measures of PA and social goal pursuit. Forbes et al., (2009) previously correlated ratings of everyday PA, measured over a weekend, with neural activation in response to monetary reward in adolescents. The present study builds on this work by extending the everyday measures to include measures relating to social goal pursuit, as well as a similar measure of PA, assessed more intensively and over a longer time period. Furthermore, rather than focusing on the anticipation and receipt of monetary reward (Forbes

¹³ Details of clinical diagnoses were not collected from the participants, nor were any participants excluded on this basis. As a result of this, it is possible that some participants in the present sample may have had a clinical diagnosis. As discussed previously, the MASQ-AD has relatively good predictive utility (Buckby et al., 2007), at a suggested cut-off of 76. Two (7.69%) participants from the student sample and three (10.3%) participants from the community sample reported MASQ-AD scores of 76 or greater. Moreover, a cut-off score of 10 on the PHQ-9 (Kroenke et al., 2001) has been suggested for the diagnosis of depression. In community sample, three (10.1%) participants reported PHQ-9 scores of 10 or greater, whilst a further five (17.9%) participants reported scores between 5-9, which would indicate mild depression.

et al., 2009) the present study extends this to investigate the receipt of social reward, as portrayed by happy facial expressions.

As discussed in previous chapters, it is generally assumed that similar patterns of activation will be elicited in response to rewarding stimuli across different age groups. However, there has been some indication that older adults may experience the so-called “Positivity Effect”, an information processing bias towards positive stimuli and away from negative stimuli (Cartensen et al., 2003; Charles et al., 2003; Mather & Cartensen, 2003). Older adults may also prioritise emotion regulation to avoid social conflict (Cartensen, Mikels, & Mather, 2006) and, consequently, may be more responsive to social stimuli that are associated with the more intrinsic goals of social connection (Baumeister & Leary, 1995; Deci & Ryan, 1991). This is supported by the finding that older adults demonstrate an attentional bias towards positive facial expressions and away from negative facial expressions (Mather & Cartensen, 2003) and exhibit decreased amygdala activation in response to negative facial expressions (Gunning-Dixon et al., 2003; Iidaka et al., 2002). Furthermore, one study focusing on neural responses to monetary and social reward reported an interaction between age and reward type in the right NAcc, with older adults showing a stronger response to social reward (Rademacher et al., 2014). Taken together, this would indicate that there are likely to be age-related changes in emotion processing, which should be taken into consideration in order to increase external validity. As such, the present research investigated the neural responses to socially rewarding facial stimuli in two non-clinical populations, distinct in terms of age. These samples were recruited from a student population (Study One) and a community population (Study Two).

5.1.7. Hypotheses.

During the present research, I focused on three key ROIs: the caudate, NAcc, and the amygdala. The caudate and the NAcc have been consistently implicated in the processing of

reward (Abler et al., 2005, 2006; Ikemoto & Panksepp, 1999; Knutson & Cooper, 2005; Knutson et al., 2001; Robinson & Berridge, 2003; Schultz, 1998), whilst activation of the amygdala has been associated with emotionally salient stimuli (Costafreda et al., 2008; Morris et al., 1998; Phan et al., 2002; Sergerie et al., 2008; Zald, 2003). Amygdala activation has also been implicated in the consummatory processing of social reward, but not monetary reward (Rademacher et al., 2010).

As discussed in previously (see Chapter Four, section 4.1), left frontal cortical activity seems to act as a neurobiological index of approach motivation (Harmon-Jones & Allen, 1997; Sutton & Davidson, 1997). There has been some suggestion that this approach-related activation might extend to the subcortical level, due to the numerous connections between the prefrontal cortex and the mesolimbic system (Posner et al., 2005). This is supported by the finding of a correlation between left lateralised amygdala activation when viewing positive facial expressions and extraversion score (Canli et al., 2002), with extraversion being a trait associated with reward responsivity. Consequently, the left and right portions of each ROI were analysed separately.

BAS Sensitivity. It was predicted that BAS-RR would correlate with ROI activation associated with viewing happy facial expressions. This was based on previous research that reported a significant association between a measure of extraversion (linked to reward responsivity) and amygdala activation in response to viewing happy facial expressions (Canli et al., 2002). This is also consistent with the conceptual definition of BAS-RR, which as a measure of the degree to which an individual responds to reward with energy and enthusiasm (Johnson, 2005) and it is likely that viewing positive facial expressions is closely related to consummatory reward processing, although further research would be required to establish this. As such, it is likely that the BAS-RR subscale would be most relevant and, consequently, no predictions were made for the other BAS subscales.

Anhedonia. It was predicted that ROI activation would negatively correlate with MASQ-AD, as anhedonia is thought to reflect reduced pleasure and enjoyment. Furthermore, a previous study reported that trait anhedonia negatively correlated with amygdala responses to viewing positive facial expressions in a sample of depressed participants (Stuhrmann et al., 2013), whilst diminished striatal activation in response to positive facial expressions has been linked to more general depressive symptoms (Monk et al., 2008; Surguladze et al., 2005; Suslow et al., 2010; Victor et al., 2010).

Hypomanic Personality Traits. It was predicted that ROI activation would correlate with HPS. Previous research has indicated a significant link between HPS score and the identification of subtle positive facial expressions after a positive mood induction (Trevisani, Johnson, & Carver, 2008), suggesting that emotion-processing alterations are linked to hypomania-related traits. Furthermore, the hyperactivation of reward structures in response to viewing positive (versus neutral) facial expressions, has been demonstrated in BD individuals (Blumberg et al., 2001, 2005; Delvecchio et al., 2012; Hassell et al., 2008; Lawrence et al., 2004) and the HPS has been linked to hypomanic symptoms (Eckblad & Chapman, 1986; Meyer & Hautzinger, 2003) and an increased likelihood of developing BD (Kwapil et al., 2000).

ESM Measures. ROI activation was expected to correlate with the ESM measure of PA, as previous research has reported a significant correlation between reward-related activation and a measure of real-world PA (Forbes et al., 2009; Forbes et al., 2010; Olino et al., 2014). Furthermore, ROI activation was also expected to correlate with the ESM measure of ST *social* goal progress, effort, and pleasure. This was based on the idea that the ST *social* goal would be most relevant to the present research, which focuses on social reward processing, so associations with the ST *achievement* goal measures were not examined in this chapter.

Summary of Hypotheses. Figure 4.1 provides a summary of the expected relationships between the trait measures of BAS sensitivity and hypomania, anhedonic symptoms and ROI activation associated with viewing happy facial expressions, compared to neutral facial expressions. A summary of the hypothesised correlations between the ESM measures of PA and goal pursuit, and ROI activation associated with viewing happy facial expressions, compared to neutral facial expressions is also provided.

Table 5.1.

Hypothesised correlations between trait and ESM measures and ROI activation associated with the happy facial expressions > neutral facial expressions contrast.

	Left Caudate	Right Caudate	Left NAcc	Right NAcc	Left Amygdala	Right Amygdala
BAS-FS						
BAS-RR	✓+	✓+	✓+	✓+	✓+	✓+
BAS-D						
MASQ-AD	✓-	✓-	✓-	✓-	✓-	✓-
HPS (Study Two)	✓+	✓+	✓+	✓+	✓+	✓+
Positive Affect	✓+	✓+	✓+	✓+	✓+	✓+
ST Social Progress (Study Two)	✓+	✓+	✓+	✓+	✓+	✓+
ST Social Effort (Study Two)	✓+	✓+	✓+	✓+	✓+	✓+
ST Social Pleasure (Study Two)	✓+	✓+	✓+	✓+	✓+	✓+

Note. MASQ-AD = Mood and Anxiety Symptom Questionnaire - Anhedonic Depression, BAS = Behavioural Activation Scale, FS = Fun-Seeking, D = Drive, RR = Reward Responsiveness, HPS = Hypomanic Personality scale, ST = Short-term. “+” denotes expectation of a positive correlation, whilst “-“ indicates the expectation of a negative correlation.

5.2. Method.

5.2.1. Study One.

Sample Size. In terms of calculating required sample size for associations between fMRI activations and individual difference variables, I assumed large ($r = .5$) effect sizes on the basis of prior research. G*Power calculations revealed a required sample size of 29 persons for fMRI. Based on prior experience, I assumed that approximately 10% of participants would not complete the study, so I aimed to recruit 32 participants for fMRI scanning such that adequate power would be attained after attrition.

Inclusion/Exclusion Criteria. In order to be invited to participate in the MRI study, participants were required to have completed at least 60% of the ratings in the ESM study to ensure representative data. For safety reasons, participants were also excluded if they had any MRI contraindications (e.g., metal implants) in accordance with the MRI scanning centre safety policy. Medication status and the presence of mental and physical health conditions were not explicitly measured, so no exclusions were made on this basis, beyond the MRI contraindications described above. No further exclusions were in place.

Participants. A subset of 28 participants was recruited from the 65 participants who had previously completed the ESM Study One (see Chapter Two). Participants were required to have completed at least 60% of the ratings in the ESM study, in order to demonstrate commitment to the study, as well as providing more representative data. They were also required to be fluent in English in order to be able to successfully engage with the tasks. For safety reasons, participants were also excluded if they had any MRI contraindications (e.g. metal implants) in accordance with the MRI scanning centre safety policy. Due to issues with E-Prime logging response times, data from two participants were not included. The final

sample consisted of 26 (13 female) participants (range = 19-54 years, $M = 24.16$ years old, $SD = 8.44$).

Trait Measures. Baseline measures of MASQ-AD (Clark & Watson, 1991) and the BAS subscales were completed, all of which showed good internal consistency (see Chapter Four, section 4.2. for Cronbach's alpha for each subscale in the fMRI study).

Experience Sampling. All participants had previously undergone a period of ESM in order to gain ecologically valid measures of everyday PA and goal pursuit. See Chapter Two (section 2.2.1) for a full description. The delay between the initial briefing for the ESM study and participation in the MRI study ranged from ten to twenty-three days.

fMRI Task. E-Prime software (Psychology Software Tools, Inc) was used to deliver and record responses. Stimuli were presented during scanning using an Epson EMP-74 digital projector system projected onto a screen at the foot of the scanner, and viewed via an angled mirror, which was attached to the head coil. Participants responded using their right index and middle fingers via a fibre-optic response button-box.

Facial Emotion Processing Task. The facial emotion-processing task was designed to investigate brain activation associated with viewing emotionally salient social stimuli (adult or infant faces with either happy or neutral expressions). This task employed an event-related fMRI design and was very similar to the task used in many previous fMRI studies reviewed above (e.g. Lawrence et al., 2004; Surguladze et al., 2002), but with some changes to the positive facial expression stimuli presented.

During the task, participants were presented with eight different facial identities of happy adult and infant faces respectively, along with neutral adult and infant faces (eight of each; see Appendix D for images). For adult faces, four male and four female identities were used for each emotional (and neutral) expression; gender was not obvious for the infant faces.

Adult face stimuli were taken from two validated sets of face stimuli – cropped Ekman faces (Young et al., 2002) and the Karolinska emotional faces (Lundqvist et al., 1998). Infant faces were provided by Pearson et al. (2010) who had previously validated them. Adult and infant faces were used to maintain consistency and allow for comparison with another study focusing on post-partum depression conducted in our lab (Williams, 2014). Furthermore, as both children and adults prefer pictures of infants (Berman, Cooper, & Mansfield, 1975; Fullard & Reiling, 1976), it was thought that the happy baby faces may have been even more rewarding. In total, participants viewed 20 happy adult faces (eight identities, each presented two or three times, at random) and 20 neutral adult faces (eight identities). They viewed the same number of happy and neutral baby faces (again with eight identities for each).

Facial stimuli were presented for 2 seconds each in one of two pseudo-random presentation orders, counterbalanced across participants. During the interstimulus interval, which lasted between 1 and 10 seconds (determined randomly, with an average of 4 seconds' duration), participants were presented with a fixation cross. Figure 5.1 depicts the trial sequence and examples of the stimuli.

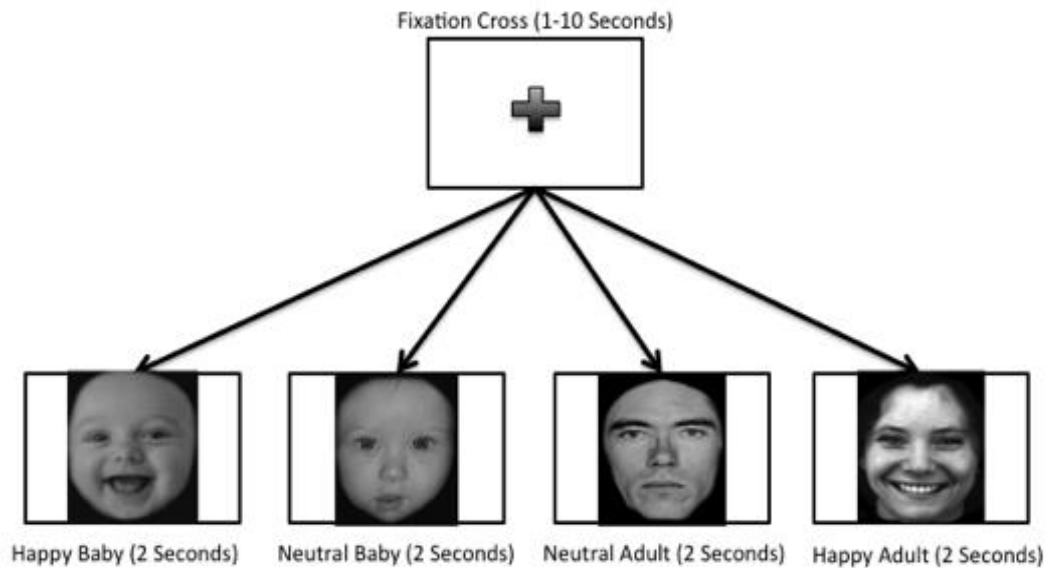


Figure 5.1.

An example of each condition in the facial emotion-processing task.

An event-related design with a variable interstimulus interval was adopted to reduce habituation of the BOLD response, which is a problem with highly repetitive and predictable stimulus presentation (e.g., Breiter et al., 1996). Performance on implicit emotion recognition tasks (requiring participants to decide the gender of faces) has been associated with greater responses in subcortical regions, including our ROIs (Morris et al., 1996; Phillips et al., 1997). Participants were therefore asked to decide the age rather than the emotional expression of each face by responding ‘young’ or ‘old’ using their index or middle finger. Participants completed the trials with 100% accuracy.

Responses to happy and neutral facial expressions were modelled separately. The present research focused on the happy facial expressions > neutral facial expressions contrast.

5.2.2. Study Two.

Sample Size. In terms of calculating required sample size for associations between fMRI activations and individual difference variables, I assumed large ($r = .5$) effect sizes on the basis of prior research. G*Power calculations revealed a required sample size of 29

persons for fMRI. Based on prior experience, I assumed that approximately 10% of participants would not complete the study, so I aimed to recruit 32 participants for fMRI scanning such that adequate power would be attained after attrition.

Inclusion/Exclusion Criteria. In order to be invited to participate in the MRI study, participants were required to have completed at least 60% of the ratings in the ESM study to ensure representative data. For safety reasons, participants were also excluded if they had any MRI contraindications (e.g., metal implants) in accordance with the MRI scanning centre safety policy. Additionally, due to possible age-related degradation in the brain (e.g., Peters, 2006; Scahill et al., 2003), participants over the age of 70 years were excluded from the MRI study. Medication status and the presence of mental and physical health conditions were not explicitly measured, so no exclusions were made on this basis, beyond the MRI contraindications described above. No further exclusions were in place.

Participants. A subset of 31 participants was recruited from the 65 participants who had previously completed the ESM Study Two (see Chapter Two). Participants were required to have completed at least 60% of the ratings in the ESM study, in order to demonstrate commitment to the study, as well as providing more representative data. They were also required to be fluent in English in order to successfully engage with the tasks. Due to possible age-related degradation in the brain (Peters, 2006; Scahill et al., 2003), participants over the age of 70 years were excluded from the MRI study. For safety reasons, participants were also excluded if they had any MRI contraindications (e.g. metal implants) in accordance with the MRI scanning centre safety policy. Due to technical issues with the fMRI files, data from three participants were excluded from the final analysis. The final sample consisted of 28 (14 female) participants (range = 38-67 years, $M = 55.61$ years old, $SD = 9.04$).

Trait Measures. Baseline measures of MASQ-AD (Clark & Watson, 1991), the BAS subscales, and HPS (Eckblad & Chapman, 1986) were completed, all of which showed good internal consistency (see Chapter Four, section 4.2.2. for Cronbach's alpha for each subscale in the fMRI study).

Participants were also asked to complete various other related measures (Appendix A), including the Revised Physical Anhedonia Scale (Chapman et al., 1976), the Revised Social Anhedonia scale (Eckblad et al., 1982), the Patient Health Questionnaire (PHQ-9; Kroenke et al., 2001). However, these measures were not included in the present analysis.

Experience Sampling. All participants had previously undergone a period of ESM in order to gain ecologically valid measures of everyday PA and ST social goal pursuit. See Chapter Two (section 2.2.2.) for a full description. The delay between the initial briefing for the ESM study and participation in the MRI study ranged from nine to thirty-one days.

fMRI Task. E-Prime software (Psychology Software Tools, Inc) was used to deliver and record responses. Stimuli were presented during scanning using an Epson EMP-74 digital projector system projected onto a screen at the foot of the scanner, and viewed via an angled mirror, which was attached to the head coil. Participants responded using their right index and middle fingers via a fibre-optic response button-box.

Facial Emotion Processing Task. A facial emotion-processing task was used to probe the BOLD response associated with viewing emotionally salient stimuli (adult or infant faces with either happy or neutral expressions). As the same task was used in Study One, refer to section 4.2.1. for a full description. Participants completed the trials by identifying age with 100% accuracy.

5.2.3. fMRI Processing & Analysis.

MR Image Acquisition. Activation during the fMRI tasks was measured using a 1.5-T Philips Gyroscan MRI scanner fitted with a quadrature head coil. During each task, brain volumes of 26 slices (3.5 mm thick and ACPC [anterior commissure-posterior commissure] orientated) were acquired interleaved using a gradient echoplanar imaging sequence (TR = 2s; TE = 45msec; voxel size = 3.5mm isotropic; FOV=270mm; flip angle = 90 degrees). For the facial emotion-processing task, 240 volumes were acquired (8 minutes). For each participant, functional data were overlaid on a high-resolution T1-weighted anatomical image for registration into standard space and functional localisation (3D T1 FFE, TR = 252 ms, TE = 4.2 ms, Voxel size = 0.9mm³, Number of Slices = 160, FOV = 230 mm, Flip angle = 30 degrees).

Data Processing. fMRI data pre-processing and statistical analyses were carried out using FEAT (fMRI Expert Analysis Tool), version 5.98, as part of FSL (FMRIB's Software Library). For each participant, standard pre-processing steps were performed. These consisted of motion correction (Jenkinson et al., 2002), non-brain removal (Smith, 2002), spatial smoothing (using a Gaussian kernel of FWHM 5mm). This was followed by normalisation based on grand-mean intensity and high-pass temporal filtering (Gaussian-weighted least-squares straight line fitting, $\sigma = 50.0s$). Registration of the participant's functional data to high-resolution T1 structural images was achieved using FLIRT (Jenkinson et al., 2002; Jenkinson & Smith, 2001). Participants' data were inspected visually for artefacts and excessive head motion (greater than 3mm; average = 0.76mm). None were found, so no participants were excluded from the analysis on these grounds.

Analysis of the Facial Emotion-Processing Task. The task was modelled within the general linear modelling framework, using the crosshair periods as baseline stimuli, with events being defined as the onset time of each face stimulus (duration 2 seconds). Individual

brain activation maps were produced for each participant for each category of facial expression (happy-face, neutral-face)

Region of Interest Analyses. Due to the a priori hypotheses regarding activation in specific brain regions reviewed previously, the anatomical ROI analyses focused on extracting the mean % BOLD signal change in three specific anatomical regions-of-interest (Figure 5.2): the caudate, the NAcc, and the amygdala.

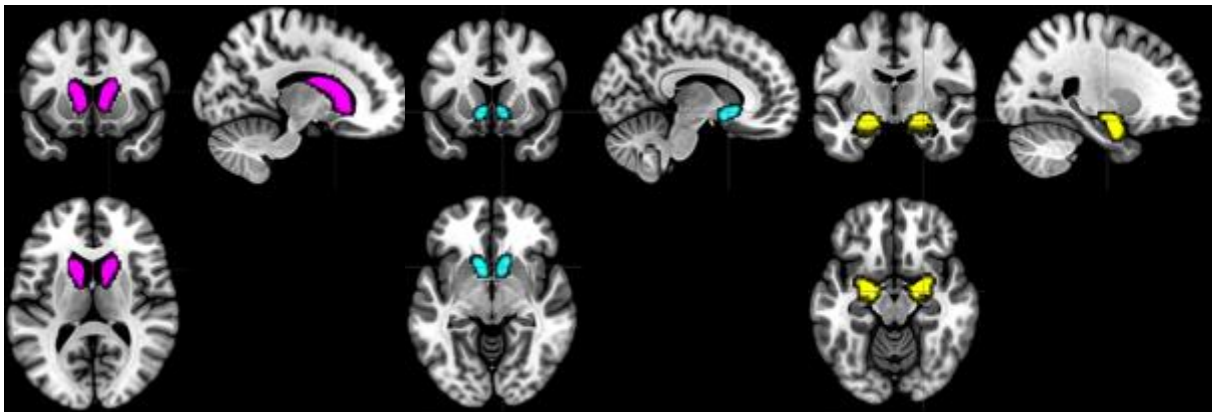


Figure 5.2.

Left/right caudate (shown in pink), left/right NAcc (shown in blue), and left/right amygdala (shown in yellow) ROIs.

This ROI analysis was implemented in FSL's Featquery tool using the Harvard–Oxford subcortical regional atlas. Note that in this atlas the caudate, the NAcc, and the amygdala are separated into left and right hemisphere regions so results are reported for these separately. For the facial emotion-processing task, the mean % BOLD signal change was extracted from each participant for the contrast involving happy facial expression > neutral facial expressions.

Exploratory Whole Brain Analyses. Supplementary whole-brain regression analyses provided additional information about regions of activation outside the a priori ROIs (detailed above) that were correlated with the trait questionnaire measures (BAS, MASQ-AD, and HPS in Study Two). Individual statistical maps for each contrast of interest were entered

into a whole-brain group-level mixed effects model. The grand-mean centred trait scores for each participant were entered as additional regressors (one for each of the measures of interest) at this group level. Contrasts were defined to examine positive and negative associations between activation across the whole brain and measure scores. Group activation maps were constructed using FLAME (FMRIB's Local Analysis of Fixed Effects; Beckman et al., 2003; Woolrich et al., 2004) and Z (gaussianised transformed) statistical maps were thresholded using clusters determined by $Z > 2.3$ and a whole brain corrected cluster significance threshold of $p < 0.05$ (Worsley, 1992). These maps indicated regions showing significant correlations (corrected for whole-brain analyses) between trait measure scores and brain activity for our contrasts of interest.

Statistical Analyses. Analysis of data was conducted using SPSS for Mac, version 21. Potential relationships between trait measures, ESM measures, and ROI activation (mean % BOLD signal change) associated with the happy facial expressions > neutral facial expressions contrast, were examined using correlation analyses. Given the non-normal distributions of BOLD activation in several of the ROIs, non-parametric Spearman's rho analyses were conducted.

5.3. Results.

5.3.1. Study One.

Preliminary Analyses. In total, the data from 26 participants (13 female) were included in the fMRI analysis. These participants consisted of a subset of those who completed the previous ESM study (see Chapter Two for a full description). Please see Chapter Four (Table 4.3) for a summary of the untransformed means and standard deviations

of scores on the baseline measures in the student sample.¹⁴ The mean scores on each of the BAS subscales and the MASQ-AD are in line with those previously reported in non-clinical samples (Bredemeier et al., 2010; Carver & White, 1994). Refer to Chapter Four, section 4.3.1. – “Preliminary Analyses” for a description of the correlations among the trait measures and ESM measures for the student sample.

5.3.2. Region of Interest Analyses.

Trait Measures. Activation associated with the happy facial expressions > neutral facial expressions contrast were correlate with the trait measures, the results of which are presented in Table 5.2. It was predicted that ROI activation would correlate with BAS-RR and negatively correlate with MASQ-AD. However, these predictions were not supported and only one significant association emerged. Left amygdala activation negatively correlated with BAS-RR, whilst a negative correlation between right amygdala activation and BAS-FS approached significance ($p = .051$).

¹⁴ Although the descriptive statistics and baseline correlations were very similar to those reported in Chapter Four, due to some technical issues, not all participants were included in the analysis. The exact descriptive statistics and baseline correlations for this sample of 26 are provided in Appendix E.

Table 5.2.

Correlations between trait measures and ROI activation for the happy facial expressions > neutral facial expressions contrast [95% confidence intervals].¹⁵

	BAS-FS	BAS-RR	BAS-D	MASQ-AD
Left Caudate	.02 [-.38, .41]	-.12 [-.49, .29]	.00 [-.40, .40]	.25 [-.16, .59]
Right Caudate	.31 [-.10, .63]	-.08 [-.46, .33]	-.16 [-.52, .25]	-.10 [-.48, .31]
Left NAcc	.10 [-.31, .48]	-.15 [-.52, .26]	-.10 [-.48, .31]	.01 [-.39, .41]
Right NAcc	.06 [-.35, .45]	-.30 [-.62, .11]	-.03 [-.42, .37]	-.17 [-.53, .24]
Left Amygdala	-.17 [-.53, .24]	-.40* [-.69, -.00]	.17 [-.24, .53]	.23 [.18, .57]
Right Amygdala	-.39 [-.68, .01]	-.09 [-.47, .32]	.04 [-.36, .43]	.12 [-.29, .49]

Note. MASQ-AD = Mood and Anxiety Symptom Questionnaire - Anhedonic Depression, BAS = Behavioural Activation Scale, FS = Fun-Seeking, D = Drive, RR = Reward Responsiveness. * $p < .05$ (two tailed).

A scatter plot was generated to investigate the relationship between BAS-RR and activation in the left amygdala (Figure 5.3).

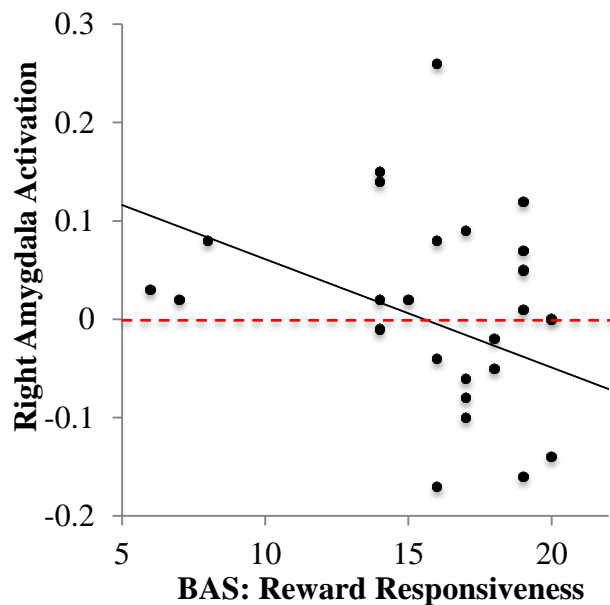


Figure 5.3.

Relationship between BAS-RR and left amygdala activation for happy facial expressions > neutral facial expressions contrast.

¹⁵ However, the significant relationships observed would not have survived Bonferroni correction for multiple comparisons, at an alpha level of .002.

ESM Measures. It was predicted that PA would correlate with ROI activation for the happy facial expressions > neutral facial expressions contrast. These hypotheses were not supported and no significant associations were found between PA and left caudate ($r_s = .15$, $p = .479$), right caudate ($r_s = .17$, $p = .388$), left NAcc ($r_s = .12$, $p = .555$), right NAcc ($r_s = .04$, $p = .836$), left amygdala ($r_s = .329$, $p = .101$), and right amygdala ($r_s = .05$, $p = .823$) activation associated with viewing happy facial expressions.

5.3.3. Exploratory Whole Brain Analyses.

Supplementary whole-brain regression analyses examined regions of activation outside of the a priori ROIs. At the group mean level, no significant activation was observed for the happy facial expressions > neutral facial expressions contrast, although significant activation was observed in regions such as the inferior frontal gyrus, the precentral and postcentral gyri, and the left putamen for the happy facial expressions > baseline contrast, which suggests that there was some activation to viewing the facial expressions in this task (see Appendix F). Furthermore, no areas outside of the a priori ROIs were found to be associated with the trait questionnaire measures (BAS subscales and MASQ-AD) at the whole-brain second (group map) level.

5.3.4. Study Two.

Preliminary Analyses. In total, the data from 28 participants (14 female) were included in the fMRI analysis. These participants consisted of a subset of those who completed the previous ESM study (see Chapters Two and Four for a full description). Please see Chapter Four (Table 4.12) for a summary of the untransformed means and standard deviations of scores on the baseline measures in the community sample.¹⁶ The mean scores

¹⁶ Although the descriptive statistics and baseline correlations were very similar to those reported in Chapter Four, due to some technical issues, not all participants were included in the analysis. The exact descriptive statistics and baseline correlations for these 28 participants are provided in Appendix E.

on each of the BAS subscales and the MASQ-AD are in line with those previously reported in non-clinical samples (Bredemeier et al., 2010; Carver & White, 1994). However, scores on the HPS were very low, and the mean score was approximately one standard deviation below the mean score reported in a prior non-clinical sample (e.g., Bentall et al., 2011). Refer to Chapter Four, section 4.3.2. – “Preliminary Analyses” for a description of the correlations among the trait measures and ESM measures for the student sample.

5.3.5. Region of Interest Analyses.

Trait Measures. ROI activation associated with the happy facial expressions > neutral facial expressions contrast was correlated with the trait measures, the results of which are presented in Table 5.3. It was predicted that ROI activation would correlate with BAS-RR and HPS, and negatively correlate with MASQ-AD. However, these hypotheses were not supported and no significant associations were observed.

Table 5.3.

Correlations between trait measures and ROI activation during the happy faces compared to neutral faces [95% confidence intervals].

	BAS-FS	BAS-RR	BAS-D	MASQ-AD	HPS
Left Caudate	-.12 [-.48, .28]	-.03 [-.41, .36]	-.12 [-.48, .28]	.29 [-.10, .61]	.27 [-.13, .59]
Right Caudate	-.25 [-.58, .15]	-.13 [-.49, .27]	-.18 [-.53, .22]	.34 [-.05, .64]	.08 [-.31, .45]
Left NAcc	.09 [-.32, .47]	-.00 [-.38, .38]	.03 [-.36, .41]	.14 [-.26, .50]	.14 [-.26, .50]
Right NAcc	-.11 [-.47, .29]	.00 [-.38, .38]	-.10 [-.47, .29]	.19 [-.21, .53]	.23 [.17, .56]
Left Amygdala	-.00 [-.38, .38]	-.11 [-.47, .29]	-.22 [-.56, .18]	-.27 [-.59, .13]	.32 [-.07, .63]
Right Amygdala	-.09 [-.46, .30]	.05 [-.34, .42]	-.09 [-.46, .30]	-.24 [-.57, .16]	.21 [-.19, .55]

Note. MASQ-AD = Mood and Anxiety Symptom Questionnaire - Anhedonic Depression, BAS = Behavioural Activation Scale, FS = Fun-Seeking, D = Drive, RR = Reward Responsiveness, HPS = Hypomanic Personality scale.

ESM Measures. It was predicted that ROI activation for the happy facial expressions > neutral facial expressions contrast would correlate with the ESM measures of PA and ST *social* goal pursuit. The correlations are presented in Table 4.4. Contrary to predictions, no significant associations emerged between the ESM measures of PA, ST *social* goal pleasure, and ROI activation when viewing happy facial expressions. However, ST *social* goal progress and effort were found to correlate with activation of the left amygdala when viewing happy facial expressions, whilst the relationship between ST *social* goal progress and right amygdala activation approached significance ($p = .066$).

Table 5.4.

Correlations between ESM measures and ROI activation for the happy facial expressions > neutral facial expressions contrast [95% confidence intervals].¹⁷

	Positive Affect	ST Social Progress	ST Social Effort	ST Social Pleasure
Left Caudate	-.31 [-.61, .08]	.04 [-.35, .42]	-.03 [-.41, .36]	.03 [-.36, .41]
Right Caudate	-.30 [-.61, .09]	-.06 [-.43, .33]	-.20 [-.54, .20]	-.09 [-.46, .30]
Left NAcc	.07 [-.32, .44]	.08 [-.31, .45]	.08 [-.45, .31]	.31 [-.08, .62]
Right NAcc	-.02 [-.40, .37]	.08 [-.31, .45]	-.04 [-.42, .35]	.15 [-.25, .50]
Left Amygdala	.16 [-.24, .51]	.59** [.27, .79]	.42* [.04, .69]	.00 [-.38, .38]
Right Amygdala	.04 [-.35, .42]	.36 [-.03, .65]	.16 [-.24, .51]	-.25 [-.58, .15]

Note. ST = Short-term. ** $p < .001$ (two tailed). * $p < .05$ (two tailed).

Scatter plots were generated to investigate the relationship between ST *social* goal progress and effort and activation in the left amygdala (Figure 4.4). A similar relationship can be observed in both associations, with those lower in ST *social* goal progress and effort exhibiting greater levels of deactivation.

¹⁷ However, the significant relationships observed would not have survived Bonferroni correction for multiple comparisons, at an alpha level of .002.

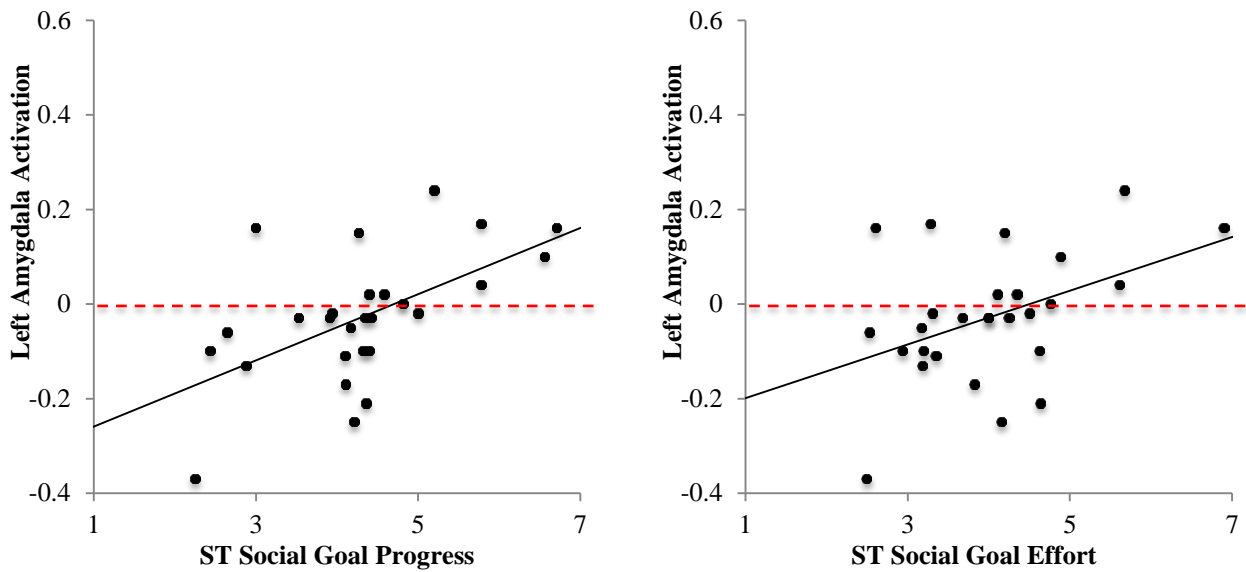


Figure 5.4.

Relationships between ST *social* goal progress and effort and left amygdala activation for happy facial expressions > neutral facial expressions contrast.

5.3.6. Exploratory Whole Brain Analyses.

Supplementary whole-brain regression analyses examined regions of activation outside the a priori ROIs. At the group mean level, no significant activation was observed for the happy facial expressions > neutral facial expressions contrast, although significant activation was observed in areas such as the fusiform gyrus, the inferior frontal gyrus, the supramarginal gyrus, and the anterior cingulate gyrus for the happy facial expressions > baseline contrast (see Appendix F). Furthermore, no areas outside of the a priori ROIs were found to be associated with the trait questionnaire measures (BAS subscales, MASQ-AD, and HPS) at the whole-brain second (group map) level.

5.3.7. Sample Differences.

Given the non-normal distributions of BOLD activation in several of the ROIs, non-parametric Mann-Whitney U analyses were conducted to assess differences in ROI activation in the student and community samples. No significant differences were found between the student and community samples for ROI activation associated with viewing happy facial

expressions (Left Caudate: $U = 311, Z = -.918, p = .366$; Right Caudate: $U = 340, Z = -.415, p = .683$; Left NAcc: $U = 310, Z = -.935, p = .357$; Right NAcc $U = 300, Z = -1.11, p = .274$; Left Amygdala: $U = 319, Z = -.779, p = .444$; Right Amygdala: $U = 347, Z = -.294, p = .777$)

5.3.8. Summary of Key Findings.

When viewing positive versus neutral facial expressions, ROI activation was not significantly associated with any of the trait measures in the predicted directions. Furthermore, no significant associations emerged between the ESM measure of PA and ROI activation, although positive correlations were observed between ST *social* goal progress and effort and left amygdala activation when viewing happy facial expressions.

5.4. Discussion.

The present research aimed to assess the relationships, in two distinct samples, between activation of the ROIs (caudate, NAcc, and amygdala) in response to viewing happy versus neutral facial expressions with various trait measures, associated with the experience of approach motivation, anhedonia, and hypomania. However, no expected associations were found; only one reached significance and this was in the opposite direction to that predicted and should be interpreted with caution (see below). Furthermore, the lack of significant activation for the happy versus neutral faces contrast at the whole-brain group map level casts doubt on whether this contrast was sensitive, making it difficult to draw valid conclusions from the present data. The tentative conclusions drawn and limitations associated with the present task are discussed below.

5.4.1. BAS Sensitivity.

Contrary to predictions, ROI activation associated with the happy facial expressions > neutral facial expressions were not found to correlate with BAS-RR, with one exception: left amygdala activation negatively correlated with BAS-RR in the student sample. This was

somewhat surprising as the expected positive correlation was based on the conceptual definition of BAS-RR, which serves as a measure of an individual's tendency to respond to reward with energy and enthusiasm. It was expected that individuals high in this trait would exhibit greater activation in response to positive facial expressions, which are likely to serve as a form of social reward (Lawrence et al., 2004). This prediction was also supported by previous findings of a significant association between a measure of extraversion (which has been associated with BAS sensitivity; Caseras, et al., 2003; Smillie & Jackson, 2006; Zelenski & Larsen, 1999) and amygdala activation in response to happy facial expressions (compared to neutral facial expressions; Canli et al., 2002). However, due to concerns about the effectiveness of the present task and the fact that it is the only significant association found for this task, across both samples, it is likely that this is the result of Type II error must be interpreted with caution.

5.4.2. Anhedonia.

Anhedonic symptoms, as measured by the MASQ-AD were not found to inversely correlate with activation in the ROIs, as was predicted. The current null findings do not support previous research, which reported a strong association between anhedonia and amygdala activation associated with the contrast between happy vs. neutral facial expressions (Stuhrmann et al., 2013). Our null findings may be related to a lack of sensitivity associated with the current task or 1.5T scanner (see below).

In addition there were several key differences between the Stuhrmunn et al. (2013) study and the present one. The first is the use of different scales to assess anhedonia: Stuhrmann et al. (2013) used the Chapman Physical Anhedonia Scale (Chapman et al., 1976), which is designed to measure trait anhedonia, whilst the present study uses the anhedonic depression subscale of the MASQ (Clark & Watson, 1991). The MASQ is designed to assess anhedonic symptoms in the preceding two weeks and thus falls somewhere between a trait

and state measure. However, the participants in the community sample also completed the Physical Anhedonia scale, the scores of which were correlated with ROI activation for the happy facial expressions > neutral facial expression contrast (see Appendix F), but no significant associations emerged with this measure either. However, Stuhmann and colleagues (2013) scanned a clinical sample of moderately to severely depressed inpatients, the majority of whom were taking antidepressant medication. Such a sample is likely to experience greater levels of depressive symptoms and have more history of mood disorder, so it may be that only more chronic anhedonia is reflected at the neural level. The authors did acknowledge that the generalisability of the findings to outpatients with less severe forms of depression is limited. This is particularly relevant to the present research, as although the present samples' anhedonia score is in line with other nonclinical samples, it was markedly lower than those observed in depressed participants, which is likely to have made it more difficult to detect associations. Despite this, a negative correlation was found between a measure of trait Social Anhedonia (Eckblad et al., 1986) and activation of the left and right caudate, and the right NAcc for the happy facial expressions > neutral facial expressions contrast, whilst the relationship with left NAcc activation approached significance (see Appendix F for details of these additional analyses). This would indicate that, unsurprisingly, social anhedonia may relate to decreased activation of the reward circuitry when presented with socially rewarding stimuli.

5.4.3. Hypomanic Personality Traits.

It was predicted that hypomanic personality traits, as measured by the HPS, would positively correlate with activation in the ROIs associated with the happy facial expressions > neutral facial expressions contrast. However, this was not found to be the case, with no significant associations being found between HPS score and ROI activation in response to happy facial expressions. As discussed previously, there were concerns about the

effectiveness of the task in eliciting the expected activation so the null findings reported here should be interpreted with caution. Moreover, as no previous study has looked at associations between hypomanic personality traits and neural responses to happy facial expressions, the predictions were based on previous findings in BD participants that reported hyperactivation in the striatal regions (Blumberg et al., 2001; Delvecchio et al., 2012; Hassell et al., 2008) and the amygdala (Blumberg et al., 2005; Lawrence et al., 2004) in response to happy facial expressions. As discussed in previous chapters, the HPS is not designed as a direct measure of BD/hypomania, but as a measure of personality traits that might indicate a predisposition to the development of BD (Eckblad & Chapman, 1986), therefore although a participant might score highly on this measure, they might not experience any hypomanic symptoms. Furthermore, the low sample mean and reduced range observed for HPS scores in the community sample was a potential barrier to detecting significant relationships between trait hypomania and neural responses to happy facial expressions.

5.4.4. ESM Measures.

It was predicted that the ESM measure of PA would correlate with activation in response to happy facial expressions in the ROIs, which was not found to be the case. Aside from concerns about the sensitivity of the current methods, there are other potential explanations for the null findings. First, the demonstrated link between real world PA and reward-related activation concerns striatal activation in responses to monetary reward anticipation and receipt (Forbes et al., 2009; Olino et al., 2014). Monetary reward has been demonstrated to be a more salient incentive than happy facial expressions (Jensen et al., 2007), which might lead to a stronger activation of the reward circuitry and be more relevant to the experience of PA. Furthermore, it should be noted that for some participants, there may have been a lengthy (more than two weeks) delay between completing the ESM measures and undertaking the scan, and so they might not provide a true representation of the participants'

level of PA at the time of the scan. Although ESM reports of PA were sometimes collected quite far in advance of the scan, there is some evidence that PA remains relatively stable (Charles et al., 2001; Costa et al., 1987), so this may not clearly explain the null findings. It may be that everyday PA may relate more to tonic levels of affect, such that it is not tightly associated with the responses to social reward observed in the scanner. Positive correlations were observed between measures of ST *social* goal progress and effort, and activation of the left amygdala when viewing happy facial expressions, in the community sample, with those individuals reporting lower ST *social* goal progress and effort exhibiting more deactivation in response to the images of happy facial expressions. This would suggest that some aspects of the present task might be related to the everyday pursuit of personally relevant social goals. Unfortunately, as no measures of ST *social* goal pursuit were collected from the student sample, it was not possible to establish if these findings would have been replicated in younger adults.

5.4.5. Limitations.

A key limitation of this research was the use of a 1.5T scanner. This may not have been sensitive enough to differentiate the activation associated with the viewing of positive relative to neutral facial expressions, consistent with the null findings observed for mean activation at the whole brain level. However, several predicted associations were observed between the trait measures and neural responses to monetary reward anticipation and receipt elicited using a card-guessing paradigm (see Chapter Four). This would suggest that there are some limitations of the task itself. When viewing the corrected maps, no significant activation was observed for happy relative to neutral facial expressions. This could relate to limitations of the stimuli used in the task. Images of both adult and infant faces were used, which, to the best of my knowledge have not been used to investigate emotion processing per se, with previous studies predominantly focusing on adult facial expressions. As discussed previously,

adults tend to demonstrate a preference for images of infants (Berman, Cooper, & Mansfield, 1975; Fullard & Reiling, 1976), with young adults rating images of infants and young children as being more attractive and likeable (Luo, Lee, & li, 2011; Volk, Lukjanczuk, & Quinsey, 2007) and have been demonstrated to activate the reward circuitry in non-parents (Glocker et al., 2009). As such, it could be that the contrast between neutral and happy infant facial expressions is smaller than for adult facial expressions. However, neural responses to the infant facial expressions and adult facial expressions were not analysed separately, due to concerns about further reducing the power/sensitivity to detect effects, in view of the 1.5T scanner. Other contrasts extracted from this task had shown some interesting associations with mood in a previous sample of mothers (Williams, 2014) and so it was hoped that the task would have been sensitive enough for use in the present research. Furthermore, the task was also very similar (except for the baby faces) to those used in many previous fMRI studies that have detected abnormal striatal and amygdala responses to happy faces in patients with depression and BD (e.g. Fu et al., 2007; Hassel et al., 2008; Lawrence et al., 2004; Surguladze et al., 2005). Whilst the happy vs. neutral faces contrast did not elicit significant whole-brain activation, the larger contrast between happy facial expressions and fixation cross baseline did (see Appendix F). For the sake of completeness, ROI responses for this contrast were also correlated with trait and ESM measures. However, no relationships were found between BOLD activation associated with the happy facial expressions > baseline contrast and the trait or ESM measures. The limited sensitivity of the main contrast in the current study is a significant issue, which makes drawing conclusions difficult. Another significant limitation is the relatively small sample size in both studies, which provided enough statistical power to detect only large correlations among variables.

5.4.6. Conclusion.

The present research explored potential associations of measures of approach motivation, anhedonia, and hypomania with social-reward related neural responses. No support was provided for the hypotheses and so it is likely that either the present task was not sensitive enough to detect these associations, or they are not present in sub-clinical samples, although an additional measure of trait social anhedonia did correlate with striatal activation, in the community sample. In addition to this, positive correlations also emerged between the ESM measures of ST *social* goal progress and effort, and left amygdala activation associated with the happy facial expressions > neutral facial expressions contrast. This would suggest that the neural responses elicited by the happy facial expressions in the scanner are of some relevance to the everyday pursuit of social goals.

In the present chapter, consideration was given to potential associations between the trait measures and the processing of social rewards. However, emotional facial expressions may be relevant to the regulation/perception of emotion, but they do not necessarily elicit the subjective experience of emotions in participants (Davidson & Irwin, 1999), whereas valenced images may elicit a more direct affective experience (Britton, Taylor, Sudheimer, & Liberzon, 2006). Moreover, due to the limited number of facial expressions, there is some restriction on the type of affective neural responses that may be examined. The following chapter (Chapter Six) seeks to address this by investigating neural responses associated with viewing valenced images that portray affiliative PA (contentment) and more general PA (excitement).

Chapter VI: Neural Responses to Pleasant Images.

6.1. Introduction.

Neuroimaging investigations of reward-related processing tend to focus on either neural responses to monetary reward (e.g., Forbes et al., 2009; Pizzagalli et al., 2009), or the response to emotional stimuli (Zhang et al., 2013). The previous chapter focused on responses to positive facial expressions, which are thought to act as a form of social reward. However, facial expressions do not necessarily elicit the subjective experience of emotion (Davidson & Irwin, 1999) and the limited number of facial expressions restricts the type of affective neural responses that may be examined. The present chapter aims to address this by focusing on the neural responses to positively valenced images, thought to elicit a more direct affective experience (Britton et al., 2006), associated with affiliative PA (contentment) and more general PA (excitement), thus capturing a broader range of positive emotion than is possible with facial expressions.

6.1.1. Emotion Processing in Healthy Participants.

The striatum and the amygdala are thought to play a crucial role in emotion and reward processing (Lang et al., 1998; Garavan et al., 2001; Hariri et al., 2002; Pessoa & Ungerleider, 2004; Wright et al., 2001). The amygdala has been particularly implicated in the processing of emotional stimuli and was traditionally thought to be responsive to negatively valenced (unpleasant) stimuli only (Alpers et al., 2009; Das et al., 2005; LeDoux, 2000; Öhman, 2005; Öhman & Mineka, 2001; Phelps & LeDoux, 2005). However, this has become a matter of some debate (Kober et al., 2008; Phan et al., 2004) following recent evidence showing that the amygdala is also responsive to positively valenced (pleasant) stimuli (Baxter & Murray, 2002; Costafreda et al., 2008; Fecteau et al., 2007; Garavan et al., 2001; Hamann & Mao, 2002; O'Doherty, 2004; Sabatinelli et al., 2007; Sabatinelli, Lang, Bradley, Costa, &

Keil, 2009), with little difference being found in amygdala response to rewarding and punishing stimuli, when the arousal level of the stimulus was controlled for. Consequently, it has been concluded that the amygdala primarily responds to the intensity (arousal level) of a stimulus and not to its valence (Anderson & Sobel, 2003; Small et al, 2003), potentially serving to tag the emotional salience of a stimulus (Sanders, Wiltgen, & Fanselow, 2003). Furthermore, considering unpleasant stimuli tend to be more arousing than pleasant stimuli (Lewis, Critchley, Rothstein, & Dolan, 2005), it would follow that the processing of unpleasant stimuli would be privileged (Costafreda et al., 2008), providing an explanation as to why the amygdala might have been more responsive to negatively valenced stimuli in previous fMRI studies.

The striatum, another structure that has been reliably implicated in the processing of emotion and reward, was also thought to respond selectively to pleasant or rewarding stimuli (McClure et al., 2004; O'Doherty et al., 2004), with a range of studies demonstrating the selective activation of striatal areas (particularly the NAcc) in response to pleasant stimuli (Aharon et al., 2001; Costa et al., 2010; Knutson & Cooper, 2005; Sabatinelli et al., 2007). However, this too has come under debate, with some research implicating the striatum in the processing of unpleasant stimuli (Becerra et al., 2001; Herwig, Abler, Walter, & Erk, 2007; Leknes & Tracey, 2008; Levita et al., 2009). One study reported that NAcc activation was significantly correlated with ratings of valence, but not with ratings of arousal (Gerdes et al., 2010), which may indicate that the striatum serves to tag the valence of a stimulus. However, activation of the caudate, a structure incorporated within the dorsal striatum, has also been found to correlate with subjective ratings of arousal, but only during the processing of negatively valenced stimuli (in this case, facial expressions), whilst activation of the ventral striatum was correlated with the increasing intensity of positive stimuli (Surguladze et al., 2003). This would suggest that arousal does have some impact on activation of the striatal

regions, with differential involvement of the sub-regions of the striatum in the processing of pleasant and unpleasant stimuli (Divac, Rosvold, & Szwarcbat, 1967; Yacubian & Büchel, 2009).

6.1.2. Emotion Processing and BAS Sensitivity.

As discussed previously (see Chapter One, section 1.1.) the RST (Gray, 1970) is a prominent, biologically based personality model that concerns individual differences in appetitive functioning, postulating two behavioural systems implicated in the mediation of individual differences in response to incentive stimuli (Pickering & Gray, 2001). One of these behavioural systems, the BAS, is thought to respond to signals of reward and non-punishment, and serves to engage behaviour to approach reward (Fowles, 1980; Gray, 1981). Moreover, activation of this system is associated with approach-type emotions and behaviours, such as happiness and aggression (Gable et al., 2000; Gray & McNaughton, 2000), which should prompt an individual to approach the stimulus that has induced this activation. Indeed, high BAS participants demonstrate a more intense response to positively valenced images (compared to negative or neutral images), rating images as more positive than other participants even if they did not consider them to be more arousing (Balconi, Brambilla, & Falbo, 2009; Balconi, Falbo, & Conte, 2012), which would suggest that those higher in BAS may be more responsive to positive stimuli (Davidson et al., 1990; Tomarken, Davidson, Wheeler, & Doss, 1992). Furthermore, ERP modulation has been found to be directly related to BAS sensitivity, with increased positive deflections in parietal regions observed in response to positively valenced images in high BAS individuals (Balconi et al., 2012). Using an experience sampling approach, previous research has demonstrated that the relationship between ratings of pleasantness and arousal changes as a function of BAS-RR, with a stronger positive relation between pleasantness and arousal for those high in BAS-RR whilst a negative relation was found for those low in BAS-RR (Kuppens, 2008). This is in

line with the conceptual nature of the BAS, which would suggest that those high in BAS-RR experience greater levels of arousal and activation in combination with pleasant states, as these pleasant states may serve to generate arousal derived from BAS activity. Consistent with this, previous research, using EEG, has reported a positive correlation between an aggregate score of the BAS and delta power in left frontal areas for stimuli high in arousal, regardless of valence (Balconi et al., 2009).

6.1.3. Emotion Processing in Depression.

Depression is characterised by maladaptive emotional responses to stressors, blunted affect, and low emotional arousal (Hammen, 2005; Heller & Nitschke, 1997; Loas et al., 1994), thus it is likely to be associated with deficits in emotion processing (Harmer et al., 2009). As discussed in the previous chapter (Chapter Five), depressed individuals are more likely to appraise their environments in accordance with negative schemas and exhibit cognitive biases toward negative stimuli (Giesler, Josephs, & Swann, 1996; Gotlib & Joormann, 2010; Kovacs & Beck, 1978). Negative bias has been reliably demonstrated in response to facial expressions (Gollan et al., 2008; Gotlib, Krasnoperova, Yue, & Joormann, 2004; Leppänen et al., 2004; Surguladze et al., 2005; cf. Dalili et al., 2015), but has also been found to extend to the processing of emotive scenes and words (Kellough, Beevers, Ellis, & Wells, 2008; Koster, De Raedt, Leyman, & De Lissnyder, 2010; Leung et al., 2009).

Increased amygdala activation in response to negative stimuli has consistently been observed in depressed participants (Anand et al., 2005; Beesdo et al., 2009; Fu et al., 2004; Peluso et al., 2009; Sheline et al., 2001; Siegle et al., 2002; Siegle, Thompson, Carter, Steinhauer, & Thase, 2007; Surguladze et al., 2005; Suslow et al., 2010). The degree of amygdala activation has been found to correlate with depressive symptom severity and psychiatric admission, whilst a negative correlation was found between these factors and the degree of amygdala activation in response to positively valenced stimuli (Dannlowksi et al.,

2008; Mingtian et al., 2012; Peluso et al., 2009). However, there is also evidence of increased amygdala activation in response to stimuli of varied valences in depressed individuals (Matthews et al., 2008; Yang et al., 2010; Etkin & Schatzberg, 2011; Liao et al., 2012; van Tol et al., 2012), although this has not been consistently demonstrated (Davidson et al., 2003; Frodl et al., 2009; Gotlib et al., 2005; Ritchey, Dolcos, Eddington, Strauman, & Cabeza, 2011). A recent meta-analysis reported a pattern of amygdala hypoactivation in response to positive stimuli in depression (Groenewold, Opmeer, de Jonge, Aleman, & Costafreda, 2013). Taken together, the amygdala hypoactivation in response to positive stimuli and the amygdala hyperactivation in response to negative stimuli may result in the inhibition of the processing of positive information, as well as stimulating the processing of negative information (Groenewold et al., 2013), which may provide an explanation for the negativity bias reported in depression (Harmer et al., 2009; Roiser, Elliott, & Sahakian, 2012).

Fewer studies have reported differences in striatal activation in response to emotive images, in depressed participants. Those that have indicate that depressed individuals exhibit decreased VS responses to positive stimuli compared to healthy controls (Epstein et al., 2006; Schaefer et al., 2006). These neural responses were negatively correlated with depression and anhedonia score (Keedwell et al., 2005a, 2005b, 2009), although these associations have not been consistently demonstrated (Harvey, Pruessner, Czechowska, & Lepage, 2007; Kumari et al., 2003; Lee et al., 2007; Mitterschiffthaler et al., 2003). Furthermore, the authors of one study, which found that depressed participants demonstrated an inability to maintain NAcc activation in response to positive stimuli (Heller et al., 2009), suggested that this may be the cause of anhedonic symptoms, i.e., that anhedonia results from the inability to sustain PA and reward responsiveness over time (Tomarken & Keener, 1998), rather than a diminished capacity per se.

6.1.4. Emotion Processing in Bipolar Disorder.

Whilst there has been a great deal of research on the processing of facial emotion in BD, likely based on the problematic social functioning observed in BD (Hoertnagl et al., 2011; Martino et al., 2011), less research has focused on responses to non-facial emotional stimuli. Two studies reported greater left amygdala activation, relative to HCs, in response to positive emotional scenes and pleasant images, in manic BD participants (Berpohl et al., 2009; Strakowski et al., 2011). These findings were thought to be the result of altered valence processing, rather than the non-specific effect of arousal, as the arousal ratings of the images did not differ for the BD participants and HCs. This research supports the idea of a mood-congruent bias in emotion processing in BD (Lembke & Ketter, 2002; Lennox, Jacob, Calder, Lupson, & Bullmore, 2004; Lior & Nachson, 1999). Taken together, the literature reviewed in the preceding sections indicates that altered emotion processing may be a key feature in the experience of depression and BD. The present research seeks to focus on potential associations between measures related to these psychopathologies and neural responses to rewarding stimuli. The following sections provide a summary of the rationale underlying this research, as well as detailing the relationships expected to emerge.

6.1.5. Study Rationale.

As discussed previously, neuroimaging research on emotion and reward processing predominantly focuses on neural responses to emotional facial expressions (see Chapter Five), but there are several limitations with making this the sole focus. First, emotional facial expressions may be relevant to the regulation/perception of emotion, but they do not necessarily elicit the subjective experience of emotions in participants (Davidson & Irwin, 1999), whereas valenced images may elicit a more direct affective experience (Britton et al., 2006). Furthermore, due to the limited number of positive facial expressions, there are restrictions on the type of positive affective neural response examined, whereas the use of

positively affective images would extend this range. Consequently, the present research focused on the neural responses to images taken from the International Affective Picture System, or IAPS. This is a catalogue of standardised images, depicting emotion-laden scenes, which have been rated in terms of their hedonic valence and arousal (Lang, Bradley, & Cuthbert, 1997). These images have been used in several neuroimaging studies, particularly those investigating alterations in emotion processing associated with mood disorders (e.g., Abler et al., 2007; Erk et al., 2010; Hamilton & Gotlib, 2008; Mitterschiffthaler et al., 2003). Previous research has predominantly focused on the neural responses associated with viewing negative stimuli and those studies that do focus on the responses to positive stimuli do not tend to differentiate between different types of PA. It has been suggested that there are two different, but interacting PA systems (Depue & Morrone-Strupinsky, 2005). The first system (“activation system”) is closely related to the BAS (Gray, 1987), and is associated with striving behaviours and reward/success anticipation (Depue & Morrone-Strupinsky, 2005). The second system (“contentment system”) is linked to contentment, peaceful wellbeing, and social safeness (Depue & Morrone-Strupinsky, 2005; Gilbert, McEwan, Hay, Irons, & Cheung, 2007). The present research aimed to account for this by selectively focusing on responses to positively valenced images, thought to portray two different types of PA, which broadly map onto the contentment and activation PA systems: contentment and excitement respectively.

The contentment condition predominantly consisted of images depicting families, non-sexually interacting couples, and children, which had previously been rated as portraying affiliation (Morrone-Strupinsky & Lane, 2007). These images were expected to be more closely related to social reward and to elicit feelings of attachment, as a previous study had used the majority of the images as secure attachment primes, activating representations of secure attachment (Norman, Lawrence, Iles, Benattayallah, & Karl, 2015). The excitement

condition consisted of non-affiliative images, depicting high-risk sports, such as sky-diving and skiing, and was expected to be more generally rewarding. As such, the present research examined potential associations between neural activation in response to affiliative and non-affiliative, positively valenced images and trait measures of motivation, anhedonia and hypomanic personality traits, as well as with measures of the everyday experience of PA and goal pursuit.

The present research therefore served several key purposes:

1. The investigation of potential associations between neural responses to emotional stimuli associated with affiliative and non-affiliative PA and measures of BAS, anhedonic symptoms, and trait hypomania.
2. The investigation of potential associations between these neural responses and ecologically valid measures of everyday PA and goal pursuit.
3. The investigation of the previously described associations in two non-clinical samples,¹⁸ distinct in terms of age.

The following sections contain a brief outline of the specific contribution that each purpose provides to existing knowledge.

Trait Measures. Despite its association with the experience of both depressive and hypomanic symptoms, to the best of my knowledge, no neuroimaging study has explored potential associations between BAS sensitivity and emotion-processing, particularly with

¹⁸ Details of clinical diagnoses were not collected from the participants, nor were any participants excluded on this basis. As a result of this, it is possible that some participants in the present sample may have had a clinical diagnosis. As discussed previously, the MASQ-AD has relatively good predictive utility (Buckby et al., 2007), at a suggested cut-off of 76. Two (7.14%) participants from the student sample and two (7.14%) participants from the community sample reported MASQ-AD scores of 76 or greater. Moreover, a cut-off score of 10 on the PHQ-9 (Kroenke et al., 2001) has been suggested for the diagnosis of depression. In community sample, two (7.14%) participants reported PHQ-9 scores of 10 or greater, whilst a further five (17.9%) participants reported scores between 5-9, which would indicate mild depression.

regards to pleasant (and thus, potentially rewarding) stimuli. Given that deficits in emotion processing have been observed in depressed (e.g., Groenewold et al., 2013) and BD participants (Berpohl et al., 2009; Strakowski et al., 2011), it would follow that focusing on a personality trait that has been implicated in both disorders within a non-clinical sample is of interest.

ESM Measures. In order to increase the ecological validity of the present research and explore whether activation elicited in response to pleasant stimuli has some relevance to everyday experience, the data collected from two earlier ESM studies (see Chapters Two for a full description) were correlated with activation in response to viewing the contentment and excitement images. ESM is a methodology used to explore subjective reactions to experiences as they occur during the course of an individual's everyday life (Telford et al., 2011; de Vries, 2006), providing ecologically valid accounts of real-life thinking, emotions, motives and behaviour (Hurlbert, 1997; see Chapter Two for a more detailed discussion). The present research focused on the relationships between measures of everyday PA, pleasure a participant experienced as the result of progress towards a *ST achievement* or *social* based goal, and neural responses associated with viewing positively valenced images.

Sample Differences. The present research also aimed to investigate the research questions outlined above in two distinct samples: a sample of younger adults recruited from the student population (Study One), and a sample of older adults recruited from the community (Study Two). This is particularly relevant as there is evidence suggesting that older adults differ in several aspects of emotional functioning. For example, compared to younger adults, older adults report decreased experience of NA (Kunzmann et al., 2000; Mroczek & Kolarz, 1998), as well as a less intense experience of PA, increased mood stability, and decreased sensation-seeking (Lawton et al., 1992). Furthermore, older adults have been found to exhibit greater amygdala activation to positively valenced images than

younger adults, irrespective of the arousal level of the images (Mather et al., 2004). This would indicate that age-related decline in amygdala activity selectively diminishes emotional arousal in response to negative (but not positive) emotional stimuli. However, as this seems to be exclusive to negatively valenced stimuli, it has been suggested that this might not be due to the deterioration of the brain, but rather the result of motivational and social factors. One explanation for this would derive from Socioemotional Selectivity Theory (SST; Cartensen, 2006; Cartensen et al., 1999), which posits that when constraints in time are perceived (as with ageing), negative experiences are seen to be less useful, as concerns for the future become less relevant and focus shifts to optimising current feeling state. This leads to emotion regulation becoming a higher priority and a diminished response to negatively valenced stimuli. Furthermore, it has been suggested that social reward might be particularly salient in older age, as the positive feelings associated with social contact become more important in driving behaviour (Cartensen, 1995; Cartensen & Turk-Charles, 1994; Kryla-Lighthall & Mather, 2008). Both social closeness (Cartensen, 1992) and social belongingness have been found to become more important as age increases (Ojha & Pramanick, 2009). One study focusing on neural responses to monetary and social reward reported an interaction between age and reward type in the right NAcc, with younger adults showing a stronger response to monetary reward (Rademacher et al., 2014), which is consistent with the idea that motivational priorities shift over a lifetime (Cartensen, 2006). The increasing importance of social closeness with age is addressed in the present research, with the focus on the neural responses to contentment images, which portray affiliative relationships. Furthermore, excitement-seeking has been found to be negatively associated with age (Costa & McCrae, 1988), thus it is important to look at responses to such images used in the present study across age groups.

6.1.6. Hypotheses.

The present research focused on two key contrasts: contentment images compared to a neutral image baseline and excitement images compared to a neutral image baseline. The following hypotheses refer to three key ROIs due to their implication in the processing of reward and positive emotional stimuli: the caudate, NAcc, and the amygdala. The left and right portions of these regions were analysed separately, based on previous findings that indicate an approach motivation related asymmetry in left frontal cortical activation (Harmon-Jones & Allen, 1997; Sutton & Davidson, 1997). There has been some suggestion that this might extend to the subcortical level, due to the numerous connections between the prefrontal cortex and the mesolimbic system (Posner et al., 2005), which is supported by the finding of left lateralised amygdala activation in manic participants, when viewing positive emotional stimuli (Berpohl et al., 2009).

BAS Sensitivity. ROI activation in response to both the contentment and the excitement images was expected to correlate with BAS-RR. This is based on the conceptual description of BAS-RR, which serves to measure the tendency of an individual to respond to rewarding stimuli with energy and enthusiasm. As such it would follow that individuals high in BAS-RR are more likely to be responsive to positive, rewarding stimuli and, therefore, to exhibit greater activation. ROI activation associated with the excitement images was expected to correlate with BAS-FS. The excitement images depicted quite high arousal and adventurous pursuits, which may be conceptually relevant to BAS-FS, measuring the tendency to impulsively seek out and approach new, potentially rewarding experiences. Finally, no significant associations were expected between ROI activation in response to either the contentment or the excitement images and BAS-D, as BAS-D measures the motivation to pursue goals, which might be less relevant to the passive viewing of positively valenced images.

Anhedonia. Negative correlations were expected between anhedonia and ROI activation in response to both the contentment and excitement images, as, conceptually, anhedonia relates to diminished PA and enjoyment, thus it would be expected that an individual high in anhedonic symptoms would be less responsive to pleasant images. This is particularly true for the contentment images, as although a negative association has been found between measures of activated PA (e.g. excitement) and depression, a stronger negative correlation has also been reported between safe/contentment PA and depression (Gilbert et al., 2008). Consistent with this, in a mixed sample of students and BD participants, the relationship between excitement PA and dysthymia was not found to be significant, whilst a moderate negative correlation emerged between contentment PA and dysthymia (Gilbert et al., 2009). Previous research has reported hypoactivation of both the amygdala (Dannlowski et al., 2008; Mingtian et al., 2012; Peluso et al., 2009) and striatal regions (Keedwell et al., 2005a, 2005b, 2009) in response to positive stimuli, in depressed participants, with amygdala response to happy facial expressions being found to negatively correlate with anhedonia specifically (Stuhrmann et al., 2013).

Hypomanic Personality Traits. HPS score was expected to correlate positively with ROI activation in response to the excitement images as, conceptually, the HPS taps into more achievement and activated PA than contentment PA. A high score on the HPS has been linked to higher rates of the experience of hypomania (Eckblad & Chapman, 1986; Meyer & Hautzinger, 2003), as well as an increased likelihood of developing BD (Kwapil et al., 2000). As such, it was hypothesised that those high in HPS would follow a similar pattern, albeit to a lesser degree, as BD individuals. Previous research has reported hyperactivation of the amygdala associated with viewing positive (versus neutral) images (Berpohl et al., 2009; Strakowski et al., 2011). Hyperactivation of the striatal regions in response to positive facial

stimuli has also been reported in BD individuals (e.g. Delvecchio et al., 2012; Hassell et al., 2008; Lawrence et al., 2004).

ESM Measures. It was predicted that ESM measures of PA would correlate significantly with ROI activation in response to both the contentment and the excitement images. Previous research has reported a significant association between measures of everyday PA and the consummatory processing of monetary reward (Forbes et al., 2009; Olino et al., 2014), whilst the present research focuses on the response to pleasant images, which is likely to be related to consummatory reward processing. Furthermore, as the present research used positively valenced, affective images, it would follow that those participants who report higher levels of PA may be more responsive to these images. A similar pattern was expected for both the excitement and contentment images, as the measure of PA used in the ESM sample related to high-arousal PA, so would seem to be conceptually related to the response to excitement. However, PA is also related to sociability (e.g. Eid, Riemann, Angleitner, & Borkenau, 2003) so a relationship would also be expected with responses to the contentment images.

With regards to the ESM measures concerning the pleasure associated with goal progress, a positive association was expected between ST *achievement* goal pleasure and ROI activation in response to the excitement images, as many of these images portray sporting endeavour and, therefore, competition with a standard of excellence (e.g. McClelland, 1985), which should be more in line with *achievement* goal pursuit. A positive correlation was also expected between the ESM measures of ST *social* goal pleasure and ROI activation associated with viewing the affiliative, contentment images, which predominantly portray social bonds. However, the converse pattern of associations, such as a negative correlation between ST *social* pleasure and responses to the excitement images were not predicted.

Summary of Hypotheses. Figure 1 provides a summary of the expected relationships between the trait measures of BAS sensitivity and hypomania, anhedonic symptoms, and ROI activation associated with viewing contentment and excitement images, compared to neutral images. A summary of the hypothesised correlations with the ESM measures and ROI activation is also provided.

Table 6.1.

Hypothesised correlations between trait and ESM measures and ROI activation associated with contentment images > neutral images and excitement images > neutral images contrasts.

	Left Caudate	Right Caudate	Left NAcc	Right NAcc	Left Amygdala	Right Amygdala
BAS-FS	✓+ Excitement	✓+ Excitement	✓+ Excitement	✓+ Excitement	✓+ Excitement	✓+ Excitement
BAS-RR	✓+	✓+	✓+	✓+	✓+	✓+
BAS-D						
MASQ-AD	✓-	✓-	✓-	✓-	✓-	✓-
HPS (Study Two)	✓+ Excitement	✓+ Excitement	✓+ Excitement	✓+ Excitement	✓+ Excitement	✓+ Excitement
Positive Affect	✓+	✓+	✓+	✓+	✓+	✓+
ST Achieve Pleasure	✓+ Excitement	✓+ Excitement	✓+ Excitement	✓+ Excitement	✓+ Excitement	✓+ Excitement
ST Social Pleasure (Study Two)	✓+ Contentment	✓+ Contentment	✓+ Contentment	✓+ Contentment	✓+ Contentment	✓+ Contentment

Note. MASQ-AD = Mood and Anxiety Symptom Questionnaire - Anhedonic Depression, BAS = Behavioural Activation Scale, FS = Fun-Seeking, D = Drive, RR = Reward Responsiveness, HPS = Hypomanic Personality scale, ST = Short-term. **Refers to activation associated with viewing both excitement and contentment images, unless otherwise specified. “+” denotes expectation of a positive correlation, whilst “-“ indicates the expectation of a negative correlation.**

6.2. Method.

6.2.1. Study One.

Sample Size. In terms of calculating required sample size for associations between fMRI activations and individual difference variables, I assumed large ($r = .5$) effect sizes on the basis of prior research. G*Power calculations revealed a required sample size of 29 persons for fMRI. Based on prior experience, I assumed that approximately 10% of participants would not complete the study, so I aimed to recruit 32 participants for fMRI scanning such that adequate power would be attained after attrition.

Inclusion/Exclusion Criteria. In order to be invited to participate in the MRI study, participants were required to have completed at least 60% of the ratings in the ESM study to ensure representative data. For safety reasons, participants were also excluded if they had any MRI contraindications (e.g., metal implants) in accordance with the MRI scanning centre safety policy. Medication status and the presence of mental and physical health conditions were not explicitly measured, so no exclusions were made on this basis, beyond the MRI contraindications described above. No further exclusions were in place.

Participants. A subset of 28 participants was recruited from the 65 participants who had previously completed the ESM Study One (see Chapter Two). Participants were required to have completed at least 60% of the ratings in the ESM study, in order to demonstrate commitment to the study, as well as providing more representative data. They were also required to be fluent in English in order to be able to engage successfully with the tasks. For safety reasons, participants were also excluded if they had any MRI contraindications (e.g., metal implants) in accordance with the MRI scanning centre safety policy. The final sample consisted of 28 (16 female) participants (range = 19-55 years, $M = 25.04$ years old, $SD =$

8.82). Depending on their preference, participants were either paid £15 or were given three course credits for completing the fMRI study.

Trait Measures. Baseline measures of MASQ-AD (Clark & Watson, 1991) and the BAS subscales were completed, all of which showed good internal consistency (see Chapter Four, Section 4.2.1. for Cronbach's alpha for each subscale in the fMRI study).

Experience Sampling. All participants had previously undergone a period of ESM in order to gain ecologically valid measures of everyday PA and goal pursuit. See Chapter Two (section 2.2.1) for a full description. The delay between the initial briefing for the ESM study and participation in the MRI study ranged from ten to twenty-three days.

fMRI Task. E-Prime software (Psychology Software Tools, Inc.) was used to deliver and record responses. Stimuli were presented during scanning using an Epson EMP-74 digital projector system projected onto a screen at the foot of the scanner, and viewed via an angled mirror, which was attached to the head coil. Participants responded using their right index and middle fingers via a fibre-optic response button-box.

Positive Affect Task. This task involved participants passively viewing 60 images of scenes chosen to convey various types of positive affect. They were predominantly selected from the International Affective Picture System (IAPS; Lang et al., 1997), a database of colour images developed to provide a set of normative emotional stimuli for use in the experimental investigation of emotion. These images have been reliably demonstrated to elicit specific affective reactions (Lang, Greenwald, Bradley, & Hamm, 1993) and have been rated in several studies (Bradley & Lang, 2007; Lang, Bradley, & Cuthbert, 1999) to allow the selection of specific image sets with respect to valence and arousal level. In the present study, these images fell into one of five conditions: excitement, contentment, amusement, awe, or neutral. Participants were presented with 12 images from each condition and a total of 60

images overall, with each image being presented at least twice (see Appendix D for images). The majority of the contentment images had previously been categorised as being of an affiliative nature, whilst several of the excitement images had been categorised as non-affiliative (Morrone-Strupinsky & Lane, 2007). The majority of the images were taken from the IAPS catalogue and so had been rated in terms of valence and arousal (Contentment: valence $M = 7.70$, arousal $M = 4.27$; Excitement: valence $M = 7.02$, arousal $M = 6.11$).¹⁹ Unfortunately, valence and arousal ratings were not collected for the images that were not taken from the IAPS catalogue, but they were very similar to the others within the category (see Appendix D).

Each image was presented for 4.5 seconds within a block of four images from each category. These blocks were presented in a pseudo-random order, with two orders counterbalanced across participants. There were no breaks in between blocks, nor any indication as to the change of condition. There were 8 blocks for each of the five conditions. During the interstimulus interval, which lasted 500 msec, participants were presented with a black screen. Figure 6.1 depicts the trial sequence and an example of an image presented for each condition. Previous research (e.g., Critchley et al., 2000) has indicated stronger subcortical emotional responses to emotional stimuli presented in an implicit emotion-processing task. This may be because “labelling” an emotion can turn a ‘hot’ emotional task into a ‘cold’ cognitive one and thus may lead to the downregulation of emotional responses (Morris et al., 1996; Phillips et al., 1997). As a result, in a similar manner to the facial emotion-processing task described previously (see Chapter Four, section 4.2.1.), participants were simply asked to decide if there was a person present in each of the images. This allowed the capture of more implicit processing of the different types of PA, without focusing on the

¹⁹ Ratings of the images in the excitement condition were significantly lower for valence ($t = -3.69$, $p = .010$), but higher for arousal ($t = 4.73$, $p = .003$). However, no significant differences were found in ROI activation in response to the excitement versus contentment images, in either sample.

type of affect that the image portrays. Responses were counterbalanced across participants, with 50% indicating the presence of a person by pressing a button with their index finger and the absence of a person in the image by pressing a button with their middle finger and vice versa for the remaining 50%. Participants correctly identified the presence or absence of a person in 99.7% of trials.

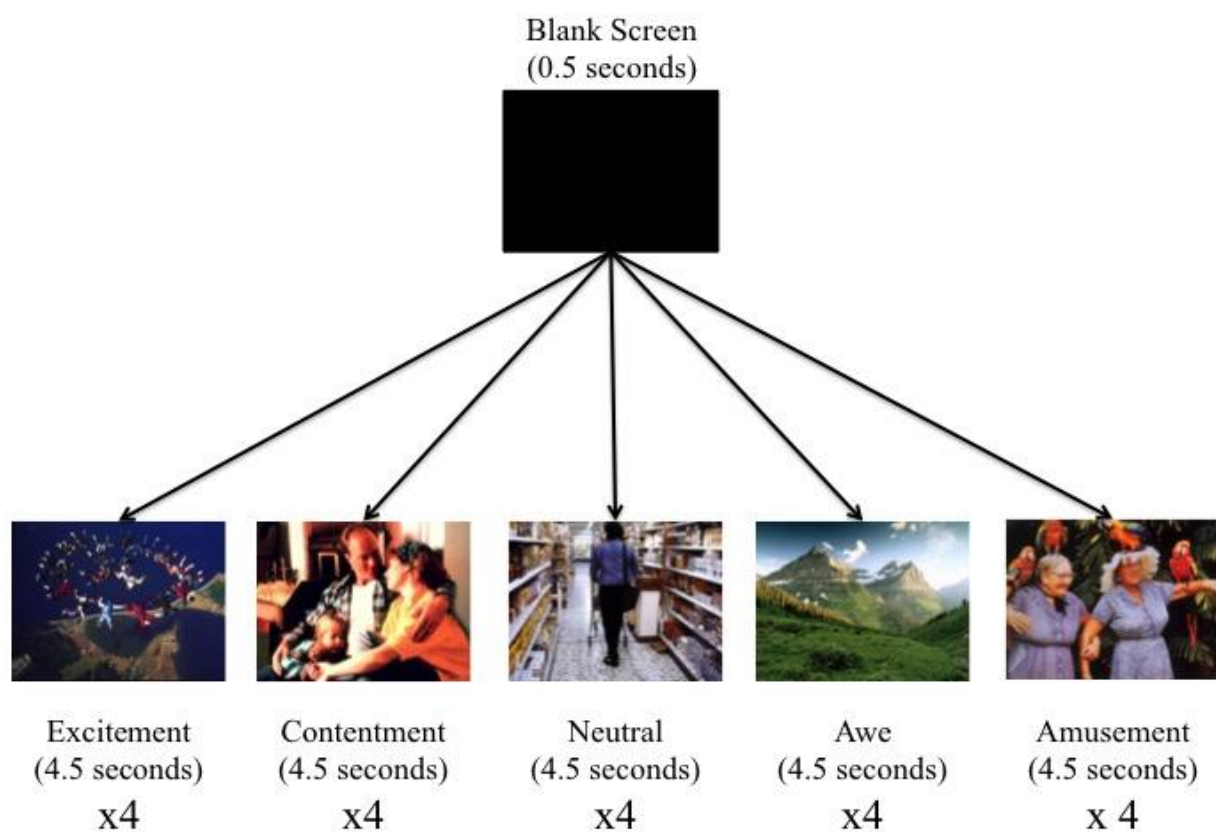


Figure 6.1.

Trial sequence and example images from each condition in the Positive Affect task.

6.2.2. Study Two.

Sample Size. In terms of calculating required sample size for associations between fMRI activations and individual difference variables, I assumed large ($r = .5$) effect sizes on the basis of prior research. G*Power calculations revealed a required sample size of 29 persons for fMRI. Based on prior experience, I assumed that approximately 10% of

participants would not complete the study, so I aimed to recruit 32 participants for fMRI scanning such that adequate power would be attained after attrition.

Inclusion/Exclusion Criteria. In order to be invited to participate in the MRI study, participants were required to have completed at least 60% of the ratings in the ESM study to ensure representative data. For safety reasons, participants were also excluded if they had any MRI contraindications (e.g., metal implants) in accordance with the MRI scanning centre safety policy. Additionally, due to possible age-related degradation in the brain (e.g., Peters, 2006; Scahill et al., 2003), participants over the age of 70 years were excluded from the MRI study. Medication status and the presence of mental and physical health conditions were not explicitly measured, so no exclusions were made on this basis, beyond the MRI contraindications described above. No further exclusions were in place.

Participants. A subset of 31 participants was recruited from the 65 participants who had previously completed the ESM Study Two (see Chapter Two). Participants were required to have completed at least 60% of the ratings in the ESM study in order to demonstrate commitment to the study, as well as providing more representative data. They were also required to be fluent in English in order to be able to engage successfully with the tasks. Due to possible age-related degradation in the brain (Peters, 2006; Scahill et al., 2003), participants over the age of 70 years were excluded from the MRI study. For safety reasons, participants were also excluded if they had any MRI contraindications (e.g., metal implants) in accordance with the MRI scanning centre safety policy.

Due to technical issues with the fMRI files, data from three participants were excluded from the final analysis. The final sample consisted of 28 (14 female) participants (range = 38-67 years, $M = 55.61$ years old, $SD = 9.04$).

Trait Measures. Baseline measures of MASQ-AD (Clark & Watson, 1991) and the BAS subscales were completed, all of which showed good internal consistency (see Chapter Four, section 4.2.2. for Cronbach's alpha for each subscale in the fMRI study).

Participants were also asked to complete various other related measures (Appendix A), including the Revised Physical Anhedonia Scale (Chapman et al., 1976), the Revised Social Anhedonia scale (Eckblad et al., 1982), the Patient Health Questionnaire (PHQ-9; Kroenke et al., 2001). However, these measures were not included in the present analysis.

ESM Sampling. All participants had previously undergone a period of ESM in order to gain ecologically valid measures of everyday PA and goal pursuit. See Chapter Two, section 2.2.1 for a full description. The delay between the initial briefing for the ESM study and participation in the MRI study ranged from nine to thirty-one days.

fMRI Task. E-Prime software (Psychology Software Tools, Inc.) was used to deliver and record responses. Stimuli were presented during scanning using an Epson EMP-74 digital projector system projected onto a screen at the foot of the scanner, and viewed via an angled mirror, which was attached to the head coil. Participants responded using their right index and middle fingers via a fibre-optic response button-box.

Positive Affect Task. Participants viewed several categories of positively valenced affective images, in order to investigate the BOLD response associated with viewing different kinds of emotionally positive images. As the same task was used in Study One, refer to section 5.2.1. for a full description. Participants correctly identified the presence or absence of a person in 93.8% of trials.

6.2.3. fMRI Processing & Analysis.

MR Image Acquisition. Activation during the fMRI tasks was measured using a 1.5-T Philips Gyroscan MRI scanner fitted with a quadrature head coil. During each task, brain

volumes of 26 slices (3.5 mm thick and ACPC [anterior commissure-posterior commissure] orientated) were acquired interleaved using a gradient echoplanar imaging sequence (TR = 2s; TE = 45msec; voxel size = 3.5mm isotropic; FOV=270mm; flip angle = 90 degrees). For the positive affect task, 390 volumes were acquired (13 minutes). For each participant, functional data were overlaid on a high- resolution T1-weighted anatomical image for registration into standard space and functional localisation (3D T1 FFE, TR = 252 ms, TE = 4.2 ms, Voxel size = 0.9mm³, Number of Slices = 160, FOV = 230 mm, Flip angle = 30 degrees).

Data Processing. fMRI data pre-processing and statistical analyses were carried out using FEAT (fMRI Expert Analysis Tool), version 5.98, as part of FSL (FMRIB's Software Library). For each participant, standard pre-processing steps were performed. These consisted of motion correction (Jenkinson et al., 2002), non-brain removal (Smith, 2002), spatial smoothing (using a Gaussian kernel of FWHM 5mm). This was followed by normalisation based on grand-mean intensity and high-pass temporal filtering (Gaussian-weighted least-squares straight line fitting, $\sigma = 50.0s$). Registration of the participant's functional data to high-resolution T1 structural images was achieved using FLIRT (Jenkinson et al., 2002; Jenkinson & Smith, 2001). Participants' data were inspected visually for artefacts and excessive head motion (greater than 3mm, average = 1.43mm). None were found, so no participants were excluded from the analysis on these grounds.

Positive Affect Task. The task was modelled within the general linear modelling framework, using periods that participants view either blank screen or an image from the neutral condition as a baseline condition, with events being defined as the onset time of each positively valenced image (duration = 4.5 seconds). Individual brain activation maps were produced for each participant within each ROI for the contentment and excitement conditions, which were contrasted with the neutral baseline. The other positive affect conditions (awe, amusement) were also entered into the regression model, but were not examined.

Region of Interest Analyses. Due to the a priori hypotheses regarding activation in specific brain regions reviewed previously, the anatomical ROI analyses focused on extracting the mean % BOLD signal change in three specific anatomical regions-of-interest (Figure 6.2): the caudate, the NAcc, and the amygdala.

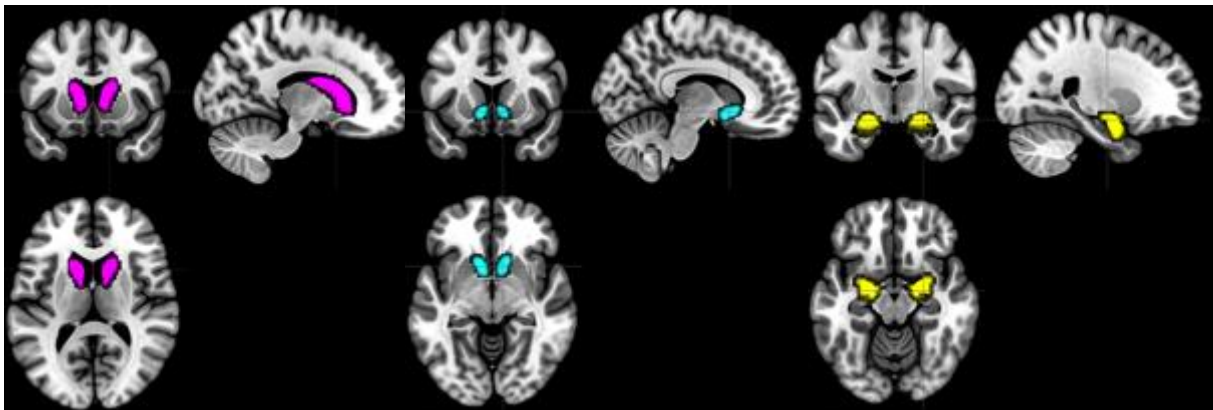


Figure 6.2.

Left/right caudate (shown in pink), left/right NAcc (shown in blue), and left/right amygdala (shown in yellow) ROIs.

This ROI analysis was implemented in FSL's Featquery tool using the Harvard–Oxford subcortical regional atlas in FSL: the caudate, the NAcc, and the amygdala are separated into left and right hemisphere regions so results are reported for these separately.

Exploratory Whole Brain Analyses. Supplementary whole-brain regression analyses provided additional information about regions of activation outside the a priori ROIs (detailed above) that were correlated with the trait questionnaire measures (BAS, MASQ-AD, and HPS in Study Two). Individual statistical maps for each contrast of interest were entered into a whole-brain group-level mixed effects model. The grand-mean centred trait and ESM measure scores for each participant were entered as additional regressors (one for each of the measures of interest) at this group level. Contrasts were defined to examine positive and negative associations between activity across the whole brain and measure scores. Data from all participants were then combined into a higher-level group analysis; using FLAME

(FMRIB's Local Analysis of Fixed Effects; Beckman et al., 2003; Woolrich et al., 2004) and Z (Gaussian transformed) statistical maps were thresholded using clusters determined by $Z > 2.3$ and a whole brain corrected cluster significance threshold of $p < 0.05$ (Worsley, 1992). These maps indicated regions showing significant correlations (corrected for whole-brain analyses) between measure scores and brain activity for our contrasts of interest.

Statistical Analyses. Analysis of data was conducted using SPSS for Mac, version 21. Potential relationships between trait measures, ESM measures, and ROI activation (mean % BOLD signal change) in response to affective images, compared to neutral images/baseline, were examined using correlation analyses. Given the non-normal distributions of BOLD activation in several of the ROIs, non-parametric Spearman's rho analyses were conducted.

6.3. Results.

6.3.1. Study One.

Preliminary Analyses. In total, the data from 28 participants (16 female) were included in the fMRI analysis. These participants consisted of a subset of those who completed the previous ESM study (see Chapter Two for a full description). Please see Chapter Four (Table 4.3.) for a summary of the untransformed means and standard deviations of scores on the baseline measures in the student sample. The mean scores on each of the BAS subscales and the MASQ-AD are in line with those previously reported in non-clinical samples (Bredemeier et al., 2010; Carver & White, 1994). Refer to Chapter Four, section 4.3.1. – “Preliminary Analyses” for a description of the correlations among the trait measures and ESM measures for the student sample.

6.3.2. Region of Interest Analyses.

Contentment Images and Trait Measures. ROI activation associated with the contentment images $>$ neutral images contrast was correlated with the trait measures, the

results of which are displayed in Table 6.2. It was predicted that ROI activation would correlate positively with BAS-RR and negatively with MASQ-AD, but no significant associations were observed. Furthermore, whilst not significant, most correlations between the BAS scales and neural responses were negative (Table 6.2).

Table 6.2.

Associations between trait measures and ROI activation for the contentment images > neutral images contrast [95% confidence intervals].

	BAS-FS	BAS-RR	BAS-D	MASQ-AD
Left Caudate	-.14 [-.50, .26]	-.04 [-.42, .35]	-.10 [-.47, .29]	-.14 [-.50, .26]
Right Caudate	-.14 [-.50, .26]	-.06 [-.43, .33]	-.07 [-.44, .32]	-.02 [-.40, .37]
Left NAcc	-.28 [-.46, .30]	-.03 [-.41, .36]	-.03 [-.41, .36]	-.33 [-.63, .06]
Right NAcc	-.28 [-.60, .12]	-.16 [-.51, .24]	.02 [-.37, .40]	-.22 [-.56, .18]
Left Amygdala	-.09 [-.46, .30]	.12 [-.28, .48]	.19 [-.21, .53]	-.01 [-.39, .37]
Right Amygdala	-.21 [-.55, .19]	-.17 [-.52, .23]	.15 [-.25, .50]	-.06 [-.43, .33]

Note. MASQ-AD = Mood and Anxiety Symptom Questionnaire - Anhedonic Depression, BAS = Behavioural Activation Scale, FS = Fun-Seeking, D = Drive, RR = Reward Responsiveness.

Contentment Images and ESM Measures. ROI activation associated with the contentment images > neutral images contrast was correlated with the ESM measures, the results of which are displayed in Table 6.3. It was predicted that ROI activation would correlate positively with the mean ESM measure of PA, a prediction that was supported; moderate correlations were found between PA and activation of the right caudate and the left NAcc. These correlations were found to be positive, whilst the associations with BAS (although not significant) tended to be negative (see Table 6.2). This was particularly interesting, as a positive correlation had been found between PA and BAS-FS in the present sample.

Table 6.3.

Correlations between ESM measures and ROI activation for the contentment images > neutral images contrast [95% confidence intervals].²⁰

	Positive Affect	ST Achieve Pleasure
Left Caudate	.30 [-.09, .61]	.03 [-.36, .41]
Right Caudate	.40* [.02, .68]	-.11 [-.47, .29]
Left NAcc	.44* [.07, .70]	-.05 [-.42, .34]
Right NAcc	.30 [-.09, .61]	-.08 [-.45, .31]
Left Amygdala	.23 [-.17, .56]	.05 [-.34, .42]
Right Amygdala	.13 [-.27, .49]	.14 [-.26, .50]

Note. ST = Short-term. * $p < .05$ (two tailed).

Scatter plots were generated to investigate the relationship between mean PA and activation in the right caudate and the left NAcc (Figure 6.3). A similar relationship can be observed for associations between PA and activation of the right caudate and left amygdala, with those low in PA exhibiting greater levels of relative deactivation whilst a few participants high in PA show positive changes in BOLD response (Figure 6.3). A similar relationship can be observed for associations between PA and activation of the right caudate and left amygdala, with those low in PA exhibiting greater levels of relative deactivation whilst a few participants high in PA show positive changes in BOLD response (Figure 6.3)

²⁰ However, the significant relationships observed would not have survived Bonferroni correction for multiple comparisons, at an alpha level of .004.

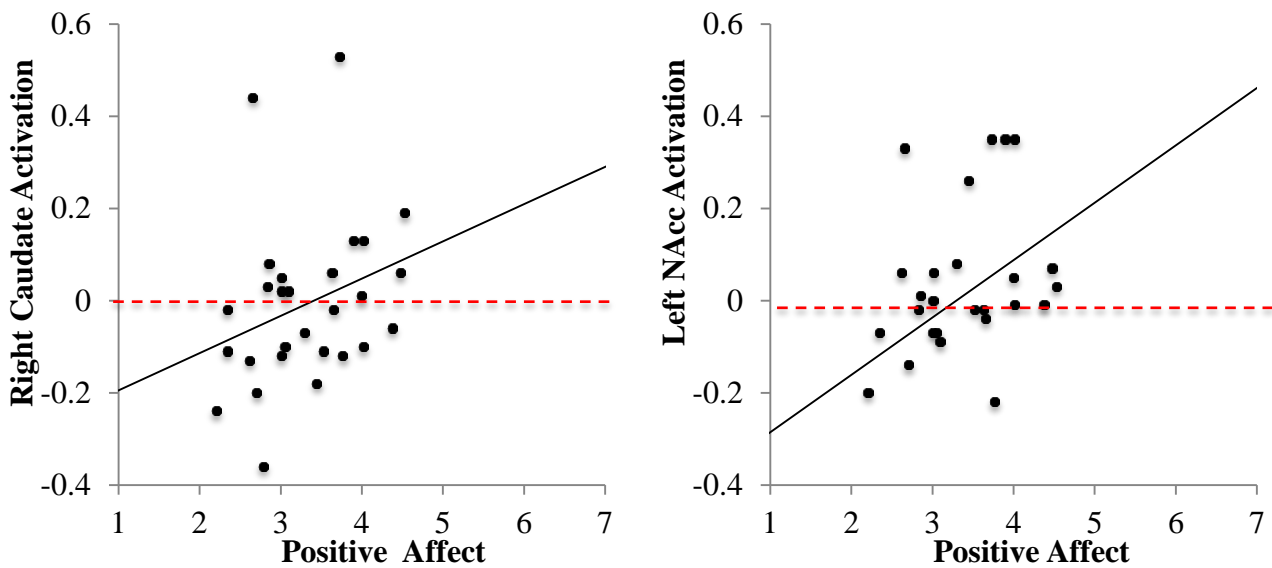


Figure 6.3.

Relationships between Positive Affect and activation of right caudate and left NAcc for contentment images > neutral images contrast.

A similar relationship can be observed for associations between PA and activation of the right caudate and left amygdala, with those low in PA exhibiting greater levels of relative deactivation whilst a few participants high in PA show positive changes in BOLD response (Figure 6.3)

Excitement Images and Trait Measures. ROI activation associated with the excitement images > neutral images contrast was correlated with the trait measures, the results of which are displayed in Table 6.4. It was predicted that ROI activation would correlate positively with BAS-RR and BAS-FS, and negatively correlate with MASQ-AD, but no significant associations emerged. Furthermore, whilst not significant, most of the associations with BAS scales were negative (as was observed for responses to contentment images).

Table 6.4.

Correlations between trait measures and ROI activation for the excitement images > neutral images contrast [95% confidence intervals].

	BAS-FS	BAS-RR	BAS-D	MASQ-AD
Left Caudate	-.18 [-.53, .22]	-.20 [-.54, .20]	-.13 [-.46, .30]	-.20 [-.49, .27]
Right Caudate	-.26 [-.58, .14]	-.17 [-.52, .23]	-.02 [-.46, .30]	-.30 [-.61, .09]
Left NAcc	-.21 [-.55, .19]	-.19 [-.53, .21]	-.16 [-.46, .30]	-.31 [-.62, .08]
Right NAcc	-.30 [-.61, .09]	-.10 [-.47, .29]	-.04 [-.46, .30]	-.14 [-.50, .26]
Left Amygdala	-.08 [-.45, .31]	.03 [-.36, .41]	.21 [-.46, .30]	-.03 [-.41, .36]
Right Amygdala	-.06 [-.43, .33]	-.08 [-.45, .31]	.29 [-.46, .30]	-.08 [-.45, .31]

Note. MASQ-AD = Mood and Anxiety Symptom Questionnaire - Anhedonic Depression, BAS = Behavioural Activation Scale, FS = Fun-Seeking, D = Drive, RR = Reward Responsiveness.

Excitement Images and ESM Measures. ROI activation associated with the contentment images > neutral images contrast was correlated with the ESM measures, the results of which are displayed in Table 6.5. It was predicted that ROI activation would correlate positively with the ESM measures of PA and ST *achievement* pleasure. Partial support was provided for these hypotheses, with a significant association emerging between activation of the right NAcc and amygdala and the measure of PA. However, no significant associations were found between ROI activation and ST *achievement* pleasure. As with the contentment images, the correlations with PA were positive, whilst the associations with the BAS subscales, although not significant, were predominantly negative, as were the associations with ST *achievement* pleasure.

Table 6.5.

Correlations between ESM measures and ROI activation for the excitement images > neutral images contrast [95% confidence intervals].²¹

	Positive Affect	ST Achieve Pleasure
Left Caudate	.17 [-.23, .52]	-.26 [-.58, .14]
Right Caudate	.22 [-.18, .56]	-.07 [-.44, .32]
Left NAcc	.29 [-.10, .61]	-.24 [-.57, .16]
Right NAcc	.48** [.12, .73]	-.29 [-.61, .10]
Left Amygdala	.07 [-.32, .44]	-.02 [-.40, .37]
Right Amygdala	.38* [.00, .67]	-.28 [-.60, .12]

Note. ST = Short-term. * $p < .05$ (two tailed). ** $p < .001$ (two tailed).

Scatter plots were generated to investigate the relationship between PA and activation in the right NAcc and the right amygdala when viewing the excitement images (Figure 6.4). A similar relationship can be observed in both associations, with those low in PA exhibiting greater levels of deactivation. Furthermore, those high in PA tended to exhibit positive changes in right NAcc activation.

²¹ However, the significant relationships observed would not have survived Bonferroni correction for multiple comparisons, at an alpha level of .004.

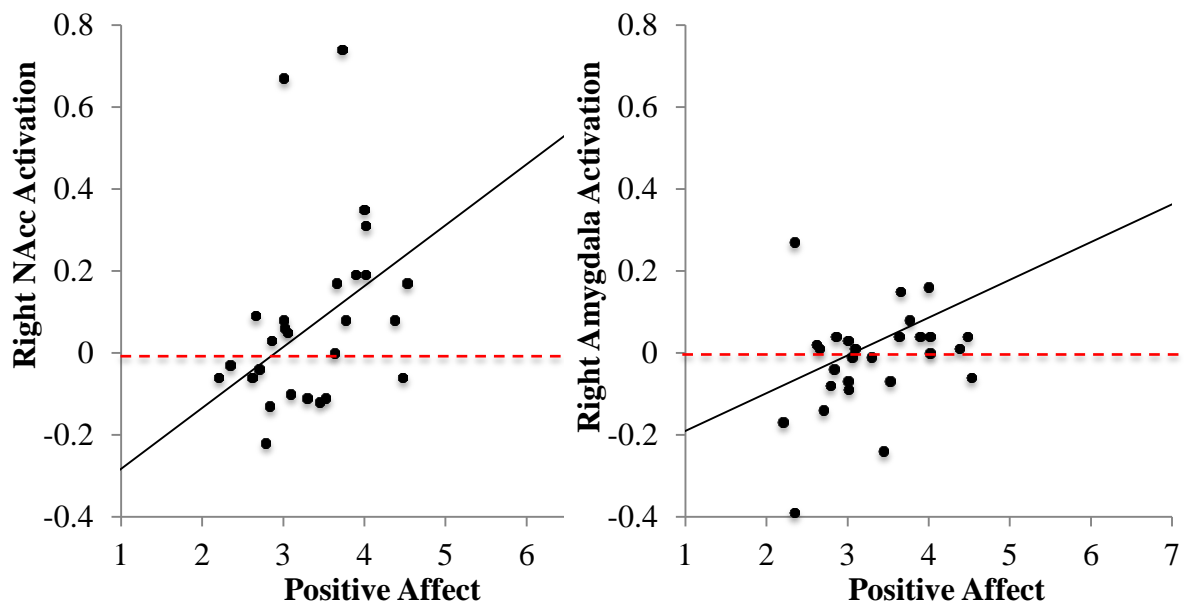


Figure 6.4.

Relationships between Positive Affect and activation of right NAcc and right amygdala for excitement images > neutral images contrast.

5.3.3. Exploratory Whole Brain Analyses.

Supplementary whole-brain regression analyses examined regions of activation outside the a priori ROIs that were associated with the trait questionnaire measures (BAS subscales and MASQ-AD). At the group mean level, no significant activation was observed for either the contentment images > neutral images contrast, or the excitement images > neutral images contrast. There were also no significant areas of correlated activation for either the contentment images > neutral images contrast, or the excitement > neutral images contrast.

6.3.4. Study Two.

Preliminary Analyses. In total, the data from 28 participants were included in the fMRI analysis. These participants consisted of a subset of those who completed the previous ESM study (see Chapters Two and Four for a full description). Please see Chapter Four (Table 4.12) for a summary of the untransformed means and standard deviations of scores on

the baseline measures in the community fMRI sample.²² The mean scores on each of the BAS subscales and the MASQ-AD are in line with those previously reported in non-clinical samples (Bredemeier et al., 2010; Carver & White, 1994). However, scores on the HPS were very low, and the mean score was approximately one standard deviation below the mean score reported in a prior non-clinical sample (e.g., Bentall et al., 2011). Refer to Chapter Four, section 4.3.2. – “Preliminary Analyses” for a description of the correlations among the trait measures and ESM measures for the student sample.

6.3.5. Region of Interest Analyses.

Contentment Images and Trait Measures. ROI activation associated with the contentment images > neutral images contrast was correlated with the trait measures, the results of which are displayed in Table 6.6. It was predicted that ROI activation would correlate positively with BAS-RR and negatively with MASQ-AD. Providing limited support for these hypotheses, a negative correlation emerged between MASQ-AD and activation of the left NAcc in response to the contentment images. However, no significant associations emerged between ROI activation and BAS-RR. Finally, BAS-FS was also found to correlate negatively with right caudate activation, an association that was unexpected. Surprisingly, most of the associations with BAS scores, whilst non-significant, were negative, as was the case for in the student sample (Study One).

Table 6.6.

Correlations between trait measures and ROI activation for contentment images > neutral images contrast [95% confidence intervals].²³

	BAS-FS	BAS-RR	BAS-D	MASQ-AD	HPS
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²² Although the descriptive statistics and baseline correlations were very similar to those reported in Chapter Four, due to some technical issues, not all participants were included in the analysis. The exact descriptive statistics and baseline correlations for these 28 participants are provided in Appendix E.

²³ However, the significant relationships observed would not have survived Bonferroni correction for multiple comparisons, at an alpha level of .004.

Left Caudate	-.31 [-.62, .08]	.03 [-.36, .41]	-.21 [-.55, .19]	.10 [-.29, .47]	.07 [-.32, .44]
Right Caudate	-.39* [-.67, -.01]	-.09 [-.46, .30]	-.26 [-.58, .14]	.15 [-.25, .50]	-.14 [-.59, .13]
Left NAcc	-.07 [-.44, .32]	-.37 [-.02, .66]	-.19 [-.53, .21]	-.42* [-.69, -.04]	-.27 [-.59, .13]
Right NAcc	.14 [-.26, .50]	.04 [-.35, .42]	.15 [-.25, .50]	-.23 [-.56, .17]	-.29 [-.61, .10]
Left Amygdala	.01 [-.37, .39]	-.06 [-.43, .33]	-.08 [-.45, .31]	-.24 [-.57, .16]	.03 [-.36, .41]
Right Amygdala	-.10 [-.47, .29]	.11 [-.29, .47]	-.14 [-.50, .26]	-.10 [-.47, .29]	-.04 [-.42, .35]

Note. MASQ-AD = Mood and Anxiety Symptom Questionnaire - Anhedonic Depression, BAS = Behavioural Activation Scale, FS = Fun-Seeking, D = Drive, RR = Reward Responsiveness, HPS = Hypomanic Personality scale. * $p < .05$ (two tailed).

Scatter plots were generated to investigate the relationships between BAS-FS and activation of the right caudate (Figure 6.5), and between MASQ-AD and left NAcc activation (Figure 6.6). The relationship between BAS-FS and right caudate activation (Figure 6.5) seems to be driven both by those high in BAS-FS exhibiting relatively more deactivation of the right caudate in response to viewing the contentment images and by those low in BAS-FS showing positive changes in BOLD response. The negative correlation between MASQ-AD and left NAcc activation (Figure 6.6) appears to be driven by those lower in MASQ-AD exhibiting greater activation of the left NAcc in response to viewing the contentment images and by those high in MASQ-AD showing relative deactivation.

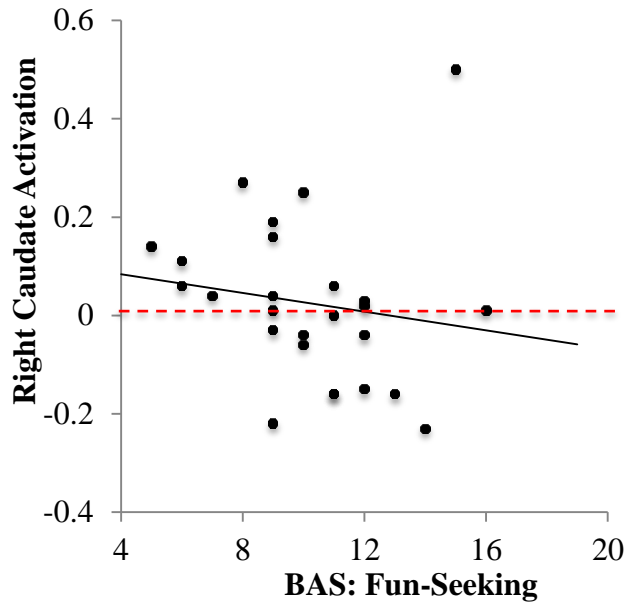


Figure 6.5.

Relationship between BAS-FS and activation of right caudate for contentment images > neutral images contrast.

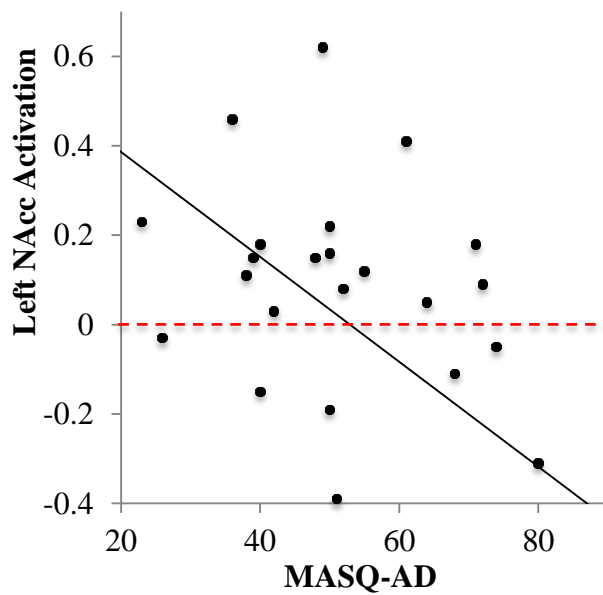


Figure 6.6.

Relationship between MASQ-AD and activation of left NAcc for contentment images > neutral images contrast.

Contentment Images and ESM Measures. ROI activation associated with the contentment images > neutral images contrast was correlated with the ESM measures, the results of which are displayed in Table 6.7. It was predicted that ROI activation would

correlate positively with ESM measures of PA and ST *social* pleasure. However, whilst most associations were positive as predicted, they were not statistically significant so these hypotheses were not supported.

Table 6.7.

Correlations between ESM measures and ROI activation for the contentment images > neutral images contrast [95% confidence intervals].

	Positive Affect	ST Achieve Pleasure	ST Social Pleasure
Left Caudate	.02 [-.37, .40]	.06 [-.33, .43]	-.20 [-.54, .20]
Right Caudate	-.05 [-.42, .34]	.09 [-.30, .46]	-.00 [-.38, .38]
Left NAcc	.34 [-.05, .64]	.39 [.01, .67]	.16 [-.24, .51]
Right NAcc	.24 [-.16, .57]	.38 [.00, .67]	.10 [-.29, .47]
Left Amygdala	.07 [-.32, .44]	.08 [-.31, .45]	-.29 [-.61, .10]
Right Amygdala	.24 [-.16, .57]	.18 [-.22, .53]	-.16 [-.51, .24]

Excitement Images and Trait Measures. ROI activation associated with the excitement images > neutral images contrast was correlated with the trait measures, the results of which are displayed in Table 6.8. It was predicted that ROI activation would correlate positively with BAS-RR and BAS-FS, and negatively with MASQ-AD. Providing limited support for these hypotheses, a negative correlation was observed between MASQ-AD and activation of the right NAcc. However, no significant associations emerged between ROI activation and either BAS-FS or BAS-RR. A scatter plot was generated to investigate the relationship between MASQ-AD and right NAcc activation (Figure 6.7). The negative correlation between MASQ-AD and right NAcc activation seems to be driven by those lower in MASQ-AD exhibiting greater activation of the right NAcc in response to viewing the excitement images.

Table 6.8.

Correlations between trait measures and ROI activation for the excitement images > neutral images contrast [95% confidence intervals].²⁴

	BAS-FS	BAS-RR	BAS-D	MASQ-AD	HPS
Left Caudate	.01 [-.37, .39]	-.15 [-.50, .25]	-.05 [-.42, .34]	-.03 [-.41, .36]	-.03 [-.41, .36]
Right Caudate	-.27 [-.59, .13]	-.20 [-.54, .20]	-.17 [-.52, .23]	-.14 [-.50, .26]	.02 [-.40, .37]
Left NAcc	.07 [-.32, .44]	-.04 [-.42, .35]	.02 [-.37, .40]	-.34 [-.05, .64]	.13 [-.27, .49]
Right NAcc	.23 [-.17, .56]	.03 [-.36, .41]	.07 [-.32, .44]	-.42* [-.69, -.04]	.03 [-.36, .41]
Left Amygdala	-.11 [-.47, .29]	-.35 [-.65, .04]	-.20 [-.54, .20]	-.12 [-.48, .28]	-.25 [-.58, .15]
Right Amygdala	.06 [-.33, .43]	-.06 [-.43, .33]	-.20 [-.54, .20]	-.23 [-.56, .17]	.06 [-.43, .33]

Note. MASQ-AD = Mood and Anxiety Symptom Questionnaire - Anhedonic Depression, BAS = Behavioural Activation Scale, FS = Fun-Seeking, D = Drive, RR = Reward Responsiveness, HPS = Hypomanic Personality scale. * $p < .05$ (two tailed).

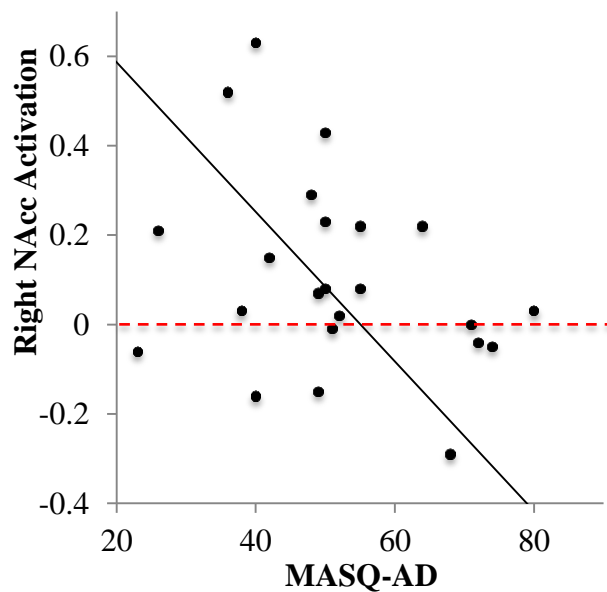


Figure 6.7.

Relationship between MASQ-AD and activation of right NAcc for excitement images > neutral images contrast.

²⁴ However, the significant relationships observed would not have survived Bonferroni correction for multiple comparisons, at an alpha level of .002.

Excitement Images and ESM Measures. ROI activation associated with the excitement images > neutral images contrast was correlated with the ESM measures, the results of which are displayed in Table 6.9. It was predicted that ROI activation would correlate with ESM measures of PA and ST *achievement* pleasure. However, these hypotheses were not supported. Whilst not anticipated, a negative correlation emerged between ST *social* pleasure and activation of both the left NAcc and the right amygdala. Furthermore, although not significant, the remaining correlations between ST *social* goal pleasure and ROI activation associated with the excitement images > neutral images contrast were also negative.

Table 6.9.

Correlations between ESM measures and ROI activation for excitement images > neutral images contrast [95% confidence intervals].²⁵

	Positive Affect	ST Achieve Pleasure	ST Social Pleasure
Left Caudate	.18 [-.22, .53]	.21 [-.19, .55]	-.22 [-.56, .18]
Right Caudate	.03 [-.36, .41]	.10 [-.29, .47]	-.26 [-.58, .14]
Left NAcc	.19 [-.21, .53]	.09 [-.30, .46]	-.44* [-.70, -.07]
Right NAcc	.24 [-.16, .57]	.08 [-.31, .45]	-.31 [-.62, .08]
Left Amygdala	.03 [-.36, .41]	.20 [-.20, .54]	-.25 [-.58, .15]
Right Amygdala	.32 [-.07, .63]	.06 [-.33, .43]	-.40* [-.68, -.02]

Note. ST = Short-term. * $p < .05$ (two tailed).

²⁵ However, the significant relationships observed would not have survived Bonferroni correction for multiple comparisons, at an alpha level of .003.

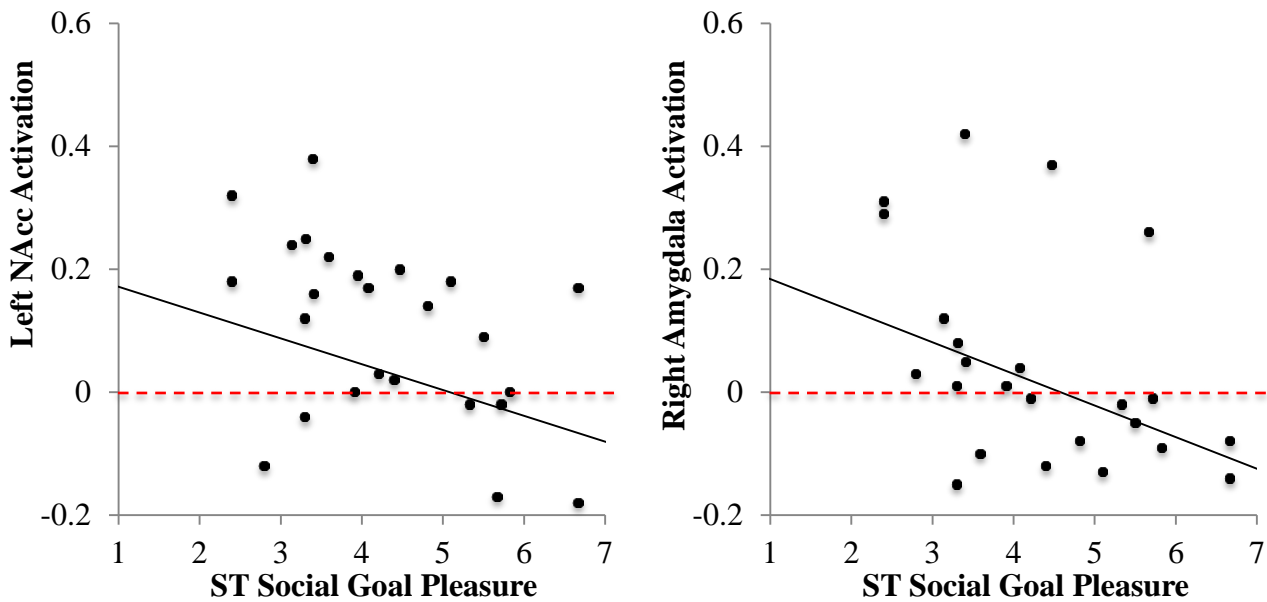


Figure 6.8.

Relationships between ST Social Goal Pleasure and activation of left NAcc and right amygdala for excitement images > neutral images contrast.

Scatter plots were generated to investigate the relationships between ST *social* pleasure and activation of the left NAcc and the right amygdala (Figure 6.8). A similar relationship can be seen in each of the ROIs, with those low in ST social goal pleasure exhibiting more activation in response to viewing the excitement images, whilst in the right amygdala those high in ST goal pleasure also reported more relative deactivation.

6.3.6. Exploratory Whole Brain Analyses.

Supplementary whole-brain regression analyses examined regions of activation outside the a priori ROIs that were associated with the trait questionnaire measures (BAS subscales, MASQ-AD, and HPS). At the group mean level, no significant activation associated with the contentment images > neutral images contrast survived thresholding, although significant activation in the lingual gyrus was associated with the excitement images > neutral images contrast (see Appendix F). There were no significant areas of correlated activation for either the contentment images > neutral images contrast, or the excitement > neutral images contrast.

6.3.7. Sample Differences.

Given the non-normal distributions of BOLD activation in several of the ROIs, non-parametric Mann-Whitney U analyses were conducted to assess differences in ROI activation in the student and community samples. No significant differences were found between the student and community samples for ROI activation associated with the contentment image contrast (Left Caudate: $U = 285$, $Z = -1.37$, $p = .087$; Right Caudate: $U = 318$, $Z = -.796$, $p = .431$; Left NAcc: $U = 291$, $Z = -1.05$, $p = .298$; Right NAcc $U = 290$, $Z = -1.28$, $p = .203$; Left Amygdala: $U = 278$, $Z = -1.49$, $p = .139$; Right Amygdala: $U = 341$, $Z = -.398$, $p = .696$) or with the excitement image contrast (Left Caudate: $U = 255$, $Z = -1.89$, $p = .059$; Right Caudate: $U = 364$, $Z = .000$, $p = 1.00$; Left NAcc: $U = 308$, $Z = -.969$, $p = .337$; Right NAcc $U = 331$, $Z = -.571$, $p = .574$; Left Amygdala: $U = 342$, $Z = -.381$, $p = .709$; Right Amygdala: $U = 353$, $Z = -.190$, $p = .853$)

6.3.8. Summary of Findings.

Table 5.10 provides a summary of the observed relationships between the trait measures of BAS sensitivity and hypomania, anhedonic symptoms, and ROI activation associated with viewing contentment and excitement images, relative to the a priori predictions. Details of the observed correlations between the ESM measures of PA and goal pursuit, and ROI activation associated with viewing contentment and excitement images are also provided.

Table 6.10.

Fate of hypotheses for correlations between trait and ESM measures and ROI activation associated with contentment images > neutral images and excitement images > neutral images contrasts, relative to the a priori hypotheses.

	Left Caudate	Right Caudate	Left NAcc	Right NAcc	Left Amygdala	Right Amygdala
BAS-FS	✕ Excitement	✓+ 2 Contentment	✕ Excitement	✕ Excitement	✕ Excitement	✕ Excitement
BAS-RR	✕	✕	✕	✕	✕	✕
BAS-D						
MASQ-AD	✕	✕	✓- 2 Contentment	✓- 2 Excitement	✕	✕
HPS (Study Two)	✕	✕	✕	✕	✕	✕
Positive Affect	✓+ 1 Contentment	✕	✓+ 1 Contentment	✓+ 1 Excitement	✕	✓+ 1 Excitement
ST Achieve Pleasure	✕	✕	✕	✕	✕	✕
ST Social Pleasure (Study Two)	✕	✕	✓- 2 Excitement	✕	✕	✓- 2 Excitement

Note. MASQ-AD = Mood and Anxiety Symptom Questionnaire - Anhedonic Depression, BAS = Behavioural Activation Scale, FS = Fun-Seeking, D = Drive, RR = Reward Responsiveness, HPS = Hypomanic Personality scale, ST = Short-term. **Subscript denotes which sample the finding was observed in (1 = student sample; 2 = community sample), whether in response to amusement or contentment images, and direction of association (i.e. “+” denotes a positive correlation, whilst “-“ indicates a negative correlation. Significant associations marked in red indicate that they were unexpected/in the opposite direction as to what was expected.**

6.4. Discussion.

The present research aimed to assess neural responses to positively valenced contentment and excitement images in two non-clinical samples, distinct in terms of age.

Relationships between ROI activation and measures of trait approach motivation and hypomania, and anhedonic symptoms were investigated, as well as potential associations with ecologically valid measures of everyday PA and ST *achievement* and *social* goal pursuit. It is important to note that at the whole-brain group map level, no significant activation was

observed for the excitement images > neutral images contrast in the student sample, or for the contentment images > neutral images contrast, in either sample. This may suggest that either the contrasts were not sensitive enough, or the scanner was not powerful enough to detect different BOLD responses to these images, which makes it difficult to draw robust conclusions, so all interpretations must be interpreted with caution.

6.4.1. BAS Sensitivity.

Contrary to predictions, no significant associations were observed between BAS-RR and ROI activation associated with viewing either contentment or amusement images (compared to a neutral baseline), in either sample. A speculative explanation for this might be that the pleasant stimuli used here may elicit responses more associated with the hedonic, ‘liking’ stage of reward processing (although further research would be required to determine this). It has been suggested that the BAS subscales, as a measure of trait approach motivation, relate more to the preparation to obtain reward, but are less relevant to the receipt of reward (Corr et al., 1995). However, in the present thesis, a significant association was found between BAS-RR and activation of the left caudate and NAcc and monetary reward receipt (in the student sample), which would suggest that at least the BAS-RR subscale is related to the more hedonic aspects of reward processing. As such, an alternative explanation of these null findings is that they may have been a result of the images used, which may have been neither arousing nor salient enough to participants, although it is not possible to determine this, as unfortunately no ratings were collected from participants.

In addition to this, no support was provided for the prediction of a positive relationship between BAS-FS and ROI activation associated with the excitement images. Surprisingly, a negative correlation was observed between BAS-FS and right caudate activation associated with viewing the contentment images, in the community sample. As this association was only found in the community sample of older adults and for one ROI, it must

be interpreted with caution, particularly as there were some concerns about the effectiveness of the task in eliciting the expected activation in all contrasts, although post hoc tests indicate that the correlations were not statistically significantly different between samples ($t = .96, p = .34$). However, it is interesting that the negative correlation with BAS-FS was found for viewing the contentment images, and not the excitement images, as BAS-FS is designed to measure the tendency to impulsively approach reward, with no regard for risk. Conceptually, this would be more in line with the excitement images and the reverse association could be seen with the contentment images, which portray affiliative relationships, such as non-sexually interacting couples and parents with children, which may explain the negative correlation observed.

6.4.2. Anhedonia.

In the community sample, anhedonia was found to correlate negatively with activation of the left NAcc when viewing the contentment images, and with activation of the right NAcc when viewing the excitement images. However, these associations were not replicated in the student sample so, although interesting and predicted, they should be interpreted with caution, particularly as there were some concerns regarding the effectiveness of the task in eliciting expected activation. Post hoc tests indicated that the correlation were not statistically significantly different between samples (contentment images, left NAcc: $t = .37, p = .71$; excitement images, right NAcc: $t = 1.08, p = .28$). However, if the neural responses to the pleasant images were indeed more related to hedonic ‘liking’ processes as suggested above, the negative association with MASQ-AD scores further suggests that the experience of anhedonia may be linked to deficits in reward/emotion processing during the consummatory ‘liking’ stage. This is in line with previous research focusing on responses to other types of reward, which demonstrated that there was a significant association between symptoms of anhedonia and striatal activation associated with viewing positive facial expressions

(Stuhrmann et al., 2013), and with the receipt of monetary reward (Wacker et al., 2009; see also results from Chapter Four). Finally, although only two significant associations emerged with MASQ-AD, it is interesting that these associations were with the NAcc, and not the amygdala. The amygdala is thought to respond to meaningful and arousing stimuli in general (Costafreda et al., 2008; Morris et al., 1998; Phan et al., 2002; Sergerie et al., 2008; Zald, 2003), whereas the striatum, particularly the NAcc, has been implicated in tracking the hedonic value and tone of reward (Berridge, 2007; Berridge & Kringelbach, 2008). This may be particularly relevant to the processing of these positively valenced (but not all highly arousing) images. Interestingly, in the additional analyses (see Appendix F, Tables F12 and F13), significant associations emerged between a measure of trait physical anhedonia and left amygdala activation associated with viewing both the contentment and excitement images, in the community sample. This would suggest that the trait components of anhedonia are more relevant to amygdala activation during the processing of pleasant stimuli, which would be in line with previous findings of a significant association, in a sample of depressed participants, between the same measure of trait physical anhedonia and amygdala activation associated with viewing positive facial expressions (Stuhrmann et al., 2013). Additionally, no significant associations emerged between the measure of trait social anhedonia and ROI activation associated with viewing the contentment images. It is also interesting that the relationships between MASQ-AD and NAcc activation when viewing the excitement and contentment images only emerged in the community sample and not in the student sample. In the ESM study, MASQ-AD was also found to correlate with ratings of PA in the community sample, but not the student sample, which suggests that anhedonia may be more closely related to anhedonia in the older adults that comprised the community sample.

6.4.3. Hypomanic Personality Traits.

Contrary to predictions, no significant associations were found between HPS and ROI activation associated with viewing the contentment or excitement images in either sample. There are several potential explanations for this, including the concerns relating to the sensitivity of the present task. Moreover, previous research that had reported greater amygdala activation associated with viewing positive stimuli, focused on a sample of BD participants experiencing a current episode of mania (Bermphohl et al., 2009). Participants in the present sample were unlikely to have been experiencing a manic episode and, in fact, had very low scores on the HPS, limiting comparisons between samples. As such, it may have been that there was not enough variance in the scores in the present, non-clinical sample, with very high scores, and/or symptoms that would meet criteria for a clinical diagnosis of BD, required to see increased activation to positively valenced stimuli.

6.4.4. ESM Measures.

Consistent with predictions, in the sample of younger adults, the ESM measure of PA was found to positively correlate with activation of the right caudate and left NAcc in response to the contentment images, and with activation of the right NAcc and amygdala in response to the excitement images. This finding would suggest that some features of the present task are of some relevance to the everyday experience of PA, particularly as associations were found with responses in several of the ROIs. However, these relationships were not replicated in the sample of older adults, which, taken with the concerns regarding the effectiveness of the task, would indicate that these associations should be interpreted with caution until replicated. An alternative explanation for the disparity in findings could relate to the clear differences in samples. Previous research (Forbes et al., 2009; Olino et al., 2014) focused on adolescents and it has been observed that adolescence may be the developmental period during which reward function is most disrupted (Forbes et al., 2012). There also

appears to be a tendency for healthy adolescents to experience rewards more intensely than adults (Ernst et al., 2005; Steinberg, 2008), whilst there has been some suggestion that adulthood may involve decreases in reward function, including greater difficulty in learning reward associations (Mell et al., 2005), decreased total earnings in reward decision-making (Brown & Ridderinkhof, 2009), and lower levels of subjective PA (Kunzmann, 2008). This may provide some indication that there is a tighter correlation between everyday PA and ROI activation associated with viewing positively affective images in the student sample, compared to the community sample.

Contrary to predictions, no significant associations were found between the measure of ST *achievement* goal pleasure and ROI activation in response to the excitement images, nor between the measure of ST *social* goal pleasure and ROI activation in response to the contentment images. However, although not predicted, in the community sample, ST *social* goal pleasure was found to correlate negatively with activation of the left NAcc, as well as the right amygdala, in response to the excitement images. Unfortunately, as no measures of ST *social* goal pleasure were collected from the student sample, it was not possible to establish if these findings would have been replicated in younger adults, although the significant negative association between ST *social* goal pleasure and BOLD response was observed in several ROIs for a contrast (excitement images > neutral images) that was found to elicit activation at the group level. It was interesting that a negative correlation was found between the measure of social goal pleasure and activation associated with viewing the non-affiliative, excitement images. However, it should be noted that the mapping between the types of pleasant image and the goal domains (i.e. contentment images and social goals, excitement images and achievement goals) is not exact. As such, it could be queried as to whether the excitement images are truly relevant to the achievement goals, although the mapping between the

contentment images and social goals is less problematic, as the images clearly portray socially relevant stimuli.

6.4.5. Limitations.

There were several limitations of the present research. First, this research was conducted using a 1.5T scanner, which may not have been sensitive enough to differentiate the activation associated with the viewing of pleasant images from that associated with the neutral baseline images. For the contentment images > neutral images contrast in both samples, and the excitement images > neutral images contrast in the sample of younger adults, no significant activation was found at the whole brain group level, which suggests that there may have been a lack of power to detect this. Moreover, the present samples were relatively small and, as such, the present research was only powered to detect large correlations among variables, so the null findings reported here may represent Type II errors.

There are several limitations of the task itself: the task employed static, standardised images, which were not of personal relevance to the individual. Similar to the use of facial expressions, these paradigms may lack ecological validity and are likely to be, at best, only weakly rewarding (Kohls et al., 2012). As such, it is likely to be advantageous to employ more dynamic stimuli, such as pleasant video clips, or at least more personally relevant images, based on, for example, an individual's hobbies and interests.

Additionally, using the ratings of arousal and valence taken from the IAPS catalogues, the IAPS images in the excitement condition were found to be significantly greater in arousal than those IAPS images in the contentment condition, but significantly lower in terms of valence. This could have introduced a potential confound to the present research, although no differences were found in ROI activation in response to the contentment and excitement images, in either sample. Finally, although the IAPS images have been rated in terms of

valence and arousal, no subjective ratings of valence, arousal or salience were collected from the present sample, so it is not possible to be sure that participants perceived them in the way that was expected, particularly as older adults have previously been demonstrated to rate pleasant images as being less arousing, but more pleasant than younger adults (Bucks et al., 2005; Grühn & Scheibe, 2008). However, no significant differences were found between the student and community sample in terms of ROI activation associated with viewing the contentment and excitement images, which would suggest that this might have been less of an issue.

6.4.6. Conclusion.

In conclusion, the present study investigated associations between neural responses associated with viewing different types of positively valenced images and measures of trait measures of motivation, anhedonia, and hypomanic personality traits in two distinct samples, consisting of either younger or older adults. No support was found for the predicted associations between BAS-RR and ROI activation associated with viewing contentment or excitement images, or between BAS-FS and neural responses to excitement images. This may provide some indication that the activation elicited by such a task is of limited relevance to the BAS. In contrast to this, negative associations were observed between anhedonic symptoms and NAcc activation to contentment and excitement images. These findings may support the idea that anhedonia (but not reduced BAS) is related to deficits in consummatory reward processing. Finally, several associations were observed, in the sample of younger adults, between a measure of everyday PA and activation in several ROIs associated with viewing contentment and excitement images, suggesting that activation elicited in this task is of some relevance to the everyday experience of PA, although this requires replication.

Chapters Four to Six have presented data regarding the neural responses to different types of positive stimuli, including monetary reward and pleasant images depicting

excitement, which were expected to be more generally rewarding, as well as positive facial expressions and the affiliative images depicting contentment, which were expected to be more socially rewarding. The following chapter (Chapter Seven) aims to explore potential associations between ROI activation in response to different rewarding stimuli to examine more directly how these are related to each other.

Chapter VII: Associations Across Reward Domains.

7.1. Introduction.

Neural responses to different types of reward are likely to overlap, but they may also have independent components (Beck et al., 2010; Rizvi, Pizzagalli, Sproule, & Kennedy, 2016; Sescousse et al., 2013). Each of the preceding chapters focused on the neural activation associated with different rewarding stimuli (money, happy faces, pleasant images). The present chapter aims to bring these data together, in an exploratory fashion, investigating potential associations (or lack thereof) between neural activation associated with the processing of different types of rewarding stimuli.

7.1.1. Reward Specific Processing.

A reward may be defined as an object, event, or stimulus that has the potential to make an individual approach and consume it and may fall into two categories: primary rewards and secondary rewards (Schultz, 2015). Primary rewards, such as food and sex, are innate and represent the basic needs of an individual to ensure their own survival and reproductive success, whereas secondary rewards, such as money and power, are not directly related to survival, but are learned through associations with lower level rewards (Schultz, 2015; Sescousse et al., 2013). It seems that although these different rewards engage a common brain network (including the striatum and the amygdala), the precise functional localisation varies across rewards, with each type activating specific regions depending on its properties (Sescousse et al., 2013). This is consistent with findings that indicate differential neural responses to different reward domains, which are predictive of real world outcomes. For example, it has previously been found that those individuals exhibiting greater striatal response to food images were more likely to gain weight, but not to engage in more sexual behaviours, whilst those individuals who exhibited greater striatal activation in response to

sexual images demonstrated the reverse pattern (Demos et al., 2012). This has also been found in other studies, with greater striatal activation in response to food stimuli being predictive of weight gain (Stice & Yokum, 2016; Stice, Burger, & Yokum, 2015), whilst greater striatal activation in response to monetary reward has been associated with substance use (Stice, Yokum, & Burger, 2013), but not the onset of weight gain/obesity (Stice & Yokum, 2016; Stice et al., 2013). Furthermore, when assessing neural responses to monetary and social reward, the anticipation of social reward (portrayed by smiling facial expressions) has been linked to the activation of a similar neural network as that associated with the anticipation of monetary reward (Rademacher et al., 2010; Rademacher et al., 2014; Spreckelmeyer et al., 2009), but differences in BOLD response were found during the outcome of reward, with the thalamus being linked to the receipt of monetary reward, whilst the amygdala was associated with the receipt of social reward (Rademacher et al., 2010). Furthermore, one EEG study reported differences in several different components (P3 and N1) between the anticipation of monetary and social reward (Flores, Münte, & Doñamayor, 2015). Taken together, the research described above would indicate that there are differences in the processing of different rewarding stimuli and is in line with the suggestion that incentive salience varies with subjective preference (McClure et al., 2004; O'Doherty, Buchanan, Seymour, & Dolan, 2006).

7.1.2. Reward General Processing.

The idea of reward specific processing is not consistently supported; several studies have reported no differences between striatal activation in response to monetary reward and either food reward (Simon et al., 2015), or erotic stimuli (Sescousse, Redouté, & Dreher, 2010). Furthermore, a relatively recent meta-analysis found no support for the idea that primary and secondary rewards might be encoded differently (Bartra, McGuire, & Kable, 2013). This is consistent with previous research that indicated that different categories of

reward recruit at least partially overlapping neural substrates (Chib, Rangel, Shimojo, & O’Doherty, 2009; Valentin & O’Doherty, 2009). Indeed, the striatum in particular has been implicated in the processing of multiple types of reward, including desirable objects (Erk, Spitzer, Wunderlich, Galley, & Walter, 2002), candy (Luking & Barch, 2013), and pleasant music (Blood & Zatorre, 2001; Menon & Levitin, 2005). Striatal activation has also been reported in response to more socially oriented rewards, such as beautiful faces (Aharon et al., 2001) and social reputation and hierarchy (Izuma et al., 2008; Zink, Tong, Chen, Bassett, Stein, & Meyer-Lindenberg, 2008). These findings are consistent with the idea that there is considerable overlap in the processing of social and non-social reward (Hare, Camerer, Knoepfle, O’Doherty, & Rangel, 2010; Izuma et al., 2008; Lin, Adolphs, & Rangel, 2012; Ruff & Fehr, 2014; Spreckelmeyer et al., 2009; Zink et al., 2008).

7.1.3. Study Rationale.

Although still relatively limited, there has been some investigation into the similarities and differences in the processing of primary and secondary rewards. However, fewer studies have focused on the similarities and differences between activation elicited by social and non-social rewards. To the best of my knowledge, no research has investigated potential correlations between ROI activation associated with monetary reward, social reward, and generally rewarding stimuli. The use of these various rewards in fMRI studies of depression and BD suggests that there is an underlying assumption that the neural responses associated with one type of reward are of relevance to the activation associated with other types of reward. The present research aims to test this assumption by exploring potential relationships between the striatal and amygdala activation associated with the processing of different types of rewarding stimuli.

7.1.4. Study Hypotheses.

The present chapter focuses on assessing potential associations between neural activation (in three ROIs: the caudate, NAcc, and amygdala) associated with: monetary reward anticipation and receipt (see Chapter Four), happy facial expressions (see Chapter Five), and pleasant images that portray excitement and contentment (see Chapter Six). As these analyses were more exploratory in nature, only tentative hypotheses were made.

Monetary Reward Anticipation and Receipt. A negative correlation was expected between ROI activation during monetary reward anticipation and receipt. This was based on the idea of prediction error, which serves as an index that brings together reward anticipation and consumption (Schultz et al., 1997). If there is a difference between an expected reward and the received reward, a prediction error is generated. This prediction error will be positive if the outcome exceeds expectation or negative if it falls short of expectation (see Chapter Four, section 4.1.3. for a more detailed discussion of prediction error). As such, it is possible that those who exhibit greater activation during monetary reward anticipation would exhibit less activation during monetary reward receipt and vice versa. Recent (unpublished) results in our lab showed that NAcc activation during monetary reward anticipation and consumption were negatively correlated, which is consistent with this hypothesis (Williams, 2014). However, as the ‘wanting’ and ‘liking’ components of reward processing are thought to be subserved by at least partially separable neural substrates (Berridge, 2007; Berridge & Robinson, 1998; Smith et al., 2011), there may be some tendency for a positive correlation between activation during reward anticipation and receipt, based on individual differences in reward sensitivity.

Monetary Reward and Happy Faces/Pleasant Images. No significant correlations were expected between activation associated with monetary reward anticipation (compared to baseline) and activation associated with viewing happy facial expressions/pleasant images

(compared to neutral facial expressions/neutral images). This follows the tentative suggestion that viewing the happy facial expressions/pleasant images would be more closely related to the hedonic reward consumption stage rather than the anticipation stage. However, monetary reward receipt is likely to map onto the consummatory stage of reward processing. As such, it was predicted that striatal activation associated with monetary reward receipt (compared to baseline) would correlate with activation associated with viewing happy facial expressions/pleasant images. Although there is some evidence of greater activation of the amygdala during social reward receipt, compared to monetary reward receipt (Rademacher et al., 2010), previous findings indicate that the striatum responds to both social and non-social reward and that there is an overlap in this activation (e.g. Lin, et al., 2012; Ruff & Fehr, 2014).

Happy Facial Expressions and Pleasant Images. Positive correlations between ROI activation in response to viewing happy facial expressions and both the excitement and contentment images were expected. This relationship was expected to be stronger between striatal activation when viewing the happy facial expressions and contentment images, as they were more socially oriented. Each of these stimuli is likely to be more closely related to reward consumption and, as discussed previously, the striatum has been found to respond to both social and non-social reward and that there is an overlap in this activation (e.g., Lin, et al., 2012; Ruff & Fehr, 2014).

7.1.5. Summary of Hypotheses.

Table 6.1 provides a summary of the expected relationships between ROI activation associated with monetary reward anticipation and receipt, viewing happy facial expressions, and viewing excitement and contentment images.

Table 7.1.

Hypothesised correlations between activation associated with different rewarding stimuli.

	£ Anticipation	£ Receipt	Happy Facial Expressions	Contentment Images
£ Receipt	✓ - or +			
Happy Faces	×	✓ +		
Contentment Images	×	✓ +	✓ ✓ +	
Excitement Images	×	✓ +	✓ +	✓ +

Note. £ = Monetary Reward. “-“ denotes the expectation of a negative correlation, whilst “+” indicates the expectation of a positive correlation. “- or +” denotes predictions in both directions.

7.2. Method.

7.2.1. Study One.

Participants. A subset of 28 participants was recruited from the 65 participants who had previously completed the ESM Study One (Chapter Two). Refer to Chapter Four, section 4.2.1 for full details of participant selection.

fMRI Tasks. E-Prime software (Psychology Software Tools, Inc.) was used to deliver and record responses. Stimuli were presented during scanning using an Epson EMP-74 digital projector system projected onto a screen at the foot of the scanner, and viewed via an angled mirror, which was attached to the head coil. Participants completed three tasks (detailed below) whilst in the scanner, and responded using their right index and middle fingers via a fibre-optic response button-box.

Card-Guessing Task. This task was designed to assess neural responses associated with the anticipatory and consummatory processing of monetary reward. During this task,

participants were required to guess whether a card would be higher or lower than 5, in order to gain reward or avoid loss (see Chapter Four, section 4.2.1. for full details). The present research focused on two contrasts of interest: monetary reward anticipation > baseline and monetary reward receipt > baseline.

Facial Emotion-Processing Task. This task was designed to assess neural responses to happy facial expressions (compared to neutral facial expressions), which are thought to serve as a social reward. Participants were shown a series of images of adults' and infants' faces with either a happy or neutral expression. For each image, participants were asked to indicate if they were viewing an adult or an infant face (see Chapter Five, section 5.2.1. for full details). The contrast of interest in the present research was happy facial expressions > neutral facial expressions.

Positive Affect Task. This task was designed to assess neural responses associated with viewing pleasant images. Participants were shown various pleasant and neutral images (predominantly taken from the IAPS catalogue; Lang, Bradley, & Cuthbert, 1997) and were asked to indicate whether or not there was a person present (see Chapter Six, section 6.2.1. for full details). The present research focused on two contrasts of interest: contentment images > neutral images and excitement images > neutral images.

6.2.2. Study Two.

Participants. A subset of 31 participants was recruited from the 65 participants who had previously completed the ESM Study Two (see Chapter Two). Refer to Chapter Four, section 4.2.2. for full details of participant selection.

fMRI Tasks. Participants undertook the same fMRI tasks as those participants in Study One: the Card-Guessing paradigm, Facial Emotion Processing task, and Positive Affect task. Refer to section 7.2.1. for details.

7.2.3. fMRI Processing & Analysis.

MR Image Acquisition. Activation during the fMRI tasks was measured using a 1.5-T Philips Gyroscan MRI scanner fitted with a quadrature head coil. During each task, brain volumes of 26 slices (3.5 mm thick and ACPC [anterior commissure-posterior commissure] orientated) were acquired interleaved using a gradient echoplanar imaging sequence (TR = 2s; TE = 45msec; voxel size = 3.5mm isotropic; FOV=270mm; flip angle = 90 degrees). Refer to Chapters Four to Six for details of image acquisition specific to each task.

Data Processing. fMRI data pre-processing and statistical analyses were carried out using FEAT (fMRI Expert Analysis Tool), version 5.98, as part of FSL (FMRIB's Software Library). For each participant, standard pre-processing steps were performed. These consisted of motion correction (Jenkinson et al., 2002), non-brain removal (Smith, 2002), spatial smoothing (using a Gaussian kernel of FWHM 5mm). This was followed by normalisation based on grand-mean intensity and high-pass temporal filtering (Gaussian-weighted least-squares straight line fitting, $\sigma = 50.0s$). Registration of the participant's functional data to high-resolution T1 structural images was achieved using FLIRT (Jenkinson et al., 2002; Jenkinson & Smith, 2001).

Region of Interest Analyses. Due to the a priori hypotheses regarding activation in specific brain regions reviewed in previous chapters, the anatomical ROI analyses focused on extracting the mean % BOLD signal change in two specific anatomical regions-of-interest (Figure 6.1): the caudate and the NAcc. For the Facial Emotion Processing and Positive Affect tasks, the analyses also included the amygdala (Figure 6.1) as an ROI. This ROI analysis was implemented in FSL's Featquery tool using the Harvard-Oxford subcortical atlas with separate ROIs for the left and right caudate, NAcc, and amygdala. As discussed previously (e.g. Chapter Four, section 4.1.), these hemisphere regions were not combined for the analysis due to potential asymmetry of activation.

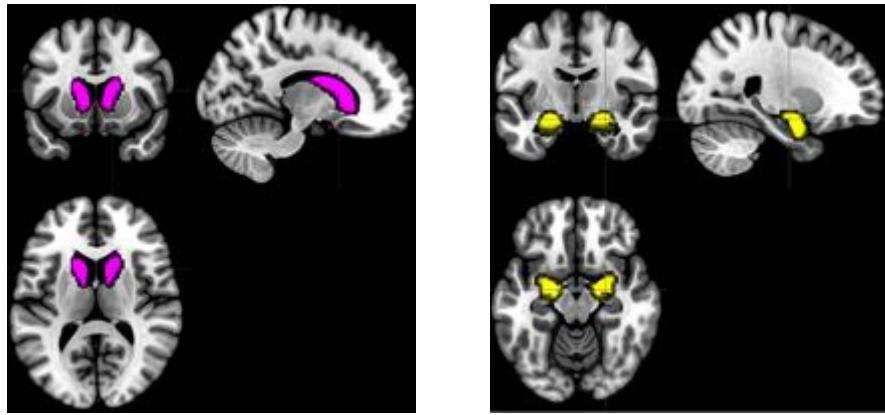


Figure 7.1.

Left/right caudate (shown in pink), left/right NAcc (shown in blue), and left/right amygdala (shown in yellow) ROIs.

Statistical Analyses. Analysis of data was conducted using SPSS for Mac, version 21. Potential relationships between striatal activation (mean % BOLD signal change) for the monetary reward anticipation > baseline, monetary reward receipt > baseline, happy facial expressions > neutral facial expressions, contentment images > neutral images, and excitement images > neutral images contrasts were examined using correlational analyses. Given the non-normal distributions of BOLD activation in several of the ROIs, non-parametric Spearman's rho analyses were conducted.

7.3. Results.

7.3.1. Study One.

Potential associations between ROI activation (of the caudate, NAcc, and amygdala) in response to different rewarding stimuli were assessed. Between-person correlations of activation associated with monetary reward anticipation and receipt, viewing happy facial expressions, and viewing contentment and excitement images, for each ROI, is presented in Tables 7.2 for the caudate, 7.3 for the NAcc ROI, and 7.4 for the amygdala ROIs.

Table 7.2.

Correlation matrix of caudate activation associated with different reward domains [95% confidence intervals].²⁶

	£ Anticipation	£ Receipt	Happy Facial Expressions	Contentment Images	Excitement Images
£ Anticipation		-.26 [-.58, .14]	.07 [-.32, .44]	.09 [-.30, .46]	.04 [-.35, .42]
£ Receipt	-.38* [-.67, .00]		.26 [-.14, .58]	.40* [.02, .68]	.16 [-.24, .51]
Happy Facial Expressions	-.04 [-.42, .35]	-.16 [-.51, .24]		-.18 [-.53, .22]	-.09 [-.46, .30]
Contentment Images	.29 [-.10, .61]	.13 [-.27, .49]	-.02 [-.40, .37]		.57** [.24, .78]
Excitement Images	.06 [-.33, .43]	.01 [-.37, .39]	-.14 [-.50, .26]	.34 [-.05, .64]	

Note. Correlations between left caudate activation are shown below the diagonal and correlations between right caudate activation (**in bold**) above the diagonal. £ = monetary reward. * $p < .05$ (two tailed). ** $p < .001$ (two tailed).

Table 7.3.

Correlation matrix of NAcc activation associated with different reward domains [95% confidence intervals].²⁷

	£ Anticipation	£ Receipt	Happy Facial Expressions	Contentment Images	Excitement Images
£ Anticipation		-.61** [-.80, -.30]	.17 [-.23, .52]	-.12 [-.48, .28]	-.19 [-.53, .21]
£ Receipt	-.56** [-.78, -.23]		-.25 [-.58, .15]	.21 [-.19, .55]	.25 [-.15, .58]
Happy Facial Expressions	-.10 [-.47, .29]	-.01 [-.39, .37]		.14 [-.26, .50]	.29 [-.10, .61]
Contentment Images	-.02 [-.40, .37]	-.02 [-.40, .37]	-.01 [-.39, .37]		.49** [.13, .74]
Excitement Images	-.08 [-.45, .31]	-.08 [-.45, .31]	.11 [-.29, .47]	.54** [.20, .76]	

²⁶ However, the significant relationships observed would not have survived Bonferroni correction for multiple comparisons, at an alpha level of .003.

²⁷ However, the significant relationships observed would not have survived Bonferroni correction for multiple comparisons, at an alpha level of .003.

Note. Correlations between left NAcc activation are shown below the diagonal and correlations between right NAcc activation (**in bold**) above the diagonal. £ = monetary reward. * $p < .05$ (two tailed). ** $p < .001$ (two tailed).

Table 7.4.

Correlation matrix of amygdala activation associated with different reward domains [95% confidence intervals].²⁸

	Happy Facial Expressions	Contentment Images	Excitement Images
Happy Facial Expressions		-.09 [-.46, .30]	.51** [.16, .75]
Contentment Images	-.21 [-.55, .19]		.04 [-.35, .42]
Excitement Images	.30 [-.09, .61]	.43* [.06, .70]	

Note. Correlations between left amygdala activation are shown below the diagonal and correlations between right amygdala activation (**in bold**) above the diagonal. * $p < .05$ (two tailed). ** $p < .001$ (two tailed).

Monetary Reward Anticipation and Receipt. Consistent with predictions, significant negative correlations were found between activation during the anticipation of reward and activation during the outcome of reward in the left caudate, and both the left and right NAcc. The significant associations were plotted (Figure 7.2). It appears that participants tended to exhibit more activation during monetary reward anticipation, but more deactivation during monetary reward receipt. Given the non-normal distributions of BOLD activation in several of the ROIs, non-parametric Wilcoxon Signed Ranks analyses were conducted to assess differences in ROI activation during reward anticipation and receipt. BOLD activation during reward receipt was significantly greater during monetary reward anticipation than during monetary reward receipt for the left ($Z = -3.62, p < .001$) and right ($Z = -2.73, p = .005$) caudate, and the left NAcc ($Z = -2.73, p = .005$), but not for the right NAcc ($Z = -1.43, p = .157$).

²⁸ However, the significant relationships observed would not have survived Bonferroni correction for multiple comparisons, at an alpha level of .009.

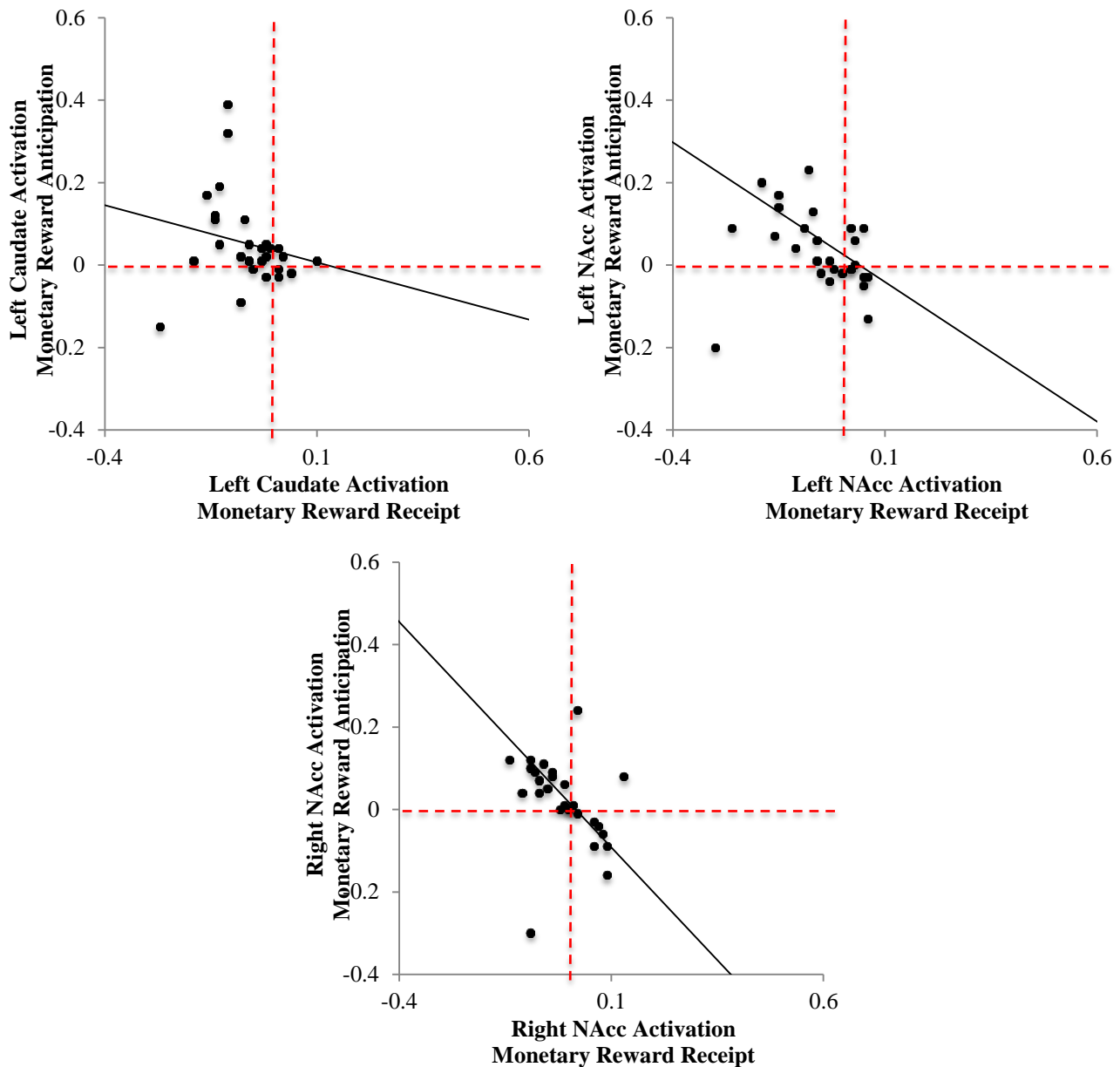


Figure 7.2.

Relationship between activation associated with reward anticipation > baseline contrast and activation associated with reward receipt > baseline contrast for the left caudate, and the left and right NAcc.

Monetary Reward and Happy Facial Expressions. Consistent with predictions, no significant associations were found between ROI activation associated with monetary reward anticipation and ROI activation associated with viewing happy facial expressions. However, contrary to predictions, no significant associations were found between ROI activation during reward receipt and when viewing happy facial expressions.

Monetary Reward and Pleasant Images. Consistent with predictions, no significant associations were found between ROI activation associated with monetary reward anticipation and ROI activation associated with viewing contentment and excitement images.

Furthermore, in partial support of the predictions, a positive correlation was found between activation of the right caudate during monetary reward receipt and when viewing contentment images, although this was the only significant association observed. The association was plotted (Figure 7.3). Those participants that exhibit more activation during monetary reward receipt tend to also exhibit less deactivation in response to contentment images.

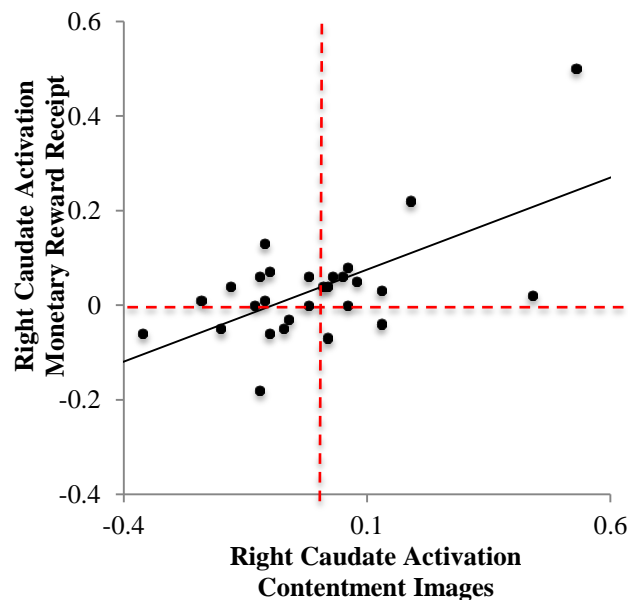


Figure 7.3.

Relationship between activation associated with reward receipt > baseline contrast and activation associated with the contentment images > neutral images contrast for the right caudate.

Happy Facial Expressions and Pleasant Images. Contrary to predictions, no significant associations were found between ROI activation associated with viewing happy facial expressions and either contentment or excitement images.

Contentment Images and Excitement Images. Consistent with predictions, activation of the right caudate, the left and right NAcc, and the left and right amygdala associated with viewing excitement images was found to correlate positively with activation associated with viewing contentment images. These associations were plotted (Figures 7.4 and 7.5). Those participants that exhibit more activation when viewing the excitement images also tend to exhibit more activation when viewing the contentment images.

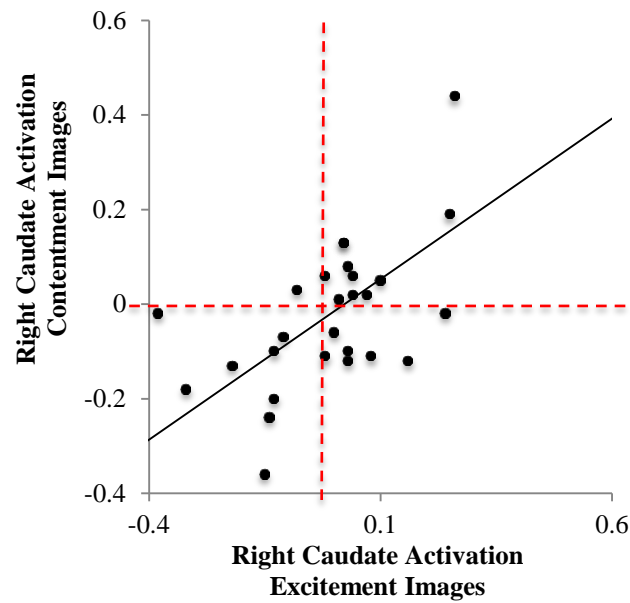


Figure 7.4.

Relationship between activation associated with excitement images > neutral images contrast and activation associated with the contentment images > neutral images contrast for the right caudate.

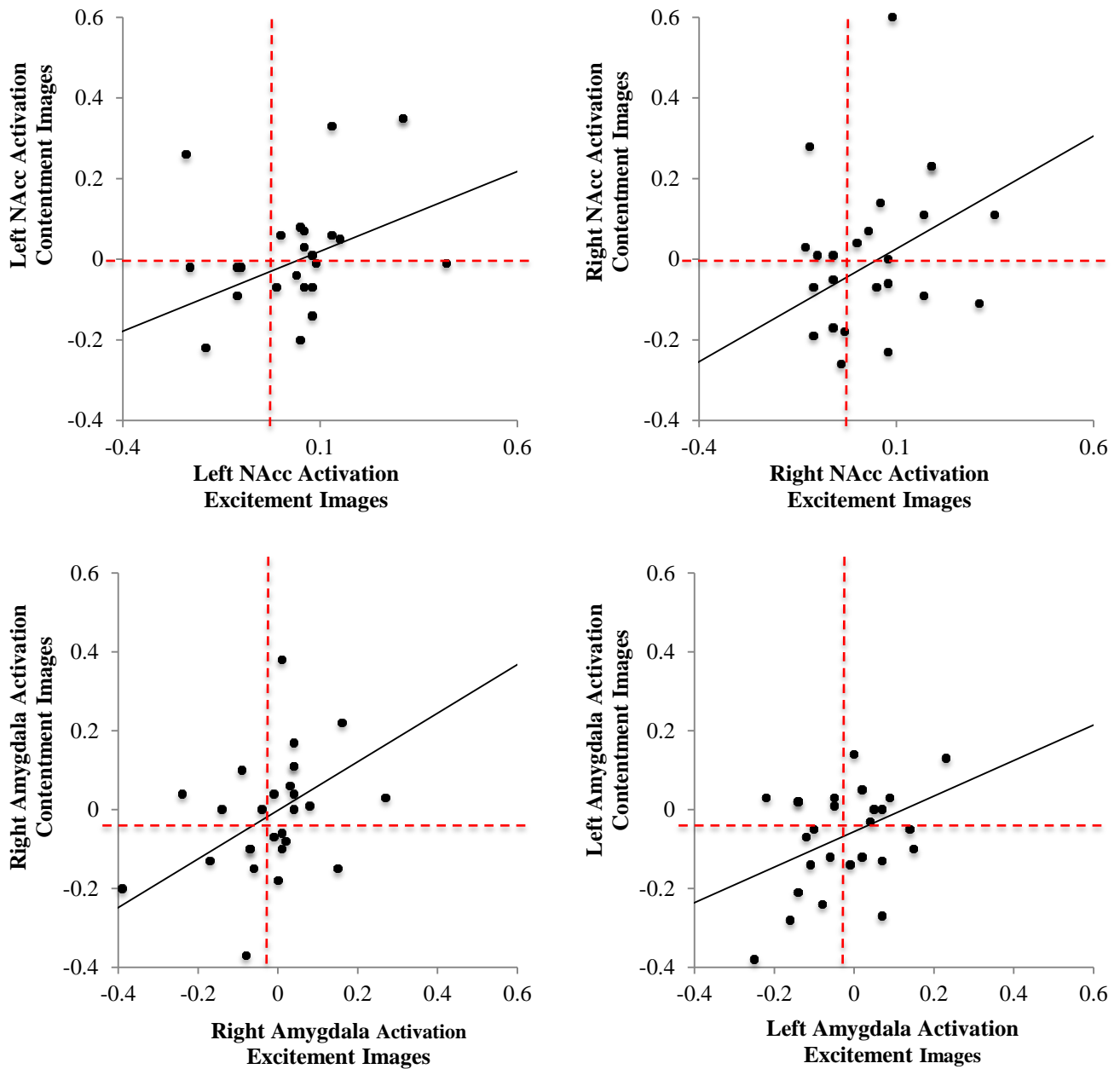


Figure 7.5.

Relationship between activation associated with excitement images > neutral images contrast and activation associated with the contentment images > neutral images contrast for left and right NAcc, and the left and right amygdala.

6.3.2. Study Two.

Potential associations between ROI activation (of the caudate, NAcc, and amygdala) in response to different rewarding stimuli, in the community sample, were explored. Between-person correlations of activation associated with monetary reward anticipation and receipt,

viewing happy facial expressions, and viewing contentment and excitement images, for each ROI, is presented in Table 7.5 for the caudate, Table 7.6 for the NAcc, and Table 7.7 for the amygdala.

Table 7.5.

Correlation matrix of caudate activation associated with different reward domains [95% confidence intervals].²⁹

	£ Anticipation	£ Receipt	Happy Facial Expressions	Contentment Images	Excitement Images
£ Anticipation		-.48** [-.73, -.12]	.07 [-.32, .44]	.13 [-.27, .49]	-.32 [-.63, .07]
£ Receipt	-.18 [-.53, .22]		-.43* [-.70, -.06]	-.05 [-.42, .34]	.30 [-.09, .61]
Happy Facial Expressions	.33 [-.06, .63]	.24 [-.16, .57]		.04 [-.35, .42]	-.31 [-.62, .08]
Contentment Images	.23 [-.17, .56]	-.19 [-.53, .21]	-.19 [-.53, .21]		.40* [.02, .68]
Excitement Images	-.10 [-.47, .29]	.19 [-.21, .53]	-.19 [-.53, .21]	.56** [.23, .78]	

Note. Correlations between left caudate activation are shown below the diagonal and correlations between right caudate activation (**in bold**) above the diagonal. £ = monetary reward. * $p < .05$ (two tailed). ** $p < .01$ (two tailed).

²⁹ However, the significant relationships observed would not have survived Bonferroni correction for multiple comparisons, at an alpha level of .003.

Table 7.6.

Correlation matrix of NAcc activation associated with different reward domains [95% confidence intervals].³⁰

	£ Anticipation	£ Receipt	Happy Facial Expressions	Contentment Images	Excitement Images
£ Anticipation		-.08 [-.45, .31]	.15 [-.25, .50]	-.01 [-.39, .37]	-.13 [-.49, .27]
£ Receipt	-.39* [-.67, -.01]		.16 [-.24, .51]	.01 [-.37, .39]	.03 [-.36, .41]
Happy Facial Expressions	.12 [-.28, .48]	.01 [-.37, .39]		-.26 [-.58, .14]	-.16 [-.51, .24]
Contentment Images	-.26 [-.58, .14]	.55** [.21, .77]	-.26 [-.58, .14]		.56** [.23, .78]
Excitement Images	.01 [-.37, .39]	.33 [-.06, .63]	.21 [-.19, .55]	.31 [-.62, .08]	

Note. Correlations between left NAcc activation are shown below the diagonal and correlations between right NAcc activation (**in bold**) above the diagonal. £ = monetary reward. * $p < .05$ (two tailed). ** $p < .01$ (two tailed).

Table 7.7.

Correlation matrix of amygdala activation associated with different reward domains.³¹

	Happy Facial Expressions	Contentment Images	Excitement Images
Happy Facial Expressions		.23 [-.46, .30]	.06 [-.46, .30]
Contentment Images	.13 [-.46, .30]		.55** [-.46, .30]
Excitement Images	.06 [-.46, .30]	.55** [-.46, .30]	

Note. Correlations between left amygdala activation are shown below the diagonal and correlations between right amygdala activation (**in bold**) above the diagonal. * $p < .05$ (two tailed). ** $p < .001$ (two tailed).

Monetary Reward Anticipation and Receipt. In line with the predictions and the findings in the sample of younger adults, activation of the right caudate and the left NAcc during monetary reward anticipation were found to correlate negatively with activation during

³⁰ However, the significant relationships observed would not have survived Bonferroni correction for multiple comparisons, at an alpha level of .003.

³¹ However, the significant relationships observed would not have survived Bonferroni correction for multiple comparisons, at an alpha level of .009.

monetary reward receipt. These associations were plotted (Figure 7.6). Responses in this sample were more evenly distributed between participants who showed activation and relative deactivation during the anticipation of reward (and the opposite during the receipt of reward) stage. These patterns of activation were again negatively correlated. Given the non-normal distributions of BOLD activation in several of the ROIs, non-parametric Wilcoxon Signed Ranks analyses were conducted to assess differences in ROI activation during reward anticipation and receipt. BOLD activation during reward anticipation was significantly greater during monetary reward receipt for the left ($Z = -2.85, p = .004$) and right ($Z = -2.41, p = .015$) NAcc, but not for the left ($Z = -1.83, p = .067$) or right ($Z = -.261, p = .799$) caudate.

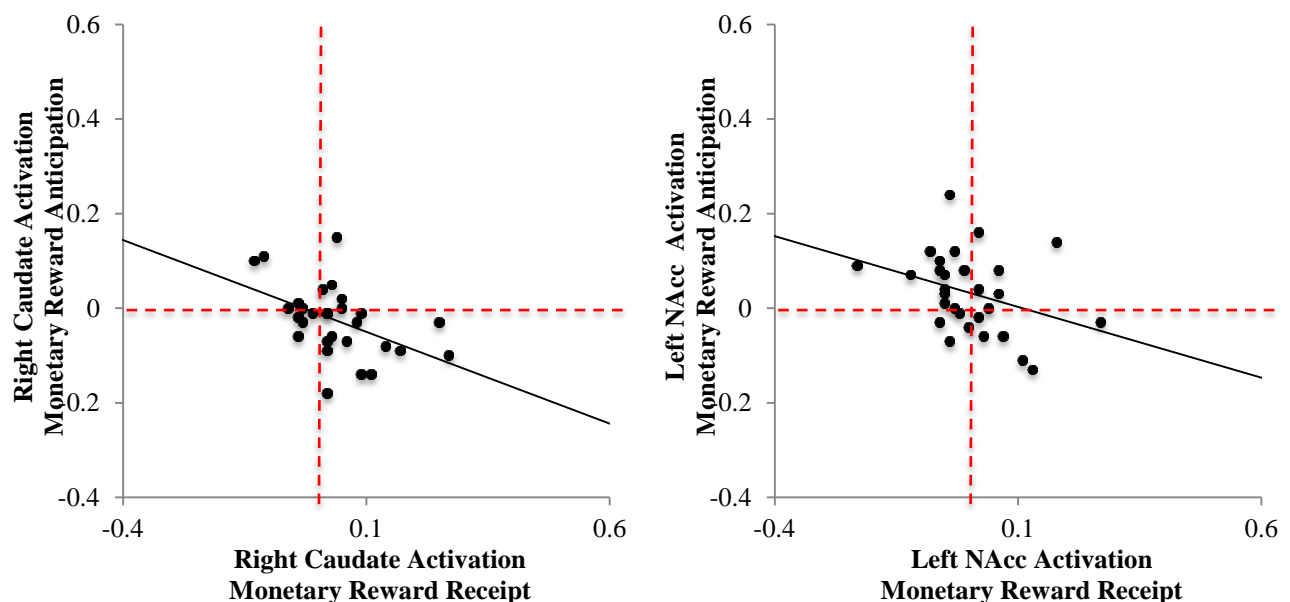


Figure 7.6.

Relationship between activation associated with monetary reward anticipation > baseline contrast and activation associated with the monetary reward receipt > baseline contrast for the right caudate and left NAcc.

Monetary Reward and Happy Facial Expressions. Consistent with predictions, no significant associations were found between ROI activation associated with monetary reward anticipation and ROI activation associated with viewing happy facial expressions. A significant negative correlation was found between right caudate activation during monetary

reward receipt and activation associated with viewing happy facial expressions. This association was plotted (Figure 7.7). Those participants who exhibited greater activation in response to monetary reward receipt tended to exhibit greater levels of deactivation in response to viewing happy facial expressions. This correlation was in the opposite direction to what was predicted and no other significant associations were found, so the predictions were not supported. Participants were relatively evenly divided between those who showed a negative and positive response to happy faces and a negative and positive BOLD response to the receipt of monetary reward.

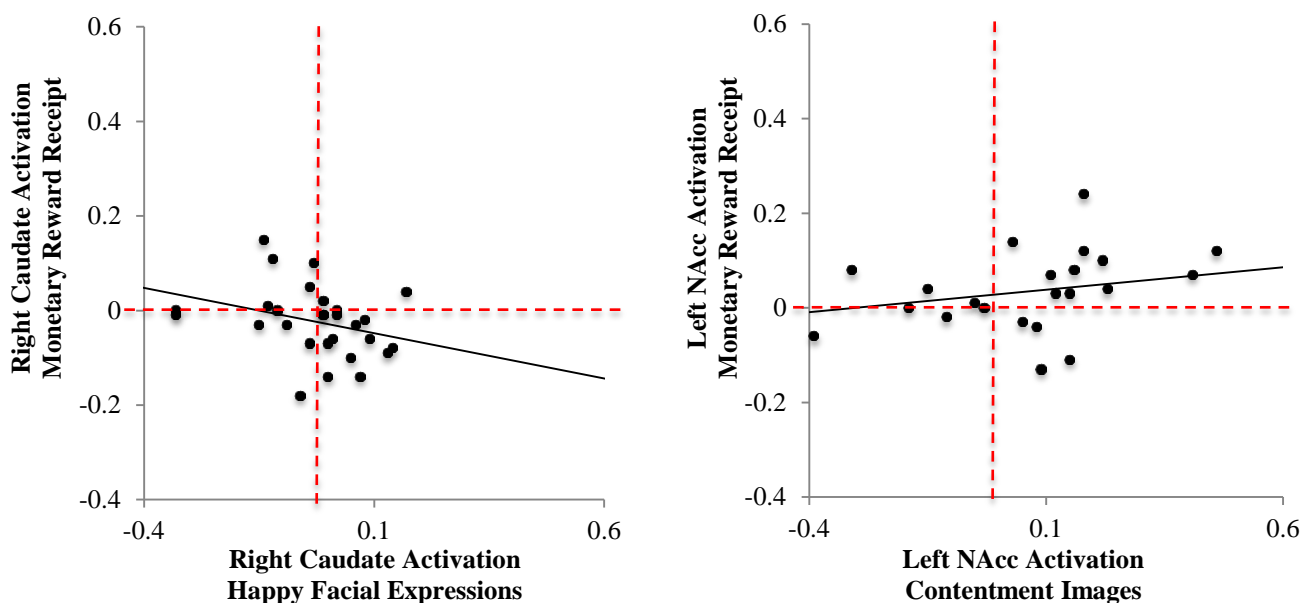


Figure 7.7.

Relationship between activation associated with monetary reward receipt > baseline contrast and activation associated with the happy facial expressions > neutral facial expressions contrast.

Monetary Reward and Pleasant Images. Consistent with predictions, no significant associations were found between ROI activation associated with monetary reward anticipation and ROI activation associated with viewing contentment and excitement images.

Furthermore, in partial support of the predictions, a positive correlation was found between activation of the left NAcc during monetary reward receipt and when viewing contentment

images, although this was the only significant association observed. The association was plotted (Figure 7.8). Those participants that exhibit more activation in response to the receipt of monetary reward also seem to exhibit more activation in response to viewing contentment images. Most participants showed positive changes in BOLD response to contentment images and receiving monetary reward and these were positively associated.

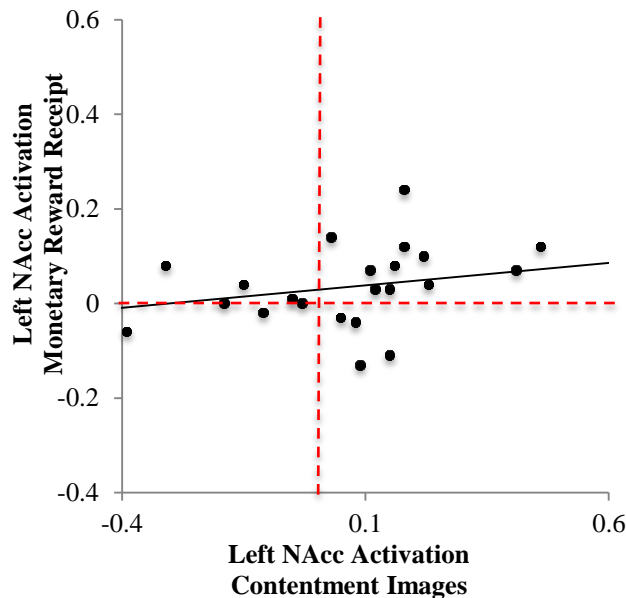


Figure 7.8.

Relationship between activation associated with monetary reward receipt > baseline contrast and activation associated with the contentment images > neutral images contrast for the left NAcc.

Happy Facial Expressions and Pleasant Images. Contrary to predictions, but consistent with the sample of younger adults, no significant associations were found between ROI activation associated with viewing happy facial expressions and either contentment or excitement images.

Contentment Images and Excitement Images. Consistent with predictions and in line with the findings in the sample of younger adults, a positive correlation was found between activation associated with viewing contentment and excitement images for the left and right caudate, the right NAcc, and the left and right amygdala. These associations were

plotted (Figure 7.9 and Figure 7.10). Most participants showed positive changes in BOLD response when viewing the excitement and contentment images (though not for right caudate activation for the latter) and these responses were positively correlated.

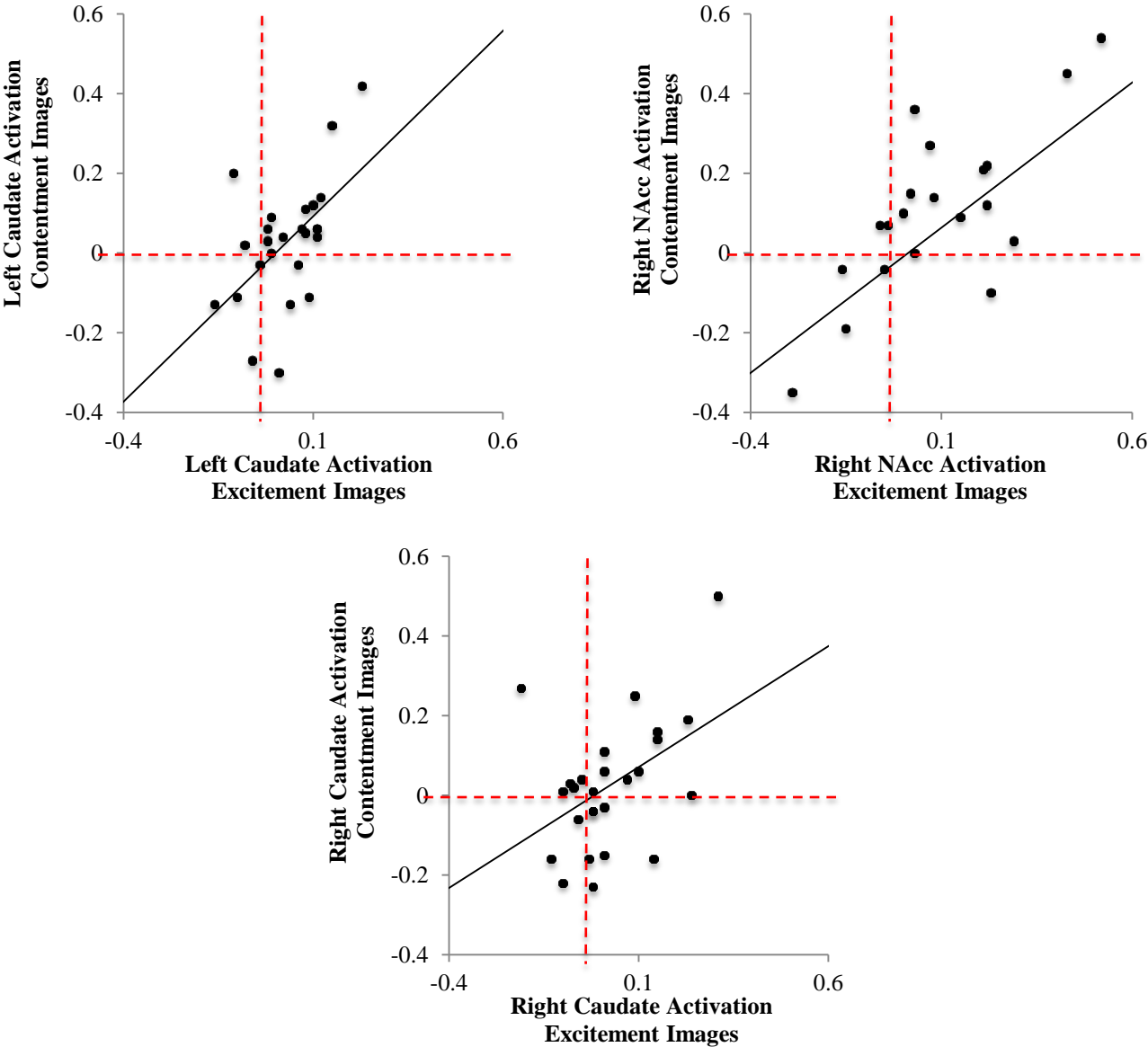


Figure 7.9.

Relationship between activation associated with excitement images > neutral images and activation associated with contentment images > neutral images for left and right caudate, and right NAcc.

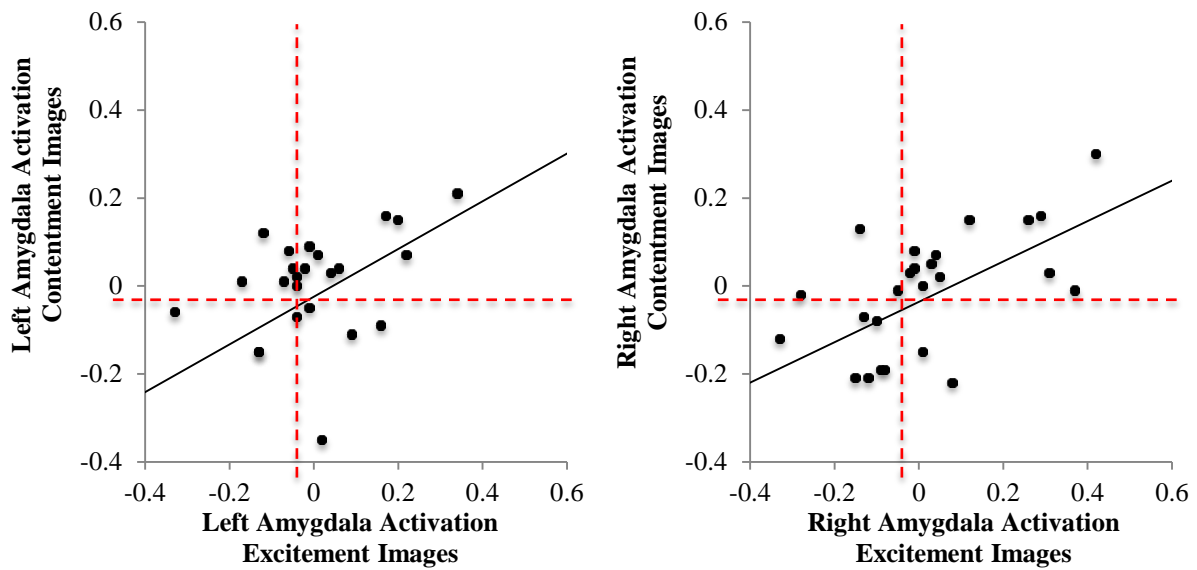


Figure 7.10.

Relationship between activation associated with excitement images > neutral images and activation associated with contentment images > neutral images for left and right amygdala.

7.4. Discussion.

The aim of the present research was to investigate potential associations between neural responses to different rewarding stimuli: monetary reward, happy facial expressions, and pleasant images.

7.4.1. Monetary Reward Anticipation and Receipt.

It was predicted that ROI activation during monetary reward anticipation would negatively correlate with ROI activation during monetary reward receipt. This prediction was supported in both samples. In the student sample, activation of the left caudate, and the left and right NAcc correlated negatively at each stage, whilst the same was found for right caudate and left NAcc activation in the community sample. This is consistent with the findings of Williams (2014), who used the same task and scanner. As such, this has been replicated in three different samples, suggesting that it is a relatively robust finding. When the negative correlations were explored, in both samples, there was a tendency for participants who demonstrated greater deactivation during monetary reward anticipation to exhibit greater

activation during monetary reward receipt. The responses in the community sample were more evenly distributed, with some participants exhibiting more deactivation during monetary reward anticipation, whilst others exhibited more relative deactivation during monetary reward receipt. This pattern could reflect prediction error, which occurs when there is a difference between an anticipated outcome and the actual outcome (Schultz et al., 1997). The findings from the present research provide evidence for a negative prediction error in the sample of younger adults, as they were found to exhibit significantly more activation during monetary reward anticipation than in response to monetary reward receipt (as reported in Chapter Four, section 4.3.1.). This would suggest that, for the sample of younger adults, the neural response to reward outcome is greater when it is not anticipated. The differences between samples may have resulted from a methodological difference: it was not possible to provide the community sample with any form of remuneration as it was possible for the student sample. As such, reward receipt was likely to have been less rewarding for the community sample and this is likely to be the cause of the lower activation during monetary reward receipt.

7.4.2. Associations between Different Reward Types.

No significant associations were expected between ROI activation during monetary reward anticipation and ROI activation when viewing happy facial expressions, or contentment and excitement images. Although it should be noted that the sample sizes were relatively small in the present study, limiting statistical power and increasing the risk of Type II errors, as expected it is not possible to reject these null hypotheses. It is beyond the scope of the present research to assess which stage of reward processing viewing happy facial expressions/pleasant images maps onto, but it is likely to be more closely related to reward consumption, or ‘liking’, whereas monetary reward anticipation is likely to be more closely related to ‘wanting’.

Positive correlations were expected between ROI activation during monetary reward receipt and when viewing happy facial expressions. This hypothesis was not supported and no significant associations were found in either sample, with the exception of one. In the sample of older adults, right caudate activation during monetary reward receipt was found to correlate negatively with right caudate activation when viewing happy facial expressions. However, this finding should be interpreted with caution, particularly as this relationship was in the opposite direction to that which was expected.

There were also concerns about the effectiveness of the facial emotion-processing task used as no significant activation emerged at the whole brain level for the positive facial expressions > neutral facial expressions contrast and no significant correlations were found with the trait measures (see Chapter Four for full details). This could also be the cause of the lack of positive correlations between ROI activation in response to viewing happy facial expressions and the contentment images. This was quite surprising as previous research has found that viewing positive facial expressions and positively valenced images elicit similar neural responses (Breiter et al., 1996; Canli et al 2002; Fitzgerald et al., 2006; Killgore & Yurgelun-Todd, 2001; Lawrence et al., 2004; Monk et al., 2008; Morris et al., 1996, 1998; Phillips et al., 1998; Sabatinelli et al., 2007; Whalen et al., 1998). Many of the contentment images portray affiliative relationships, so it was expected that, at the very least, ROI activation associated with viewing the contentment images would have been correlated with activation associated with viewing positive facial expressions.

Contrary to predictions, few associations were found between striatal activation during monetary reward receipt and activation associated with viewing contentment and excitement images, it is likely that both map onto the consummatory stage of reward processing. In the student sample, a positive correlation was observed between right caudate activation during monetary reward receipt and when viewing contentment images. A similar relationship was

found for activation of the left NAcc in the community sample. One explanation as to why these associations were observed with activation in response to the contentment images, but not the excitement images, is that the contentment images were perceived as being more rewarding. As ratings were not collected from the present samples, the present research cannot assess this directly, although some support is provided by previous valence ratings of the images, which were found to be significantly higher for the contentment images. Finally, as predicted, positive correlations were found between activation when viewing contentment images and when viewing excitement images. These associations were found for left and right caudate, and left and right amygdala activation in both samples, for the left NAcc in the sample of younger adults, and for the right NAcc in the sample of older adults. These images were presented in the same task and very close in time to each other, so it is likely that some carry-over effects contribute to these correlations. However, taken together, these findings provide some support that, for the striatum at least; there is some overlap in the neural activation associated with the processing of different rewards. These findings were observed across both samples, which would suggest that these relationships remain relatively stable across different life stages. This is consistent with previous research that has suggested that there are few differences between younger and older adults for reward-related tasks that do not have a learning component (Mata et al., 2011). Indeed, older adults have previously been demonstrated to show intact striatal responses to monetary reward outcomes (Cox et al., 2008; Samanez-Larkin et al., 2007; Schott et al., 2007; Spaniol et al., 2015) and is in line with the present research, which found no significant differences in ROI activation to happy facial expressions, contentment images, and excitement images between the student sample and the older community sample. The student sample was found to exhibit significantly greater striatal activation, compared to the community sample, during monetary reward receipt. However, this is likely to be the result of a methodological difference, as the student sample

received payment, which they believed was contingent on their performance on the task, whereas the community sample were given no payment for their participation.

7.4.4. Limitations.

There were several limitations to the present analysis. The first is the use of a relatively low powered (1.5 T) scanner, which may not have been sensitive enough to differentiate BOLD activation for particular contrasts. Furthermore, the contrasts for the happy facial expressions and the pleasant images compared activation with viewing these images to a baseline involving neutral images, whereas the neural responses to the anticipation and outcome of monetary reward were compared to a fixation cross baseline (as facilitated by the slow event-related design). This should mean that the activation associated with the image contrasts should relate solely to how rewarding the stimulus is, whilst activation associated with the monetary reward contrasts may relate to other factors as well. The use of different baseline could partially account for the limited overlap between activation to different rewards types. Finally, a further limitation of the present studies is the small sample size in both studies, such that the findings must be interpreted with caution and significant findings require replication. Statistical power was adequate only to detect large-sized ($r > .5$) associations (Cohen, 1992) between variables, so the possibility of Type II errors should be considered.

7.4.3. Conclusion.

In conclusion, several associations were found between striatal activation associated with stimuli that are likely to be more closely related to reward consumption, with significant associations found between activation during monetary reward receipt and when viewing contentment images, and more consistently between activation associated with viewing the more socially rewarding contentment images, and the more generally rewarding excitement images. This would suggest that there are some similarities in the processing of different

types of reward. These findings were observed across both samples, which would suggest that this is an association that remains stable across different life stages. Furthermore, striatal activation associated with monetary reward anticipation was found to correlate negatively with activation during monetary reward receipt, in both samples. This would indicate that activation during the different stages of reward processing are negatively related to each other and should be assessed separately.

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Chapter VIII: General Discussion.

The research presented in this thesis focused on the everyday experience of PA, goal pursuit, and neural responses to positive stimuli across different reward domains. Potential associations were explored between these factors and trait measures of approach motivation, trait vulnerability for hypomania, and anhedonic symptoms. In this final chapter, a summary of the rationale, methodology, and key findings of the present research will be provided. The key findings will then be considered in relation to each other and to previously identified gaps in the literature, including a discussion of their wider clinical and theoretical implications. The chapter will then conclude with a description of the limitations of the present research and suggestions for future directions.

8.1. Theoretical Background.

The BAS, activated by signals of reward and the absence of punishment, is an approach related, positive-reinforcement motivational system. It is thought to regulate appetitive motivation and goal-directed behaviour through the experience of PA (Gray, 1981). Activation of the BAS has been associated with increased motor behaviour, incentive reward motivation, and positive goal striving cognitions and emotions, such as hope and happiness (Depue & Collins, 1999; Gray, 1994), as well as with anger when goal striving is frustrated or blocked (Carver, 2004; Harmon-Jones & Allen, 1998; Harmon-Jones & Sigelman, 2001). It has been suggested that greater BAS sensitivity should be reflected in increased willingness to engage in goal-directed behaviours, and greater experience of positive feelings when exposed to cues of impending reward (Carver & White, 1994; Depue & Iacono, 1989). The neural underpinnings of the BAS are thought to consist of a number of cortical and sub-cortical structures, including the amygdala, caudate-putamen, and the nucleus accumbens (Gray, 1987, 1990; Smillie, 2008), which have also been implicated in reward processing (e.g.,

Berridge et al., 2009; Haber and Knutson, 2010; Hikosaka et al., 2008; Kringelbach & Berridge, 2009; Smillie, 2008). Consistent with this are findings that BAS sensitivity is associated with neural activation during anticipatory reward processing (Caseras et al., 2013), as well as hedonic consummatory reward processing (Kim et al., 2015; Simon et al., 2010) and responses to food images (Beaver et al., 2006).

Abnormalities in BAS activation are thought to underlie several different psychopathologies, which are also associated with alterations in reward processing and goal pursuit. BAS hypoactivation has been linked to disorders in which an individual might experience low mood, withdrawal, and decreased goal striving/pursuit (Campbell-Sills, Liverant, & Brown, 2004), which is particularly relevant to the experience of depression. Low BAS sensitivity has been related to the experience of anhedonia, a defining symptom of depression (e.g., Kasch et al., 2002; Pinto-Meza et al., 2006; Quilty et al., 2014). Consistent with this model, depression-related deficits in striatal activation have been reported during both anticipatory and consummatory reward processing (e.g., Forbes et al., 2009; Keedwell et al., 2005; Pizzagalli et al., 2009; Smoski et al., 2011; Stoy et al., 2012; Ubl et al., 2015; Zhang et al., 2013), with several studies relating these deficits directly to the experience of anhedonia (Stoy et al., 2012; Stuhrmann et al., 2013; Ubl et al., 2015; Wacker et al., 2009; Zhang et al., 2016). Conversely, greater BAS sensitivity has been linked to disorders that are characterized by elevated mood and impulsivity (Meyer et al., 1999; Meyer et al., 2001), such as bipolar disorder (Alloy & Abramson, 2010; Alloy et al., 2009; Johnson, 2005; Urosevic et al., 2008). High BAS sensitivity is thought to underlie hypomanic and manic episodes, during which individuals exhibit excessive goal-directed and pleasure-seeking behaviour (Johnson, 2005; Leibenluft et al., 2003), with goal-striving events being found to significantly increase the likelihood of hypomanic and manic symptoms in BD individuals (Johnson et al., 2000; Johnson et al., 2008; Nusslock et al., 2007). Consistent with this, BD appears to be

characterised by a hypersensitivity to reward-relevant stimuli (Gruber et al., 2008; Gruber et al., 2011; Urosevic et al., 2008), with bipolar and at-risk participants (as assessed using the HPS) demonstrating greater activation of the NAcc, compared to HCs, during the more motivational reward anticipation stage (Caseras et al., 2013; Nusslock et al., 2012; O’Sullivan et al., 2011).

8.2. Key Research Questions.

Based on the literature described above, the present research aimed to provide answers to the following key questions:

1. *Are individual differences in BAS sensitivity associated with the everyday experience of positive affect and goal pursuit, and neural responses to different types of rewarding stimuli?*
2. *Are individual differences in anhedonic symptoms associated with the everyday experience of positive affect and goal pursuit, and neural responses to different types of rewarding stimuli?*
3. *Are individual differences in hypomanic personality traits associated with the everyday experience of positive affect and goal pursuit, and neural responses to different types of rewarding stimuli?*
4. *Are reward-related neural responses to different stimuli related to the everyday experience of positive affect and goal pursuit?*

Figure 8.1 provides a summary of the expected relationships between the “trait” measures (trait BAS sensitivity, trait hypomania, and anhedonic symptoms) and the ESM and MRI outcome measures investigated in the present research (*addressing research questions 1-3*). Figure 8.2 provides a summary of the expected relationships between the ESM measures of PA and ST goal pursuit and the neural responses associated with different rewarding stimuli (*addressing research question 4*).

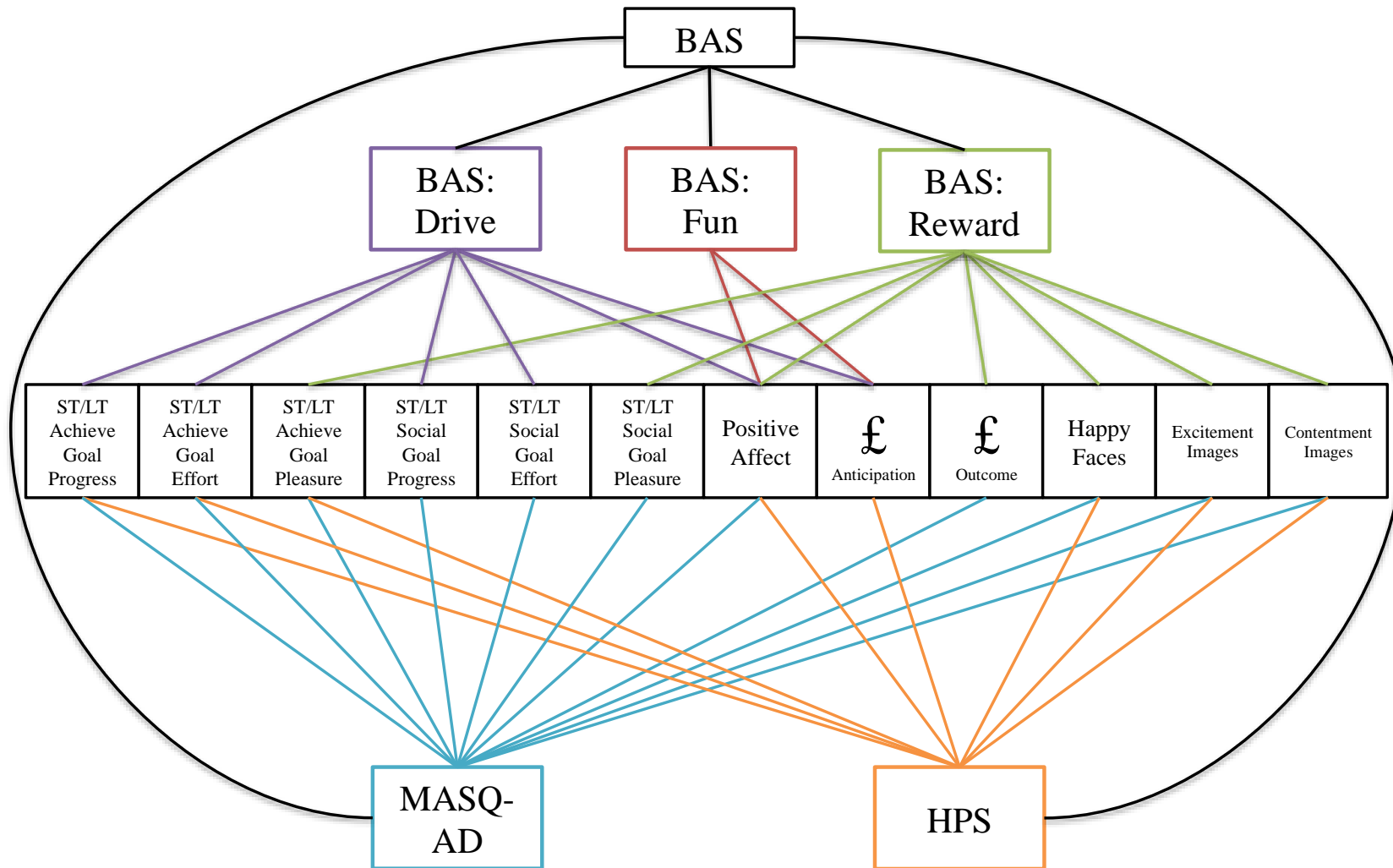


Figure 8.1.

A “nomological net” illustrating the expected associations between the “trait” measures and the outcome measures investigated in the present research.

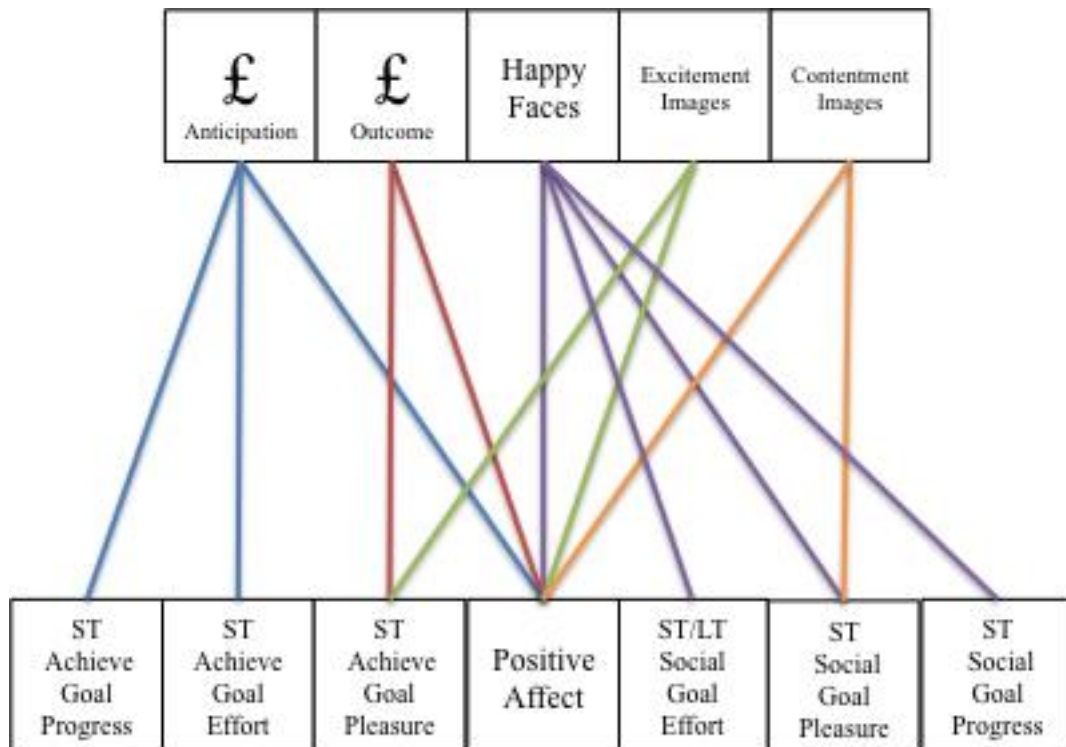


Figure 8.2.

A diagram illustrating the expected relationships between the ESM measures and the neural responses associated with different rewarding stimuli.

8.3. Summary of Methods.

This section provides a brief description of the methods and rationale for the research presented in this thesis, organised by methodology. Potential age-related differences in motivation were taken into account as constructs of interest were assessed in two samples, distinct in terms of age.

Experience Sampling (Chapter Two). Research linking BAS sensitivity to the experience of PA and goal pursuit has yielded inconsistent results, whilst few studies have directly assessed the links with the related constructs of anhedonia and trait hypomania. Consequently, a primary aim of the present research was to explore potential associations between the measures of BAS sensitivity, anhedonic symptoms and trait hypomania, and the everyday experience of PA and goal pursuit. A method of data collection that was high in

ecological validity (ESM) was used, enabling the investigation of real-world affective experience and the pursuit of different goals, which varied in terms of domain (social and achievement) and in terms of the degree of sustained effort taken to attain them (LT and ST).

MRI (Chapters Four, Five, Six, and Seven). BAS sensitivity has been associated with activation of reward-related brain structures, but it is unclear as to whether it is more relevant to anticipatory or consummatory reward processing. Additionally, the reported relationships between BAS sensitivity and reward related activation have focused on the neural responses to monetary reward (with the exception of one study which focused on neural responses to images of appetising foods; Beaver et al., 2006). The present research aimed to extend this by exploring potential associations between BAS sensitivity and neural responses associated with different types of reward (e.g., monetary and social rewards). Moreover, the present research also investigated the relationships between the BAS related constructs of anhedonia and hypomania, and reward-related activation. Finally, as there is some suggestion that different types of reward are encoded by specific, but overlapping neural pathways, an exploratory analysis was conducted to explore possible associations between striatal activation elicited by different types of reward, in order to assess whether the processing of one type of reward is related to another and whether the traits under investigation are linked to general reward sensitivity or domain specific reward responses.

ESM and MRI (Chapters Four, Five, and Six). There have been suggestions that more of a focus should be placed on assessing the relevance of reward-related neural activation, observed in the scanner, to real world experience. Previous studies have reported a significant association between ecologically valid measures of PA and reward-related neural responses in a sample of depressed and HC adolescents (Forbes et al., 2009), and a sample of adolescents at-risk for depression and HCs (Olino et al., 2014). As adolescence is a time of great change, it is important to assess whether these associations are similar across different

life stages, which the present research examined. The present research also aimed to extend these findings, relating measures of real-world achievement and social goal pursuit to activation elicited by various rewarding stimuli.

8.4. Summary of Key Findings.

This section will provide a brief description of the key findings from each chapter, and whether these supported the a priori hypotheses. The findings are evaluated and discussed in detail in section following this one.

Relationships among Trait Measures. Consistent with predictions, the three BAS subscales (BAS-FS, BAS-RR, and BAS-D) were found to intercorrelate positively in both of the larger ESM samples, although this did not extend entirely to the MRI subsets; significant relationships were only found between BAS-FS and BAS-RR in the student sample, whilst BAS-RR correlated with BAS-FS and BAS-D in the community sample. HPS was also expected to correlate positively with the BAS subscales, but only limited support was found for this, with only a significant association found between HPS and BAS-FS in the community sample. Conversely, MASQ-AD was expected to correlate negatively with the BAS subscales and HPS. The support for this was mixed; a moderate negative correlation was found between MASQ-AD and the BAS-FS/BAS-D subscales in the community sample, but no significant associations emerged in the student sample. Finally, no significant associations emerged between HPS and MASQ-AD in the community sample.

Trait and ESM Measures.

BAS Sensitivity. It was predicted that the ESM measure of state PA would correlate with each of the BAS subscales. In line with this, mean levels of PA were found to correlate positively with BAS-FS in both samples, and with BAS-D in the student sample. Concerning goal pursuit, a significant positive association was expected between BAS-D and all measures

of achievement and social goal pursuit, but this was not supported and no significant associations emerged in either sample. Additionally, BAS-RR was expected to correlate with pleasure associated with progress, for all goal types (LT/ST, social/achievement). In partial support of this, BAS-RR was found to correlate positively with LT *social* goal pleasure, but also with LT *social* goal progress and ST *social* goal effort. Finally, no relationships were expected between BAS-FS and the measures of goal pursuit. However, unexpectedly, this BAS subscale was most consistently implicated, being found to correlate positively with LT *social* goal pleasure and ST *achievement* goal progress in the student sample, and ST *achievement* goal and *social* goal effort in the community sample. Furthermore, it was also found to moderate the relationship between PA and ST *achievement* progress in the community sample, with a stronger association between PA and ST *achievement* progress in participants lower in BAS-FS.

Anhedonia. MASQ-AD was expected to correlate negatively with the measures of PA and goal pursuit across all of the goal types (LT/ST, achievement/social). Providing limited support for this, an inverse association was found between MASQ-AD and PA in the community sample, but not in the student sample. Furthermore, there was little evidence that anhedonic symptoms were related to everyday goal pursuit, with only one negative association emerging between MASQ-AD and ST *achievement* goal effort in the community sample. Finally, in line with predictions, in the community sample, MASQ-AD was found to moderate the relationship between PA and ST *achievement* progress, with a stronger positive association between ST *achievement* goal progress and PA for persons lower in MASQ-AD than for persons higher in MASQ-AD.

Hypomanic Personality Traits. HPS was expected to correlate with the measures of PA and LT/ST *achievement* goal pursuit. However, this prediction was not supported and no significant associations emerged involving HPS.

Relationships Among Positive Affect and Goal Pursuit Measures. It was hypothesised that PA would correlate positively with each of the goal pursuit measures, across all goals (LT/ST, achievement/social), both at the within-and the between-person level. Surprisingly, this was not found to be the case in either sample and no significant associations emerged. In addition, it was anticipated that the goal pursuit measures for each type of goal would intercorrelate positively, and that there would be some relationship between these measures across different types of goal. These predictions were predominantly supported: goal progress, effort, and pleasure intercorrelated for each goal type, and the measures of ST *achievement* and *social* goal pursuit were also found to correlate. However, no relationships were found between the measures of LT *achievement* and *social* goal pursuit, nor between measures of LT and ST *achievement* goal pursuit.

Trait Measures and Reward-Related Activation.

BAS Sensitivity. BAS-FS was expected to correlate positively with striatal activation during monetary reward anticipation, and with both striatal and amygdala activation associated with viewing happy facial expressions and excitement images. Very little support was provided for these hypotheses; although BAS-FS was found to correlate with left NAcc activation in the community sample during monetary reward anticipation, the other predicted relationships were not observed. Moreover, in the community sample, BAS-FS was also found to correlate positively with right caudate activation associated with viewing contentment images, a finding that was not anticipated. In addition to this, significant associations were predicted between BAS-D and striatal activation elicited during monetary reward anticipation, but this was not supported and no associations emerged between BAS-D and the neural responses to any of the reward stimuli presented in this research. Finally, it was thought that BAS-RR would correlate with striatal activation during monetary reward receipt, and with activation of both the striatum and the amygdala associated with viewing happy

facial expressions and contentment/excitement images. In line with predictions, BAS-RR correlated with activation of the left caudate and NAcc in the student sample during monetary reward receipt, although the other predicted relationships were not observed.

Anhedonia. A negative association was expected between MASQ-AD and striatal activation during both the anticipation and receipt of monetary reward. In line with this, MASQ-AD negatively correlated with activation of the right caudate during monetary reward receipt, in the student sample, whilst the negative association with right NAcc activation approached significance. However, there was no evidence of a relationship between MASQ-AD and striatal activation during monetary reward anticipation. Furthermore, it was also predicted that MASQ-AD would negatively correlate with activation of the striatum and amygdala associated with viewing happy facial expressions and contentment/excitement images. Partially supporting this, MASQ-AD was found to correlate negatively with activation of both the left and the right NAcc in response to contentment images, in the community sample, although no other significant relationships were observed.

Hypomanic Personality Traits. It was predicted that HPS would correlate with activation during monetary reward anticipation and in response to viewing happy facial expressions and excitement images. However, the data did not support these predictions and no other relationships were found between HPS and reward-related activation.

Positive Affect, Goal Pursuit, and Reward-Related Activation. Mean levels of PA during ESM was expected to correlate positively with striatal activation associated with monetary reward anticipation and receipt, viewing happy facial expressions, and viewing pleasant images. A significant relationship emerged, in the student sample, between PA and activation of the left caudate and NAcc in response to the contentment images and activation of the right NAcc and amygdala in response to the excitement images. The data did not

support the other predicted associations between PA and reward-related activation, with only one other (unexpected) association found; PA negatively correlated with right caudate activation in response to monetary reward anticipation in the community sample.

Furthermore, it was predicted that ST *achievement* goal progress and effort would correlate with striatal activation during monetary reward anticipation, whilst ST *achievement* goal pleasure was expected to relate to striatal activation during monetary reward receipt.

However, these predictions were not supported and no significant associations were seen. In addition to this, the measures of ST *social* goal pursuit (progress, effort, and associated pleasure) were expected to correlate positively with BOLD activation associated with viewing happy facial expressions, in the community sample. Some support was provided for this prediction, with significant positive associations emerging between ST *social* goal progress and effort, and activation of the left amygdala associated with the happy facial expressions > neutral facial expressions contrast. Finally, relationships between ST *social* pleasure and the neural responses associated with neural responses to the affiliative, contentment images, as well as between ST *achievement* pleasure and neural responses to the excitement images were anticipated. The hypotheses were not supported, but a significant negative association was found between ST *social* pleasure and the left NAcc and right amygdala in response to viewing the contentment images in the community sample.

Associations Across Reward Domains. Striatal activation during monetary reward anticipation was expected to correlate negatively with activation during monetary reward receipt. This was observed for activation of the left caudate and both the left and right NAcc, in the student sample, and for activation of the right caudate and left NAcc in the community sample. Additionally, positive correlations were predicted between striatal activation in response to receiving monetary reward, viewing happy facial expressions, and viewing the contentment/excitement images. Some support was provided for this, with a relationship

between activation of the right caudate during reward receipt and when viewing contentment images in the student sample, whilst a similar relationship emerged with activation of the left NAcc in the community sample. Finally, as predicted, positive correlations were found between activation when viewing contentment images and when viewing excitement images. These associations were found for left and right caudate activation in both samples, for the left NAcc in the sample of younger adults, and for the right NAcc in the sample of older adults.

8.5. Integration of Findings.

This section will provide a discussion of the key findings, organised by the research questions detailed above, with some consideration to the potential implications, both theoretical and practical.

Are individual differences in BAS sensitivity associated with the everyday experience of positive affect and goal pursuit, and neural responses to different types of rewarding stimuli?

The BAS subscales were found to intercorrelate, in the both of the larger ESM samples, supporting the idea that the constructs measures are related (Heubeck et al., 1998; Leone et al., 2001; Ross et al., 2002). However, different patterns of results emerged between each scale and measures of affect, goal pursuit, and reward-related neural activation, which would suggest that, whilst they are related, the constructs are distinct in terms of their implications for goal pursuit and reward processing, and so should be assessed separately. This is particularly true for associations with state PA, which was found to correlate with BAS-FS in both samples, and with BAS-D in the student sample. This would suggest that BAS-FS is more related to the everyday experience of PA, which is in line with its conceptual definition as the tendency to pursue reward impulsively. It would follow that individuals who are more likely to seek out reward, regardless of the consequences, would experience greater

levels of state PA, as not only is it likely that the frequency of rewarding experiences would be greater, but also those high in impulsivity may be more sensitive to signals of reward and thus more susceptible to the experience of PA (Gray, 1981). Participants did not complete measures of trait PA, so it is not possible to assess whether this would be more relevant to the other BAS subscales, which do not focus on impulsivity, but more stable aspects of reward responsivity. However, BAS-RR was not associated with PA, so this relationship may be more about the readiness to seek sensation, rather than the sensitivity to reward itself, particularly as ESM samples PA randomly in everyday life, rather than just following a reward.

Of the BAS subscales, BAS-D, measuring the motivation to pursue goals, was expected to be the most relevant to goal pursuit and anticipatory reward processing, yet the data presented in this thesis do not support this assertion. However, it may be that the types of goals assessed in the present research, as well as the relatively small amounts of monetary reward offered in the scanner were simply not appetitive enough to be associated with BAS-D. Consistent with this, previous research linked BAS-D with striatal activation when viewing images of appetising foods (Beaver et al., 2006), whilst another study, using the same card-guessing paradigm as the present research, did not report an association between BAS-D and neural responses during monetary reward anticipation (Caseras et al., 2013). Delicious foods are likely to be far more appetitive than a small amount of monetary reward, or progress towards a less directly rewarding goal. It is possible that BAS-D captures the response to more directly or immediately rewarding incentives.

On the other hand, it was expected that BAS-RR, measuring the responsiveness to reward, would be more relevant to the more consummatory aspects of goal pursuit and reward processing. In terms of goal pursuit, although few associations were found between BAS-RR and the goal pursuit measures, those that did emerge related to the pursuit of social goals.

Conceptually, the social goals were likely to be more hedonic and intrinsically motivating than the achievement goals (see Appendix B for examples) as achievement goals may be less likely to fulfil the fundamental needs outlined by Self-Determination Theory, particularly for the student sample (e.g. Deci & Ryan, 2000). This is in line with the theoretical definition of BAS-RR. These findings were particularly interesting as, to the best of my knowledge; no previous research has linked BAS sensitivity to the pursuit of more socially oriented goals. The present findings would indicate that the BAS is of relevance to social goal pursuit, suggesting that it is a general approach motivational system, which is linked to approach goal pursuit. However, it is interesting that the significant associations between BAS-RR and social goal pursuit were not limited to the more hedonic pleasure associated with progress, as was expected, but also correlated with measures of effort and progress. This implies that BAS-RR is also relevant to the motivational aspects of goal pursuit.

Finally, BAS-FS, measuring the tendency to impulsively approach reward, was not expected to be conducive to goal pursuit, potentially even being detrimental to it, due to distraction. However, it emerged as the subscale most consistently associated with goal pursuit measures, particularly in the community sample of older adults. This provides support for the idea that the relationships between BAS-FS and goal pursuit may not remain stable across different life stages. Finally, it was interesting that it was predominantly with the measures of ST goal pursuit that BAS-FS was found to correlate, although it did also correlate with LT *social* pleasure as well. Although likely to require some planning, the ST goals are more in keeping with the impulsivity measured by BAS-FS than the LT goals, which would have required more sustained effort. Consistent with this, BAS-FS was also found to correlate with striatal activation during the more motivational anticipatory processing of monetary reward in the community sample (as in Caseras et al., 2013), but not with activation in

response to stimuli that are likely to be more closely related to consummatory reward processing, such as happy facial expressions and contentment/excitement images.

Are individual differences in anhedonic symptoms associated with the everyday experience of positive affect and goal pursuit, and neural responses to different types of rewarding stimuli?

Low BAS sensitivity is a key vulnerability for anhedonia (e.g., Kasch et al., 2002; Pinto-Meza et al., 2006; Quilty et al., 2014) and as such scores on BAS measures were expected to correlate negatively with anhedonic symptoms. However, only limited support was provided for this, with negative correlations emerging between MASQ-AD and BAS-FS and BAS-D in the community sample only. Furthermore, MASQ-AD was also found to correlate negatively with mean levels of PA in the same sample. This may indicate that anhedonia is more closely related to BAS sensitivity and affective experience in the sample of older adults. It may be that anhedonia, as measured here, reflects more stable trait-like anhedonia in the community sample of older adults, whereas in the student sample of younger adults, it may reflect more temporary state anhedonia. However, in the additional analyses (see Appendix F) measures of trait physical and social anhedonia were not found to correlate with the BAS subscales or PA with the exception of a negative correlation between BAS-FS and trait social anhedonia in the fMRI subset, which would suggest that this is not the case

The most consistent findings in this thesis relate to associations with the measure of anhedonic symptoms, MASQ-AD. Anhedonia, which can be defined as an attenuated experience of PA when encountering rewarding stimuli, was found to correlate negatively with a state measure of PA in the community sample only, as well as with activation associated with monetary reward receipt, in the student sample, and pleasant images, in the community sample. However, there was little evidence of a relationship between MASQ-AD

and goal pursuit, nor with neural responses associated with the more motivational stage of monetary reward anticipation. Taken together, this would provide some indication that anhedonic symptoms (at least in what is likely to be a predominantly non-clinical population) relate more to measures of hedonic experience, such as PA and consummatory reward processing, rather than the more motivational goal pursuit and anticipatory reward processing, which is consistent with research in the area (e.g., Epstein et al., 2006; Keller et al., 2013; Wacker et al., 2009). It has been suggested that there are different subtypes of anhedonia, including anticipatory, motivational, and consummatory anhedonia. Anticipatory anhedonia relates to a decreased expected/experienced enjoyment when anticipating something pleasant, whereas motivational anhedonia is characterised by a diminished willingness to expend effort for reward, and consummatory anhedonia is reflected in decreased enjoyment of pleasant events (Frey et al., 2015; Treadway & Zald, 2011). With questions such as “*Felt like nothing was very enjoyable*” and “*Felt bored*”, it is likely that the MASQ-AD is more relevant to consummatory anhedonia (Huys, Pizzagalli, Bogdan, & Dayan, 2013). As such, it is not surprising that these associations emerged with activation associated with consummatory reward processing rather than with measures of goal pursuit. Future research could determine whether the relationships between reward processing and goal pursuit differ for each anhedonic subtype. Consistent with this, is the findings from the additional analyses (see Appendix F), in which measures of trait physical and social anhedonia were found to correlate with neural responses elicited by the fMRI tasks. For example, a measure of trait social anhedonia was found negatively correlate with striatal activation associated with viewing happy facial expressions, whilst no association emerged with a measure of trait physical anhedonia.

The present research demonstrates that individual differences in anhedonia are also present in sub-clinical populations (Franken et al., 2007; Harvey et al., 2007; Keller et al.,

2013), and that these do relate to the deficits in reward-related brain activation associated with the experience of depression (Forbes et al., 2009; Keedwell et al., 2005; Pizzagalli et al., 2009). The wider implications of this concern the conceptualisation of anhedonia as an endophenotype of depression (Berghorst & Pizzagalli, 2010; Hasler et al., 2004; Pizzagalli, 2014). Not only is it defining feature of the disorder (APA, 2013), it is relatively homogenous, easy to quantify, and is linked to the dysfunction in the neural reward circuitry (Hasler et al., 2004; Pizzagalli et al., 2005; Wacker et al., 2009). As such, it may provide valuable insights into the mechanisms underlying depression, which may allow the early identification of at risk individuals, information about the likely course of the disorder, and potentially inform the development of treatments.

Are individual differences in hypomanic personality traits associated with the everyday experience of positive affect and goal pursuit, and neural responses to different types of rewarding stimuli?

Positive correlations were expected between the HPS measure and ROI activation associated with monetary reward anticipation, viewing happy facial expressions, and viewing excitement images. However, no support was found for these predictions. This is perhaps not surprising considering that the majority of previous research has reported an association between striatal responses during reward anticipation and hypomanic symptoms in euthymic patients with bipolar disorder (Caseras et al., 2013; Nusslock et al., 2012). The HPS is not designed as a direct measure of bipolar/hypomania, but as a measure of personality traits that might indicate a predisposition to the development of bipolar disorder (Eckblad & Chapman, 1986), therefore although a participant might score highly on this measure, they might not experience any hypomanic symptoms. In addition the present sample were older than those in the aforementioned studies and reported low scores and limited variance on the HPS, which may have contributed to the lack of observed associations between the HPS, BAS subscales, and striatal activation during anticipatory reward processing. It is likely that a more varied

range of scores, including a greater representation of those at the higher end of the scale would be required for associations with HPS to manifest.

Are reward-related neural responses to different stimuli related to the everyday experience of positive affect and goal pursuit?

Few associations were found between fMRI measures and ecologically valid measures of state PA and ST goal pursuit. Indeed, we were not able to replicate the results from two previous studies, which had reported a positive correlation between the everyday experience of PA and striatal activation associated with the anticipation and outcome of reward, in adolescent samples (Forbes et al., 2009; Olino et al., 2014). Due to the limited power of the present studies, any assertion is tentative and requires further replication, but this would indicate that the Card-Guessing paradigm (see Chapter Four) might be of limited relevance to everyday affective experience, at least in adult samples. Adolescents have been found to report lower state PA (Larson et al., 2002), as well as altered striatal response to reward, compared to adults and children (Bjork et al., 2004; Ernst et al., 2005; Forbes et al., 2010; Galvan et al., 2006), whilst adulthood has been linked to decreases in reward function (Brown & Ridderinkhof, 2009; Mell et al., 2005). It could therefore be that experience of PA and the reward response are more closely related in adolescents, or perhaps it is related to the different life structures of adolescents and adults in terms of how PA is derived from rewards. For example, it may be that adulthood involves an increasing decoupling of immediate incentives and the everyday experiences of PA. However, the 3T scanner used in the previous research relating real-world PA to reward-related activation was more powerful than the 1.5T scanner used in the present research, so the null findings reported here may also reflect the limited sensitivity of our scanner and task to detect neural responses. Due to concerns with the efficacy of the Facial Emotion-Processing task (see Chapter Five) in eliciting the expected activation, it is not possible to confidently conclude the relevance of the associated brain function to everyday affective experience, although a positive correlation was found between

ST *social* goal progress and effort, and left amygdala activation associated with viewing happy facial expressions. Of the tasks utilised in the present research, the activation associated with viewing the pleasant images in the Positive Affect task, was most consistently associated with the ESM measures of PA in the student sample and negatively correlated with social goal pursuit in the community sample. These findings indicate that the Positive Affect task is most effective at eliciting activation that has some relevance to the everyday experience of affect, whilst the monetary reward task may be less relevant than anticipated, particularly as social incentives are probably more frequent than monetary incentives in most participant's daily lives. Considering that valenced images are thought to elicit a more direct affective experience (Britton et al., 2006), the relationships between real-world PA and reward-related activation to the affective images are not surprising.

Although the present research focused on the key research questions detailed above, it may also offer some insight into the everyday pursuit of different goals and responses to different types of rewarding stimuli, a brief discussion of which will be provided here.

Goal Pursuit. It was expected that everyday goal pursuit would be related to the experience of PA, but the findings presented here would indicate that this is not the case: no significant associations emerged between the measures of goal pursuit and state PA. This suggests that the experience of transient PA is not linked to everyday achievement or social goal pursuit, which is surprising as previous research has indicated an association (Affleck et al., 1998; Harris et al., 2003). However, it is possible that the goals provided by participants, though subjectively important, were not intrinsically motivating and thus less related to PA. Although previous research did not specify that participants were required to provide intrinsically motivating goals, there were some key differences. For example, Affleck and colleagues (1998) investigated goal pursuit in fibromyalgia patients, whilst Harris et al. (2003) focused on work-related goals in call-centre employees, samples somewhat different

from the student and community samples in the present research. Furthermore, Moberly & Watkins (2010) asked participants to note down goals on an ad hoc basis, rating progress eight times daily. Although PA was not measured in this study, a significant negative association was found between NA and goal progress. However, this study may have been more biased as participants chose their current salient goal at the same time that they rated progress on it. In addition to this, in the present research it is also possible that participants were engaging in other enjoyable activities, which may then have resulted in greater levels of PA, despite no goal progress being made. Finally, perhaps too few goal pursuits were being tracked and monitored in the present research, or participants may not have been aware of their most salient goals.

Unsurprisingly, measures of progress, effort, and pleasure (associated with progress) were found to intercorrelate positively for each type of goal, with a relationship also being found between measures of ST *achievement* and *social* goal pursuit. However, this did not extend to the LT goals; although progress, effort, and pleasure intercorrelated for both goals, no relationships were found between the measures of social and achievement goal pursuit. Finally, measures of LT *achievement* goal pursuit were not found to correlate with measures of ST *achievement* goal pursuit. This would indicate that the pursuit of the different types of goals is relatively independent, at least in terms of LT goal pursuit. This would be consistent with a Control Theory account, which suggests that goals can be arranged in a hierarchy of subordinate, concrete goals and more abstract, superordinate goals (Carver & Scheier, 1998). Control Theory proposes that a particular level in the hierarchy may be dominant at any given time, reflecting whether an individual is focusing attention on a more abstract or concrete level. Although not necessarily hierarchically connected, the ST goals are likely to be more related to the subordinate, concrete goals, whereas the LT goals are likely to map onto the more abstract, superordinate goals, thus mapping onto different hierarchical levels.

Furthermore, as not all goals can be actively pursued at once, some goals may be pursued at the cost of others, leading to goal conflict (Emmons & King, 1998). This independence of goal pursuit may provide a further explanation as to why no association was observed between the LT *achievement* and ST *achievement* goal measures, as the pursuit of one goal may have precluded the pursuit of the other. However, independent pursuit of different goals is not always viewed as problematic, as with goal conflict, but may also serve to ensure diversity in goal pursuit, such that an individual does not place all their eggs in one basket in terms of goal striving and attainment (Segerstrom & Nes, 2006; Riediger & Freund, 2001).

In the community sample, in which both ST *social* and *achievement* goals were assessed, positive correlations were found across all of the ST goal pursuit measures, which would suggest that there is some relationship between ST *social* and *achievement* goal pursuit in the short-term. Another possible explanation for this is that the goals that the community sample provided were generally more intrinsically motivated in general (see Appendix B). For example, the ST *achievement* goal of “*Plan and arrange activities for holiday*” is likely to be more hedonic and intrinsically motivating than “*Finish my essay*”. This would be an interesting avenue for future research, but it is beyond the scope of the present research to provide an answer to this.

Neural Responses Across Reward Types. Potential associations between striatal activation associated with different rewarding stimuli were assessed. It was expected that striatal activation associated with monetary reward anticipation and receipt would negatively correlate. This relationship consistently emerged in both samples, suggesting that it is a robust finding, which suggests that the anticipation and outcome phases of reward processing differ and should be assessed separately. Additionally, it was expected that striatal activation during monetary reward receipt and when viewing happy facial expressions and pleasant images would correlate positively, but this hypothesis was largely unsupported. In the student sample,

a positive correlation was observed between right caudate activation during monetary reward receipt and when viewing contentment images. A similar relationship was found for activation of the left NAcc in the sample of older adults. One explanation as to why these associations were observed with activation in response to the contentment images, but not the excitement images is that the contentment images were perceived as being more rewarding, perhaps because, in line with self-determination theory (e.g. Deci & Ryan, 2000), affiliation is a more universal motive tendency. Taken together, these findings provide some support that, for the striatum at least; there is some overlap in the neural activation associated with the processing of different types of rewards that map onto a similar stage of reward processing.

8.6. Limitations.

The present research has many advantages, including the use of an ecologically valid method to assess potential associations between trait measures of approach motivation and hypomania, anhedonic symptoms and everyday affective responses and measures of both long and short-term goal pursuit in both the achievement and social domain. Additionally, it explored potential associations between the aforementioned trait measures and neural responses to a diverse range of rewarding stimuli, as well as using a multi-method approach to determine the extent to which reward-related activation is relevant to everyday experiences. However, there were several key limitations that should be noted.

A substantial limitation of this research was the use of a relatively low powered (1.5T) scanner, which may not have been sensitive enough to differentiate BOLD activation in our small subcortical ROIs for some of the more subtle contrasts. Consistent with this is the lack of neural activation observed at the corrected whole brain, group level during both the Facial Emotion-Processing task and the Positive Affect task. Furthermore, the relatively small sample size meant that the present research was only powered to detect large correlations (with the exception of the within-person analyses in the ESM sample), which greatly

increases the risk of Type II errors. It has been demonstrated that neuroimaging research in particular is often subject to low statistical power, limiting the reliability of the research by increasing the chances of Type II errors (Button et al., 2013). Consequently, no correction was applied to alpha in the present research as this would have further reduced the already limited statistical power. However, by not applying this correction, there is a risk of Type I error and so the present findings must be interpreted with caution and require replication.

Secondly, there are also limitations of the use of ESM and self-report in general, particularly with the use of the signal-contingent method, which means that participants only provide ratings when they are alerted, thus they may not have been experiencing strong levels of affect when they completed the ratings and so this method may not have accurately captured the true extent of an individual's affective experience. Furthermore, it has been demonstrated that individuals tend to recall peak emotional experiences, both high and low, rather than average levels of affect (Do, Rupert, & Walford, 2008; Fredrickson, 2000; Kahneman, Fredrickson, Schreiber, & Redelmeier, 1993). As such, ESM, which measures tonic PA may not be sensitive to these peaks, which may be more closely related with reward activation. Moreover, the use of ESM could have exaggerated the relationships for certain measures (e.g., the relationship between goal progress and goal effort), as increased self-focus, brought about by the regular ratings, is suggested to increase the salience of discrepancies between desired and perceived progress (Carver & Scheier, 1998). This is particularly relevant due to the very high intercorrelation between the measures of ST *achievement* goal pursuit, particularly in the community sample, suggesting that participants might have simply been providing the same ratings across the measures on some occasions. Additionally, having to define specific goals and then track their progress etc. may have some effect on an individual's behaviour (e.g., by encouraging goal progress at a higher rate than if participants were not recording it). This issue of reactivity is not well understood in ESM

research (Barta, Tennen, & Litt, 2011). Finally, there is also likely to have been a degree of sampling bias in terms of the individuals who volunteered and completed the study; as the present research was quite burdensome it is possible that those participants who completed the research may have been more generally motivated and willing to expend effort than those who did not.

Finally, there are some general limitations to the MRI tasks used, particularly as they involved static images that were not personally relevant to the participant. This was less of an issue for the Card-Guessing paradigm as it focused on monetary reward, which is likely to be more generally salient and motivating to participants, offering greater utility than pleasant images. Furthermore, ratings of how rewarding the participants found each of the stimuli were not collected, so it was not possible to assess whether the individual did indeed find them rewarding, and, if so, how rewarding they were, which is of particular relevance to research that aims to assess individual differences.

8.7. Future Directions.

The present section provides a brief discussion of potential avenues that future research might follow, building on the research presented in this thesis.

Whilst many psychological interventions aim to reduce levels of NA, fewer focus on increasing levels of PA (Craske, Meuret, Ritz, Treanor, & Dour, 2016). Behavioural activation (BA) is one such treatment that does address this, by systematically increasing exposure to positive activities in the attempt to reverse patterns of low approach behaviour, through the use of activity scheduling. This scheduling of activities, which would otherwise be avoided, requires the development of short, medium, and long-term goals (Martell et al., 2001; Veale, 2008), which would map well onto the aspects of the present research, particularly the assessment of ST and LT goal pursuit. As such, it would be interesting to

conduct a similar ESM study in a sample of depressed participants, pre and post BA treatment. As discussed previously, higher scores on the measure of anhedonic symptoms were likely under-represented in the present samples, but by focusing on a depressed sample, there is a greater likelihood of more extreme scores, thus providing greater variance to detect relationships between anhedonia and the measures of affect and goal pursuit. Furthermore, the expectation of a reward or loss is considered to be an important psychological mechanism targeted by BA and this has been demonstrated with previous research, which has reported increased caudate activation during anticipatory reward processing after BA treatment (Dichter et al., 2009). Taken together, along with its reported efficacy at treating depressive symptoms (Cuijpers, van Straten, & Warmerdam, 2007; Ekers, Richards, & Gilbody, 2008; Ekers et al., 2014; Mazzucchelli, Kame, & Rees, 2009), it would also be interesting to assess potential relationships between BAS sensitivity, anhedonic symptoms, and the neural responses to rewarding stimuli before and after BA treatment.

The present research aimed to assess neural responses to rewarding stimuli across domains, exploring potential patterns of associations, but it was not possible to directly compare activation associated with similar manipulations of monetary and social reward within one task. In order to address this, it may be beneficial to use an alternative task in the scanner, which aims to assess neural responses to both monetary and social reward, during both reward anticipation and consumption (e.g., Spreckelmeyer et al., 2010). Furthermore, as discussed previously, it has been suggested that anhedonia may also be associated with motivational deficits (McCarthy, Treadway, & Blanchard, 2015; Treadway & Zald, 2011). This could be assessed using a task that investigates an individual's willingness to expend effort to obtain reward; such as the Effort Expenditure for Reward Task (EEfRT; Treadway & Zald, 2011). This task has previously been adapted for use in the scanner, demonstrating that, behaviourally, depressed individuals were less willing to expend effort to obtain reward,

which was accompanied by reduced caudate activation associated with high effort trials, relative to low effort trials (Yang et al., 2016), suggesting that is a sensitive and appropriate task. It would be interesting to assess the specific association between activation associated with effort expenditure and anhedonic symptoms, as well as with ratings of everyday goal effort.

The proposed future research would allow the exploration of the mechanisms underlying BA, providing some indication as to whether there is a reduction in anhedonic symptoms, an increase in everyday PA and improvements in daily goal pursuit, and whether any changes in reward-related activation associated with treatment could be linked with changes in everyday affective experience.

8.8. Summary and Conclusions.

In conclusion, the research presented in this thesis indicates that some aspects of the BAS, particularly the more impulsive, Fun-Seeking traits, are related to the everyday experience of PA, as well as to both social and achievement goal pursuit. Interestingly, there also appears to be some age-related differences, with BAS-FS being particularly implicated in the community sample. This would suggest that in the older adults, PA and goal pursuit were more closely linked to impulsive reward-seeking, which may be in line with the idea that as one ages, the focus shifts to more hedonic goals. However, it is a distinct empirical question as to whether the goals provided by the older adults were qualitatively more hedonic than those provided by the student sample. Further work would be required to examine this in the present sample. Moreover, the present research also focused on the pursuit of social goals, as well as achievement goals. To my knowledge, the RST made no specific predictions about the relationships between BAS sensitivity and social goal pursuit, but the present research provides evidence for a link. Furthermore, different relationships were found between BAS sensitivity and the measures of social and achievement goal pursuit, which would indicate that

there are some differences between the pursuit of social and achievement goals, in terms of BAS sensitivity. Taken together, the present research would indicate that BAS sensitivity is of some, albeit limited relevance to the everyday experience of PA and goal pursuit. It could be that more appetitive goals need to be investigated for the hypothesised associations to emerge consistently. Whilst the BAS seems to be of some relevance to the motivational aspects of goal pursuit, few associations emerged between the BAS subscales and reward-related activation. Some associations were observed with activation elicited during the card-guessing task, during which participants were required to make an active choice, whilst no associations emerged with activation associated with the passive viewing of happy facial expressions or pleasant images, suggesting that there may need to be a more motivational component for associations with BAS sensitivity to emerge.

Anhedonia was more consistently related to neural responses to stimuli that are likely to map on to the consummatory reward processing stage, whereas no associations were found between anhedonia, goal pursuit and reward anticipation. This suggests that anhedonia may reflect deficits in reward consumption, rather than reward anticipation. Taken together with the limited relationships found between scores on the MASQ-AD and the BAS subscales, this provides evidence for the idea that low BAS sensitivity may not be as closely related to anhedonia as initially thought, at least in a predominantly non-clinical sample.

Finally, the present research calls into question the ecological validity of some neuroimaging tasks, with few associations emerging between the ESM measures of PA and goal pursuit and reward-related activation. There were two exceptions to this: PA and ST *social* goal pleasure correlated with activation elicited during the Positive Affect task, and ST *social* goal progress and effort, which correlated with activation elicited during the Facial Emotion-Processing task. This would indicate that tasks, which are designed to elicit a more direct affective experience might have more relevance to real-world affective and goal pursuit

experience. Given the importance of goals for providing structure and meaning in people's lives (which may be absent in depression), there needs to be more research on the neural correlates of long-term goal pursuit, including processes relating to intrinsic goals that are inherently enjoyable and associated with greater persistence and psychological need satisfaction.

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Appendix A: Questionnaire Measures.

BIS/BAS Scales (Carver & White, 1994).

The questions comprising each subscale is comprised as follows: BAS-FS is highlighted in pink, BAS-RR in blue, and BAS-D in green.

Each item of this questionnaire is a statement that a person may either agree with or disagree with. For each item, indicate how much you agree or disagree with what the item says. Please respond to all the items; do not leave any blank. Choose only one response to each statement. Please be as accurate and honest as you can be. Respond to each item as if it were the only item. That is, don't worry about being "consistent" in your responses. Choose from the following four response options:

- 1 = very true for me
- 2 = somewhat true for me
- 3 = somewhat false for me
- 4 = very false for me

1. A person's family is the most important thing in life.

1 2 3 4

2. Even if something bad is about to happen to me, I rarely experience fear or nervousness.

1 2 3 4

3. I go out of my way to get things I want.

1 2 3 4

4. When I'm doing well at something I love to keep at it.

1 2 3 4

5. I'm always willing to try something new if I think it will be fun.

1 2 3 4

6. How I dress is important to me.

1 2 3 4

7. When I get something I want, I feel excited and energized.

1 2 3 4

8. Criticism or scolding hurts me quite a bit.

1 2 3 4

9. When I want something I usually go all-out to get it.

1 2 3 4

10. I will often do things for no other reason than that they might be fun.

1 2 3 4

11. It's hard for me to find the time to do things such as get a haircut.

1 2 3 4

12. If I see a chance to get something I want I move on it right away.

1 2 3 4

13. I feel pretty worried or upset when I think or know somebody is angry at me.

1 2 3 4

14. When I see an opportunity for something I like I get excited right away.

1 2 3 4

15. I often act on the spur of the moment.

1 2 3 4

16. If I think something unpleasant is going to happen I usually get pretty "worked up."

1 2 3 4

17. I often wonder why people act the way they do.

1 2 3 4

18. When good things happen to me, it affects me strongly.

1 2 3 4

19. I feel worried when I think I have done poorly at something important.

1 2 3 4

20. I crave excitement and new sensations.

1 2 3 4

21. When I go after something I use a "no holds barred" approach.

1 2 3 4

22. I have very few fears compared to my friends.

1 2 3 4

23. It would excite me to win a contest.

1 2 3 4

24. I worry about making mistakes.

1 2 3 4

MASQ-62 (Clark & Watson, 1991)

The questions comprising the MASQ-AD subscale are highlighted in pink.

Below is a list of feelings, sensations, problems, and experiences that people sometimes have. Read each item and then mark the appropriate choice on the answer sheet. Use the choice that best describes **how much** you have felt or experienced things this way **this past week, including today**. Use this scale when answering:

- | Not at all | A little bit | Moderately | Quite a bit | Extremely |
|---|--------------|------------|-------------|--|
| 1 | 2 | 3 | 4 | 5 |
| ___ 1. Felt sad | | | | ___ 33. Felt really slowed down |
| ___ 2. Startled easily | | | | ___ 34. Was disappointed in myself |
| ___ 3. Felt cheerful | | | | ___ 35. Felt nauseous |
| ___ 4. Felt afraid | | | | ___ 36. Felt hopeless |
| ___ 5. Felt discouraged | | | | ___ 37. Felt dizzy or lightheaded |
| ___ 6. Hands were shaky | | | | ___ 38. Felt sluggish or tired |
| ___ 7. Felt optimistic | | | | ___ 39. Felt really "up" or lively |
| ___ 8. Had diarrhoea | | | | ___ 40. Had pain in my chest |
| ___ 9. Felt worthless | | | | ___ 41. Felt really bored |
| ___ 10. Felt really happy | | | | ___ 42. Felt like I was choking |
| ___ 11. Felt nervous | | | | ___ 43. Looked forward to things with enjoyment |
| ___ 12. Felt depressed | | | | ___ 44. Muscles twitched or trembled |
| ___ 13. Was short of breath | | | | ___ 45. Felt pessimistic about the future |
| ___ 14. Felt uneasy | | | | ___ 46. Had a very dry mouth |
| ___ 15. Was proud of myself | | | | ___ 47. Felt like I had a lot of interesting things to do |
| ___ 16. Had a lump in my throat | | | | ___ 48. Was afraid I was going to die |
| ___ 17. Felt faint | | | | ___ 49. Felt like I had accomplished a lot |
| ___ 18. Felt unattractive | | | | ___ 50. Felt like it took extra effort to get started |
| ___ 19. Had hot or cold spells | | | | ___ 51. Felt like nothing was very enjoyable |
| ___ 20. Had an upset stomach | | | | ___ 52. Heart was racing or pounding |
| ___ 21. Felt like a failure | | | | ___ 53. Felt like I had a lot to look forward to |
| ___ 22. Felt like I was having a lot of fun | | | | ___ 54. Felt numbness or tingling in my body |
| ___ 23. Blamed myself for a lot of things. | | | | ___ 55. Felt tense or "high-strung" |
| ___ 24. Hands were cold and sweaty | | | | ___ 56. Felt hopeful about the future |
| ___ 25. Felt withdrawn from other people | | | | ___ 57. Felt like there wasn't anything interesting or fun to do |
| ___ 26. Felt keyed up, "on edge" | | | | ___ 58. Seemed to move quickly and easily |
| ___ 27. Felt like I had a lot of energy | | | | ___ 59. Muscles were tense or sore |
| ___ 28. Was trembling or shaking | | | | ___ 60. Felt really good about myself |
| ___ 29. Felt inferior to others | | | | ___ 61. Thought about death or suicide |
| ___ 30. Had trouble swallowing | | | | ___ 62. Had to urinate frequently |
| ___ 31. Felt like crying | | | | |
| ___ 32. Was unable to relax | | | | |

HPS (Eckblad & Chapman, 1986).

Please answer each item true or false. Please do not skip any items. It is important that you answer every item, even if you are not quite certain which is the best answer. An occasional item may refer to experiences that you have had only when taking drugs. Unless you have had the experience at other times (when not under the influence of drugs), mark it as if you have not had that experience.

Some items may sound like others, but all of them are slightly different. Answer each item individually, and don't worry about how you answered a somewhat similar previous item.

Circle either:

-
- | | | |
|------|-------|---|
| True | False | 1. I consider myself to be pretty much an average kind of person. |
| True | False | 2. It would make me nervous to play the clown in front of other people. |
| True | False | 3. I am frequently so "hyper" that my friends kiddingly ask me what drug I'm taking. |
| True | False | 4. I think I would make a good nightclub comedian. |
| True | False | 5. Sometimes ideas and insights come to me so fast that I cannot express them all. |
| True | False | 6. When with groups of people, I usually prefer to let someone else be the centre of attention. |
| True | False | 7. In unfamiliar surroundings, I am often so assertive and sociable that I surprise myself. |
| True | False | 8. There are often times when I am so restless that it is impossible for me to sit still. |
| True | False | 9. Many people consider me to be amusing but kind of eccentric. |
| True | False | 10. When I feel an emotion, I usually feel it with extreme intensity. |
| True | False | 11. I am frequently in such high spirits that I can't concentrate on any one thing for too long. |
| True | False | 12. I sometimes have felt that nothing can happen to me until I do what I am meant to do in life. |
| True | False | 13. People often come to me when they need a clever idea. |
| True | False | 14. I am no more self-aware than the majority of people. |
| True | False | 15. I often feel excited and happy for no apparent reason. |
| True | False | 16. I can't imagine that anyone would ever write a book about my life. |
| True | False | 17. I am usually in an average sort of mood, not too high and not too low. |
| True | False | 18. I often have moods where I feel so energetic and optimistic that I feel I could outperform almost anyone at anything. |
| True | False | 19. I have such a wide range of interests that I often don't know what to do next. |

- True False 20. There have often been times when I had such an excess of energy that I felt little need to sleep at night.
- True False 21. My moods do not seem to fluctuate any more than most people's do.
- True False 22. I very frequently get into moods where I wish I could be everywhere and do everything at once.
- True False 23. I expect that someday I will succeed in several different professions.
- True False 24. When I feel very excited and happy, I almost always know the reason why.
- True False 25. When I go to a gathering where I don't know anyone, it usually takes me a while to feel comfortable.
- True False 26. I think I would make a good actor, because I can play many roles convincingly.
- True False 27. I like to have others think of me as a normal kind of person.
- True False 28. I frequently write down the thoughts and insights that come to me when I am thinking especially creatively.
- True False 29. I have often persuaded groups of friends to do something really adventurous or crazy.
- True False 30. I would really enjoy being a politician and hitting the campaign trail.
- True False 31. I can usually slow myself down when I want to.
- True False 32. I am considered to be kind of a "hyper" person.
- True False 33. I often get so happy and energetic that I am almost giddy.
- True False 34. There are so many fields I could succeed in that it seems a shame to have to pick one.
- True False 35. I often get into moods where I feel like many of the rules of life don't apply to me.
- True False 36. I find it easy to get others to become sexually interested in me.
- True False 37. I seem to be a person whose mood goes up and down easily.
- True False 38. I frequently find that my thoughts are racing.
- True False 39. I am so good at controlling others that it sometimes scares me.
- True False 40. At social gatherings, I am usually the "life of the party".
- True False 41. I do most of my best work during brief periods of intense inspiration.
- True False 42. I seem to have an uncommon ability to persuade and inspire others.
- True False 43. I have often been so excited about an involving project that I didn't care about eating or sleeping.
- True False 44. I frequently get into moods where I feel very speeded-up and irritable.
- True False 45. I have often felt happy and irritable at the same time.

- True False 46. I often get into excited moods where it's almost impossible for me to stop talking.
- True False 47. I would rather be an ordinary success in life than a spectacular failure.
- True False 48. A hundred years after I'm dead, my achievements will probably have been forgotten.

The Revised Physical Anhedonia Scale (Chapman, Chapman, & Raulin, 1976).

Here are some statements about attitudes and experiences. Please mark each statement as true or false to describe your own attitudes and experiences. We want you to describe yourself as you have been during most of your adult life. Some of the items may refer to experiences that you have had while taking drugs or medications. Unless you have had the experience at times other than when you were taking drugs, mark the item as if having had the experience. Please mark every statement, even if you are not quite sure about the answer.

Some items may sound like others, but all of them are slightly different. Answer each item individually, and don't worry about how you answered a somewhat similar previous item.

Circle either:

- | | | |
|------|-------|---|
| True | False | 1. I have usually found lovemaking to be intensely pleasurable. |
| True | False | 2. When eating a favourite food, I have often tried to eat slowly to make it last longer. |
| True | False | 3. I have often enjoyed the feel of silk, velvet, or fur. |
| True | False | 4. I have sometimes enjoyed feeling the strength in my muscles. |
| True | False | 5. Dancing, or the idea of it, has always seemed dull to me. |
| True | False | 6. I have always found organ music dull and unexciting. |
| True | False | 7. The taste of food has always been important to me. |
| True | False | 8. I have had very little fun from physical activities like walking, swimming, or sports. |
| True | False | 9. I have seldom enjoyed any kind of sexual experience. |
| True | False | 10. On hearing a good song, I have seldom wanted to sing along with it. |
| True | False | 11. I have always hated the feeling of exhaustion that comes from vigorous activity. |
| True | False | 12. The colour that things are painted has seldom mattered to me. |
| True | False | 13. The sound of rustling leaves has never much pleased me. |
| True | False | 14. Sunbathing isn't really more fun than lying down indoors. |
| True | False | 15. There just are not many things that I have ever really enjoyed doing. |
| True | False | 16. I don't know why some people are so interested in music. |
| True | False | 17. Flowers aren't as beautiful as many people claim. |
| True | False | 18. I have always loved having my back massaged. |
| True | False | 19. I never wanted to go on any of the rides at an amusement park. |

- True False 20. Trying new foods is something I have always enjoyed.
- True False 21. The warmth of an open fireplace hasn't especially soothed and calmed me.
- True False 22. Poets always exaggerate the beauty and joys of nature.
- True False 23. When I have seen a statue, I have had the urge to feel it.
- True False 24. I have always had a number of favourite foods.
- True False 25. I don't understand why people enjoy looking at the stars at night.
- True False 26. I have had very little desire to try new kinds of foods.
- True False 27. I never have the desire to take off my shoes and walk through a puddle barefoot.
- True False 28. I've never cared much about the texture of food.
- True False 29. When I have walked by a bakery, the smell of fresh bread has often made me hungry.
- True False 30. I have often enjoyed receiving a strong, warm handshake.
- True False 31. I have often felt uncomfortable when my friends touch me.
- True False 32. I have never found a thunderstorm exhilarating.
- True False 33. Standing on a high place and looking out over the view is very exciting.
- True False 34. I have often found walks to be relaxing and enjoyable.
- True False 35. The sound of the rain falling on the roof has made me feel snug and secure.
- True False 36. I like playing with and petting soft little kittens or puppies.
- True False 37. The sound of organ music has often thrilled me.
- True False 38. Beautiful scenery has been a great delight to me.
- True False 39. The first winter snowfall has often looked pretty to me.
- True False 40. Sex is okay, but not as much fun as most people claim it is.
- True False 41. I have sometimes danced by myself just to feel my body move with the music.
- True False 42. I have seldom cared to sing in the shower.
- True False 43. One food tastes as good as another to me.
- True False 44. On seeing a soft, thick carpet, I have sometimes had the impulse to take off my shoes and walk barefoot on it.

- True False 45. After a busy day, a slow walk has often felt relaxing.
- True False 46. The bright lights of a city are exciting to look at.
- True False 47. The beauty of sunsets is greatly overrated.
- True False 48. It has always made me feel good when someone I care about reaches out to touch me.
- True False 49. I have usually found soft music boring rather than relaxing.
- True False 50. I have usually finished my bath or shower as quickly as possible just to get it over with.
- True False 51. The smell of dinner cooking has hardly ever aroused my appetite.
- True False 52. When I pass by flowers, I have often stopped to smell them.
- True False 53. Sex is the most intensely enjoyable thing in life.
- True False 54. I think that flying a kite is silly.
- True False 55. I've never cared to sunbathe; it just makes me hot.
- True False 56. The sounds of a parade have never excited me.
- True False 57. It has often felt good to massage my muscles when they are tired or sore.
- True False 58. When I'm feeling a little sad, singing has often made me feel happier.
- True False 59. A good soap lather when I'm bathing has sometimes soothed and refreshed me.
- True False 60. A brisk walk has sometimes made me feel good all over.
- True False 61. I have been fascinated with the dancing of flames in a fireplace

The Revised Social Anhedonia Scale (Eckblad, Chapman, Chapman, & Mishlove, 1982).

Here are some statements about attitudes and experiences. Please mark each statement as true or false to describe your own attitudes and experiences. We want you to describe yourself as you have been during most of your adult life. Some of the items may refer to experiences that you have had while taking drugs or medications. Unless you have had the experience at times other than when you were taking drugs, mark the item as if having had the experience. Please mark every statement, even if you are not quite sure about the answer.

Some items may sound like others, but all of them are slightly different. Answer each item individually, and don't worry about how you answered a somewhat similar previous item.

Circle either:

- | | | |
|------|-------|--|
| True | False | 1. Having close friends is not as important as many people say. |
| True | False | 2. I attach very little importance to having close friends. |
| True | False | 3. I prefer watching television to going out with other people. |
| True | False | 4. A car ride is much more enjoyable if someone is with me. |
| True | False | 5. I like to make long distance phone calls to friends and relatives. |
| True | False | 6. Playing with children is a real chore. |
| True | False | 7. I have always enjoyed looking at photographs of friends. |
| True | False | 8. Although there are things that I enjoy doing by myself, I usually seem to have more fun when I do things with other people. |
| True | False | 9. I sometimes become deeply attached to people I spend a lot of time with. |
| True | False | 10. People sometimes think that I am shy when I really just want to be left alone. |
| True | False | 11. When things are going really good for my close friends, it makes me feel good too. |
| True | False | 12. When someone close to me is depressed, it brings me down also. |
| True | False | 13. My emotional responses seem very different from those of other people. |
| True | False | 14. When I am alone, I often resent people telephoning me or knocking on my door. |
| True | False | 15. Just being with friends can make me feel really good. |
| True | False | 16. When things are bothering me, I like to talk to other people about it. |
| True | False | 17. I prefer hobbies and leisure activities that do not involve other people. |
| True | False | 18. It's fun to sing with other people. |
| True | False | 19. Knowing that I have friends who care about me gives me a sense of security. |
| True | False | 20. When I move to a new city, I feel a strong need to make new friends. |

- True False 21. People are usually better off if they stay aloof from emotional involvements with most others.
- True False 22. Although I know I should have affection for certain people, I don't really feel it.
- True False 23. People often expect me to spend more time talking with them than I would like.
- True False 24. I feel pleased and gratified as I learn more and more about the emotional life of my friends.
- True False 25. When others try to tell me about their problems and hang-ups, I usually listen with interest and attention.
- True False 26. I never had really close friends in high school.
- True False 27. I am usually content to just sit alone, thinking and daydreaming.
- True False 28. I'm much too independent to really get involved with other people.
- True False 29. There are few things more tiring than to have a long, personal discussion with someone.
- True False 30. It made me sad to see all my high school friends go their separate ways when high school was over.
- True False 31. I have often found it hard to resist talking to a good friend, even when I have other things to do.
- True False 32. Making new friends isn't worth the energy it takes.
- True False 33. There are things that are more important to me than privacy.
- True False 34. People who try to get to know me better usually give up after awhile.
- True False 35. I could be happy living all alone in a cabin in the woods or mountains.
- True False 36. If given the choice, I would much rather be with others than be alone.
- True False 37. I find that people too often assume that their daily activities and opinions will be interesting to me.
- True False 38. I don't really feel very close to my friends.
- True False 39. My relationships with other people never get very intense.
- True False 40. In many ways, I prefer the company of pets to the company of people.

Patient Health Questionnaire (PHQ-9; Kroenke, Spitzer, & Williams, 2001).

Nine Symptom Checklist*

Name _____ Date _____

Over the **last 2 weeks**, how often have you been bothered by any of the following problems?

	Not at all	Several days	More than half the days	Nearly every day
1. Little interest or pleasure in doing things.....	0	1	2	3
2. Feeling down, depressed, or hopeless.....	0	1	2	3
3. Trouble falling or staying asleep, or sleeping too much.....	0	1	2	3
4. Feeling tired or having little energy.....	0	1	2	3
5. Poor appetite or overeating.....	0	1	2	3
6. Feeling bad about yourself — or that you are a failure or have let yourself or your family down.....	0	1	2	3
7. Trouble concentrating on things, such as reading the newspaper or watching television.....	0	1	2	3
8. Moving or speaking so slowly that other people could have noticed? Or the opposite — being so fidgety or restless that you have been moving around a lot more than usual.....	0	1	2	3
9. Thoughts that you would be better off dead or of hurting yourself in some way.....	0	1	2	3

(For office coding: Total Score ____ = ____ + ____ + ____)

If you checked off any problems, how difficult have these problems made it for you to do your work, take care of things at home, or get along with other people?

- | | | | |
|---|---|---|--|
| Not difficult
at all
<input type="checkbox"/> | Somewhat
difficult
<input type="checkbox"/> | Very
difficult
<input type="checkbox"/> | Extremely
difficult
<input type="checkbox"/> |
|---|---|---|--|

The PHQ was developed by Drs. Robert L. Spitzer, Janet B.W. Williams, Kurt Kroenke and colleagues. Reproduced with permission of Dr. Spitzer for use in clinical practice. Copyright held by Pfizer Inc, but may be photocopied ad libitum.

Physician assessment of score needs to consider number of positive responses, severity, context, and how disabling the symptoms are. General guidance is: <5— no depression; 5-9: mild depression; 10-14: mild to moderate; 15-19: mod-severe; >20: severe. You can generally follow the mild depression or refer for counseling and if mod-severe start pharmacotherapy with the goal of remission. This tool can assist initial diagnosis and follow effectiveness of treatment to remission. A combination of pharmacotherapy and cognitive behavior therapy is generally more effective than either alone for moderate to severe depression. As with any screen, it is an assist to clinical judgment, but does not replace it ->

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Appendix B: ESM Documentation.

Study One ESM Brief.

Goal Pursuit in Everyday Life.

Purpose of Study

The purpose of this study is to examine the everyday experience of working towards both long-term and short-term goals. It aims to improve our understanding of the feelings and mood states associated with progress (or lack of) made towards pertinent goals.

Procedures

Participating in the study will require the completion of various questions at several points of the day, over the next seven days. You will be provided with a watch that will alert you as to when you need to respond to these questions and can enter the majority of the answers directly into the watch. You will also be provided with a booklet, in which there is space to provide answers that cannot be entered directly into the watch (this is only applicable for the first and last set of questions each day). The booklet may also serve as an aide memoire for the other questions.

At the start of the study you will be asked to complete various questionnaires that are designed to assess how you are feeling and how you might approach goals. You will also be required to think of two goals that you wish to work towards, but cannot achieve within the week (you should expect to be able to make a small amount of progress towards these goals on most days over the course of the study). One of these goals should be achievement oriented (e.g., “Do well in my degree coursework”), whilst the other should be more social and relationship-oriented (e.g., “Get on with my housemates better”). You will be asked to provide various ratings concerning these goals each evening (when alerted by the watch).

Each day you will be asked to think of another achievement oriented goal that you wish to achieve by the end of the day (e.g. “Finish my cognitive psychology essay”). This goal should not be a trivial one that you can expect to achieve in a very short period of time or with a single action (e.g., “Post my mum’s birthday card”), but rather one that requires sustained effort over many minutes or hours, such as the example at the beginning of this paragraph. You will be asked to provide ratings concerning these daily goals at various points throughout the day.

The watch will alert you to provide ratings eight times a day. Although these alerts will occur at random and unpredictable times, they will only occur within the time frame that you have chosen to be consistent with your waking hours, and there will be at least thirty minutes between each alert. You will also have the option of ‘snoozing’ the watch to delay reporting your ratings for a few minutes if you are temporarily unable to do so.

At the end of the study, you will make an appointment to return the watch (which remains the property of the University of Exeter) and receive a debriefing. If you wish to receive feedback about the ratings you have provided, please let the researcher know, so that this may be arranged.

If you successfully complete at least 70% of the ratings (and there is no medical reason that you may be exempt), you may be invited to participate in the fMRI experiment. If this is the case, the researcher will get in contact with you to arrange a convenient time.

Any data (including all questionnaires and booklets) will only be seen by the researcher and her supervisors to assist in analysing information for the purposes of the study described. There will be no identifying information on the materials, but rather a number will be assigned.

Furthermore, any data will be used solely for the purposes above in accordance with the ethical standards of confidentiality that govern psychologists. Should you wish to withdraw, this data can be destroyed at any time.

Remuneration

For first-year psychology undergraduate students participating in this study, the following remuneration shall apply:

For the initial everyday sampling study = 2.5 credits.

For the fMRI study = 1.5 credits + a possible £5 bonus.

For all other participants or those not needing course credits:

For the initial everyday sampling study = £15.

For the fMRI study = £10 + a possible £5 bonus.

Potential Risks and Ethical Considerations

The main risk associated with the questionnaires and ratings is possible discomfort when answering some of the personal questions.

Answering the questions at various points during the day may cause some inconvenience, but this is minimised by constraining this to a twelve-hour time of your choice, in order to minimise sleep disturbances etc.

Benefits

If you should choose to, the researcher is able to provide feedback as to what ratings you provided. This will provide you with information about how your feelings and mood fluctuate across the course of the week. It will also indicate any patterns that emerge about goal pursuit. Some people report that the process of recording experiences offers them greater insight into themselves.

Confidentiality

The information you give which is recorded will be kept strictly confidential, except as may be required by the law or professional guidelines for psychologists. All information will be identified by an identification number, not your name. Any form that requires your name (e.g., this consent form) will be stored separately from the other material. Your name or other identifying information will never be associated with any research reports or publications that use the results of your questionnaires or interviews.

Withdrawal/Premature Completion

Your participation in the study is voluntary, and you may discontinue at any time, without prejudice. If you decide to withdraw from the study at any time and for any reason, you will be remunerated at a pro-rated amount for the days that you have completed.

Invitation to ask further questions

You should ask any questions you have concerning this study before you sign the consent form.

Study One ESM Booklet.

To start with please think of two long-term goals, one related to achievement and one related to social relationships, both of which you will be actively working towards on most days, but are not going to achieve in the next week.

Long-term Goal One.

Examples of a long-term achievement goal might be “Train for a marathon” or “Work towards getting a first in my degree”. Please write your goal in the space provided below:

.....
.....

Please write down a word that could be used to remind you of this goal:

Now please write down a reason why you would like to achieve this goal. Examples of this might be “So that I get fit and healthy” or “So that I don’t end up doing a job I hate”.

I am pursuing this goal so that...

.....
.....

Long-term Goal Two.

Examples of a long-term social goal might be “Make more of an effort with my boyfriend/girlfriend” or “Make an effort to speak to new people”. Please write your goal in the space provided below:

.....
.....

Please write down a word that represents this goal to you:

Now please write down a reason why you would like to achieve this goal. Examples of this might be “So that I have a good relationship” or “So that people won’t dislike me”.

I am pursuing this goal so that...

.....
.....

Daily Goal One.

Please provide your daily goal in the space provided below. Please remember that this should be an achievement-based goal, which will require you to actively work towards achieving it across the course of the day e.g. “I will work on my essay/report”.

.....
.....

Daily Goal Two.

Please provide your daily goal in the space provided below. Please remember that this should be an achievement-based goal, which will require you to actively work towards achieving it across the course of the day e.g. “I will work on my essay/report”.

.....
.....

Daily Goal Three.

Please provide your daily goal in the space provided below. Please remember that this should be an achievement-based goal, which will require you to actively work towards achieving it across the course of the day e.g. “I will work on my essay/report”.

.....
.....

Daily Goal Four.

Please provide your daily goal in the space provided below. Please remember that this should be an achievement-based goal, which will require you to actively work towards achieving it across the course of the day e.g. “I will work on my essay/report”.

.....
.....

Daily Goal Five.

Please provide your daily goal in the space provided below. Please remember that this should be an achievement-based goal, which will require you to actively work towards achieving it across the course of the day e.g. “I will work on my essay/report”.

.....
.....

Daily Goal Six.

Please provide your daily goal in the space provided below. Please remember that this should be an achievement-based goal, which will require you to actively work towards achieving it across the course of the day e.g. "I will work on my essay/report".

.....
.....

Daily Goal Seven.

Please provide your daily goal in the space provided below. Please remember that this should be an achievement-based goal, which will require you to actively work towards achieving it across the course of the day e.g. "I will work on my essay/report".

.....
.....

Study Two ESM Brief.

Goal Pursuit in Everyday Life.

Purpose of Study

The purpose of this study is to examine the everyday experience of working towards both achievement and social based goals. It aims to improve our understanding of the feelings and mood states associated with progress (or lack of) made towards pertinent goals.

Procedures

Participating in the study will require the completion of various questions at several points of the day, over the next seven days. You will be provided with a watch that will alert you as to when you need to respond to these questions and can enter the majority of the answers directly into the watch. You will also be provided with a booklet, in which there is space to provide answers that cannot be entered directly into the watch. The booklet may also serve as an aide memoire for the other questions.

At the start of the study you will be asked to complete various questionnaires that are designed to assess how you are feeling and how you might approach goals. You will also be required to think of two goals that you wish to work towards, but cannot achieve within the week (you should expect to be able to make a small amount of progress towards these goals on most days over the course of the study). One of these goals should be achievement oriented (e.g., “Excel at work or in a hobby”) whilst the other should be more social and relationship-oriented (e.g., “Improve my relationship with a family member/friend”). You will be asked to provide various ratings concerning these goals each day (when alerted by the watch).

The watch will alert you to provide ratings six times a day. Although these alerts will occur at random and unpredictable times, they will only occur within the time frame that you have chosen to be consistent with your waking hours, and there will be at least thirty minutes between each alert. You will also have the option of ‘snoozing’ the watch to delay reporting your ratings for a few minutes if you are temporarily unable to do so. There is also an option for disabling the watch for a period of time, should you need to engage in any activity where the alert might cause a problem.

At the end of the study, you will make an appointment to return the watch (which remains the property of the University of Exeter) and receive a debriefing. If you wish to receive feedback about the ratings you have provided, please let the researcher know, so that this may be arranged.

If you successfully complete at least 70% of the ratings and there is no medical reason that you may be exempt from having a MRI scan, you may be invited to participate in the fMRI experiment. If this is the case, the researcher will arrange a convenient time with you when you return the watch. However, this will depend on your questionnaire scores and the number of participants required. You are under no obligation to participate in the fMRI study if you’re invited.

Any data (including all questionnaires and booklets) will only be seen by the researcher and her supervisors to assist in analysing information for the purposes of the study described. There will be no identifying information on the materials, but rather a number will be assigned.

Furthermore, any data will be used solely for the purposes above in accordance with the ethical standards of confidentiality that govern psychologists. Should you wish to withdraw, this data can be destroyed at any time.

Remuneration

There is no direct payment for participation in this study.

Potential Risks and Ethical Considerations

The main risk associated with the questionnaires and ratings is possible discomfort when answering some of the personal questions, which focus on symptoms of depression, feelings and mood states as well as progress towards your goals.

Answering the questions at various points during the day may cause some inconvenience, but this is minimised by constraining this to a twelve hour time of your choice, in order to minimise sleep disturbances etc., as well as having the option to snooze or disable the watch.

Benefits

There are no direct benefits of participating in this study. However, if you should choose to, the researcher is able to provide feedback on the ratings you provided. This will provide you with information about how your feelings and mood fluctuate across the course of the week. It will also indicate any patterns that emerge about goal pursuit. Some people report that the process of recording experiences offers them greater insight into themselves.

Confidentiality

The information you give which is recorded will be kept strictly confidential, except as may be required by the law or professional guidelines for psychologists. All information will be identified by an identification number, not your name. Any form that requires your name (e.g., this consent form) will be stored separately from the other material in a secure, locked filing cabinet in the researcher's office. Your name or other identifying information will never be associated with any research reports or publications that use the results of your questionnaires or interviews.

Withdrawal/Premature Completion

Your participation in the study is voluntary, and you may discontinue at any time, without prejudice. We ask that you would still return the watch to the researcher. We would provide you with a stamped, addressed envelope for this purpose.

Invitation to ask further questions

You should ask any questions you have concerning this study before you sign the consent form.

Study Two ESM Booklet.

To start with please think of two long-term goals, one related to achievement and one related to social relationships, both of which you will be actively working towards on most days, but are not going to achieve in the next week.

Long-term Goal One.

Examples of a long-term achievement goal might be “Train for a marathon” or “Excel at work or a hobby”. Please write your goal in the space provided below:

.....
.....

Please write down a word that could be used to remind you of this goal:

Now please write down a reason why you would like to achieve this goal. Examples of this might be “So that I get fit and healthy” or “In order to increase satisfaction”.

I am pursuing this goal so that...

.....
.....

Please rate how important this goal is to you, from 1 (*not very important*) to 7 (*extremely important*):

1 2 3 4 5 6 7

Long-term Goal Two.

Examples of a long-term social goal might be “Make more of an effort with my partner” or “Make an effort to speak to new people”. Please write your goal in the space provided below:

.....
.....

Please write down a word that represents this goal to you:

Now please write down a reason why you would like to achieve this goal. Examples of this might be “So that I have a good relationship” or “So that people won’t dislike me”.

I am pursuing this goal so that...

.....
.....

Please rate how important this goal is to you, from 1 (*not very important*) to 7 (*extremely important*):

1 2 3 4 5 6 7

Please keep this booklet with you over the next seven days. Each morning you will need to think of a daily achievement and social goal that you wish to pursue and attain that day. This goal cannot be one that you can complete in a short period of time (e.g. “Pay in a cheque at the bank”), but rather one that will require you to actively strive towards over a longer period during the day (e.g. “Complete all of my planned chores for the day”).

Day One.

Please provide your daily goals in the space provided below. Please remember that there should be an achievement-based goal and a social based goal, which will serve to further progress on your long-term goals.

Achievement.....

Social.....

Day Two.

Please provide your daily goals in the space provided below. Please remember that there should be an achievement-based goal and a social based goal, which will serve to further progress on your long-term goals.

Achievement.....

Social.....

Day Three.

Please provide your daily goals in the space provided below. Please remember that there should be an achievement-based goal and a social based goal, which will serve to further progress on your long-term goals.

Achievement.....

Social.....

Day Four.

Please provide your daily goals in the space provided below. Please remember that there should be an achievement-based goal and a social based goal, which will serve to further progress on your long-term goals.

Achievement.....

Social.....

Day Five.

Please provide your daily goals in the space provided below. Please remember that there should be an achievement-based goal and a social based goal, which will serve to further progress on your long-term goals.

Achievement.....

Social.....

Day Six.

Please provide your daily goals in the space provided below. Please remember that there should be an achievement-based goal and a social based goal, which will serve to further progress on your long-term goals.

Achievement.....

Social.....

Day Seven.

Please provide your daily goals in the space provided below. Please remember that there should be an achievement-based goal and a social based goal, which will serve to further progress on your long-term goals.

Achievement.....

Social.....

Study One and Two ESM Consent Form.



Consent Form:

Approach and avoidance motivation in depression: a combined ESM and fMRI approach.

Lead Researcher:

Natasha Bloodworth (nlb206@exeter.ac.uk)

Nature of Research:

The purpose of this study is to examine the everyday experience of towards both achievement and social based goals. It aims to improve our understanding of the feelings and mood states associated with progress (or lack of) made towards pertinent goals.

Consent:

I understand that I am able to withdraw from the study at any time, without prejudice

I understand the watch that I have been provided with remains the property of University of Exeter and agree to return it at the end of the study

I would like to receive feedback on the results of this study

If yes, please provide an email address.....

I am happy to be contacted for future research

I give my informed consent to participate in this study. I have read and understand the consent form.

Signed..... Print Name..... Date

Study One and Two ESM Debrief.

Goal Pursuit in Everyday Life.

The purpose of this study was to examine the relationships between depression scores, certain personality traits and the association that these have with the everyday pursuit of different types of goals.

It is thought that higher depression scores are associated with lower levels of trait approach behaviour (the tendency to approach rewards) and higher levels of trait avoidance (the tendency to avoid punishments). This, in turn, is thought to lead to a greater discrepancy between how much progress an individual wants to make towards a goal and their perception of how much progress they actually make. This greater discrepancy is anticipated to be associated with higher levels of more negative emotions and lower levels of positive emotion.

The data from the fMRI study enables us to investigate the relationship between these depression symptom scores, personality traits and the activation of different brain areas involved in processing rewards and punishments.

It is thought that those with higher depression scores will be less sensitive to reward and more sensitive to punishment. This, in turn, should be associated with differences in activation between participants with higher depression scores and those with lower depression scores.

If you have any questions or concerns regarding this study, please do not hesitate to ask either now or at a later date via email (nlb206@exeter.ac.uk).

Thank you again for your co-operation

Study One Goal Examples.

LT Achievement Goals:

“Save up enough money to travel to South Africa”

“Find a graduate job”

“Get a job at a bank or financial institution”

“Take part in volunteering work”

“Complete my PhD”

LT Social Goals:

“See my friends from home more”

“Improve relationship with boyfriend”

“Make more contact with my family”

“Make more of an effort with housemates”

“Make an effort to meet new people”

ST Achievement Goals:

“Finish 40% of report”

“Work on my project”

“Learn verbs and vocab”

“Revise 3 topics”

“Work on my essays”

Study Two Goal Examples.

ST Achievement Goals:

“Clean the car, outside and inside”

“Complete the chores my wife has been asking me to do for a while”

“Have a clear out and tidy my office”

“Plan and arrange activities for holiday”

“Sort out all paperwork and pay bills”

ST Social Goals:

“Try and spend more quality time with my kids”

“Speak nicely to all of my colleagues today and don’t get irritated with them”

“Visit with my Grandson”

“Get in contact with some old friends and try and arrange a dinner”

“Make sure that I contact family members to catch up on what is going on with them”

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Appendix C: MRI Documentation.

Study One MRI Brief.

Goal Pursuit in Everyday Life (fMRI study)

Purpose of Study

The purpose of this study is to investigate individual differences in how people process reward and punishment, using fMRI. Previous research has suggested that the activation of certain brain areas is associated with the personality traits investigated in the rating part of the study that you have already completed. Your participation in both parts of this study will allow us to relate brain function back to the everyday experience of goal pursuit and reward.

Procedures

At the start of the study you will be asked to complete various questionnaires that are designed to assess how you are feeling and how you might approach goals. You will have already completed these before you participated in the first part of the study but we would like up-to-date ratings. The scanning session will involve you lying down in a non-invasive MRI scanner, which records changes in blood flow in the brain (please see fMRI information sheet for more detail). You will then complete two tasks that are designed to assess how you respond to different rewards and punishment. Both tasks will involve you trying to win as much and lose as little money as possible. If you complete the first task with an above average score, you will receive a £5 bonus.

During the first task you will be asked to guess whether a card that you are about to be shown is higher or lower than 5. If you are correct you will win and earn a reward, or avoid losing points, depending on the trial type.

For the second task, you will view some images of different faces. You will be asked to indicate which of these faces are old and young.

For the final task, you will be shown various images. You will need to indicate if a person is present.

You will be given breaks at various intervals throughout these tasks.

Remuneration

For students participating in this study, the following remuneration shall apply:

For the fMRI study = 1.5 credits + a possible £5 bonus.

For all other participants:

For the fMRI study = £10 + a possible £5 bonus.

Potential Risks and Ethical Considerations

You will have completed a safety checklist before this study to make sure that it is safe for you to participate in this part of the study.

Confidentiality

The information you give which is recorded will be kept strictly confidential, except as may be required by the law or professional guidelines for psychologists. All information will be identified by an identification number, not your name. Any form that requires your name (e.g., this consent form) will be stored separately from the other material. Your name or other identifying information will never be associated with any research reports or publications that use the results of your questionnaires or interviews.

Withdrawal/Premature Completion

Your participation in the study is voluntary, and you may discontinue at any time, without prejudice. If you decide to withdraw from the study at any time and for any reason, you will still receive payment for your participation.

Invitation to ask further questions

You should ask any questions you have concerning this study before you sign the consent form.

Study Two MRI Brief.

Goal Pursuit in Everyday Life (fMRI study)

Purpose of Study

The purpose of this study is to investigate individual differences in how people process reward and punishment, using fMRI. Previous research has suggested that the activation of certain brain areas is associated with the personality traits investigated in the rating part of the study that you have already completed. Your participation in both parts of this study will allow us to relate brain function back to the everyday experience of goal pursuit and reward.

Procedures

The scanning session will involve you lying down in a non-invasive MRI scanner, which records changes in blood flow in the brain (please see fMRI information sheet for more detail). You will then complete two tasks which are designed to assess how you respond to different rewards and punishment. Both tasks will involve you trying to win as much and lose as little money as possible.

During the first task you will be asked to guess whether a card that you are about to be shown is higher or lower than 5. If you are correct you will win and earn a reward, or avoid losing points, depending on the trial type.

For the second task, you will view some images of different faces. You will be asked to indicate which of these faces are old and which are young.

The third task will be very similar to a task that you have completed in a previous study. You will be asked to choose whether to complete a difficult task (more button presses in a shorter amount of time) for more money, or an easier task, for less money. You will only have to complete the actual task on a certain amount of trials, but as these are randomly assigned, please make each of your selections assuming that you will have to complete the task.

For the final task, you will be shown various images. You will need to indicate if a person is present.

At the end of the study you will be asked various questions that are designed to assess how you are feeling.

You will be given breaks at various intervals throughout these tasks.

Remuneration

There is no direct payment for this study.

Potential Risks and Ethical Considerations

You will have completed a safety checklist before this study to make sure that it is safe for you to participate in this part of the study.

Confidentiality

The information you give which is recorded will be kept strictly confidential, except as may be required by the law or professional guidelines for psychologists. All information will be identified by an identification number, not your name. Any form that requires your name (e.g., this consent form) will be stored separately from the other material. Your name or other identifying information will never be associated with any research reports or publications that use the results of your questionnaires or interviews.

Withdrawal/Premature Completion

Your participation in the study is voluntary, and you may discontinue at any time, without prejudice. If you decide to withdraw from the study at any time and for any reason, you will still receive payment for your participation.

Invitation to ask further questions

You should ask any questions you have concerning this study before you sign the consent form.

Study One and Two MRI Screening Form.

Participant Safety Checklist

Name:

Date of Birth:

Weight:

Please check the following list carefully, answering all appropriate questions. Please do not hesitate to ask staff, if you have any queries regarding these questions.

1. Do you have a pacemaker, artificial heart valve or coronary stent? Yes No

2. Have you ever had major surgery? Yes No
If yes, please give brief details:

3. Do you have any aneurysm clips (clips put around blood vessels during surgery)? Yes No

4. Do you have any implants in your body? Yes No

5. Do you have any of the following?

- | | | |
|-----|----|---|
| Yes | No | Joint replacements, pins or wires |
| Yes | No | Implanted cardioverter defibrillator (ICD) |
| Yes | No | Electronic implant or device |
| Yes | No | Magnetically-activated implant or device |
| Yes | No | Neurostimulation system |
| Yes | No | Spinal cord stimulator |
| Yes | No | Insulin or infusion pump |
| Yes | No | Implanted drug infusion pump |
| Yes | No | Internal electrodes or wires |
| Yes | No | Bone growth/bone fusion stimulator |
| Yes | No | Any type of prosthesis |
| Yes | No | Heart valve prosthesis |
| Yes | No | Eyelid spring or wire |
| Yes | No | Metallic stent, filter or coil |
| Yes | No | Shunt (spinal or intraventricular) |
| Yes | No | Vascular access port and/or catheter |
| Yes | No | Wire mesh implant |
| Yes | No | Bone/joint pin, screw, nail, wire, plate etc. |
| Yes | No | Other Implant |

6. Do you have an artificial limb, calliper or surgical corset? Yes No

7. Do you have any shrapnel or metal fragments, for example from working in a machine tool shop? Yes No

7. Do you have a cochlear implant? Yes No

8. Do you wear dentures, plate or a hearing aid? Yes No

9. Are you wearing a skin patch (e.g. anti-smoking medication), have any tattoos, body piercing, permanent makeup or coloured contact lenses? Yes No

10. Are you aware of any metal objects present within or about your body, other than those described above? Yes No

11. Are you susceptible to claustrophobia? Yes No

12. Do you suffer from blackout, diabetes, epilepsy or fits? Yes No

For women:

13. Are you pregnant or experiencing a late menstrual period? Yes No

14. Do you have an intra-uterine contraceptive device fitted? Yes No

15. Are you taking any type of fertility medication or having fertility treatment? Yes No

Important Instructions

Remove all metallic objects before entering the scanner room including hearing aids, mobile phones, keys, glasses, hair pins, jewellery, watches, safety pins, paperclips, credit cards, magnetic strip cards, coins, pens, pocket knives, nail clippers, steel-toed boots/shoes and all tools. Loose metallic objects are especially prohibited within the MR environment.

I have understood the above questions and have marked the answers correctly.

Signature Date
(Participant/Parent/Guardian)

MR Centre Staff Signature

Study One and Two MRI Consent Form.

Exeter MR Research Centre

University of Exeter

RESEARCH CONSENT FORM FOR MRI SCANNING

The participant should complete the whole of this sheet himself/herself.

Have you read the Information Sheet? Yes No

Have you had the opportunity to ask questions and discuss this study? Yes No

Have you received satisfactory answers to all of your questions? Yes No

Have you received enough information about the study? Yes No

Who has explained the procedure and study to you (write name)?

Do you understand that you are free to withdraw from the study at any time without having to give a reason? Yes No

Do you agree to take part in this study? Yes No

All the personal information we are going to ask you is required to determine whether it is safe and suitable for you to undergo an MRI scan. This information will be kept separately from your scan and once the scan is complete the scan data be referred anonymously. We will not pass on your personal information to third parties.

The consent form you have signed indicates that you have agreed for your scan data to be used for the study you have been recruited for. However, your scan data can form part of a substantial resource that we can draw on in the future, for example for teaching or further scientific studies. We would like to ask you to consider giving additional consent for your data to be used anonymously in this way.

This consent is entirely optional. Answering "No" to the following questions will not affect whether you can take part in the study for which you have been recruited.

I consent for my scan data to be used for education purposes Yes No

I consent for my scan data to be used in further scientific studies Yes No

NAME IN BLOCK LETTERS:

Signed: _____ Date: _____

NAME OF RESEARCHER:

Signed: _____

Card-Guessing Task Instructions.

CARD GAME

You are about to participate in a Card Game. You will be required to guess if a card you will see is higher or lower than 5 (it can be 1-9). Depending on your response and on the trial type you are playing, you could either win or lose money, or keep your winnings even.

You will have to guess if the next card is going to be lower (press the button with your index finger) or higher (press the button with your middle finger) than 5 when you see a question mark on the screen. At this point, you won't have any indication of the value of the card, so you can only guess. After your choice, you will see yellow shuffling hands with either an arrow pointing up or an arrow pointing down.



The shuffling / arrow pointing up means:

If your guess is RIGHT, you will win £1, which will be added to your total winnings.

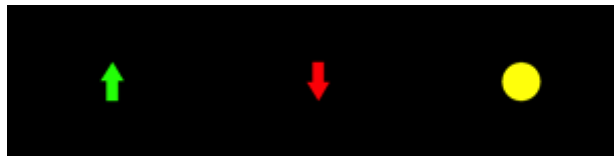
If your guess is WRONG, you won't win anything and your total winnings will remain even.

The shuffling / arrow hand pointing down means:

If your guess is WRONG, you will lose 50p which will be deducted from your total winnings.

If your guess is RIGHT, you will avoid losing and your total winnings will remain even.

After a short while you will see the outcome card number followed by an indication of the result: Green arrow pointing upwards if you won money, red arrow pointing downwards if you lost money, or a yellow circle if your total winnings remain the same.



After winning money, please press either with finger to "collect" your money. That is, you should press either button again after seeing the green arrow pointing upwards. To make this easier, just press after every outcome, regardless of whether you won or lost or stayed the same; this will ensure that you collect your money.

You will be required to play several cards one after the other, so please keep watching the screen to not miss any trials.

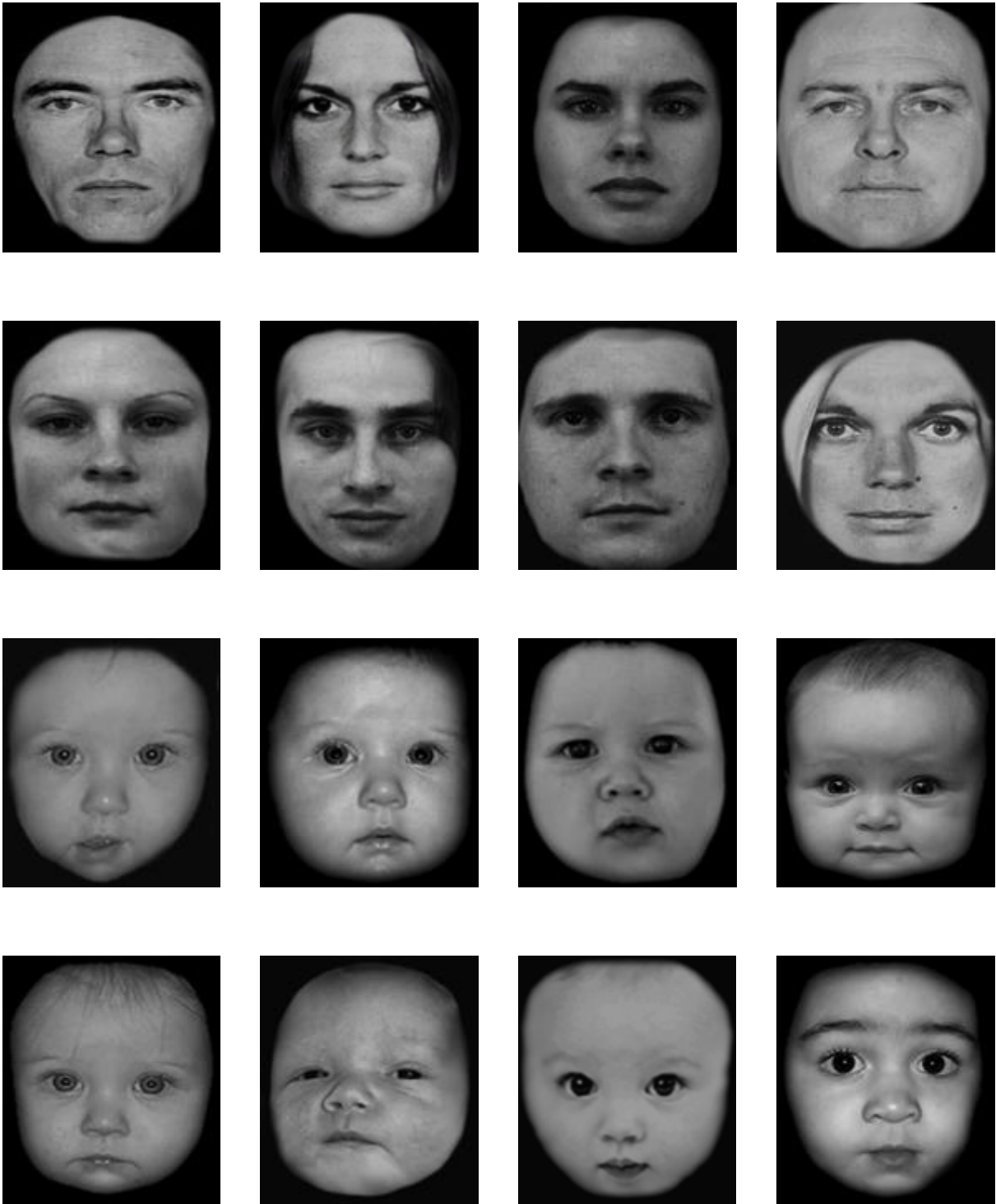
Now we are going to practice the task so you can get the hang of it before going into the scanner. If you have any questions now or after practising the task, please do not hesitate to ask before we move into the scanner. Thank you.

Appendix D: MRI Task Stimuli.

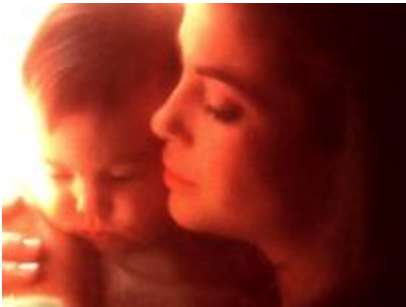
Positive Facial Expressions.



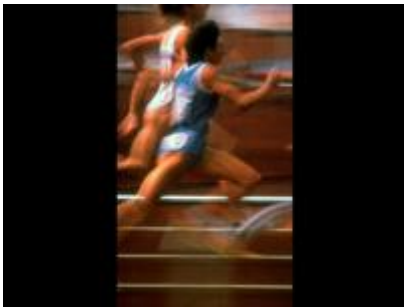
Neutral Facial Expressions.



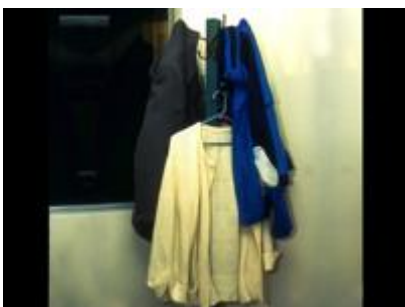
Contentment Images.



Excitement Images.



Neutral Images.



Amusement Images.



Awe Images.



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Appendix E: Additional Descriptive Statistics.

Study One Happy Faces Task Descriptive Statistics.

Due to technical issues during data collection, the data from two participants were not included in the analysis. The descriptive statistics for the trait measures are present in Table E1 and the relationships between these trait measures are presented in Table E2.

Table E1.

Descriptive statistics of the trait measures in Study One Happy Faces fMRI subset.

	Mean	<i>SD</i>	Min	Max
BAS-FS	12.23	2.80	6.00	16.00
BAS-RR	15.96	3.83	6.00	20.00
BAS-D	11.81	2.14	7.00	15.00
MASQ-AD	55.54	13.56	31.00	81.00

Note. MASQ-AD = Mood and Anxiety Symptom Questionnaire - Anhedonic Depression, BAS = Behavioural Activation Scale, FS = Fun-Seeking, D = Drive, RR = Reward Responsiveness.

Table E2.

Correlation matrix of trait measures in Study One Happy Faces fMRI subset.

	BAS-FS	BAS-RR	BAS-D
BAS-RR	.48* [.12, .73]		
BAS-D	-.04 [-.42, .35]	.02 [-.37, .40]	
MASQ-AD	-.05 [-.42, .34]	-.16 [-.51, .24]	.18 [-.22, .53]

Note. MASQ-AD = Mood and Anxiety Symptom Questionnaire - Anhedonic Depression, BAS = Behavioural Activation Scale, FS = Fun-Seeking, D = Drive, RR = Reward Responsiveness. * $p < .05$ (two tailed).

Study Two Happy Faces Task Descriptive Statistics.

Due to some technical issues during data collection, the data from two participants were not included in the analysis. The descriptive statistics for the trait measures are present in Table E3 and the relationships between these trait measures are presented in Table E4. The descriptive statistics for the ESM measures are also displayed in Table E5 and the relationships between the trait measures and the ESM measures are provided in Table E6.

Table E3.

Descriptive statistics of the trait measures in Study Two Happy Faces fMRI subset

	Mean	<i>SD</i>	Min	Max
BAS-FS	10.04	2.85	5.00	16.00
BAS-RR	14.86	2.88	10.00	20.00
BAS-D	8.14	3.53	4.00	16.00
MASQ-AD	54.54	15.62	26.00	87.00
HPS	10.07	7.57	0.00	32.00

Note. MASQ-AD = Mood and Anxiety Symptom Questionnaire - Anhedonic Depression, BAS = Behavioural Activation Scale, FS = Fun-Seeking, D = Drive, RR = Reward Responsiveness, HPS = Hypomanic Personality scale.

Table E4.

Correlation matrix of trait measures in Study Two Happy Faces fMRI subset [95% confidence intervals].

	BAS-FS	BAS-RR	BAS-D	MASQ-AD
BAS-RR	.48** [.12, .73]			
BAS-D	.39* [.01, .67]	.66** [.37, .83]		
MASQ-AD	-.44* [-.70, .07]	-.26 [-.58, .14]	-.33 [-.63, .06]	
HPS	.18 [-.22, .53]	-.07 [-.44, .32]	-.07 [-.44, .32]	-.08 [-.45, .31]

Note. MASQ-AD = Mood and Anxiety Symptom Questionnaire - Anhedonic Depression, BAS = Behavioural Activation Scale, FS = Fun-Seeking, D = Drive, RR = Reward Responsiveness, HPS = Hypomanic Personality scale. * $p < .05$ (two tailed). ** $p < .001$ (two tailed).

Table E5.

Person-level descriptive statistics of ESM measures in Study Two Happy Faces fMRI subset

	Mean	<i>SD</i>	Min	Max
Positive Affect	3.90	1.00	1.40	6.43
ST Social Pleasure	4.26	1.18	2.40	6.67

Note. Positive affect is a composite score (range = 1-7). ST = Short-term.

Table E6.

Correlations between trait measures and ESM measures for Study Two Happy Faces fMRI subset [95% confidence intervals].

	BAS-FS	BAS-RR	BAS-D	MASQ-AD	HPS
Positive Affect	.41* [.03, .69]	-.06 [-.43, .33]	.09 [-.30, .46]	-.57** [-.78, -.24]	.25 [-.15, .58]
ST Social Pleasure	.02 [-.37, .40]	.01 [-.37, .39]	-.18 [-.53, .22]	.06 [-.33, .43]	.10 [-.29, .47]

Note. MASQ-AD = Mood and Anxiety Symptom Questionnaire - Anhedonic Depression, BAS = Behavioural Activation Scale, FS = Fun-Seeking, D = Drive, RR = Reward Responsiveness, HPS = Hypomanic Personality scale, ST = Short-term. ** $p < .001$ (two tailed). * $p < .05$ (two tailed).

Study Two Positive Affect Task Descriptive Statistics.

Due to some technical issues during data collection, the data from three participants were not included in the analysis. The descriptive statistics for the trait measures are present in Table E7 and the relationships between these trait measures are presented in Table E8. The descriptive statistics for the ESM measures are also displayed in Table E9 and the relationships between the trait measures and the ESM measures are provided in Table E10.

Table E7.

Descriptive statistics for the trait measures in Study Two Positive Affect fMRI subset.

	Mean	<i>SD</i>	Min	Max
BAS-FS	9.90	2.76	5.00	16.00
BAS-RR	14.87	2.79	10.00	20.00
BAS-D	8.07	3.42	4.00	16.00
MASQ-AD	54.53	16.03	23.00	87.00
HPS	10.92	8.60	0.00	32.00

Note. MASQ-AD = Mood and Anxiety Symptom Questionnaire - Anhedonic Depression, BAS = Behavioural Activation Scale, FS = Fun-Seeking, D = Drive, RR = Reward Responsiveness, HPS = Hypomanic Personality scale.

Table E8.

Correlation matrix of the trait measures in Study Two Positive Affect fMRI subset [95% confidence intervals].

	BAS-FS	BAS-RR	BAS-D	MASQ-AD
BAS-RR	.43* [.06, .70]			
BAS-D	.37* [-.02, .66]	.63** [.33, .82]		
MASQ-AD	-.30 [-.61, .09]	-.07 [-.44, .32]	-.13 [-.49, .27]	
HPS	-.26 [-.58, .14]	-.09 [-.46, .30]	-.36 [-.65, .03]	-.04 [-.42, .35]

Note. MASQ-AD = Mood and Anxiety Symptom Questionnaire - Anhedonic Depression, BAS = Behavioural Activation Scale, FS = Fun-Seeking, D = Drive, RR = Reward Responsiveness, HPS = Hypomanic Personality scale. ** $p < .001$ (two tailed). * $p < .05$ (two tailed).

Table E9.

Person-level descriptive statistics for ESM measures in Study Two Positive Affect fMRI subset.

	Mean	SD	Min	Max
Positive Affect	4.09	1.16	1.40	6.98
ST Achieve Pleasure	3.34	1.14	1.46	6.71
ST Social Pleasure	4.28	1.22	2.40	6.67

Note. Positive affect is a composite score (range = 1-7). ST = Short-term.

Table E10.

Correlations between trait measures and ESM measures for Study Two Positive Affect MRI subset [95% confidence intervals].

	BAS-FS	BAS-RR	BAS-D	MASQ-AD	HPS
Positive Affect	.35 [-.04, .65]	-.01 [-.39, .37]	.06 [-.33, .43]	-.55** [-.77, -.21]	.10 [-.29, .47]
ST Achieve Pleasure	.13 [-.27, .49]	-.11 [-.47, .29]	.10 [-.29, .47]	-.27 [-.59, .13]	-.12 [-.48, .28]
ST Social Pleasure	.09 [-.30, .46]	-.30 [-.61, .09]	-.03 [-.41, .36]	-.09 [-.46, .30]	.09 [-.30, .46]

Note. ST = MASQ-AD = Mood and Anxiety Symptom Questionnaire - Anhedonic Depression, BAS = Behavioural Activation Scale, FS = Fun-Seeking, D = Drive, RR = Reward Responsiveness, HPS = Hypomanic Personality scale, ST = Short-term. ** $p < .001$ (two tailed).

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Appendix F: Additional Measures and Analyses.

Study One Additional Measures.

Participants completed the full MASQ-62, which also includes the General Distress – Depression, General Distress – Anxiety, and Anxious Arousal subscales, alongside the Anhedonic Depression subscale used in the present research. The descriptive statistics for each of the additional subscales, as well as the aggregate of all of the subscales is provided in Table F1 for the full ESM sample and Table F2 for the fMRI subset.

Table F1.

Descriptive statistics for additional trait measures in Study One ESM sample.

	Mean	<i>SD</i>	Min	Max
MASQ-GDD	24.62	8.55	13.00	54.00
MASQ-GDA	19.88	5.49	12.00	36.00
MASQ-AA	23.95	5.63	17.00	46.00
MASQ-Total	124.70	25.97	80.00	209.00

Note. MASQ-GDD = Mood and Anxiety Symptom Questionnaire – General Distress Depression, MASQ-GDA = Mood and Anxiety Symptom Questionnaire – General Distress Anxiety, MASQ-AA = Mood and Anxiety Symptom Questionnaire – Anxious Arousal, MASQ-Total = Aggregate score of MASQ subscales.

Table F2.

Descriptive statistics for additional trait measures in Study One fMRI subset.

	Mean	<i>SD</i>	Min	Max
MASQ-GDD	23.39	5.91	17.00	38.00
MASQ-GDA	18.57	5.36	11.00	31.00
MASQ-AA	21.86	6.80	12.00	37.00
MASQ-Total	117.54	23.09	87.00	169.00

Note. MASQ-GDD = Mood and Anxiety Symptom Questionnaire – General Distress Depression, MASQ-GDA = Mood and Anxiety Symptom Questionnaire – General Distress Anxiety, MASQ-AA = Mood and Anxiety Symptom Questionnaire – Anxious Arousal, MASQ-Total = Aggregate score of MASQ subscales.

Study Two Additional Measures.

Participants completed the full MASQ-62, which also includes the General Distress – Depression, General Distress – Anxiety, and Anxious Arousal subscales, alongside the Anhedonic Depression subscale used in the present research. Participants also completed the Patient Health Questionnaire (PHQ-9; Kroenke et al., 2001) and the Chapman Physical (Chapman et al., 1976) and Social (Eckblad et al., 1982) Anhedonia scales. The descriptive statistics for each of the additional subscales, as well as the aggregate of the MASQ subscales is provided in Table F3 for the full ESM sample and Table F4 for the fMRI subset.

Table F3.

Descriptive statistics for additional trait measures in Study Two ESM sample.

	Mean	<i>SD</i>	Min	Max
MASQ-GDD	20.07	9.02	12.00	54.00
MASQ-GDA	16.64	7.17	10.00	41.00
MASQ-AA	22.22	7.46	7.00	54.00
MASQ-Total	112.60	29.64	65.00	219.00
PHQ-9	3.98	4.60	0.00	24.00
Physical Anhedonia	12.51	6.54	0.00	35.00
Social Anhedonia	22.53	5.26	0.00	30.00

Note. MASQ-GDD = Mood and Anxiety Symptom Questionnaire – General Distress Depression, MASQ-GDA = Mood and Anxiety Symptom Questionnaire – General Distress Anxiety, MASQ-AA = Mood and Anxiety Symptom Questionnaire – Anxious Arousal, MASQ-Total = Aggregate score of MASQ subscales, PHQ-9 – Patient Health Questionnaire.

Table F3.

Descriptive statistics for additional trait measures in Study Two fMRI Subset.

	Mean	<i>SD</i>	Min	Max
MASQ-GDD	20.94	9.97	12.00	49.00
MASQ-GDA	15.78	7.14	10.00	41.00
MASQ-AA	22.13	8.34	7.00	54.00
MASQ-Total	113.86	29.78	65.00	219.00
PHQ-9	3.91	3.96	0.00	15.00
Physical Anhedonia	13.06	6.88	3.00	35.00
Social Anhedonia	23.06	4.57	13.00	30.00

Note. MASQ-GDD = Mood and Anxiety Symptom Questionnaire – General Distress Depression, MASQ-GDA = Mood and Anxiety Symptom Questionnaire – General Distress Anxiety, MASQ-AA = Mood and Anxiety Symptom Questionnaire – Anxious Arousal, MASQ-Total = Aggregate score of MASQ subscales, PHQ-9 – Patient Health Questionnaire.

Study Two ESM Additional Analyses.

The present research focused on associations with the Anhedonic Depression subscale of the MASQ, in order to maintain consistency across studies. However, the community sample in Study also completed the Physical Anhedonia (Chapman et al., 1976) and Social Anhedonia (Eckblad et al., 1982). The following sections present the correlations between these anhedonia measures and the data from the ESM and fMRI studies.

The correlations between the BAS subscales, MASQ-AD, HPS, and anhedonia scales in the full ESM sample are presented in Table F4. Physical and Social Anhedonia were expected to negatively correlate with the BAS subscales and HPS, and positively correlate with MASQ-AD. However, these predictions were not supported.

Table F4.

Correlation matrix of the trait measures in Study Two ESM sample [95% confidence intervals].

	BAS-FS	BAS-RR	BAS-D	MASQ-AD	HPS	Physical Anhedonia
BAS-RR	.43* [.19, .62]					
BAS-D	.37* [.12, .58]	.63** [.44, .77]				
MASQ-AD	-.30 [-.52, -.04]	-.07 [-.33, .19]	-.13 [-.38, .14]			
HPS	-.26 [-.49, .00]	-.09 [-.34, .18]	-.36 [-.57, -.11]	-.04 [-.30, .22]		
Physical Anhedonia	-.07 [-.33, .19]	-.04 [-.30, .22]	-.11 [-.36, .16]	-.02 [-.28, .24]	-.05 [-.31, .21]	
Social Anhedonia	-.09 [-.34, .18]	.12 [-.15, .37]	-.05 [-.31, .21]	.07 [-.19, .33]	-.03 [-.29, .23]	.38** [.13, .58]

Note. MASQ-AD = Mood and Anxiety Symptom Questionnaire - Anhedonic Depression, BAS = Behavioural Activation Scale, FS = Fun-Seeking, D = Drive, RR = Reward Responsiveness, HPS = Hypomanic Personality scale. * $p < 0.05$ (two tailed).

The measures of Physical and Social Anhedonia were correlated with the ESM measures of PA and ST achievement and social goal pursuit, the results of which are

presented in Table F5. A negative correlation was expected between Physical Anhedonia PA, and achievement goal pursuit. A negative correlation was expected between Physical Anhedonia PA, and social goal pursuit. However, no significant associations emerged.

Table F5.

Between-person correlations between the additional trait measures and PA and ST achievement and social goal measures [95% confidence intervals].

	Physical Anhedonia	Social Anhedonia
Positive Affect	.00 [-.26, .26]	.08 [-.18, .33]
ST Achieve Progress	.05 [-.21, .31]	.11 [-.16, .36]
ST Achieve Pleasure	.03 [-.23, .29]	.08 [-.18, .33]
ST Achieve Effort	.08 [-.18, .33]	.15 [-.12, .40]
ST Social Progress	.03 [-.23, .29]	.05 [-.21, .31]
ST Social Pleasure	.07 [-.19, .33]	.03 [-.23, .29]
ST Social Effort	.03 [-.23, .29]	.14 [-.13, .39]

Note. ST = Short-term goal.

Study Two Card-Guessing Task Additional Analyses.

The relationships between the BAS subscales, MASQ-AD, HPS, and anhedonia scales in the fMRI sample are presented in Table F6. Physical and Social Anhedonia were expected to negatively correlate with the BAS subscales and HPS, and positively correlate with MASQ-AD. Limited support was provided for these hypotheses, with a negative correlation emerging between BAS-FS and Social Anhedonia, and positive correlations between MASQ-AD and Social and Physical Anhedonia.

Table F6.

Correlation matrix of the trait measures in Study Two Card-guessing MRI subset [95% confidence intervals].

	BAS-FS	BAS-RR	BAS-D	MASQ-AD	HPS	Physical Anhedonia
BAS-RR	.43* [.06, .70]					
BAS-D	.36 [-.03, .65]	.63** [.33, .82]				
MASQ-AD	-.42* [-.69, -.04]	-.26 [-.58, .14]	-.37* [-.66, .02]			
HPS	.18 [-.53, .22]	-.09 [-.46, .30]	-.12 [-.48, .28]	-.04 [-.42, .35]		
Physical Anhedonia	-.30 [-.61, .09]	-.25 [-.58, .15]	-.36 [-.65, .03]	.54** [.20, .76]	.12 [-.28, .48]	
Social Anhedonia	-.39* [-.67, .01]	-.05 [-.42, .34]	-.23 [-.56, .17]	.64** [.34, .82]	-.35 [-.65, .04]	.21 [-.19, .55]

Note. MASQ-AD = Mood and Anxiety Symptom Questionnaire - Anhedonic Depression, BAS = Behavioural Activation Scale, FS = Fun-Seeking, D = Drive, RR = Reward Responsiveness, HPS = Hypomanic Personality scale. ** $p < .001$ (two tailed). * $p < .05$ (two tailed).

Spearman's rho analyses were conducted to explore the potential relationships between the measures of Physical and Social Anhedonia and activation of the caudate and NAcc associated with the monetary reward anticipation > baseline (Table F7) and monetary reward receipt > baseline (Table F8) contrasts. Negative correlations were expected between the measure of Physical Anhedonia and ROI activation during both reward anticipation and

reward receipt, but the data did not support these predictions, although the relationship with left NAcc activation during reward receipt approached significance ($p = .055$).

Table F7.

Correlations between additional trait measures and ROI activation for reward anticipation > baseline contrast [95% confidence intervals].

	Physical Anhedonia	Social Anhedonia
Left Caudate	.01 [-.37, .39]	.31 [-.08, .62]
Right Caudate	-.03 [-.41, .36]	.26 [-.14, .58]
Left NAcc	.00 [-.38, .38]	-.36 [-.65, .03]
Right NAcc	-.08 [-.45, .31]	.07 [-.32, .44]

Table F8.

Correlations between additional trait measures and ROI activation for reward receipt > baseline contrast [95% confidence intervals].

	Physical Anhedonia	Social Anhedonia
Left Caudate	-.12 [-.48, .28]	-.02 [-.40, .37]
Right Caudate	-.18 [-.53, .22]	-.06 [-.43, .33]
Left NAcc	.11 [-.29, .47]	.36 [-.03, .65]
Right NAcc	.21 [-.46, .30]	.56** [.23, .78]

** $p < .01$ (two tailed).

Study Two Happy Faces Task Additional Analyses.

The relationships between the BAS subscales, MASQ-AD, HPS, and anhedonia scales in the full ESM sample are presented in Table F9. Physical and Social Anhedonia were expected to negatively correlate with the BAS subscales and HPS, and positively correlate with MASQ-AD. These predictions were largely unsupported, with the exception of positive correlation between MASQ-AD and Physical Anhedonia.

Table F9.

Correlation matrix of the trait measures in Study Two Happy Faces MRI subset [95% confidence intervals]

	BAS-FS	BAS-RR	BAS-D	MASQ-AD	HPS	Physical Anhedonia
BAS-RR	.48** [.12, .73]					
BAS-D	.39* [.01, .67]	.66** [.37, .83]				
MASQ-AD	-.44* [-.70, .07]	-.26 [-.58, .14]	-.33 [-.63, .06]			
HPS	.18 [-.22, .53]	-.07 [-.44, .32]	-.07 [-.44, .32]	-.08 [-.45, .31]		
Physical Anhedonia	-.26 [-.58, .14]	-.35 [-.65, .04]	-.10 [-.47, .29]	.40* [.02, .68]	.21 [-.19, .55]	
Social Anhedonia	.17 [-.23, .52]	.22 [-.18, .56]	.26 [-.14, .58]	.36 [-.03, .65]	-.04 [-.42, .35]	.24 [-.16, .57]

Note. MASQ-AD = Mood and Anxiety Symptom Questionnaire - Anhedonic Depression, BAS = Behavioural Activation Scale, FS = Fun-Seeking, D = Drive, RR = Reward Responsiveness, HPS = Hypomanic Personality scale. * $p < .05$ (two tailed).

The measures of Physical and Social Anhedonia were correlated with activation of the caudate, NAcc, and amygdala associated with the happy facial expressions > neutral facial expressions contrast. Negative correlations were expected between Social Anhedonia and ROI activation in response to the happy facial expressions, a prediction that was largely supported. The results are presented in Table F10. Negative correlations were observed between Social Anhedonia and activation of the left and right caudate, as well as the right

NAcc. The negative association between Social Anhedonia and left NAcc activation approached significance ($p = .055$).

Table F10.

Correlations between additional trait measures and ROI activation for happy facial expressions > neutral facial expressions contrast [95% confidence intervals].

	Physical Anhedonia	Social Anhedonia
Left Caudate	.01 [-.37, .39]	-.49** [-.74, -.13]
Right Caudate	-.28 [-.60, .12]	-.48** [-.73, -.12]
Left NAcc	-.29 [-.61, .10]	-.37 [-.66, .02]
Right NAcc	.11 [-.29, .47]	-.58** [-.79, -.25]
Left Amygdala	.16 [-.24, .51]	-.21 [-.55, .19]
Right Amygdala	.05 [-.34, .42]	-.33 [-.63, .06]

** $p < .001$ (two tailed).

Scatter plots (Figure F2) were generated to examine the relationships between Social Anhedonia and activation of the left and right caudate, and the right NAcc. For the left caudate and right NAcc, the relationship appears to be driven by those high in Social Anhedonia exhibiting relatively more deactivation in response to the happy facial expressions. For the right caudate, this relationship is more evenly split between activation and deactivation.

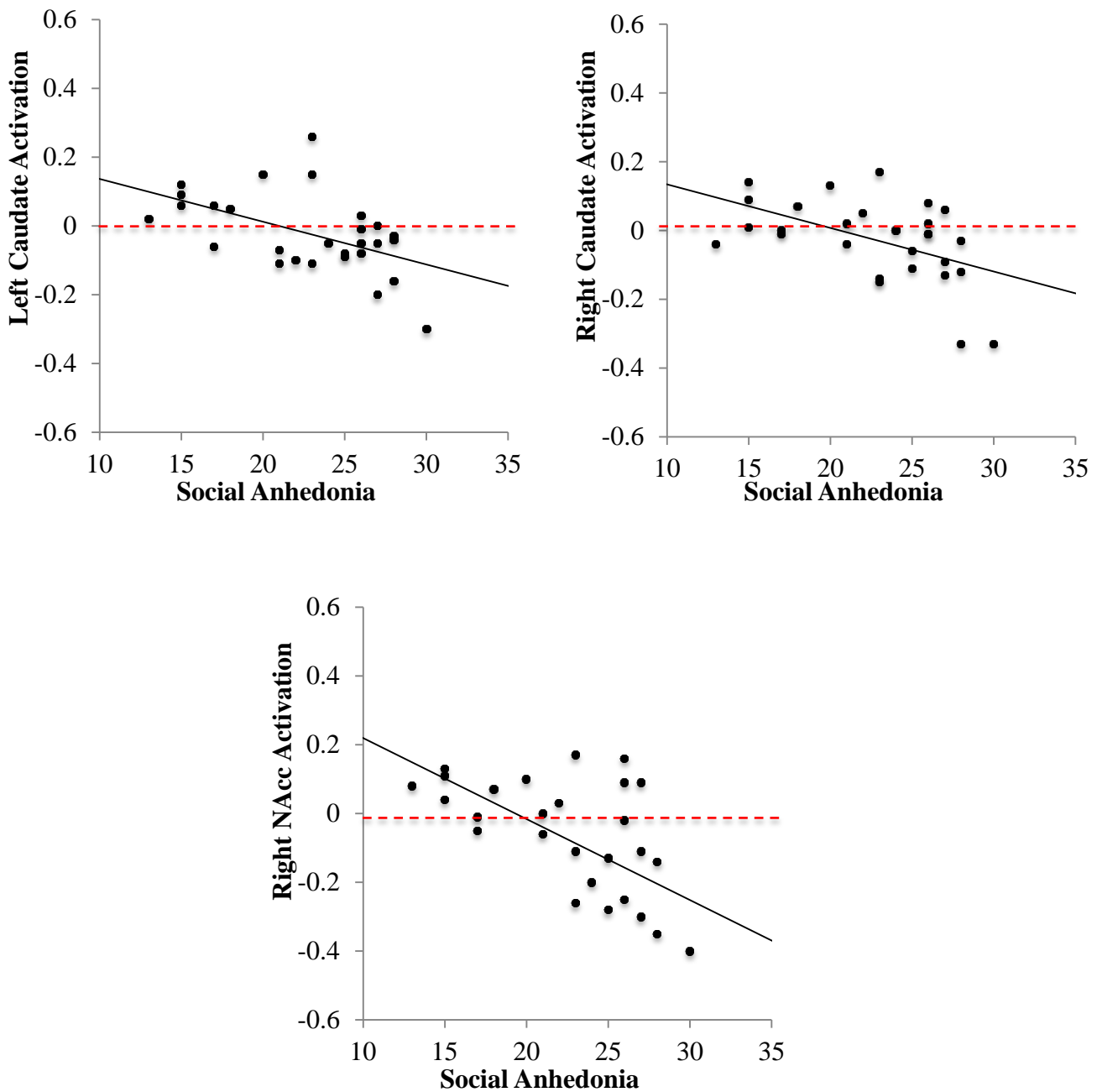


Figure F1.

Relationships between Social Anhedonia and activation of left and right caudate, and right NAcc for happy facial expressions > neutral facial expressions contrast.

Study Two Positive Affect Task Additional Analyses.

The relationships between the BAS subscales, MASQ-AD, HPS, and anhedonia scales in the full ESM sample are presented in Table F11. Physical and Social Anhedonia were expected to negatively correlate with the BAS subscales and HPS, and positively correlate with MASQ-AD. No support was provided for these predictions.

Table F11.

Correlation matrix of the trait measures in Study Two MRI subset [95% confidence intervals].

	BAS-FS	BAS-RR	BAS-D	MASQ-AD	HPS	Physical Anhedonia
BAS-RR	.43* [.06, .70]					
BAS-D	.37* [-.02, .66]	.63** [.33, .82]				
MASQ-AD	-.30 [-.61, .09]	-.07 [-.44, .32]	-.13 [-.49, .27]			
HPS	-.26 [-.58, .14]	-.09 [-.46, .30]	-.36 [-.65, .03]	-.04 [-.42, .35]		
Physical Anhedonia	.14 [-.26, .50]	-.15 [-.50, .25]	-.15 [-.50, .25]	.24 [-.16, .57]	-.01 [-.39, .37]	
Social Anhedonia	-.05 [-.42, .34]	-.13 [-.49, .27]	-.15 [-.50, .25]	.18 [-.53, .22]	.12 [-.28, .48]	.24 [-.16, .57]

Note. MASQ-AD = Mood and Anxiety Symptom Questionnaire - Anhedonic Depression, BAS = Behavioural Activation Scale, FS = Fun-Seeking, D = Drive, RR = Reward Responsiveness, HPS = Hypomanic Personality scale. ** $p < .001$ (two tailed). * $p < .05$ (two tailed).

The measures of Physical and Social Anhedonia were correlated with activation of the caudate, NAcc, and amygdala associated with the contentment images > neutral images (Table F12) and the excitement images > neutral images (Table F13) contrasts. Negative correlations were expected between Social Anhedonia and ROI activation in response to the contentment images, and between Physical Anhedonia and ROI activation in response to both contentment and excitement images. Providing limited support for these hypotheses, positive correlations emerged between the measure of Physical Anhedonia and the activation of the left amygdala associated with viewing both the contentment and the excitement images. No support was provided for the prediction that Social Anhedonia would correlate with ROI activation associated with viewing contentment images. Indeed, contrary to hypotheses, positive correlations emerged between Social Anhedonia and left NAcc activation when viewing the contentment images.

Table F12.

Correlations between additional trait measures and ROI activation for contentment images > neutral images contrast [95% confidence intervals].

	Physical Anhedonia	Social Anhedonia
Left Caudate	.04 [-.35, .42]	.30 [-.09, .61]
Right Caudate	-.03 [-.41, .36]	-.00 [-.38, .38]
Left NAcc	-.32 [-.63, .07]	.49* [.13, .74]
Right NAcc	.17 [-.23, .52]	.14 [-.26, .50]
Left Amygdala	-.65** [-.83, .36]	-.07 [-.44, .32]
Right Amygdala	-.17 [-.52, .23]	.23 [-.17, .56]

** $p < .001$ (two tailed). * $p < .05$ (two tailed).

Table F13.

Correlations between additional trait measures and ROI activation for excitement images > neutral images contrast [95% confidence intervals].

	Physical Anhedonia	Social Anhedonia
Left Caudate	-.05 [-.42, .34]	.03 [-.36, .41]
Right Caudate	-.23 [-.56, .17]	-.26 [-.58, .14]
Left NAcc	-.28 [-.60, .12]	-.14 [-.50, .26]
Right NAcc	.02 [-.37, .40]	-.14 [-.50, .26]
Left Amygdala	-.54** [-.76, -.20]	.25 [-.15, .58]
Right Amygdala	-.23 [-.56, .17]	-.27 [-.59, .13]

** $p < .001$ (two tailed).

Scatter plots were generated to explore the relationships between Physical Anhedonia and left amygdala activation associated with the contentment images > neutral images contrast (Figure F2) and for the excitement images > neutral images contrast (Figure F3). The relationships between physical anhedonia and left amygdala activation were similar for the contentment and excitement images contrast, with a relatively even split between activation and deactivation.

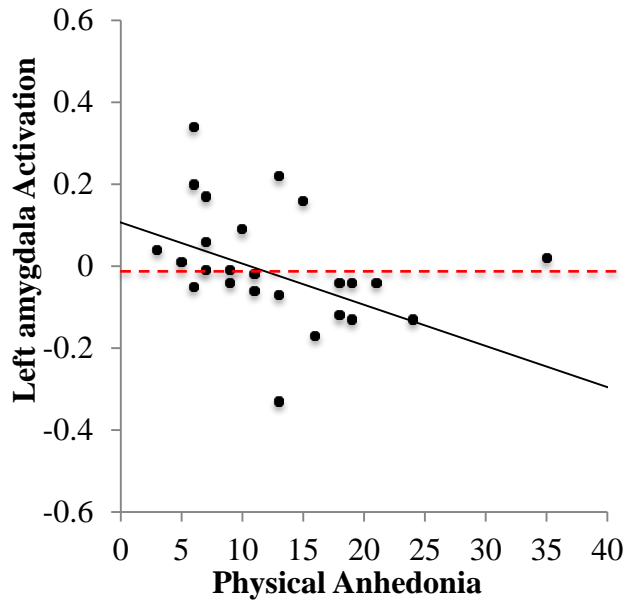


Figure F2.

Relationship between Physical Anhedonia and activation of the left amygdala for contentment images > neutral images contrast.

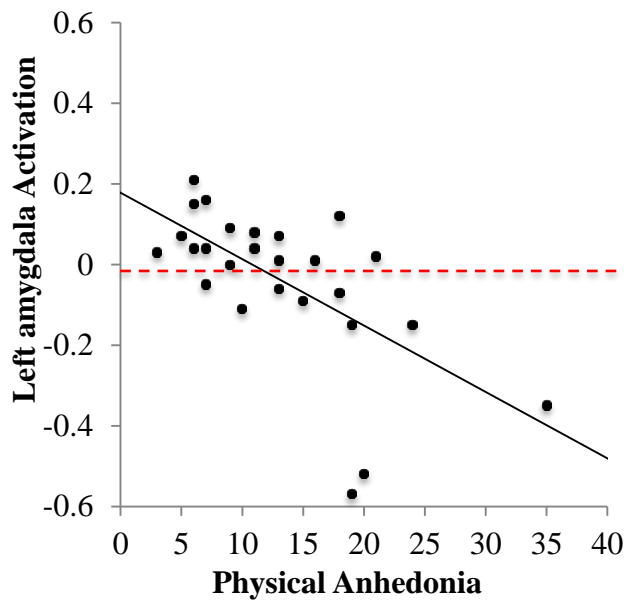


Figure F3.

Relationship between Physical Anhedonia and activation of the left amygdala for excitement images > neutral images contrast.

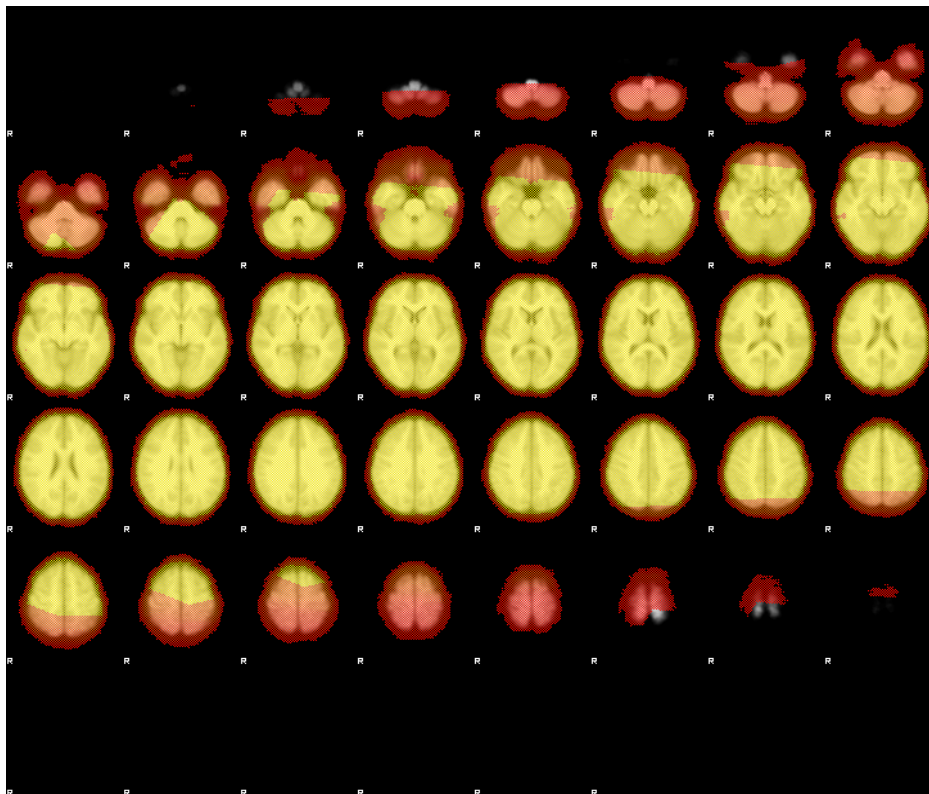
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Appendix G: Supplementary MRI Information.

Study One: Card-Guessing Paradigm.

Figure G1 illustrates the sum of all input masks after transformation into standard space, demonstrating that the relevant brain regions of interest were covered by the scanner.

Furthermore, Figures G2 to G9 provide examples of the time series plots associated with each ROI, for each contrast. These raw data plots are taken from the peak voxel within each ROI from three random participants. For the time series plots (Figures G2 to G9), the red line indicates the raw signal, the green line indicates the specified model, and the blue line indicates the model fit. Taken together, Figures G1 to G9 provide evidence that the signal was detected in the relevant ROIs.



1 participant  27 participants

Figure G1.

Sum of all input masks after transformation to standard space.

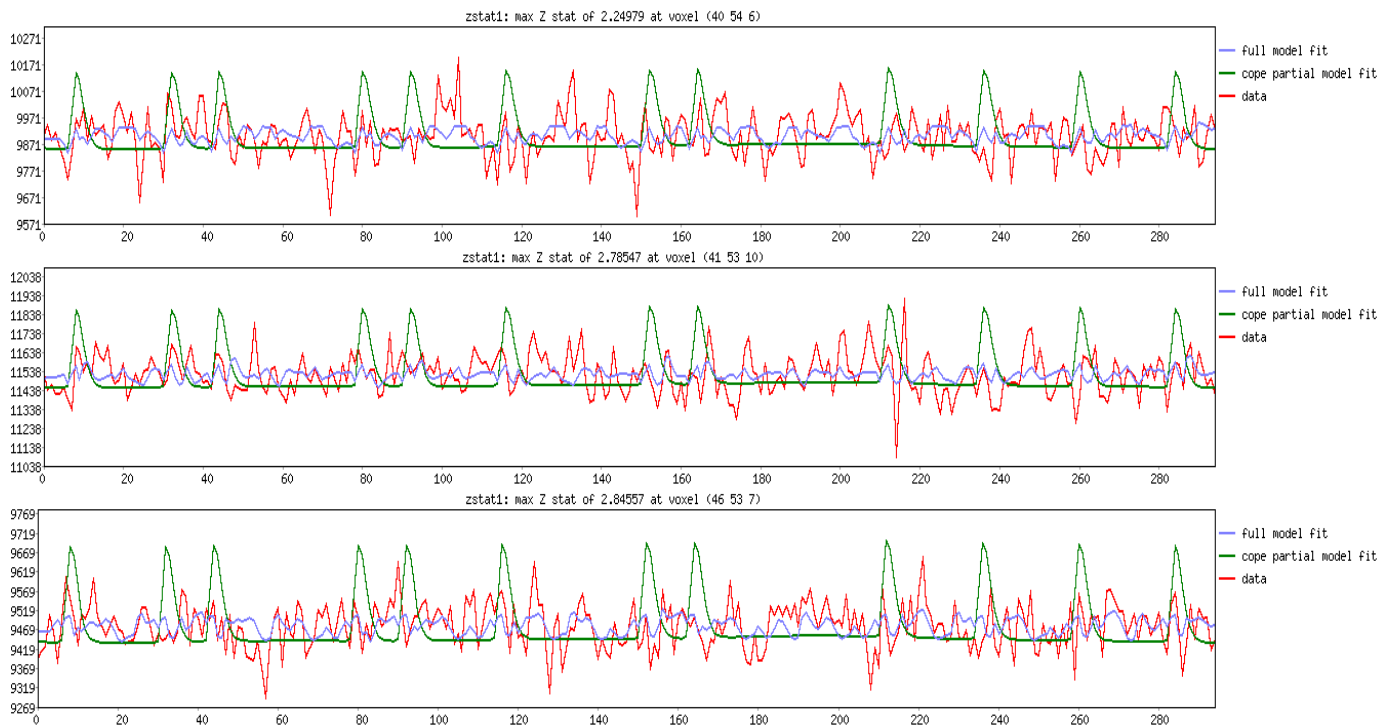


Figure G2.

Examples of Mean Time Series Plot for the left NAcc, for the reward anticipation > baseline contrast.

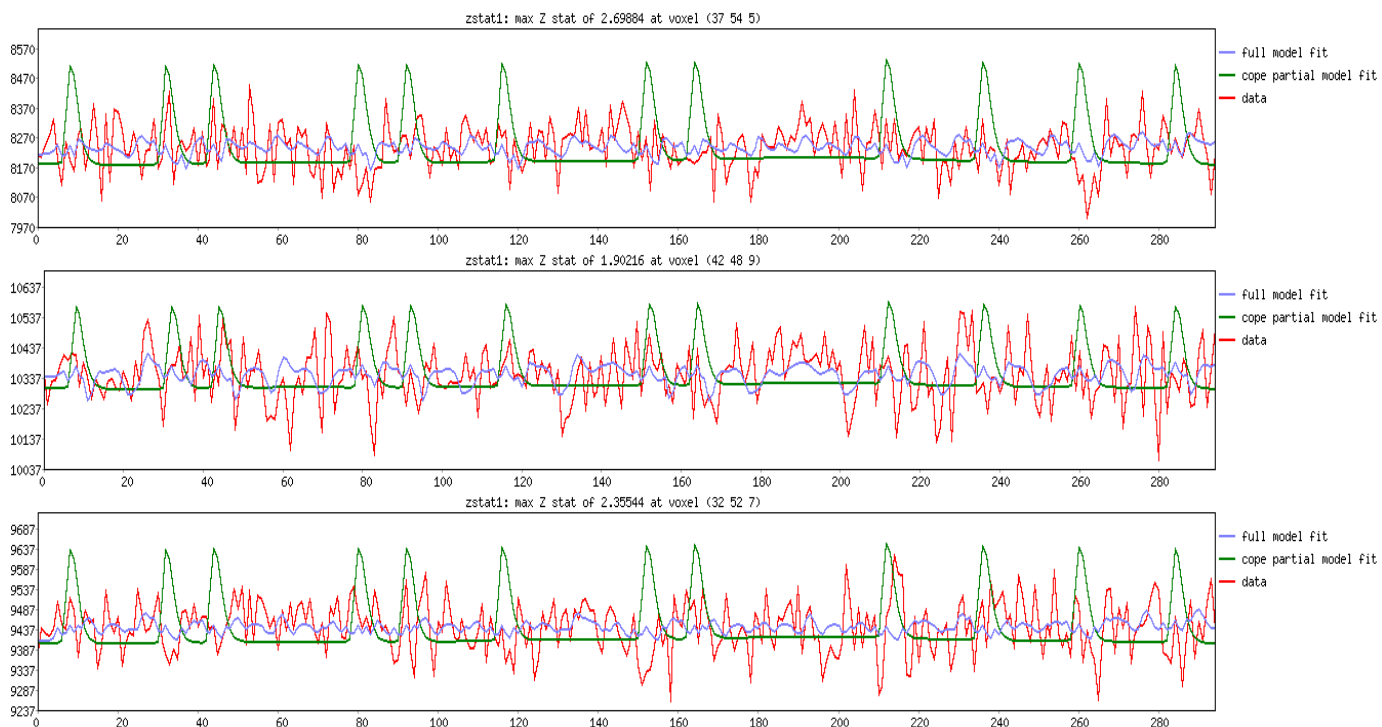


Figure G3

Examples of Mean Time Series Plot for the right NAcc, for the reward anticipation > reward baseline contrast.

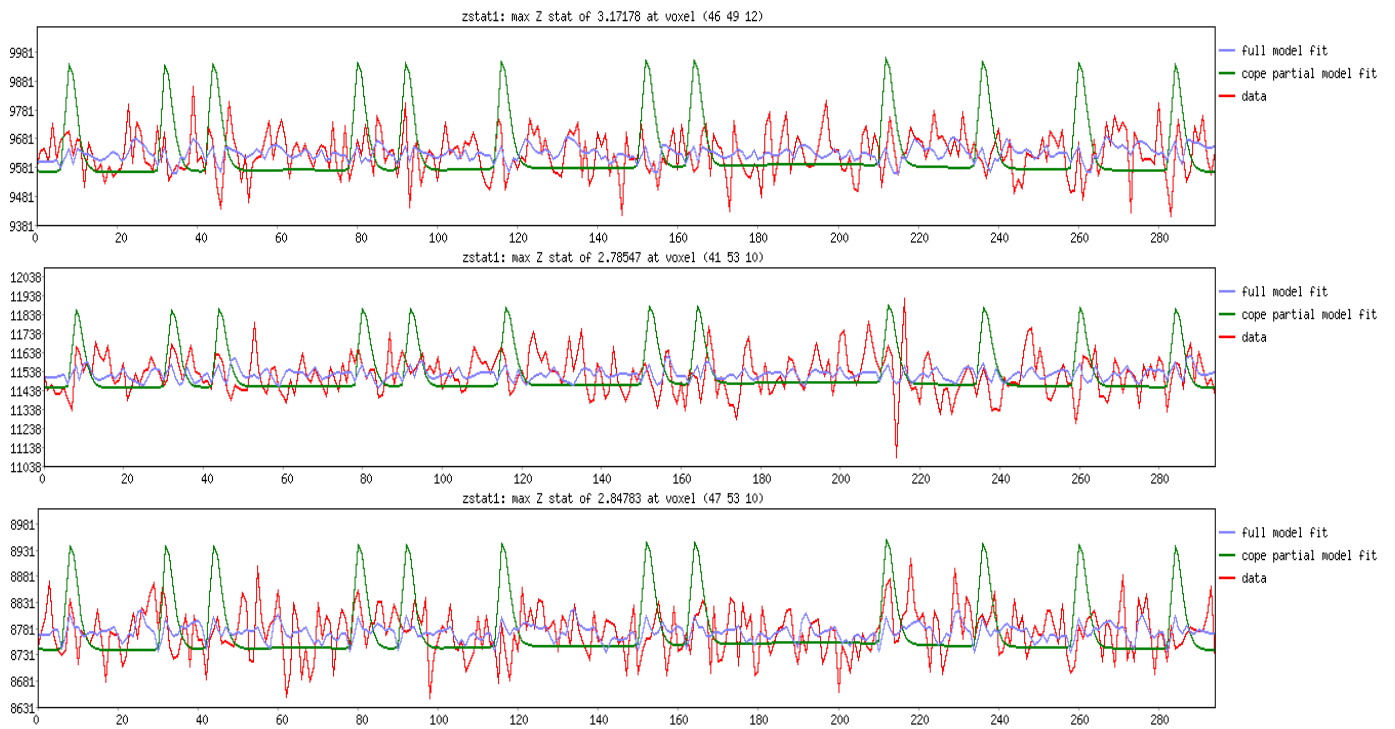


Figure G4.

Examples of Mean Time Series Plot for the left caudate, for the reward anticipation > baseline contrast.

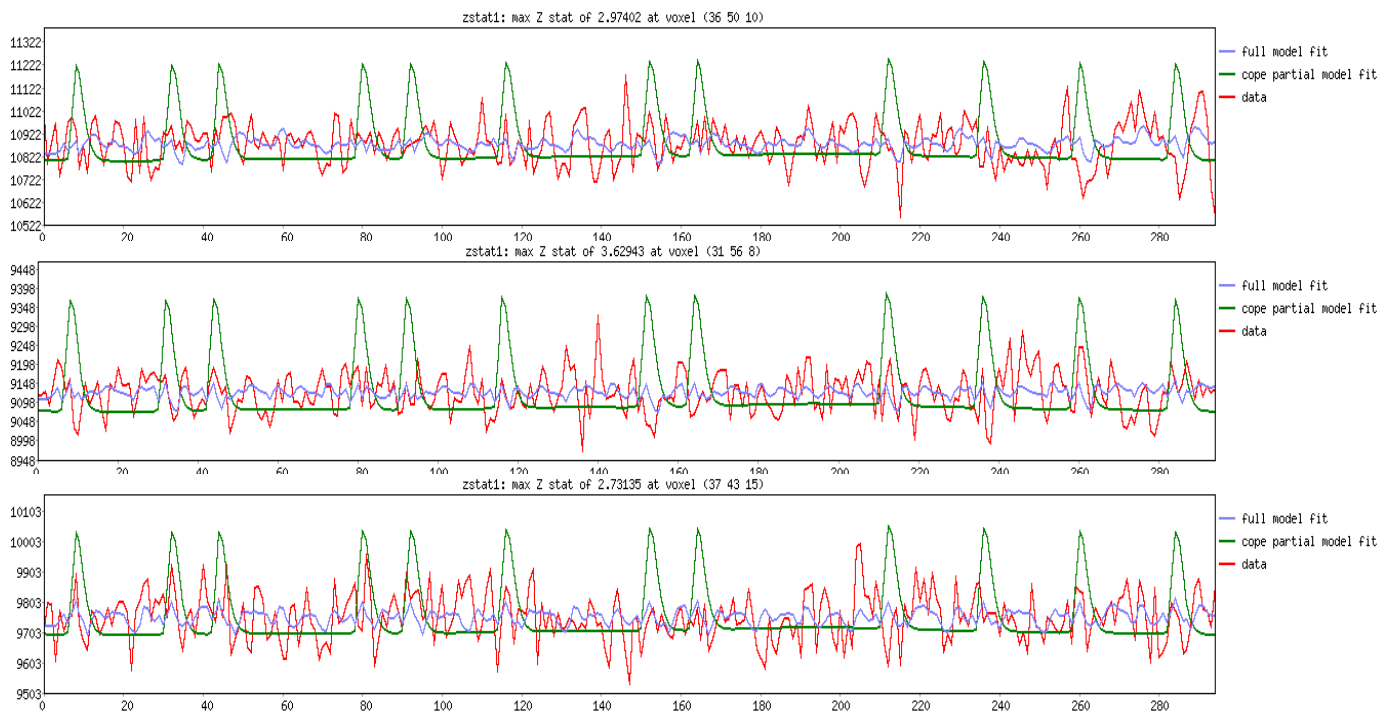


Figure G5.

Examples of Mean Time Series Plot for the right caudate, for the reward anticipation > baseline contrast.

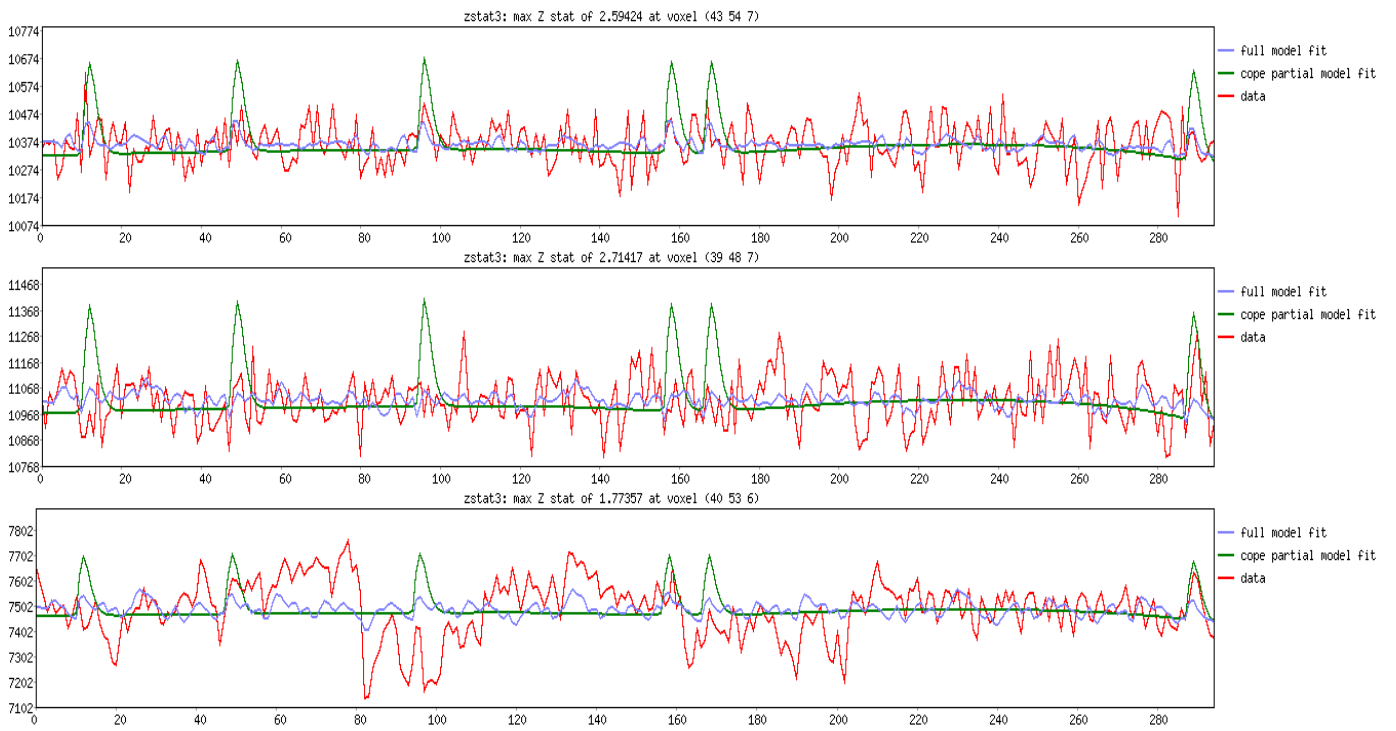


Figure G6.

Examples of Mean Time Series Plot for the left NAcc, for the reward outcome > baseline contrast.

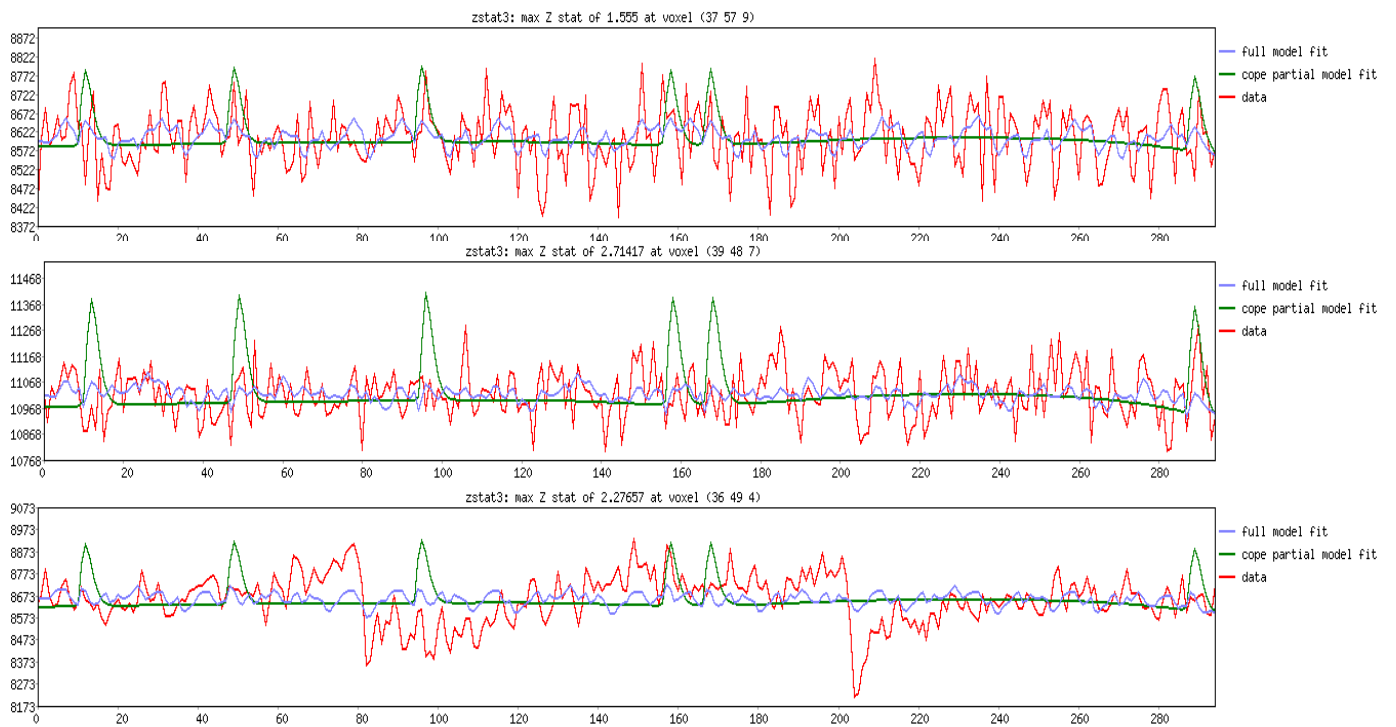


Figure G7.

Examples of Mean Time Series Plot for the right NAcc, for the reward outcome > baseline contrast.

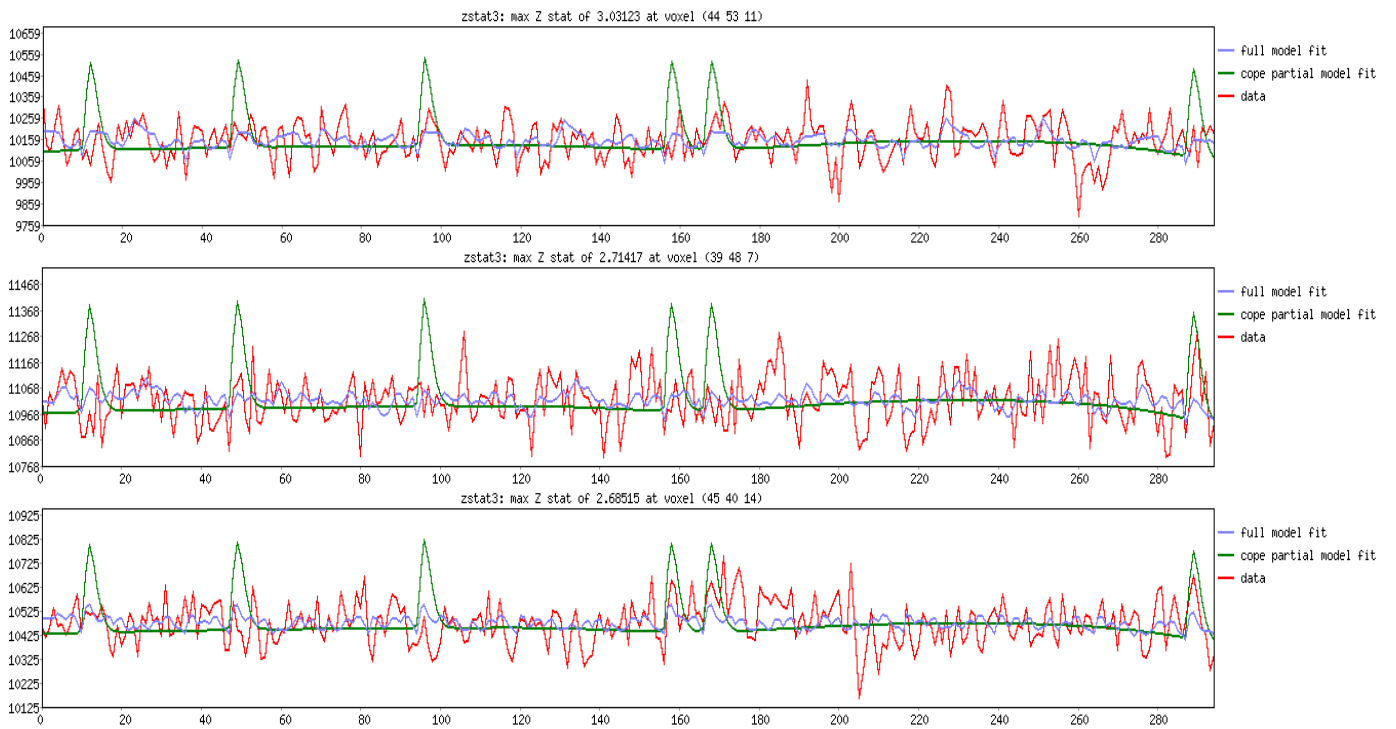


Figure G8.

Examples of Mean Time Series Plot for the left caudate, for the reward outcome > baseline contrast.

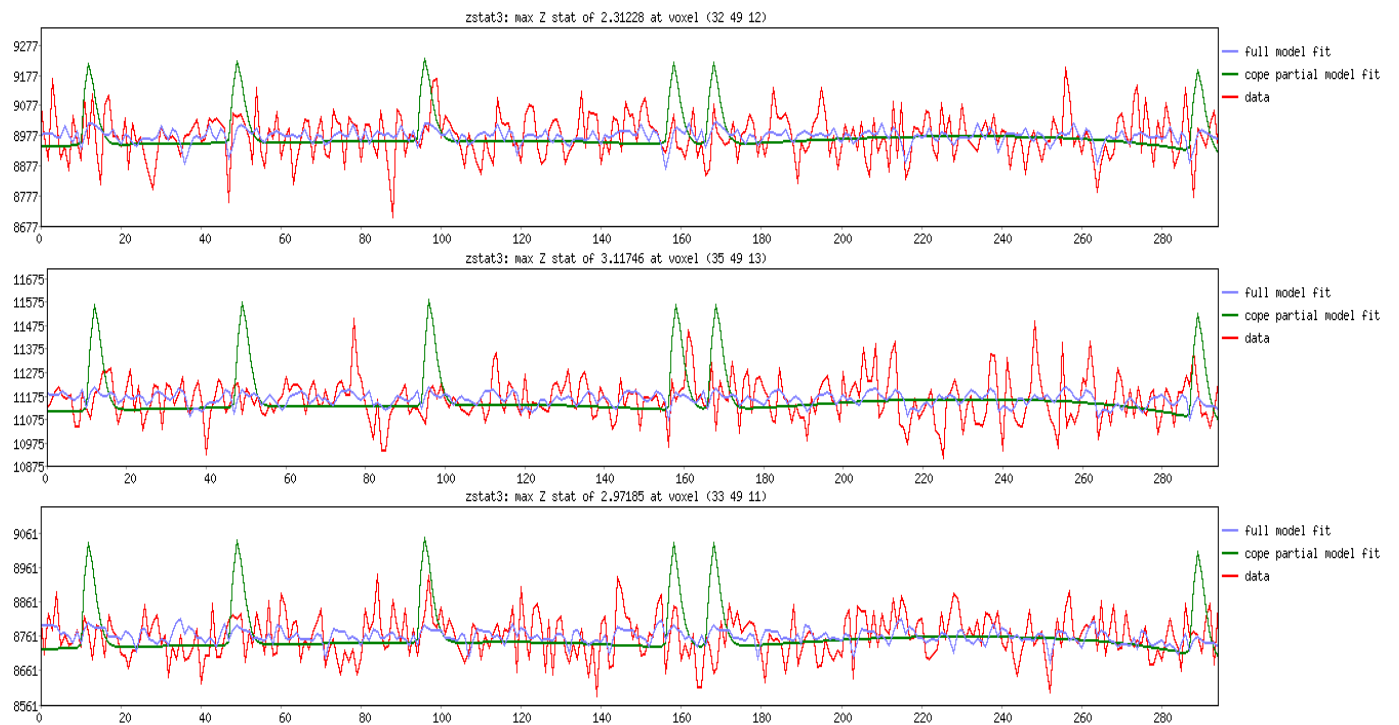


Figure G9.

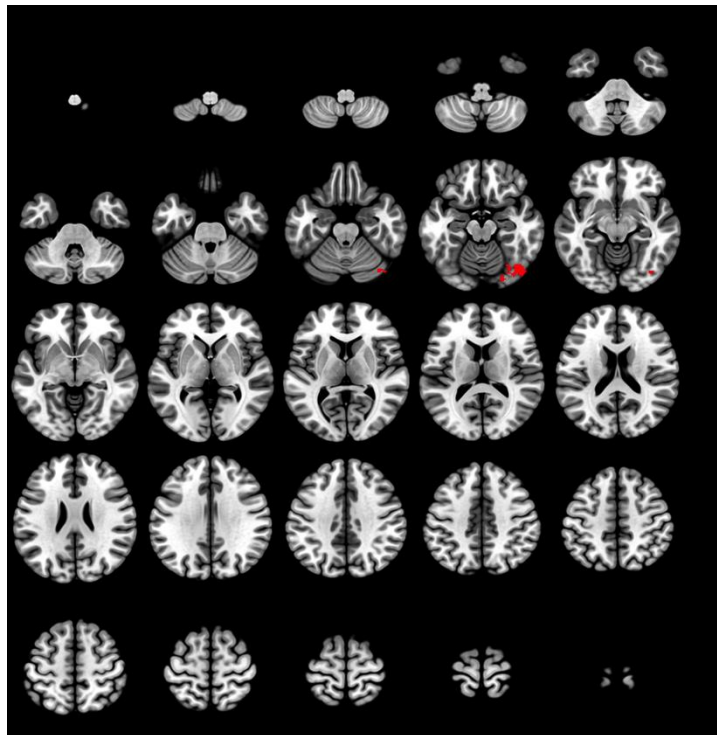
Examples of Mean Time Series Plot for the right caudate, for the reward outcome > baseline contrast.

Table G1.

Coordinates for significant clusters of activation associated with monetary reward anticipation > baseline contrast.

Cluster	Voxels	Z-Max	Z-Max X (mm)	Z-Max Y (mm)	Z-Max Z (mm)	Region
1	278	3.2	44	-76	-20	Lateral Occipital Cortex

Note. Reported clusters survived thresholding using clusters determined by $Z > 2.3$ and a (corrected) cluster significance threshold of $p = .05$. Anatomical regions as defined by the Harvard-Oxford Cortical and Subcortical Structural Atlases.



Note. Statistic images were thresholded using clusters determined by $Z > 2.3$ and a (corrected) cluster significance threshold of $p = .05$.

Figure G10.

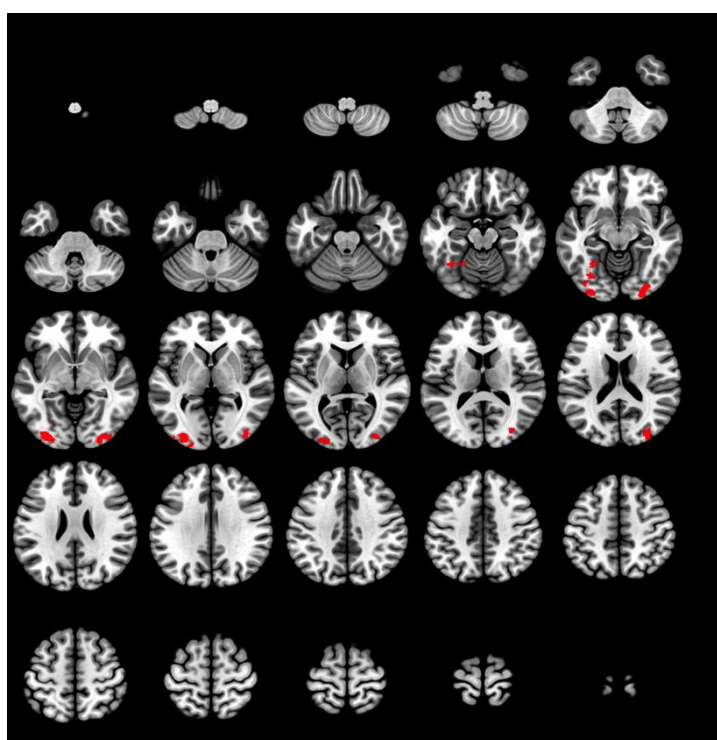
Group map, monetary reward anticipation > baseline contrast.

Table G2.

Coordinates for significant clusters of activation associated with monetary reward receipt > baseline contrast.

Cluster	Voxels	Z-Max	Z-Max X (mm)	Z-Max Y (mm)	Z-Max Z (mm)	Region
1	536	3.69	-30	-92	0	Occipital Pole
2	435	3.57	26	-96	-10	Occipital Pole

Note. Reported clusters survived thresholding using clusters determined by $Z > 2.3$ and a (corrected) cluster significance threshold of $p = .05$. Anatomical regions as defined by the Harvard-Oxford Cortical and Subcortical Structural Atlases.



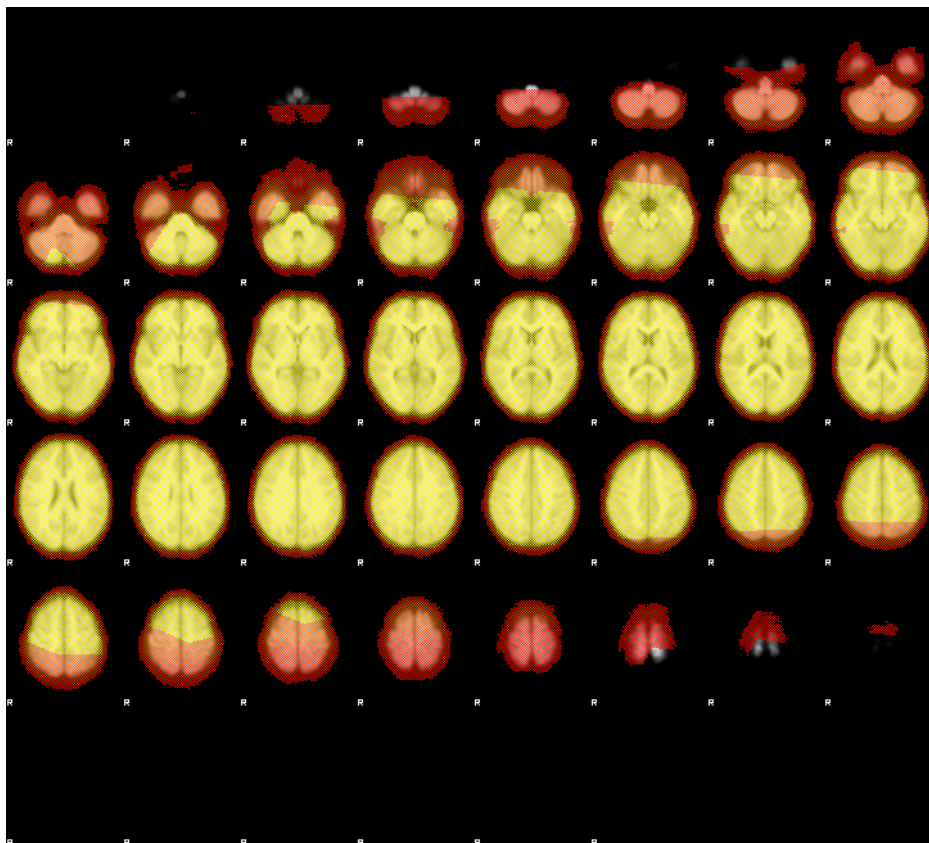
Note. Statistic images were thresholded using clusters determined by $Z > 2.3$ and a (corrected) cluster significance threshold of $p = .05$.

Figure G11.

Group map, monetary reward receipt > baseline contrast.

Study Two: Card-Guessing Paradigm.

Figure G12 illustrates the sum of all input masks after transformation into standard space, demonstrating that the relevant brain regions of interest were covered by the scanner. Furthermore, Figures G13 to G20 provide examples of the time series plots associated with each ROI, for each contrast. These raw data plots are taken from the peak voxel within each ROI from two random participants. For the time series plots (Figures G13 to G20), the red line indicates the raw signal, the green line indicates the specified model, and the blue line indicates the model fit. Taken together, Figures G12 to G20 provide evidence that the signal was detected in the relevant ROIs.



1 participant  29 participants

Figure G12.

Sum of all input masks after transformation to standard space.

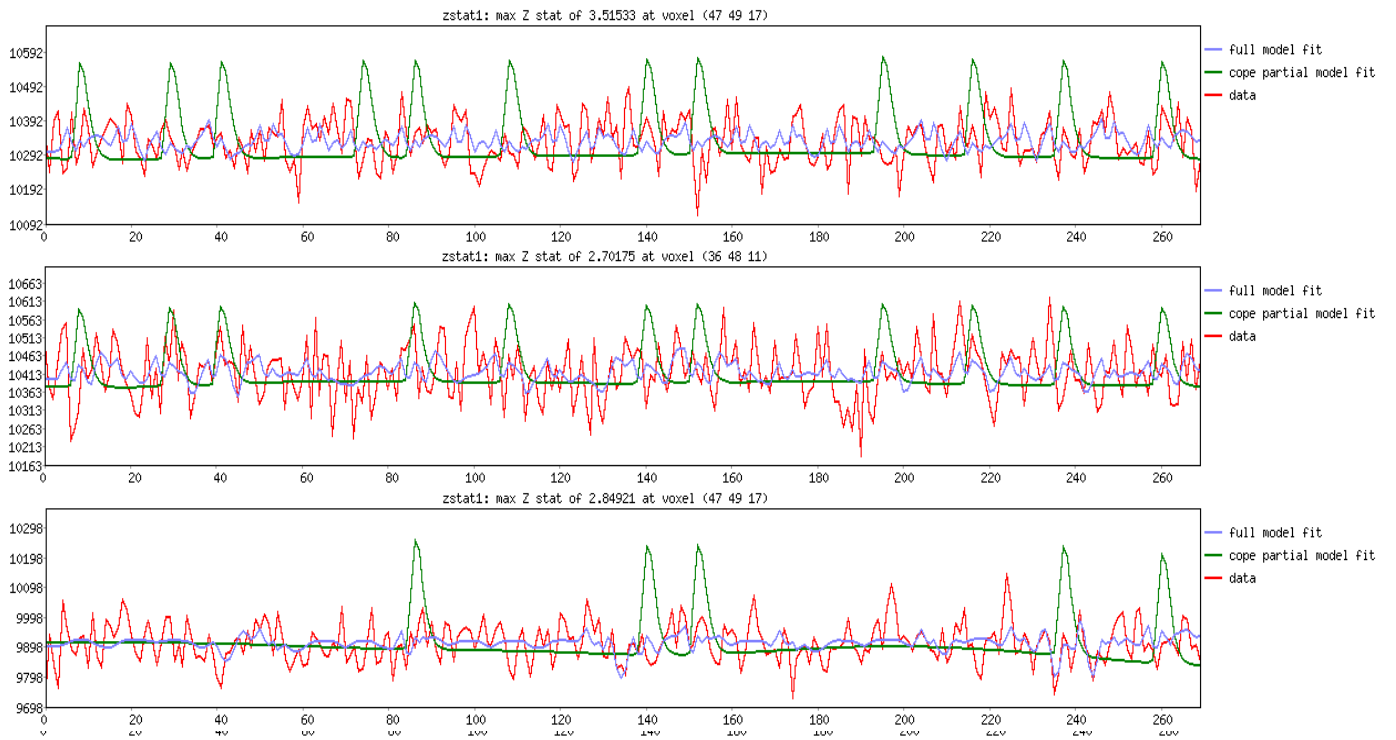


Figure G13.

Examples of Mean Time Series Plot for the left NAcc, for the reward anticipation > baseline contrast.

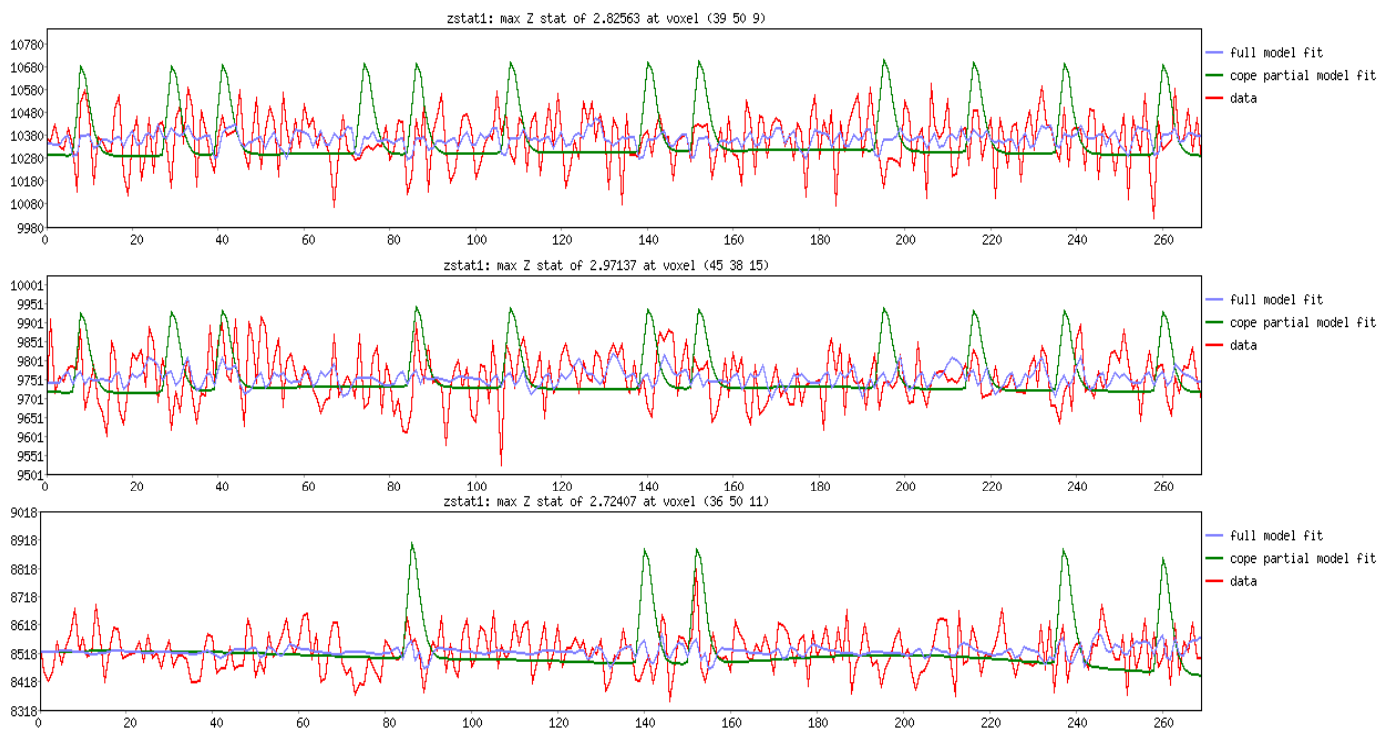


Figure G14.

Examples of Mean Time Series Plot for the right NAcc, for the reward anticipation > baseline contrast.

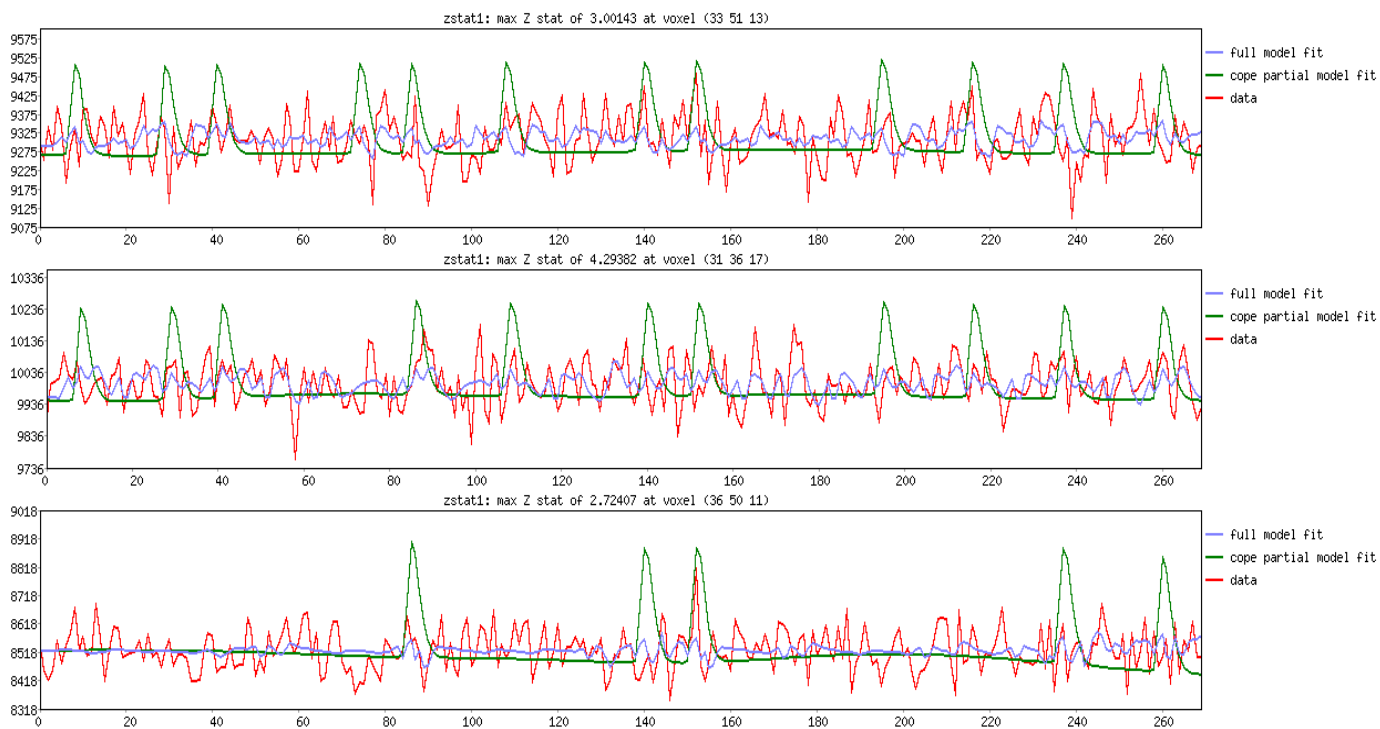


Figure G15.

Examples of Mean Time Series Plot for the right caudate, for the reward anticipation > baseline contrast.

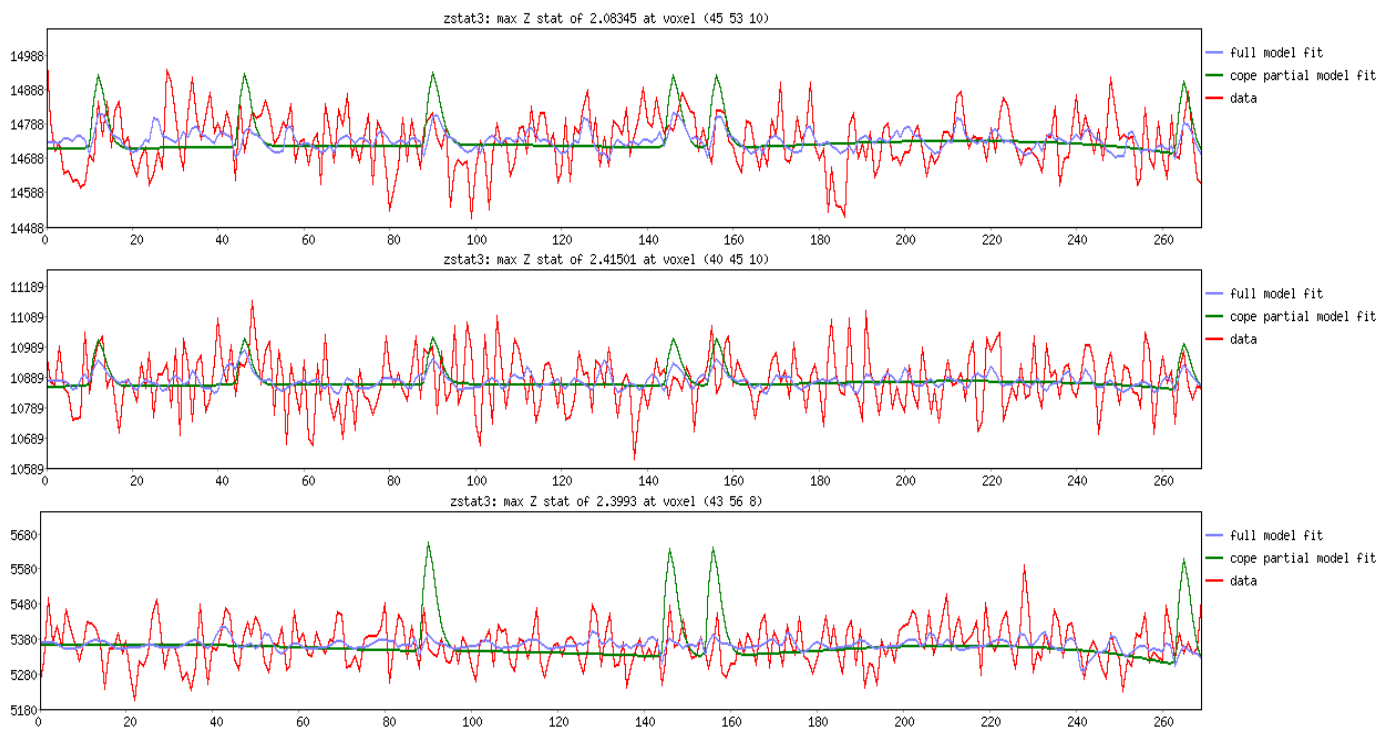


Figure G16.

Examples of Mean Time Series Plot for the right caudate, for the reward anticipation > baseline contrast.

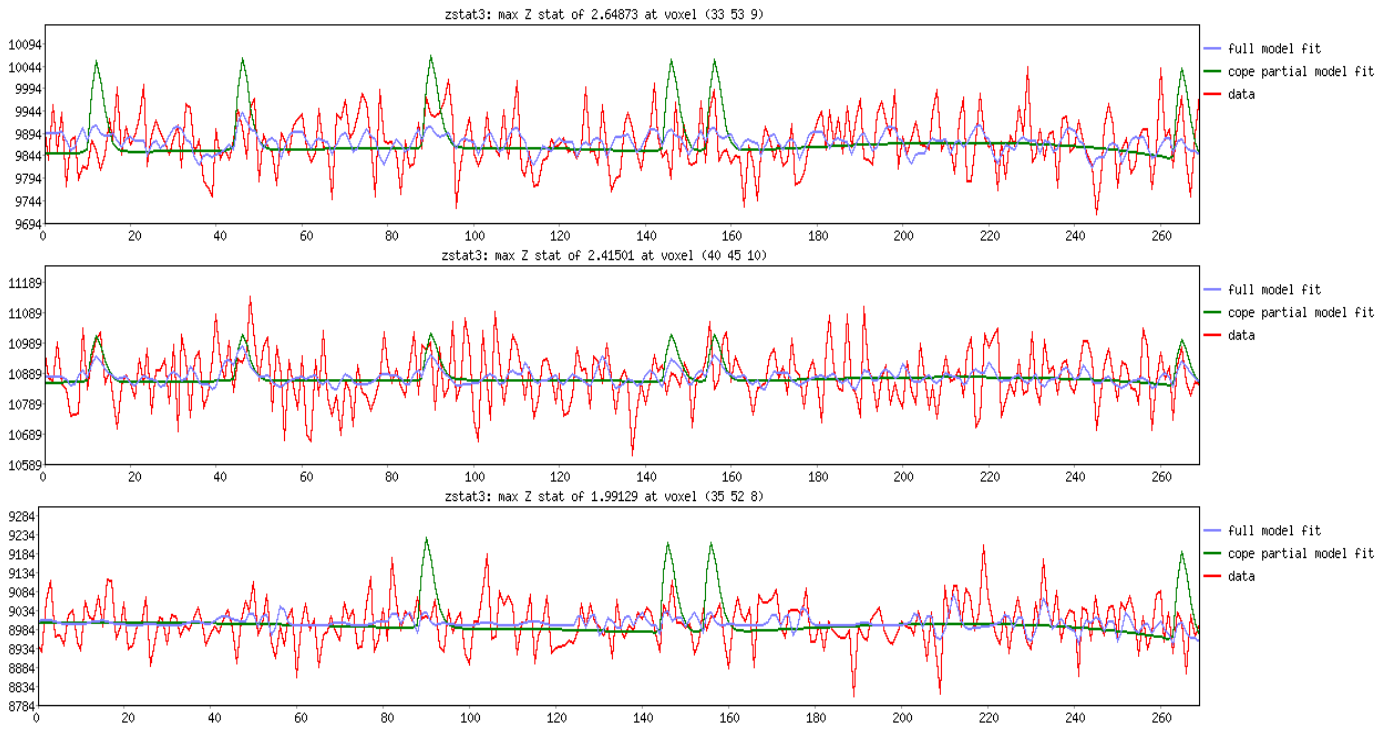


Figure G17.

Examples of Mean Time Series Plot for the left NAcc, for the reward outcome > baseline contrast.

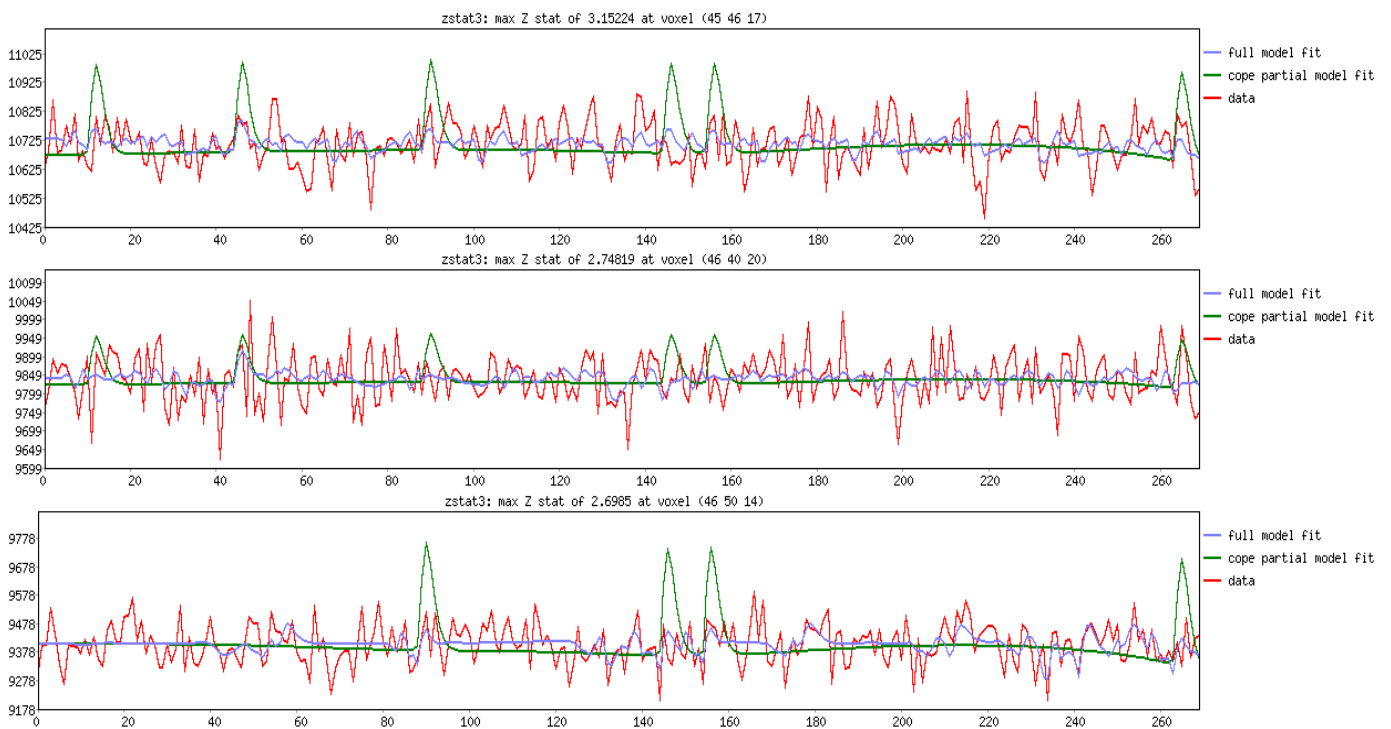


Figure G18.

Examples of Mean Time Series Plot for the right NAcc, for the reward outcome > baseline contrast.

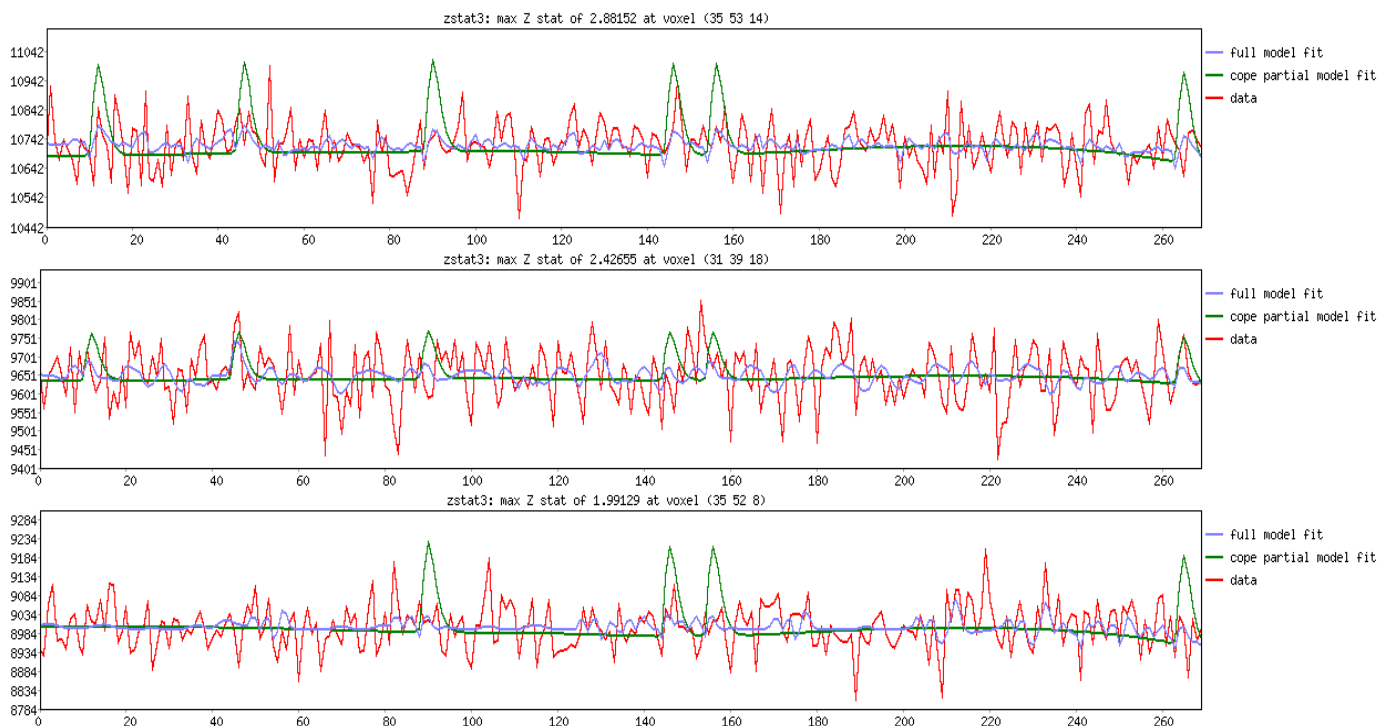


Figure G19.

Examples of Mean Time Series Plot for the left caudate, for the reward outcome > baseline contrast.

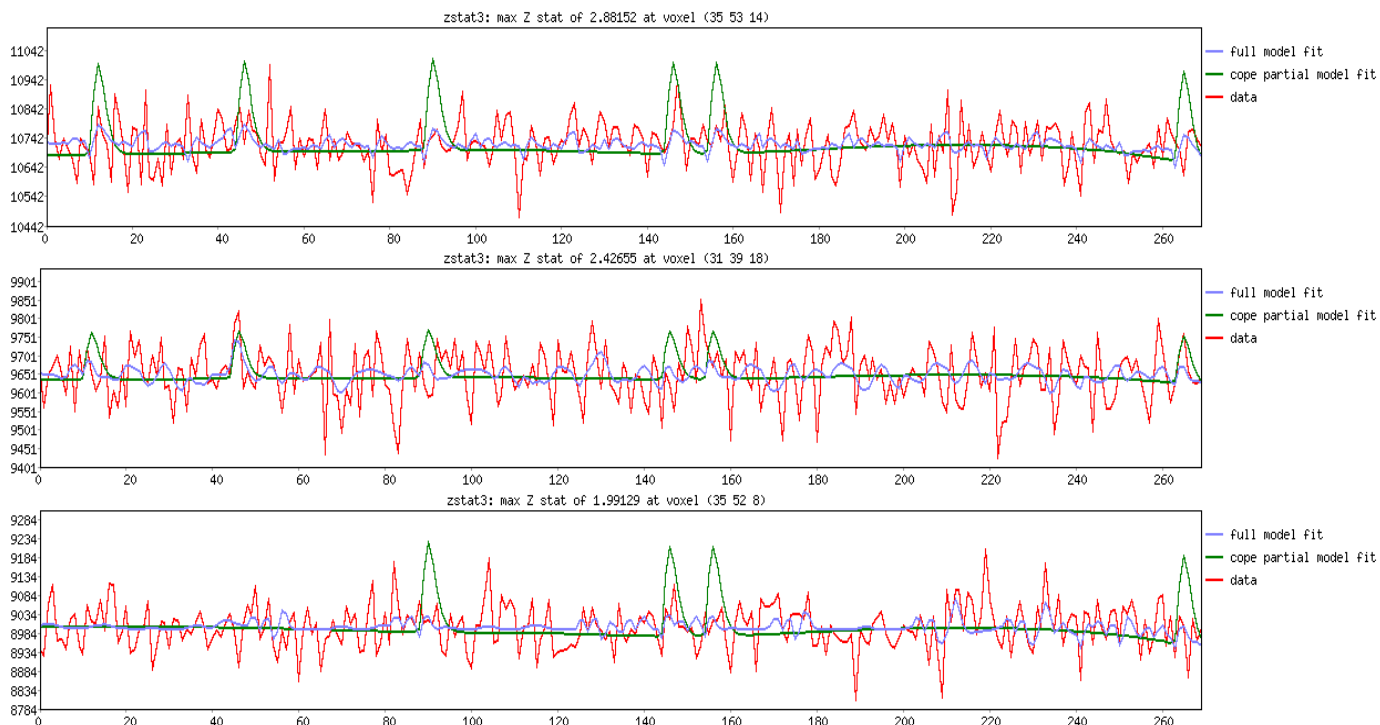


Figure G20.

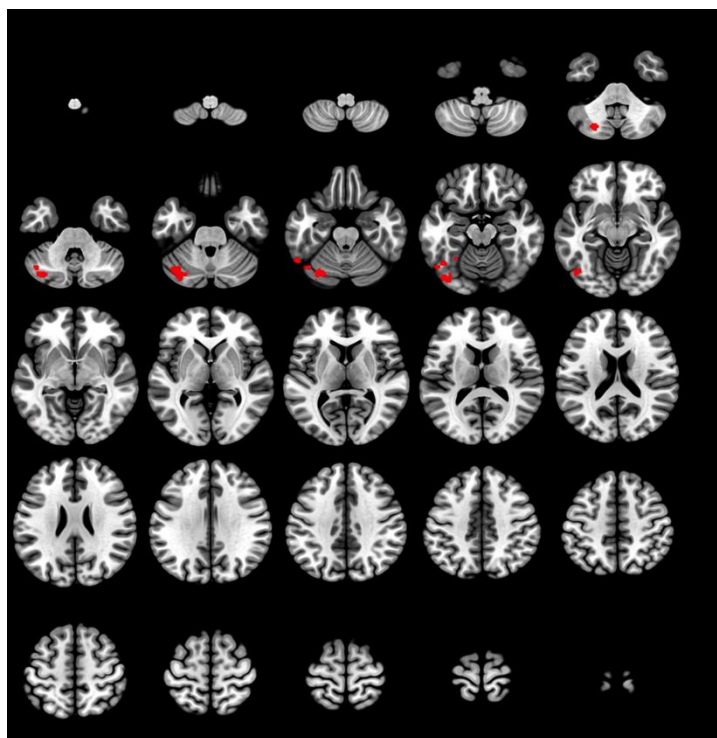
Examples of Mean Time Series Plot for the right caudate, for the reward outcome > baseline contrast.

Table G3.

Coordinates for significant clusters of activation associated with monetary reward anticipation > baseline contrast.

Cluster	Voxels	Z-Max	Z-Max X (mm)	Z-Max Y (mm)	Z-Max Z (mm)	Region
1	651	3.61	-40	-72	-32	Extends into Occipital Fusiform Gyrus

Note. Reported clusters survived thresholding using clusters determined by $Z > 2.3$ and a (corrected) cluster significance threshold of $p = .05$. Anatomical regions as defined by the Harvard-Oxford Cortical and Subcortical Structural Atlases.



Note. Statistic images were thresholded using clusters determined by $Z > 2.3$ and a (corrected) cluster significance threshold of $p = .05$.

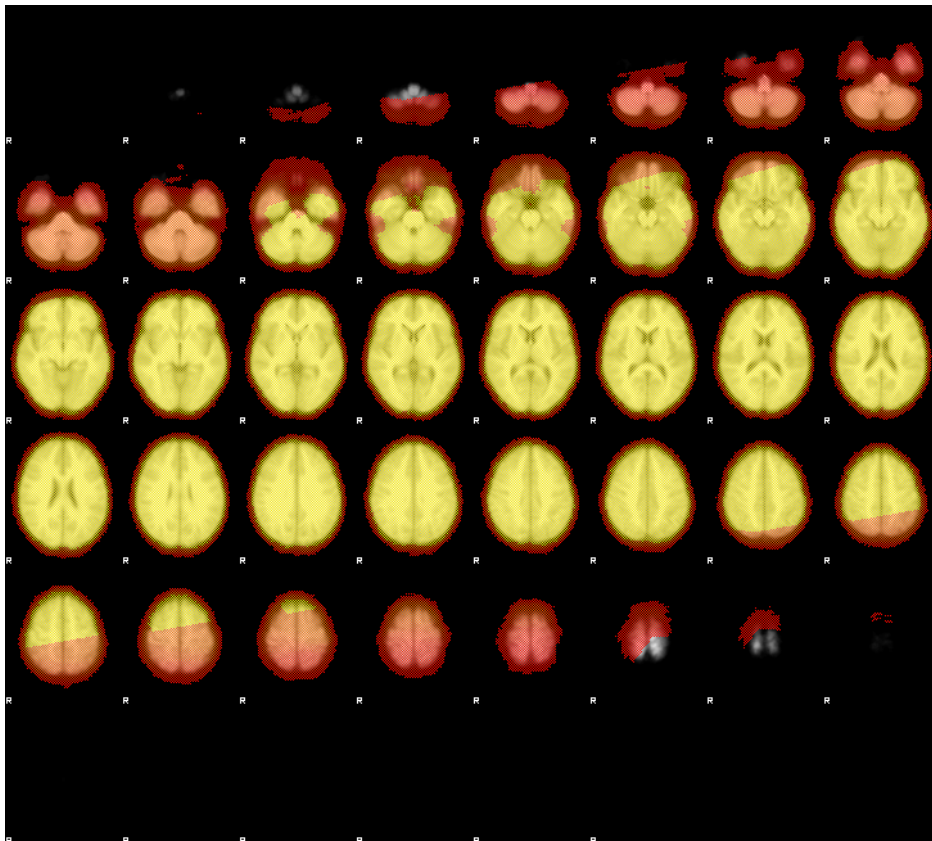
Figure G21.

Group map, monetary reward anticipation > baseline contrast.

No clusters of activation survived thresholding for the reward receipt > baseline contrast in the community sample (Study Two).

Study One: Happy Faces Task.

Figure G22 illustrates the sum of all input masks after transformation into standard space, demonstrating that the relevant brain regions of interest were covered by the scanner. Furthermore, Figures G23 to G28 provide examples of the time series plots associated with each ROI, for each contrast. These raw data plots are taken from the peak voxel within each ROI from three random participants. For the time series plots (Figures G23 to G28), the red line indicates the raw signal, the green line indicates the specified model, and the blue line indicates the model fit. Taken together, Figures G22 to G28 provide evidence that the signal was detected in the relevant ROIs.



1 participant  26 participants

Figure G22.

Sum of all input masks after transformation to standard space.



Figure G23.

Examples of Mean Time Series Plot for the left NAcc, for the happy facial expressions > neutral facial expressions contrast.



Figure G24.

Examples of Mean Time Series Plot for the right NAcc, for the happy facial expressions > neutral facial expressions contrast.

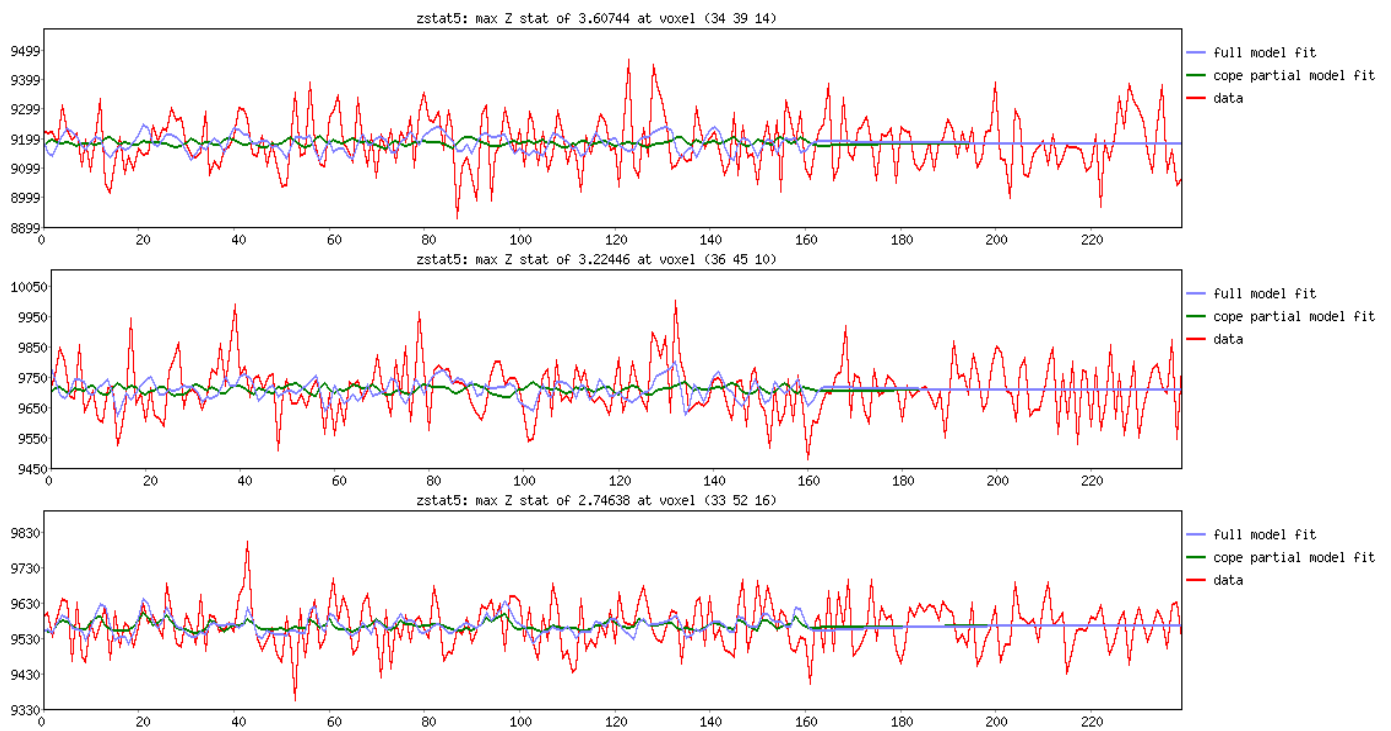


Figure G25.

Examples of Mean Time Series Plot for the left caudate, for the happy facial expressions > neutral facial expressions contrast.

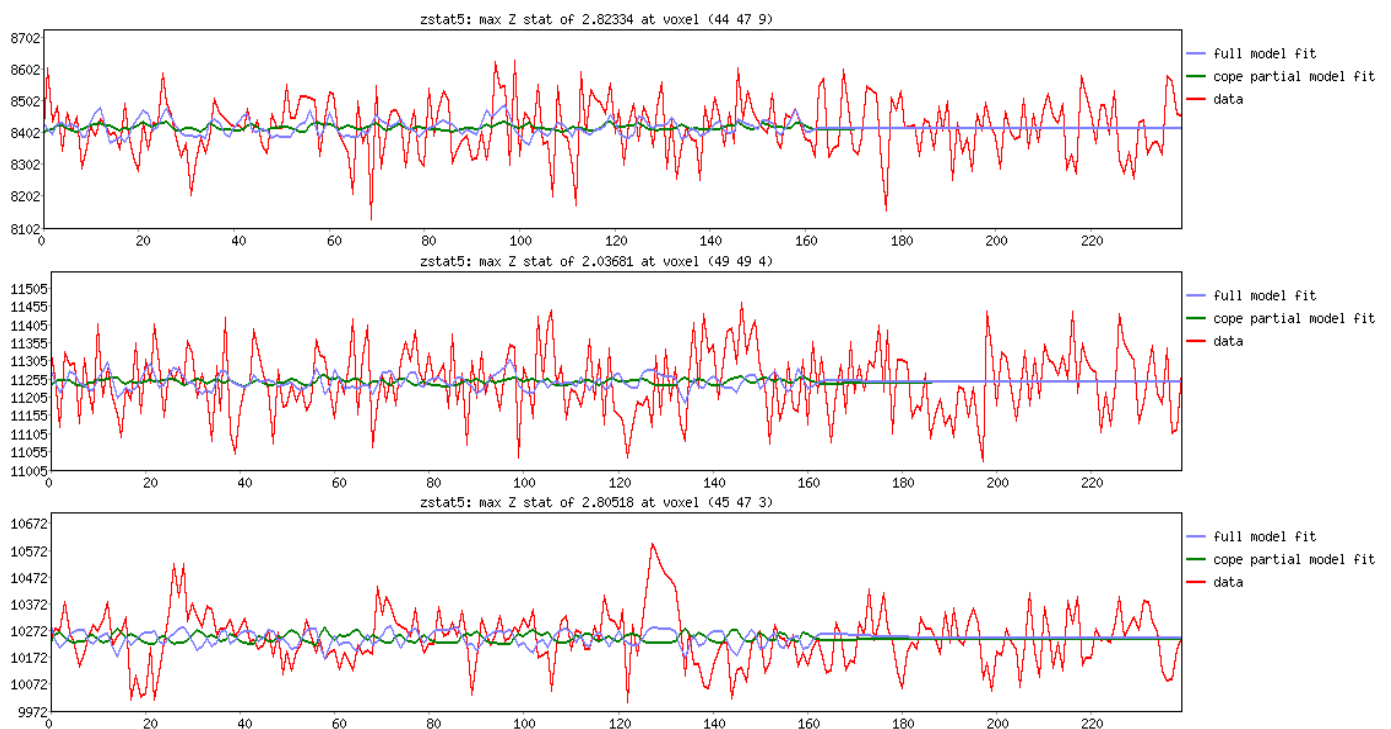


Figure G26.

Examples of Mean Time Series Plot for the right caudate, for the happy facial expressions > neutral facial expressions contrast.

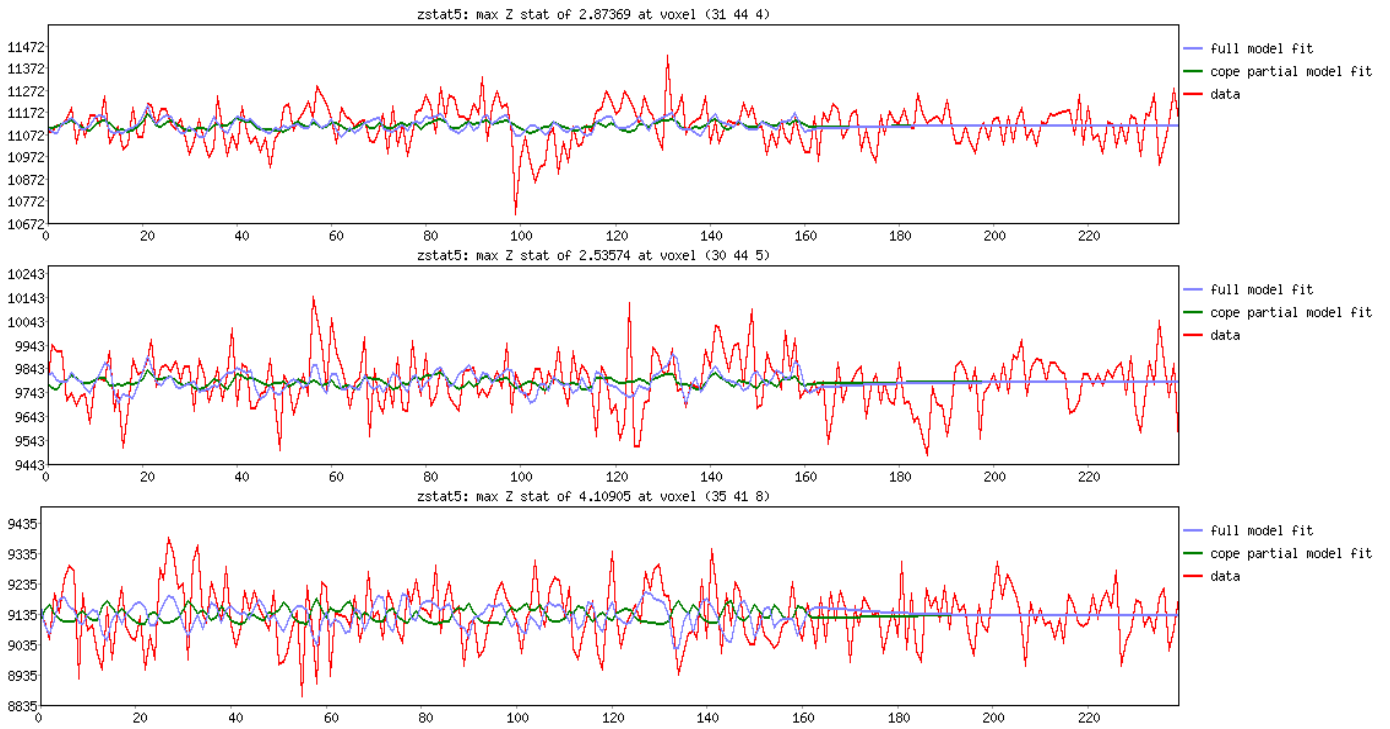


Figure G27.

Examples of Mean Time Series Plot for the left amygdala, for the happy facial expressions > neutral facial expressions contrast.

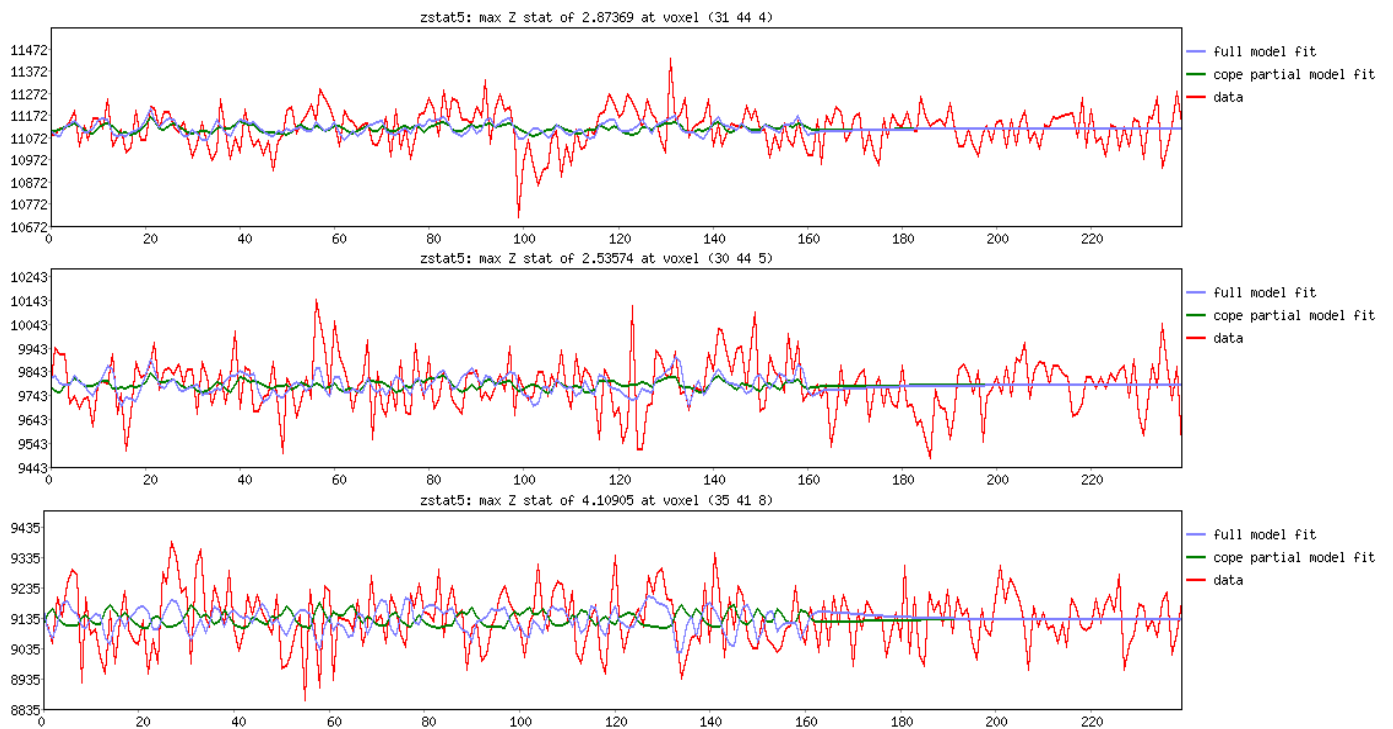


Figure G28.

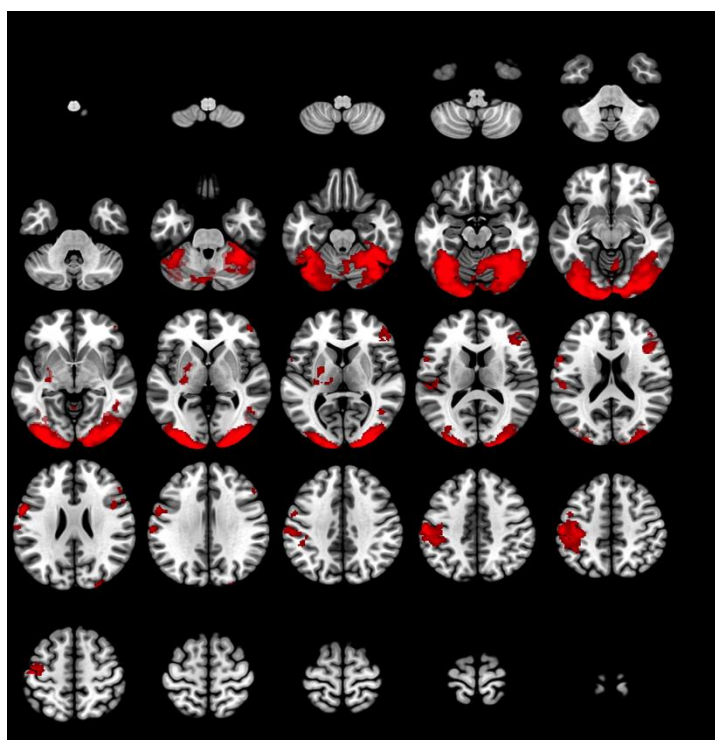
Examples of Mean Time Series Plot for the right amygdala, for the happy facial expressions > neutral facial expressions contrast.

Table G4.

Coordinates for significant clusters of activation associated with happy facial expressions > baseline contrast.

Cluster	Voxels	Z-Max	Z-Max X (mm)	Z-Max Y (mm)	Z-Max Z (mm)	Region
1	14538	6.25	-38	-64	-20	Temporal Occipital Fusiform Cortex
2	1723	4.36	-60	-20	44	Postcentral Gyrus
3	656	3.83	42	20	20	Inferior Frontal Gyrus
4	361	4.25	-58	2	26	Precentral Gyrus
5	351	3.34	-28	-18	2	Left Putamen

Note. Reported clusters survived thresholding using clusters determined by $Z > 2.3$ and a (corrected) cluster significance threshold of $p = .05$. Anatomical regions as defined by the Harvard-Oxford Cortical and Subcortical Structural Atlases.



Note. Statistic images were thresholded using clusters determined by $Z > 2.3$ and a (corrected) cluster significance threshold of $p = .05$.

Figure G29.

Group map, happy facial expressions > baseline.

Study Two: Happy Faces Task.

Figure G30 illustrates the sum of all input masks after transformation into standard space, demonstrating that the relevant brain regions of interest were covered by the scanner. Furthermore, Figures G31 to G36 provide examples of the time series plots associated with each ROI, for each contrast. These raw data plots are taken from the peak voxel within each ROI from three random participants. For the time series plots (Figures G31 to G36), the red line indicates the raw signal, the green line indicates the specified model, and the blue line indicates the model fit. Taken together, Figures G30 to G36 provide evidence that the signal was detected in the relevant ROIs.

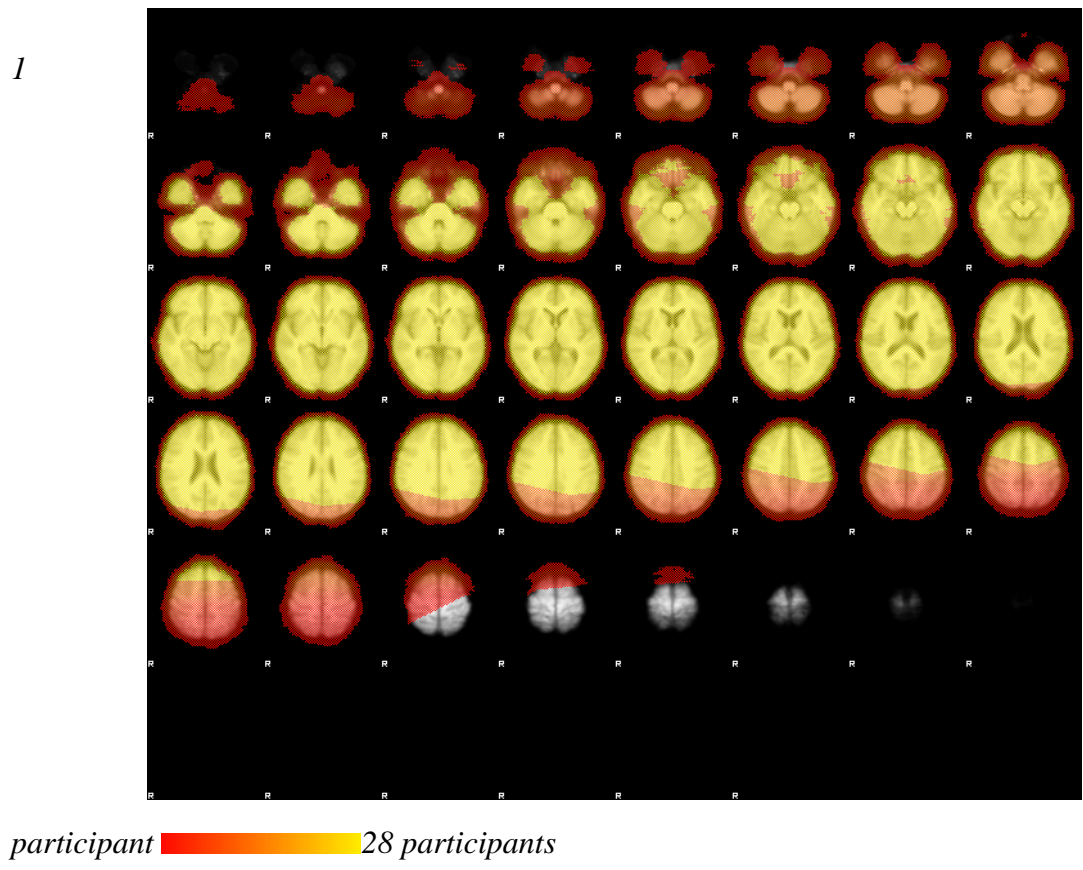


Figure G30.

Sum of all input masks after transformation to standard space.

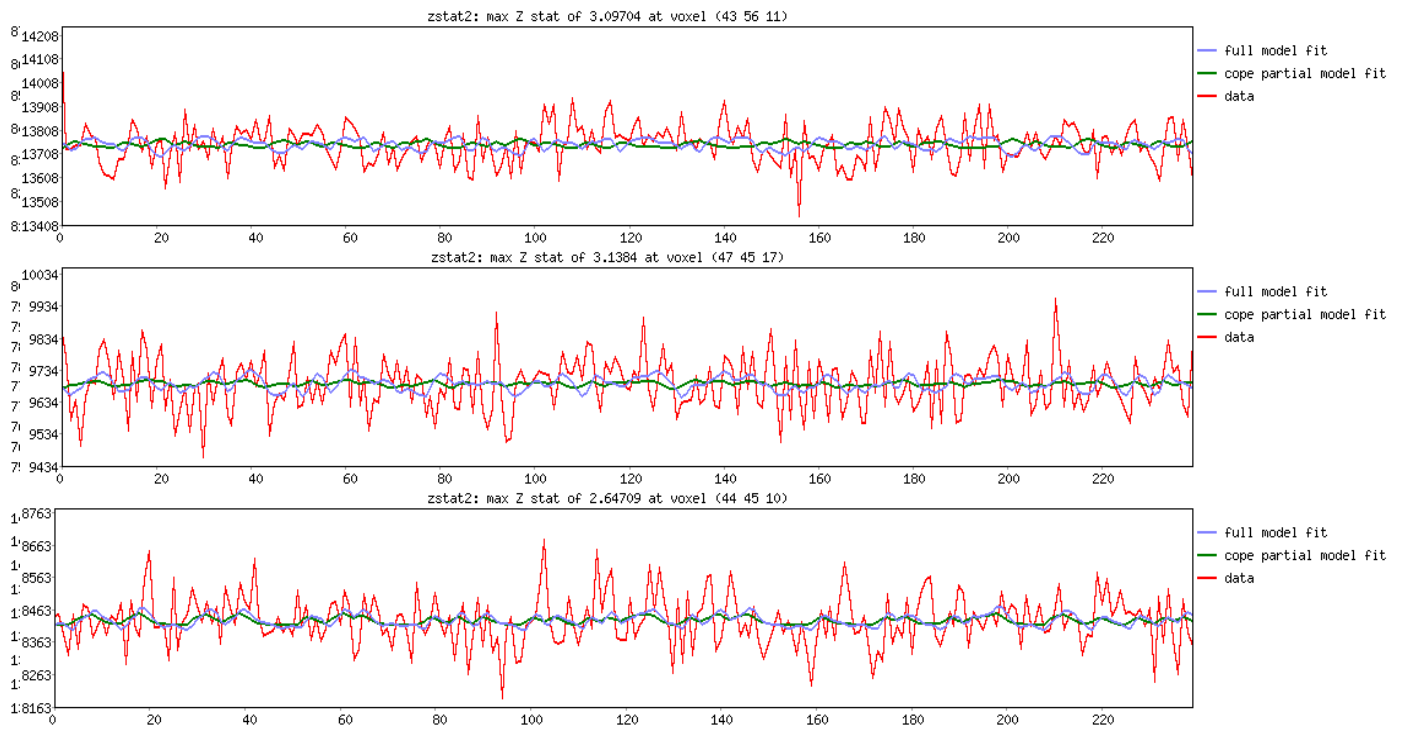


Figure G31.

Examples of Mean Time Series Plot for the left NAcc, for the happy facial expressions > neutral facial expressions contrast.

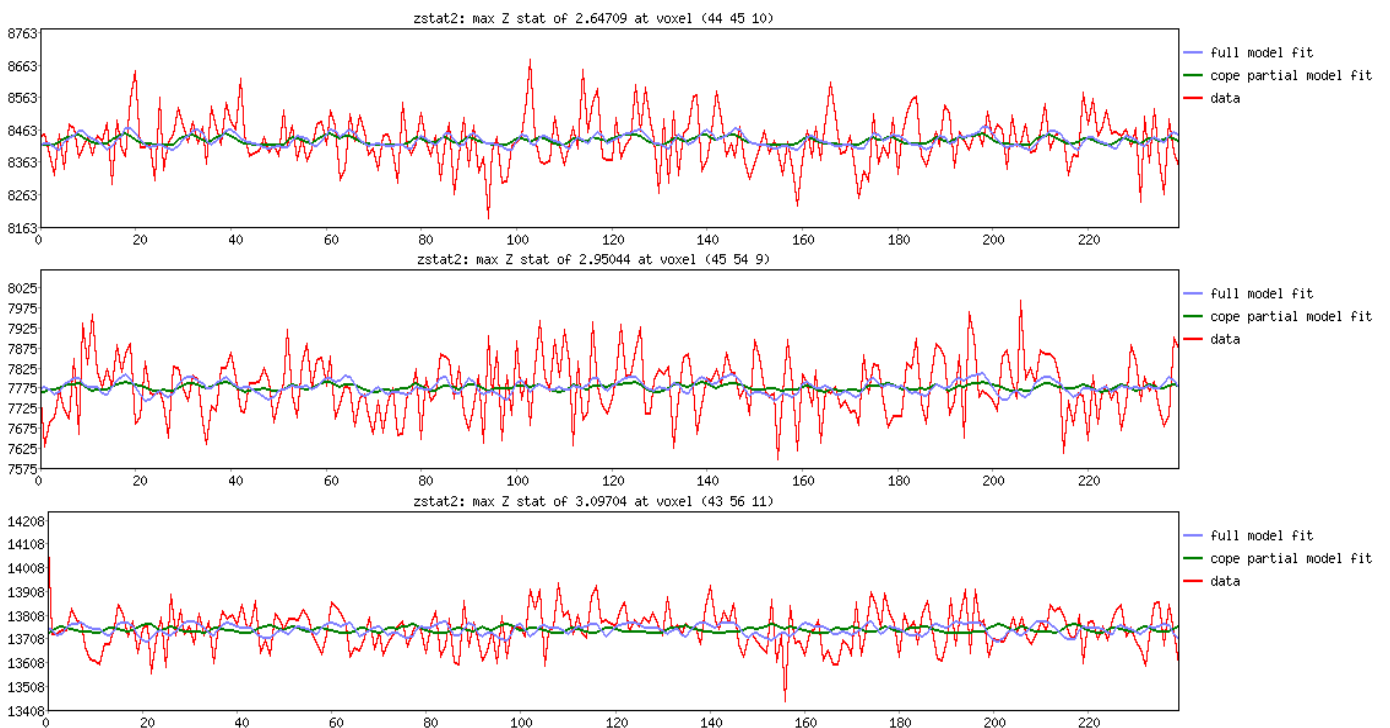


Figure G32.

Examples of Mean Time Series Plot for the right NAcc, for the happy facial expressions > neutral facial expressions contrast.

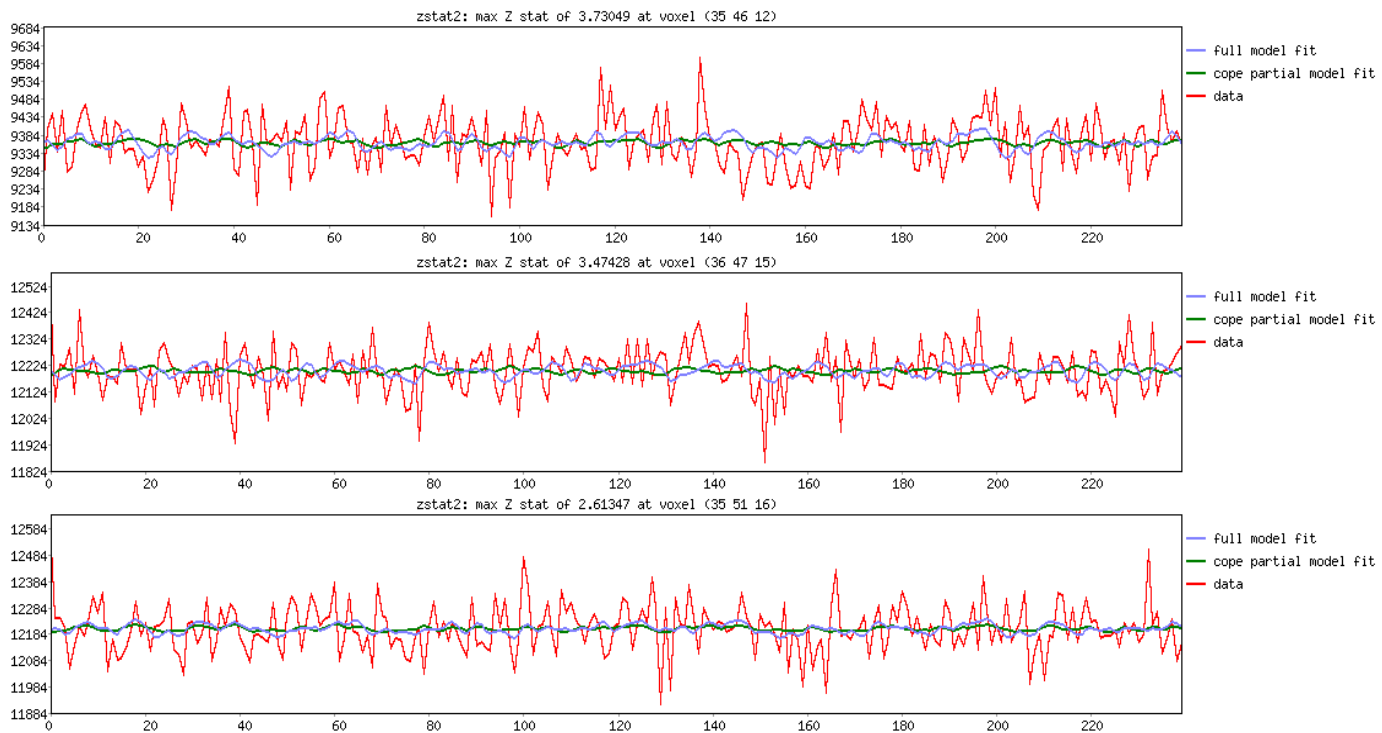


Figure G33.

Examples of Mean Time Series Plot for the left caudate, for the happy facial expressions > neutral facial expressions contrast.

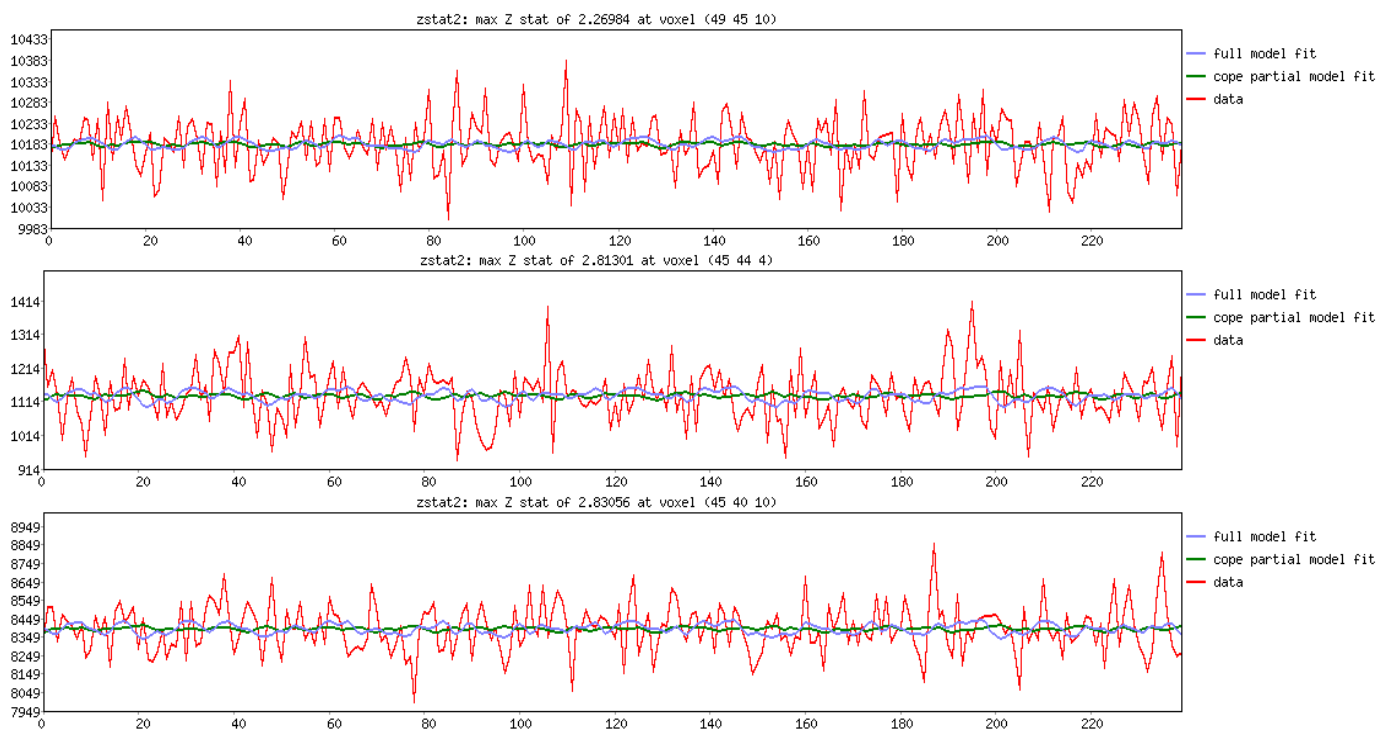


Figure G34.

Examples of Mean Time Series Plot for the right caudate, for the happy facial expressions > neutral facial expressions contrast.

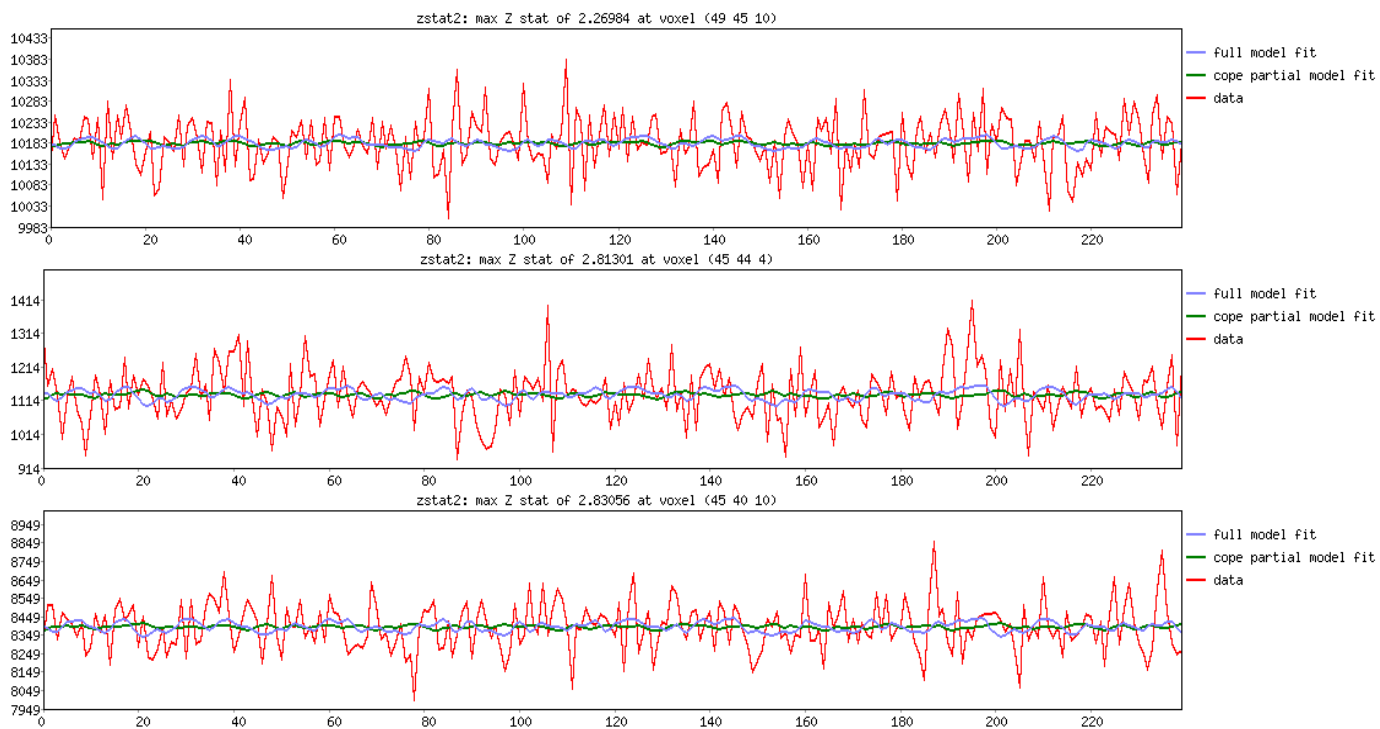


Figure G35.

Examples of Mean Time Series Plot for the left amygdala, for the happy facial expressions > neutral facial expressions contrast.



Figure G36.

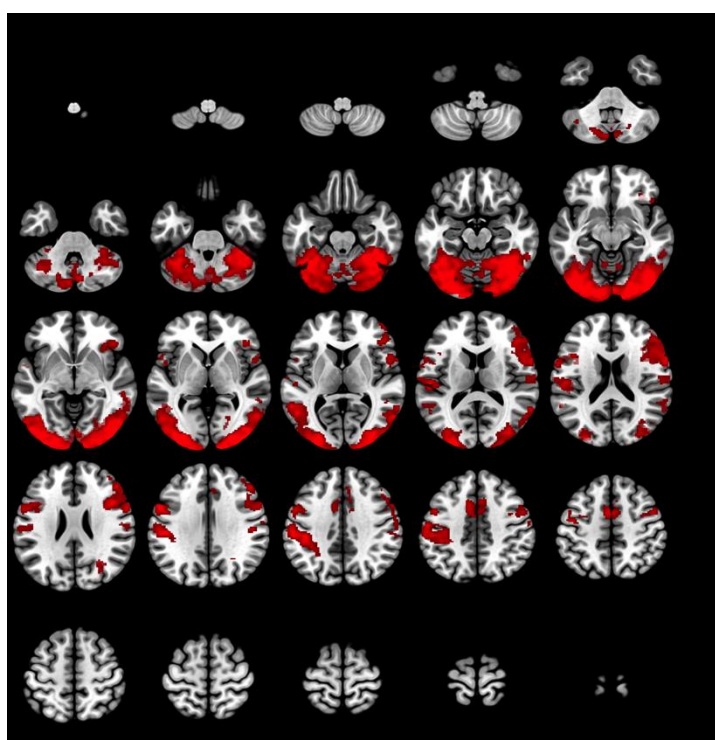
Examples of Mean Time Series Plot for the right amygdala, for the happy facial expressions > neutral facial expressions contrast.

Table G5.

Coordinates for significant clusters of activation associated with happy facial expressions > baseline contrast.

Cluster	Voxels	Z-Max	Z-Max X (mm)	Z-Max Y (mm)	Z-Max Z (mm)	Region
1	19999	6.52	-28	-86	-18	Occipital Fusiform Gyrus
2	3476	4.68	44	12	26	Inferior Frontal Gyrus
3	2905	4.88	-50	-24	32	Supramarginal Gyrus
4	756	4.11	-4	-2	48	Anterior Cingulate Gyrus

Note. Reported clusters survived thresholding using clusters determined by $Z > 2.3$ and a (corrected) cluster significance threshold of $p = .05$. Anatomical regions as defined by the Harvard-Oxford Cortical and Subcortical Structural Atlases.



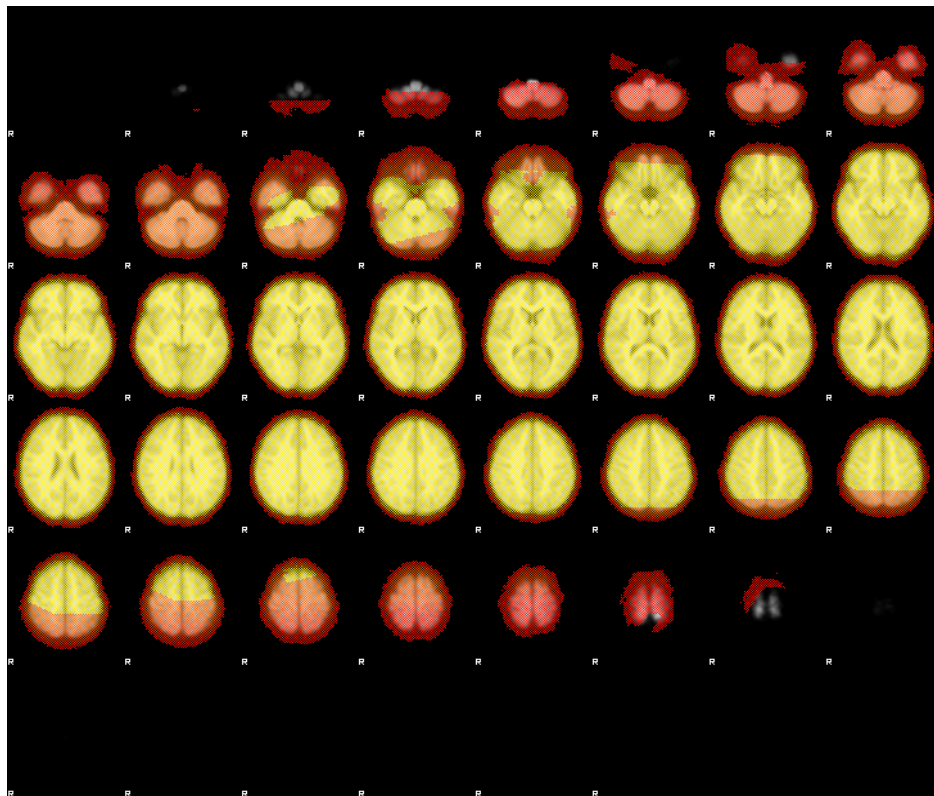
Note. Statistic images were thresholded using clusters determined by $Z > 2.3$ and a (corrected) cluster significance threshold of $p = .05$.

Figure G37.

Group map, happy facial expressions > baseline contrast.

Study One: Positive Affect Task.

Figure G38 illustrates the sum of all input masks after transformation into standard space, demonstrating that the relevant brain regions of interest were covered by the scanner. Furthermore, Figures G39 to G50 provide examples of the time series plots associated with each ROI, for each contrast. These raw data plots are taken from the peak voxel within each ROI from three random participants. For the time series plots (Figures G39 to G50), the red line indicates the raw signal, the green line indicates the specified model, and the blue line indicates the model fit. Taken together, Figures G38 to G50 provide evidence that the signal was detected in the relevant ROIs.



1 participant  *28 participants*

Figure G38.

Sum of all input masks after transformation to standard space.



Figure G39.

Examples of Mean Time Series Plot for the left NAcc for the excitement images > neutral images contrast.

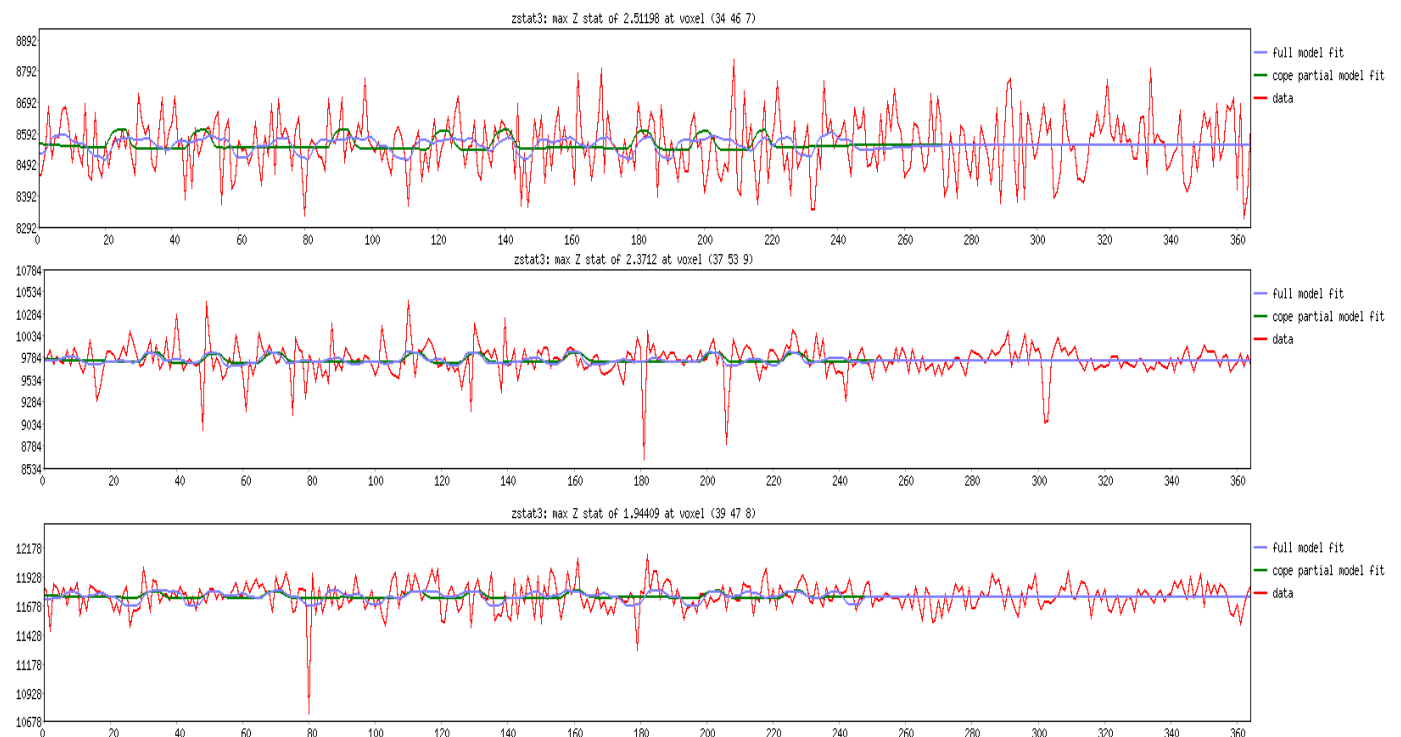


Figure G40.

Examples of Mean Time Series Plot for the right NAcc for the excitement images > neutral images contrast.

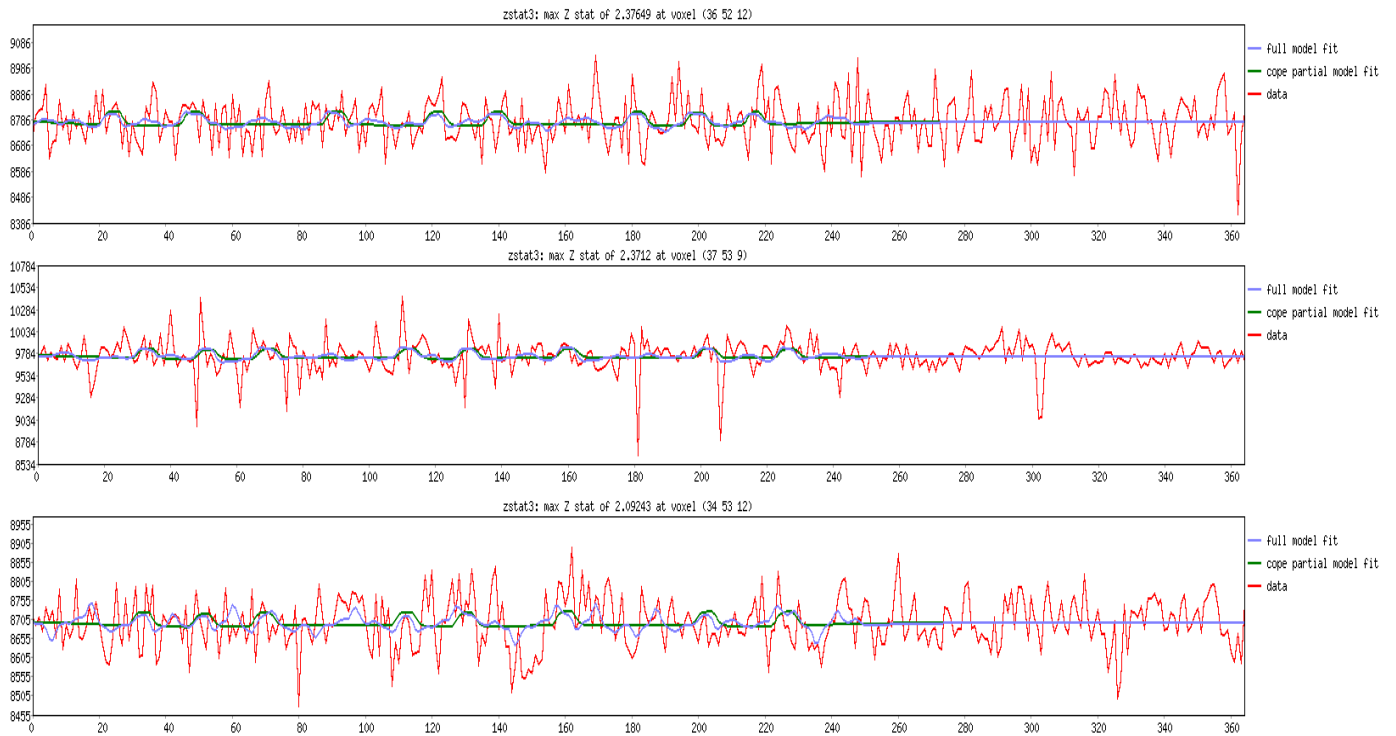


Figure G41.

Examples of Mean Time Series Plot for the left caudate for the excitement images > neutral images contrast.

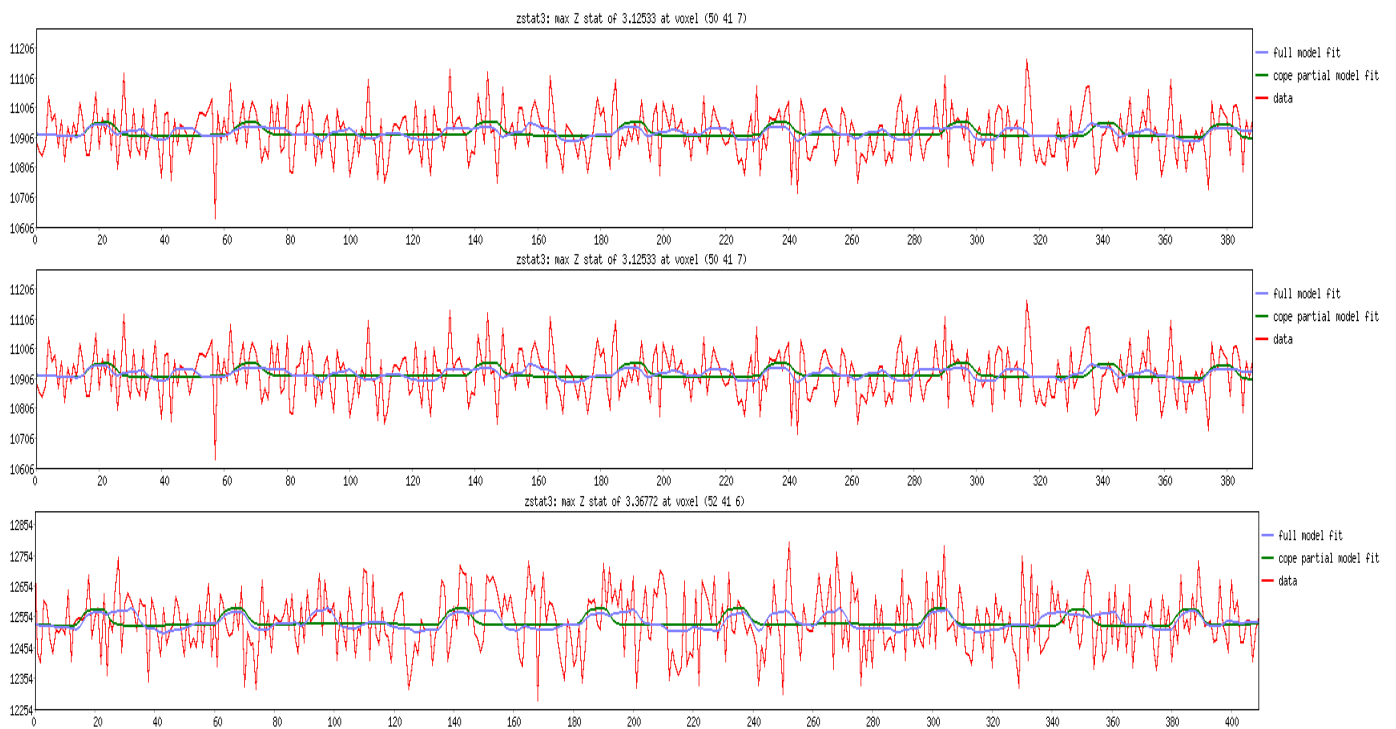


Figure G42.

Examples of Mean Time Series Plot for the right caudate for the excitement images > neutral images contrast.

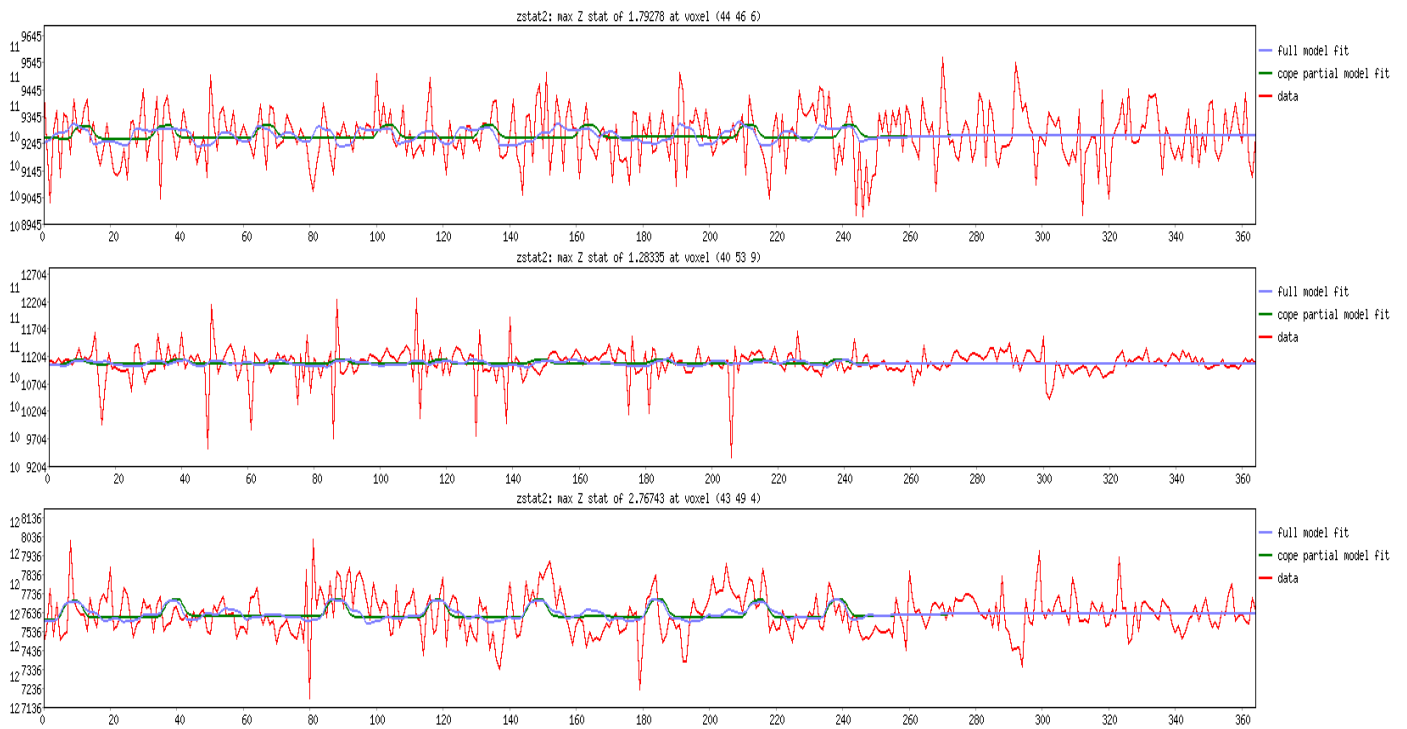


Figure G43.

Examples of Mean Time Series Plot for the left amygdala for the excitement images > neutral images contrast.

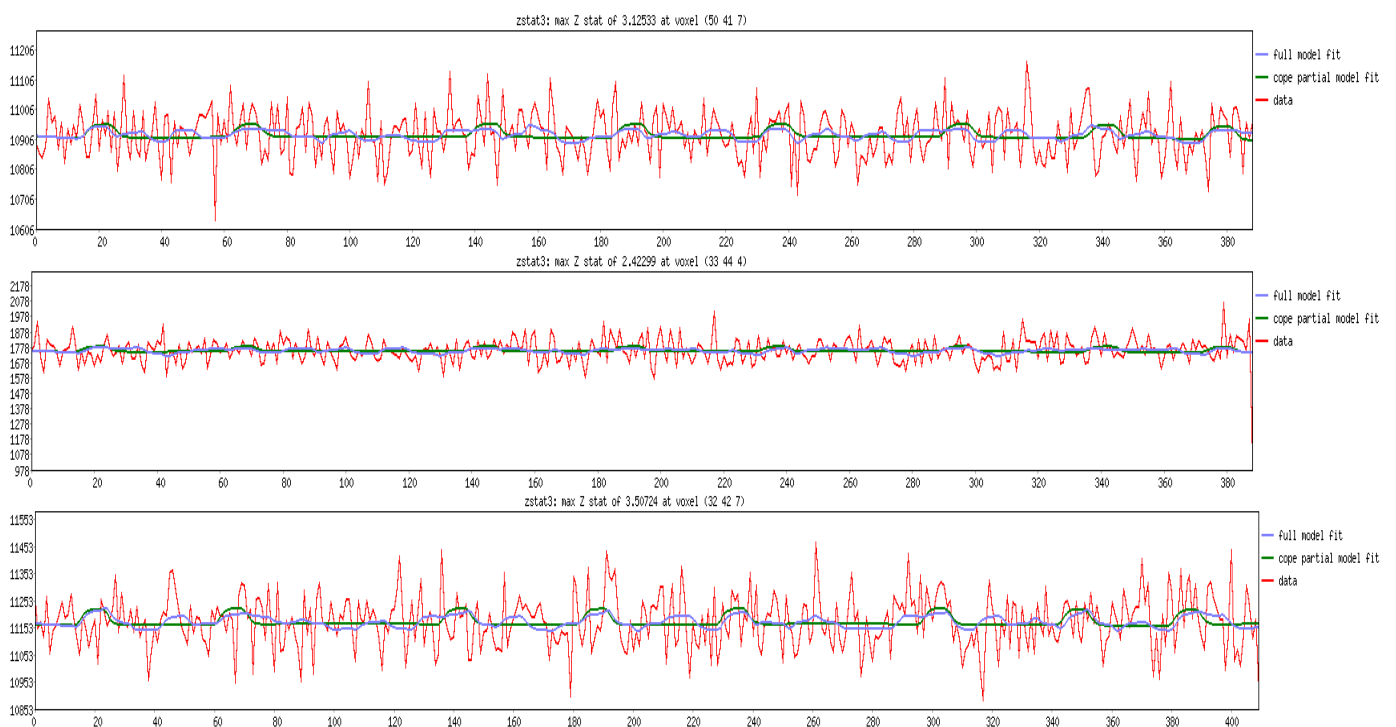


Figure G44.

Examples of Mean Time Series Plot for the right amygdala for the excitement images > neutral images contrast.



Figure G45.

Examples of Mean Time Series Plot for the left NAcc for the contentment images > neutral images contrast.

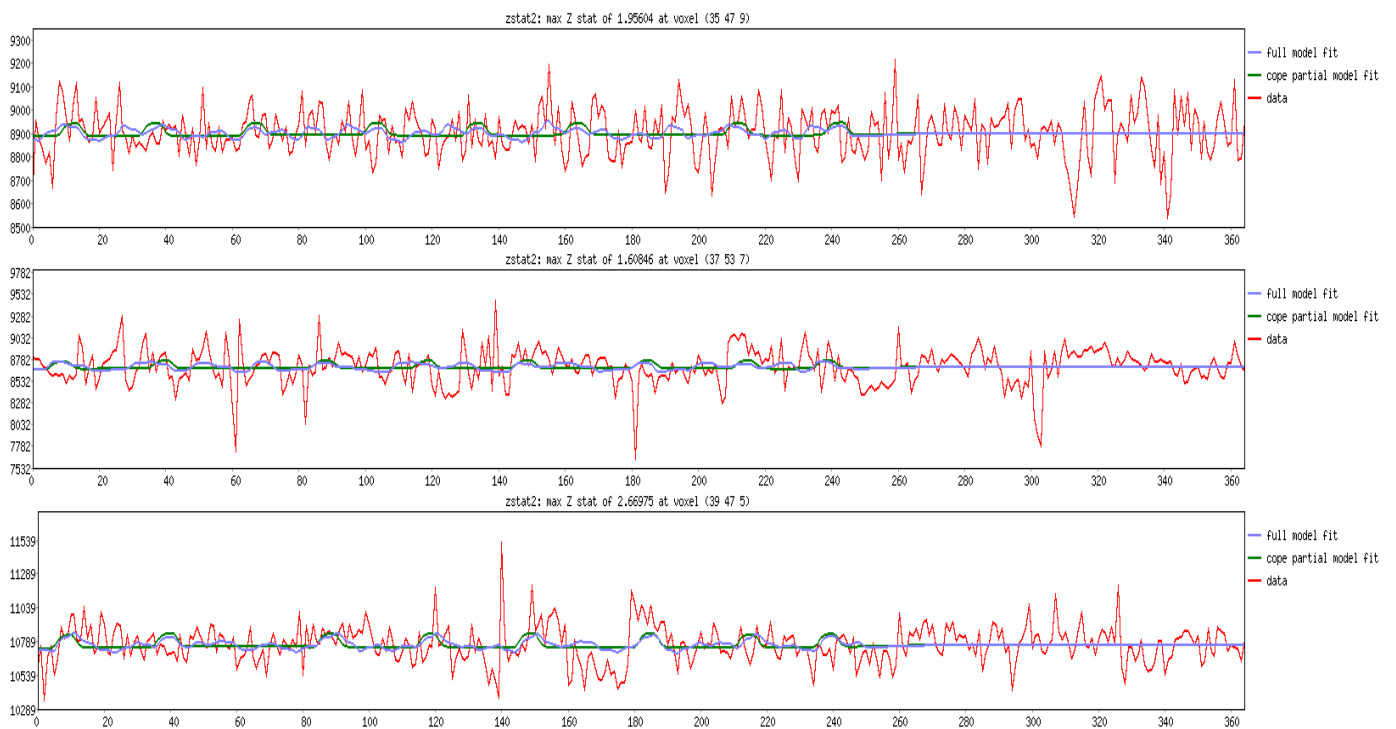


Figure G46.

Examples of Mean Time Series Plot for the right NAcc for the contentment images > neutral images contrast.

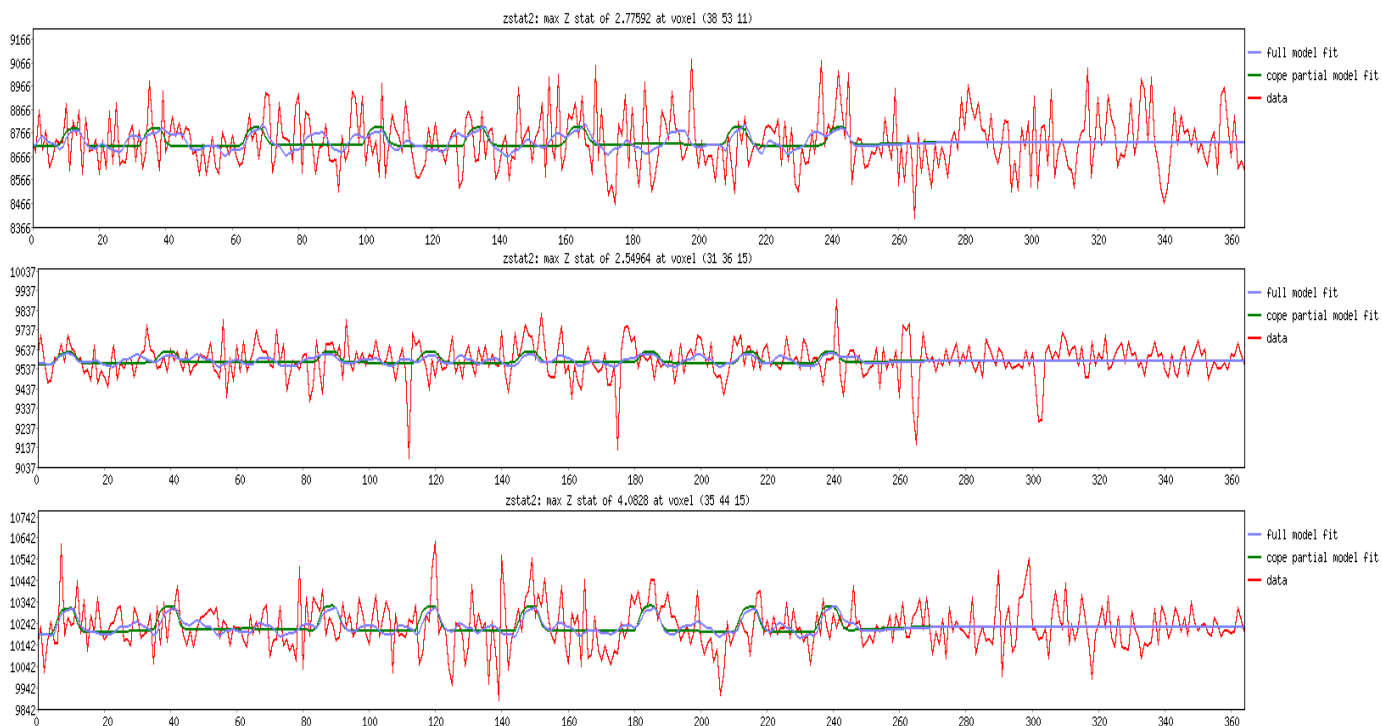


Figure G47.

Examples of Mean Time Series Plot for the left caudate for the contentment images > neutral images contrast.

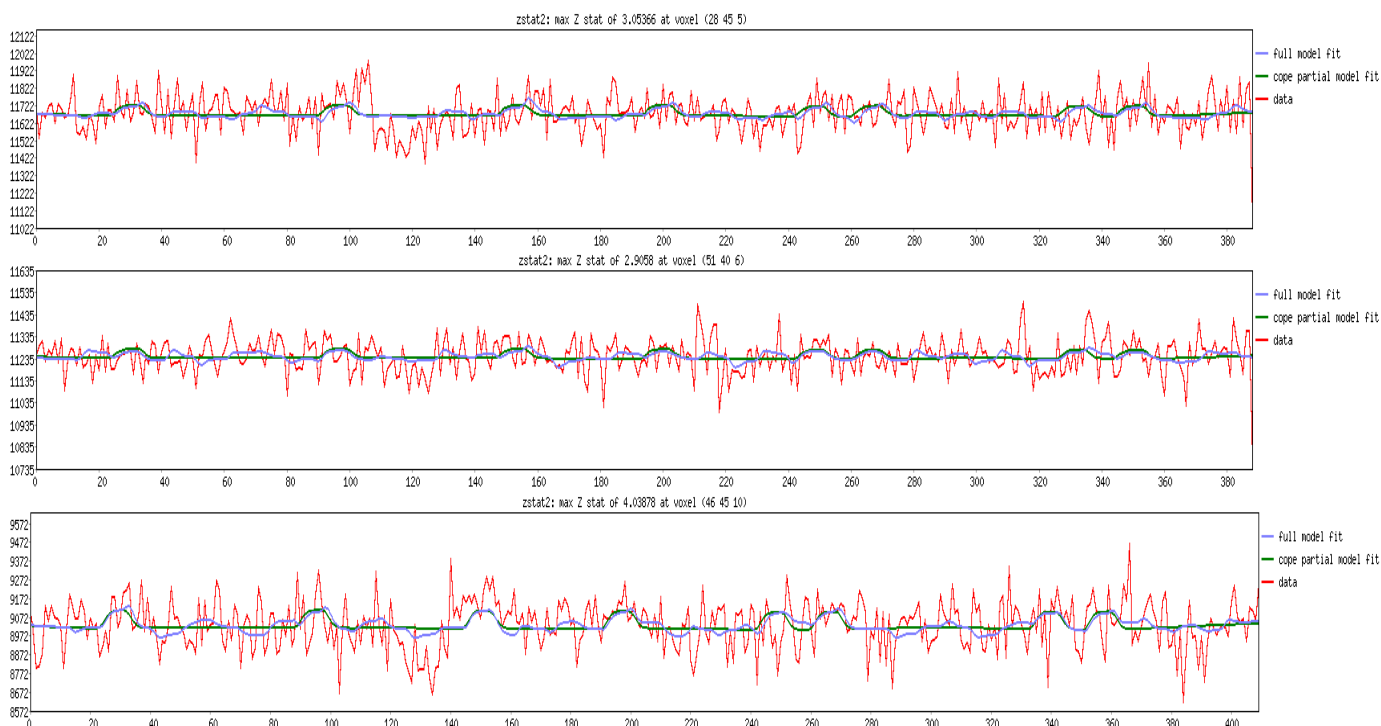


Figure G48.

Examples of Mean Time Series Plot for the right caudate for the contentment images > neutral images contrast.

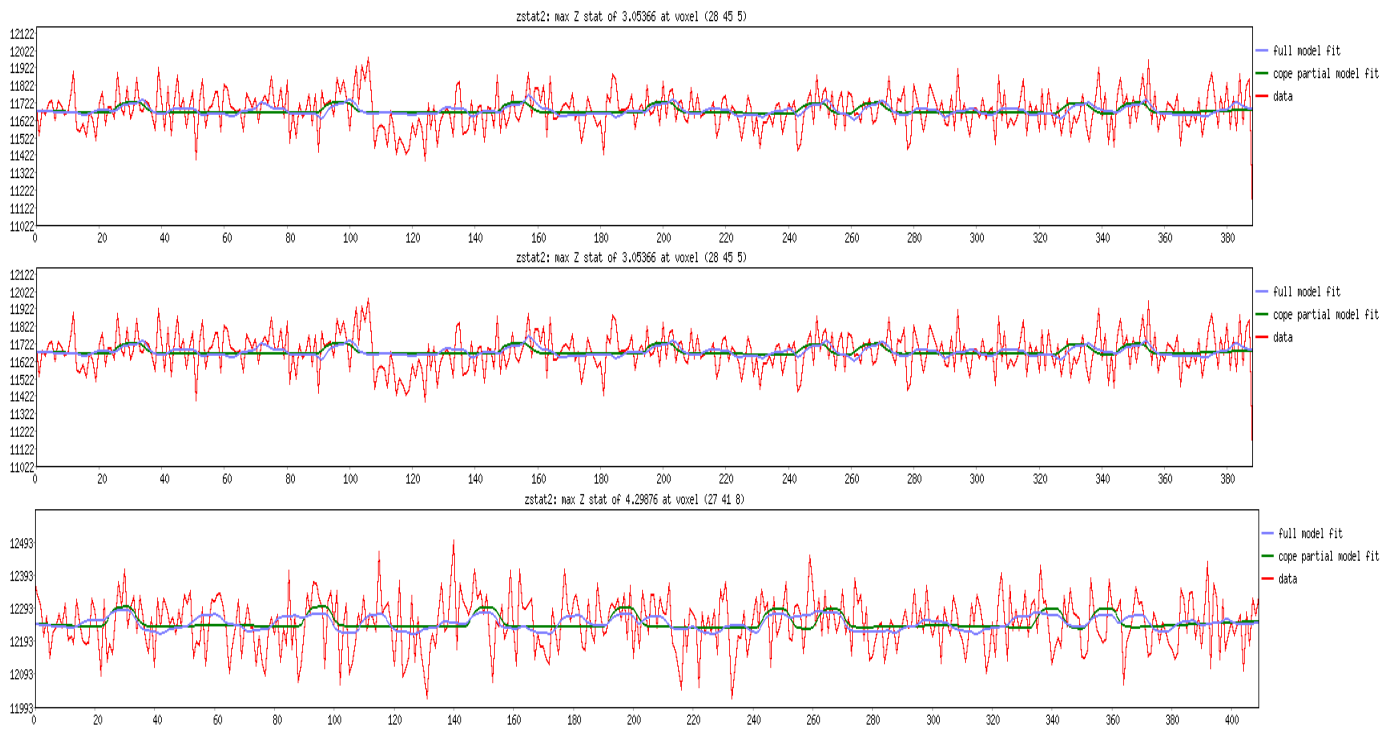


Figure G49.

Examples of Mean Time Series Plot for the left amygdala for the contentment images > neutral images contrast.

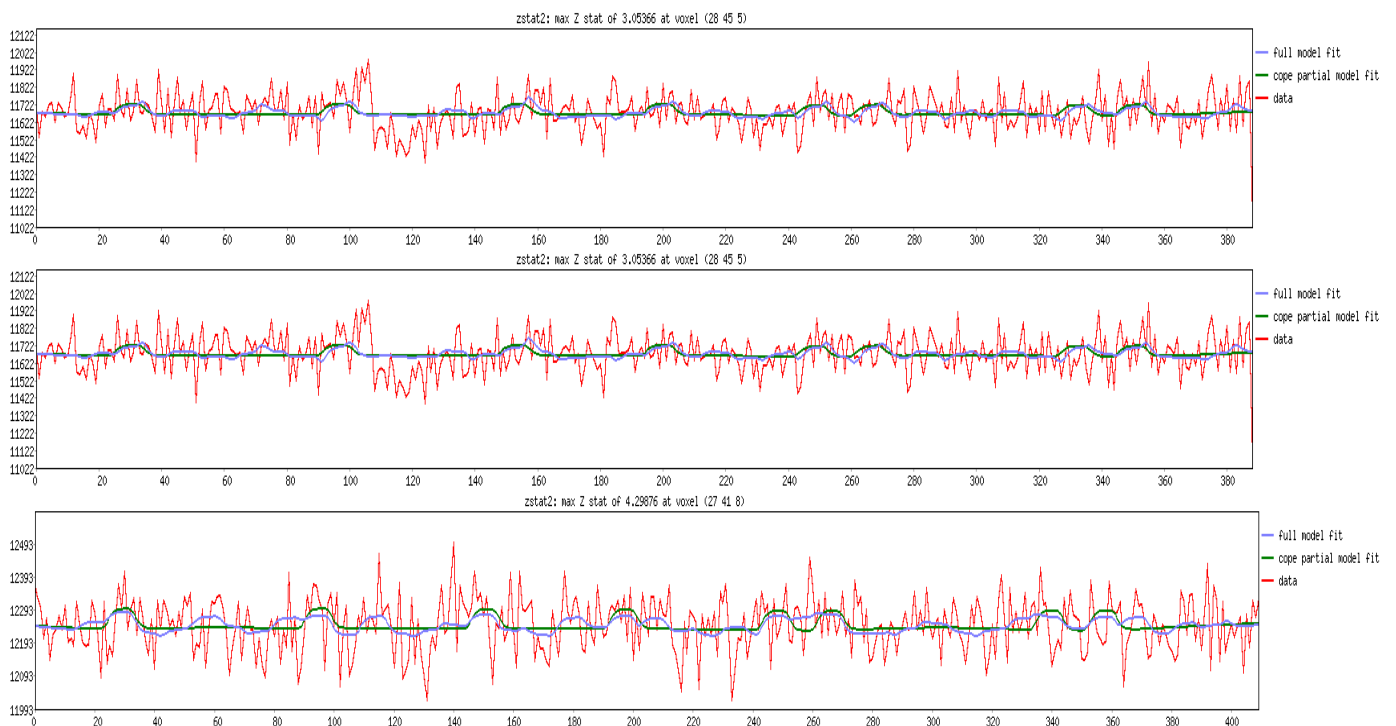
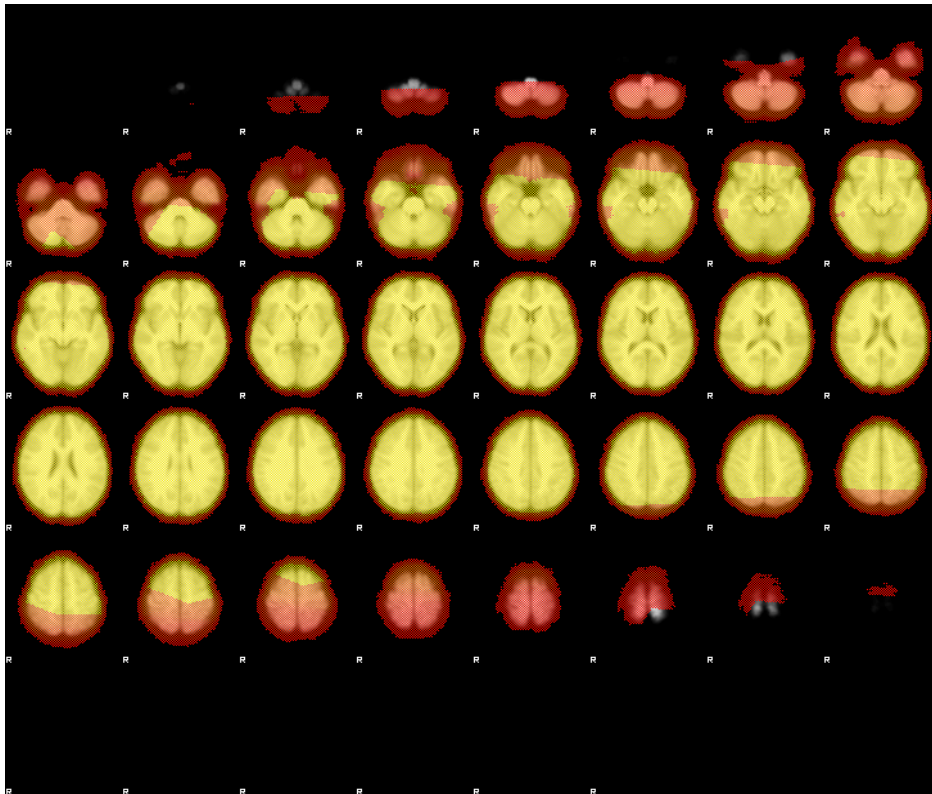


Figure G50.

Examples of Mean Time Series Plot for the right amygdala for the contentment images > neutral images contrast.

Study Two: Positive Affect Task.

Figure G51 illustrates the sum of all input masks after transformation into standard space, demonstrating that the relevant brain regions of interest were covered by the scanner. Furthermore, Figures G52 to G63 provide examples of the time series plots associated with each ROI, for each contrast. These raw data plots are taken from the peak voxel within each ROI from three random participants. For the time series plots (Figures G52 to G63), the red line indicates the raw signal, the green line indicates the specified model, and the blue line indicates the model fit. Taken together, Figures G51 to G63 provide evidence that the signal was detected in the relevant ROIs.



1 participant  *28 participants*

Figure G51.

Sum of all input masks after transformation to standard space.

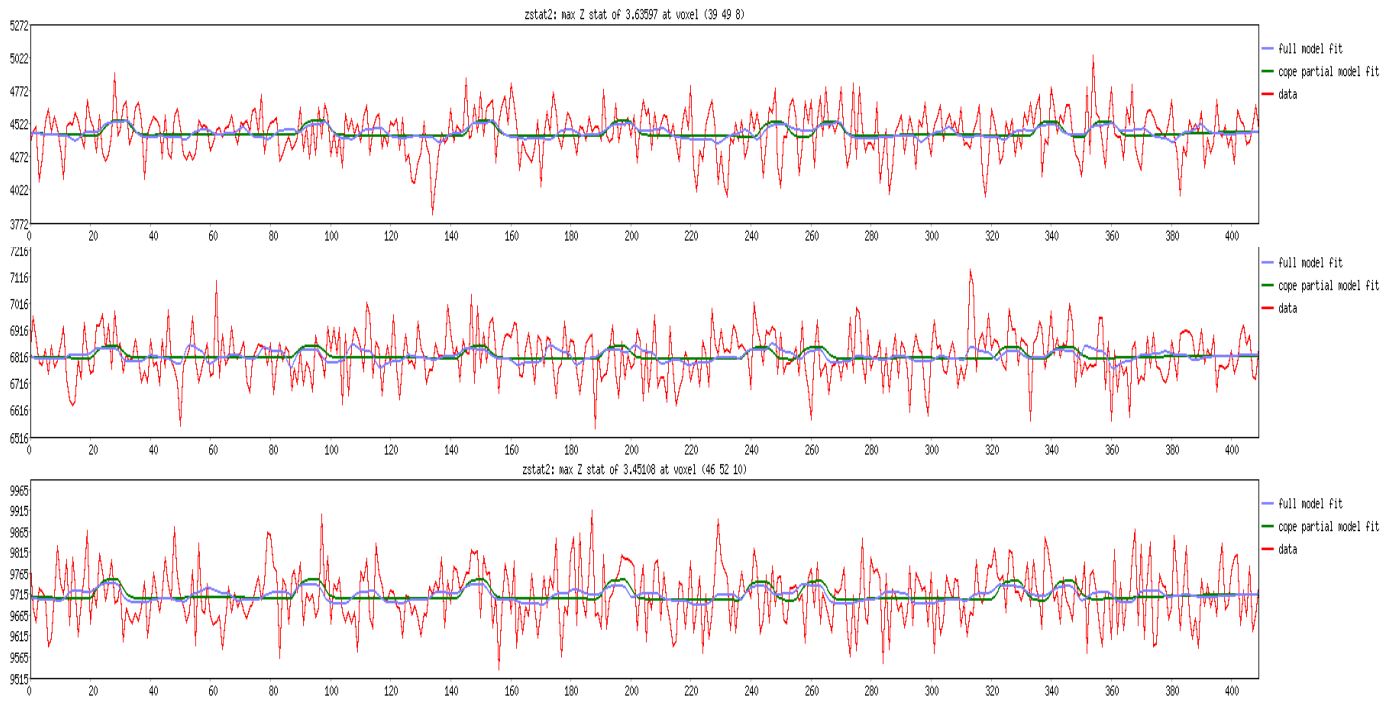


Figure G52.

Examples of Mean Time Series Plot for the left NAcc for the excitement images > neutral images contrast.

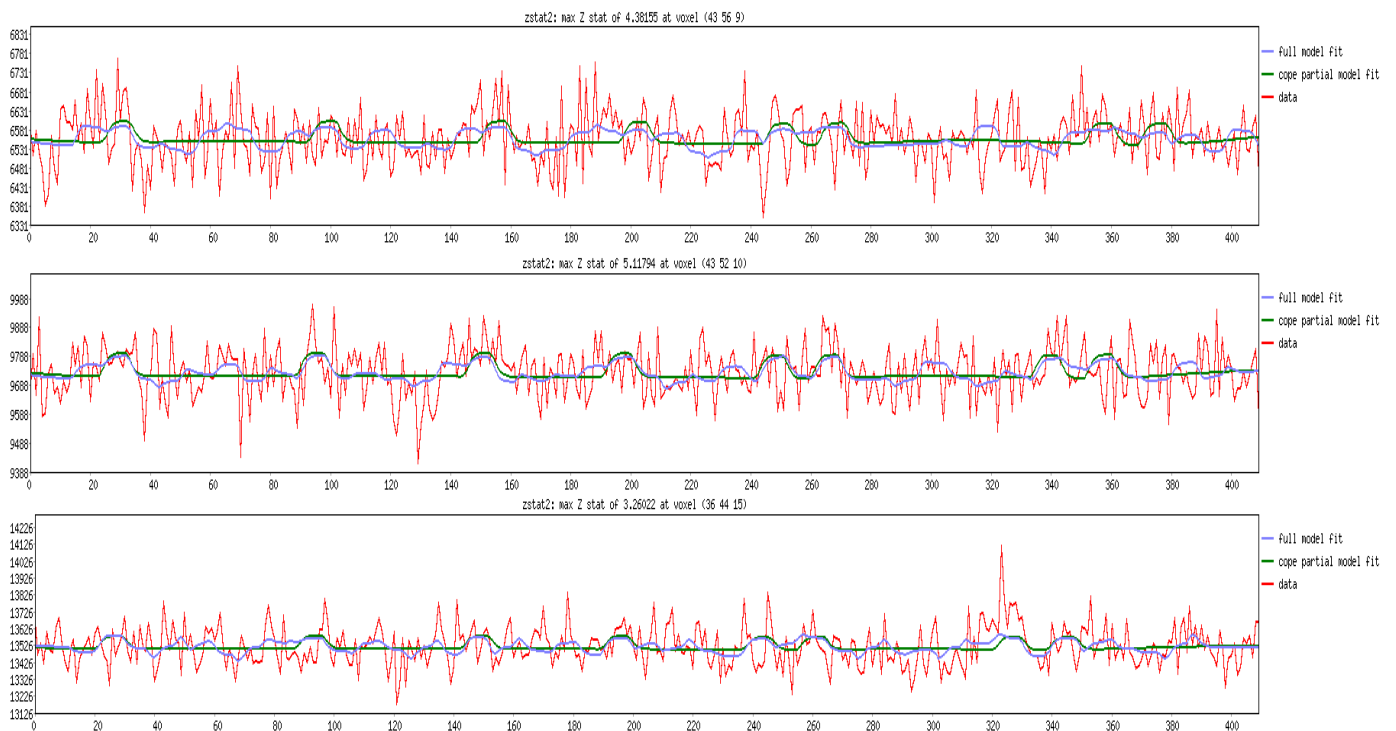


Figure G53.

Examples of Mean Time Series Plot for the right NAcc for the excitement images > neutral images contrast.



Figure G54.

Examples of Mean Time Series Plot for the left caudate for the excitement images > neutral images contrast.

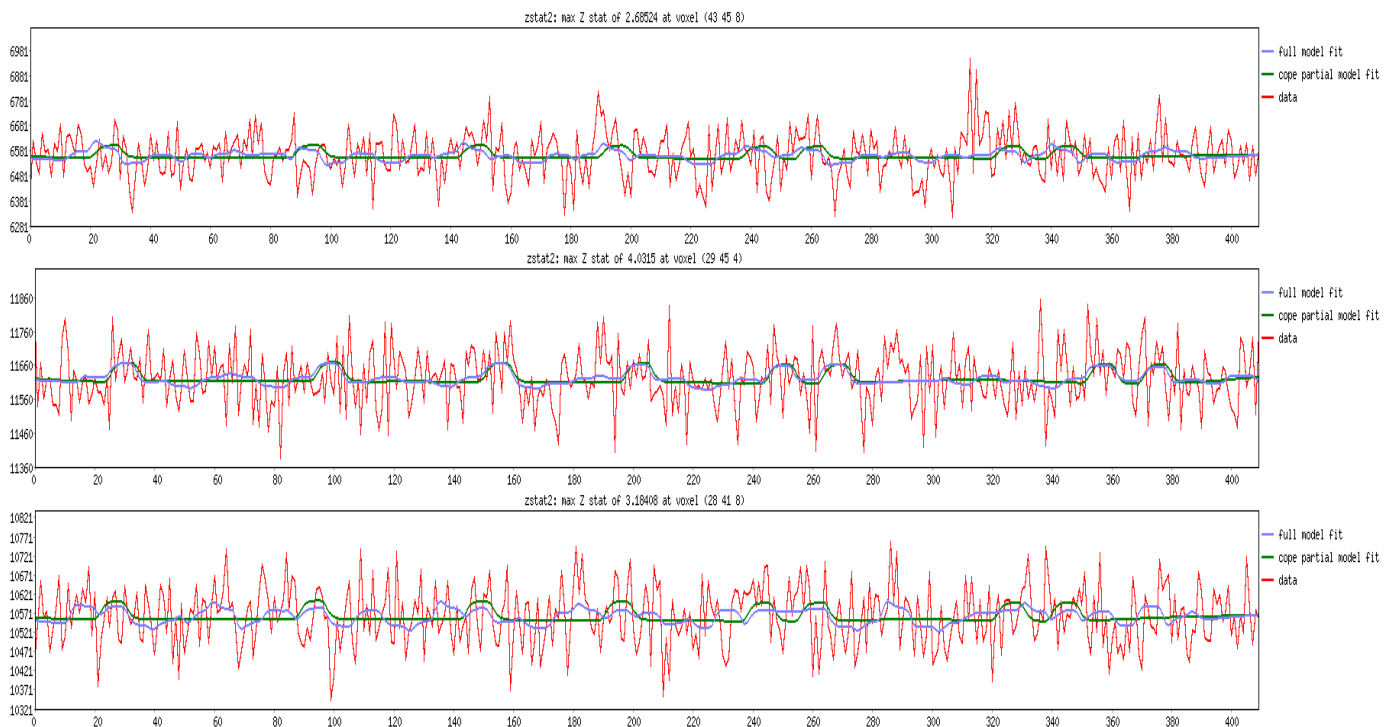


Figure G55.

Examples of Mean Time Series Plot for the right caudate for the excitement images > neutral images contrast.

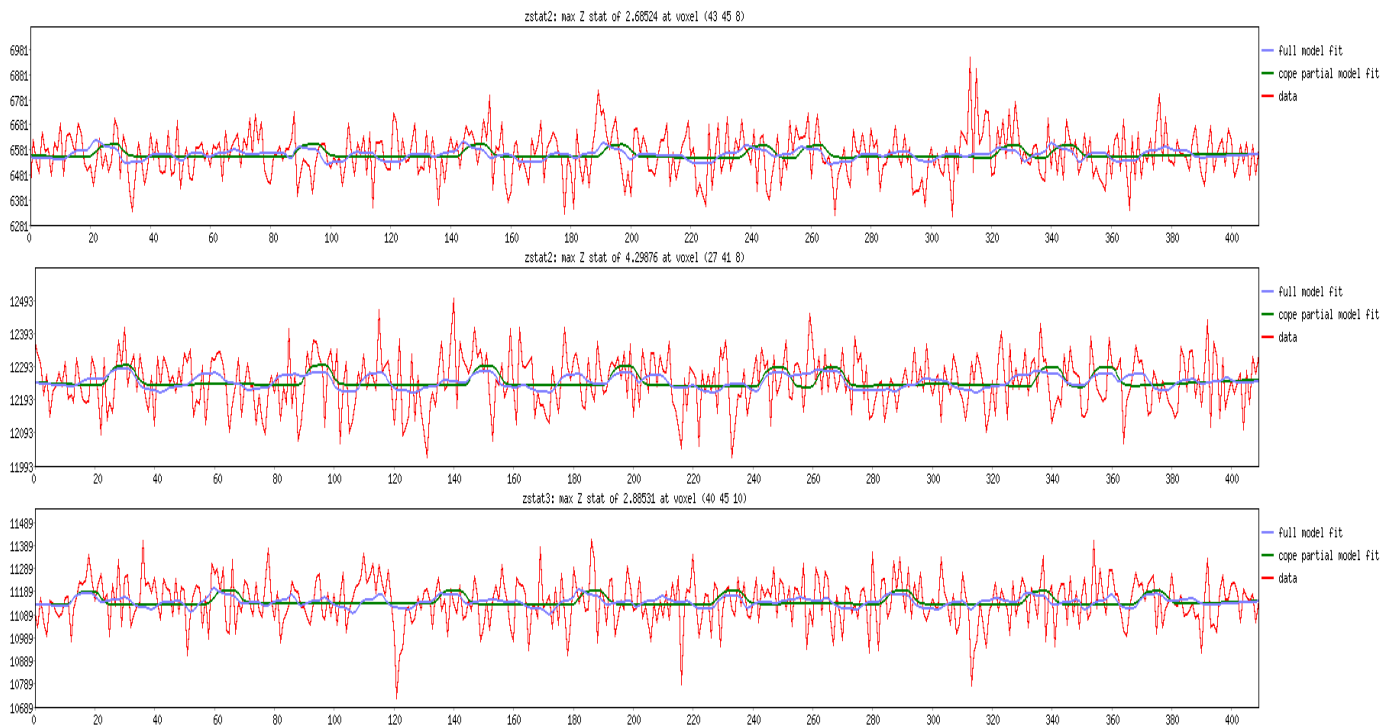


Figure G56.

Examples of Mean Time Series Plot for the left amygdala for the excitement images > neutral images contrast.



Figure G57.

Examples of Mean Time Series Plot for the right amygdala for the excitement images > neutral images contrast.

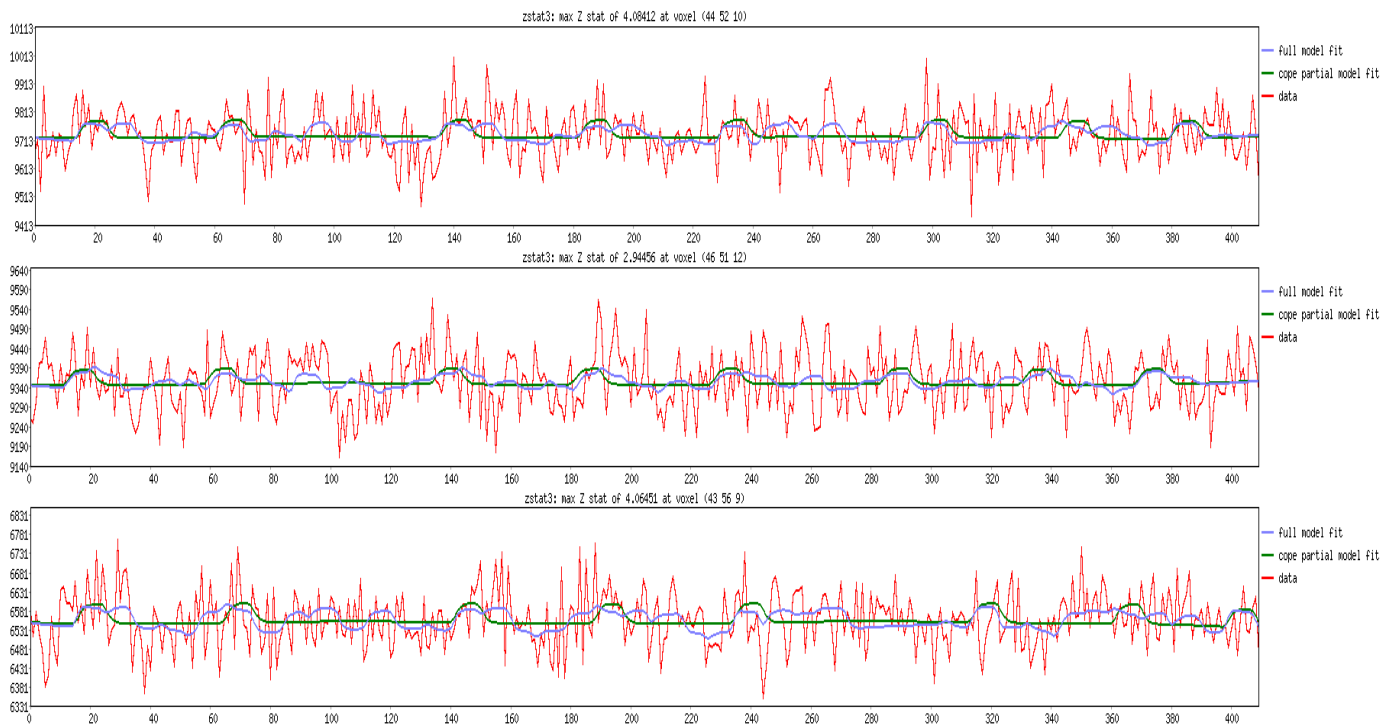


Figure G58.

Examples of Mean Time Series Plot for the left NAcc for the contentment images > neutral images contrast.

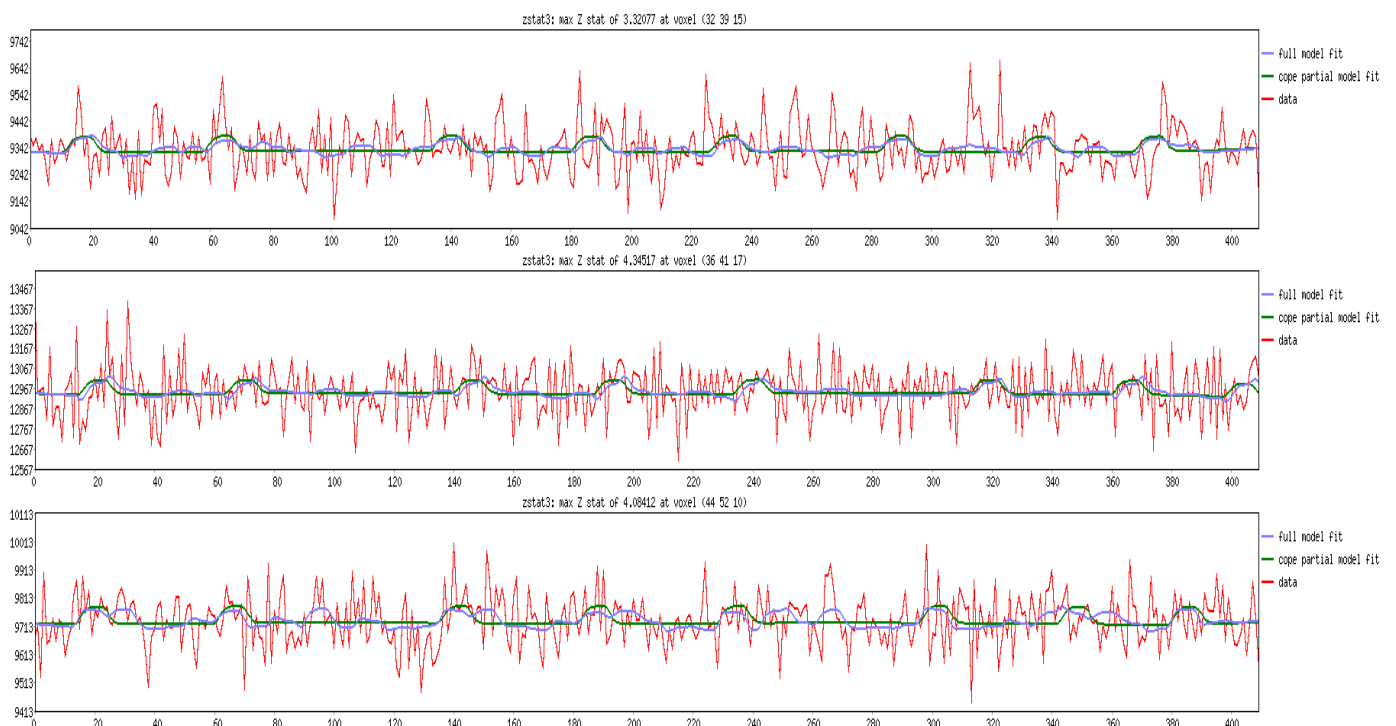


Figure G59.

Examples of Mean Time Series Plot for the right NAcc for the contentment images > neutral images contrast.

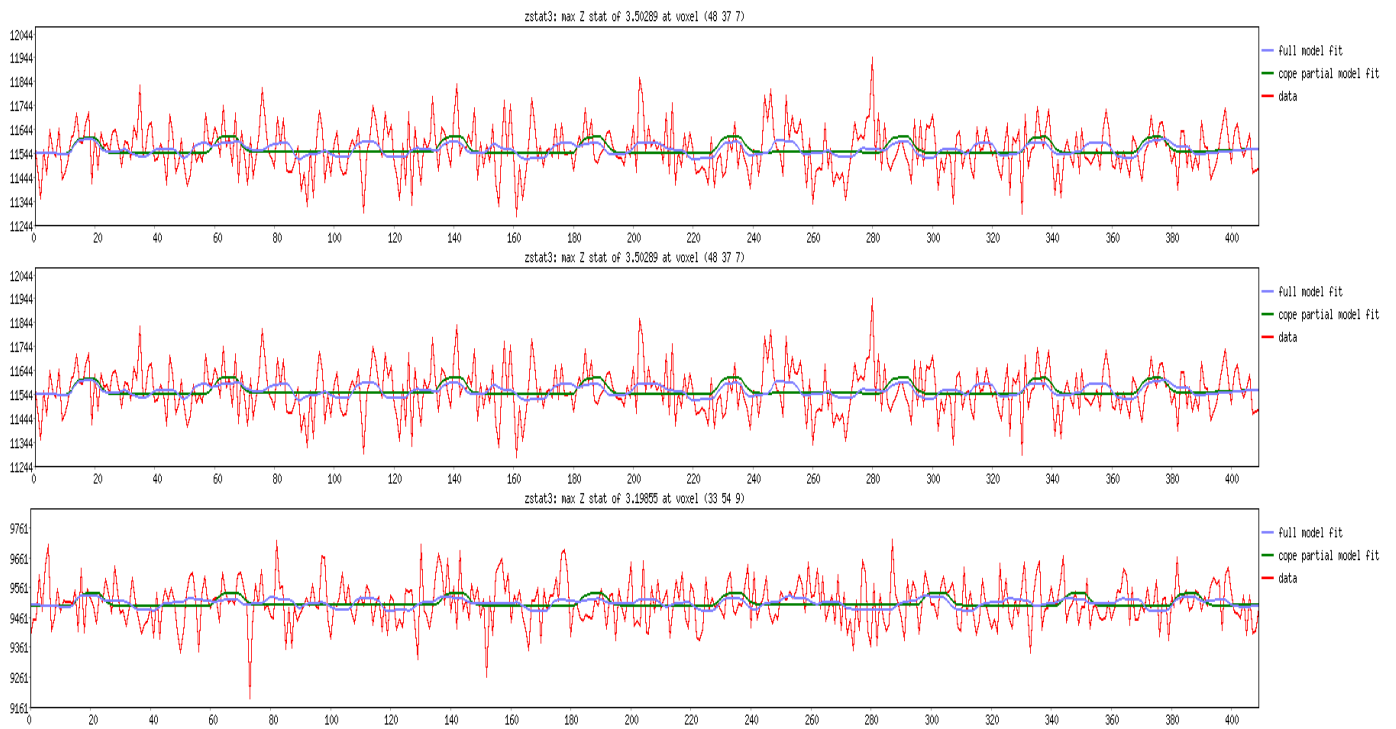


Figure G60.

Examples of Mean Time Series Plot for the left caudate for the contentment images > neutral images contrast.

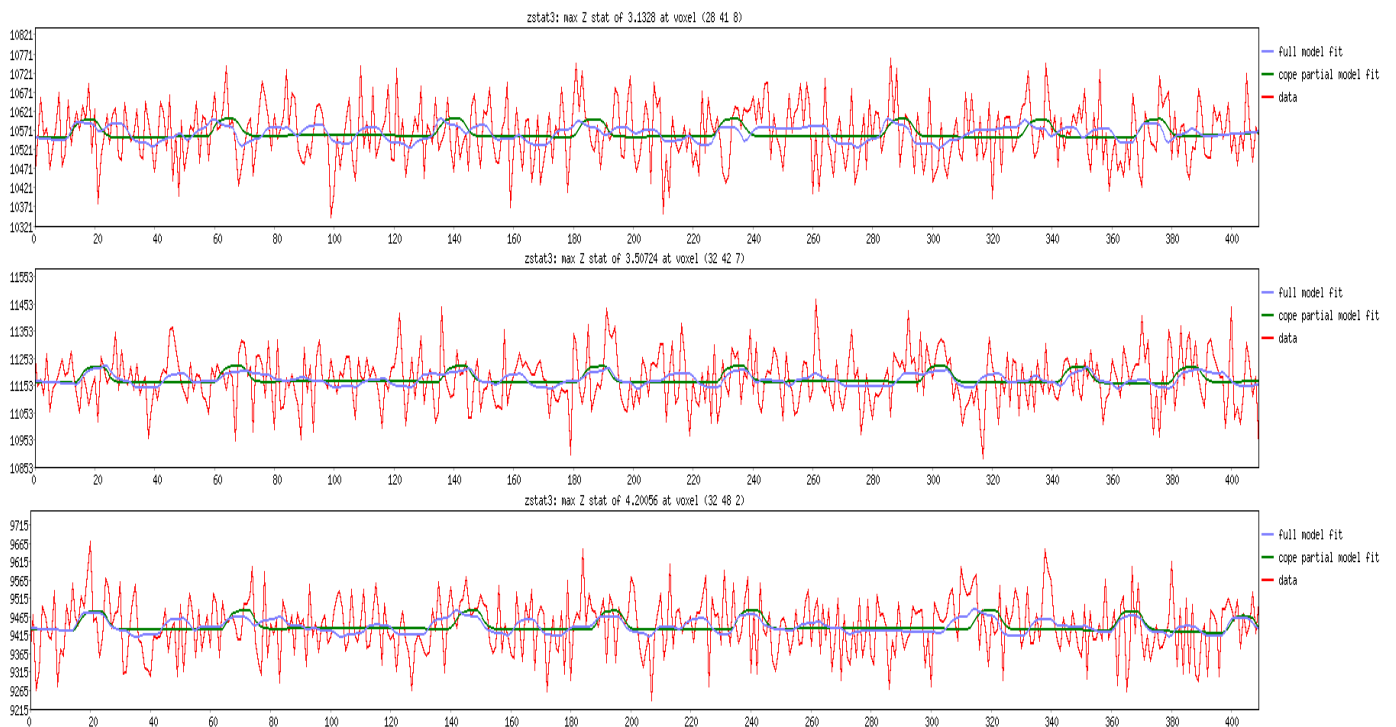


Figure G61.

Examples of Mean Time Series Plot for the right caudate for the contentment images > neutral images contrast.

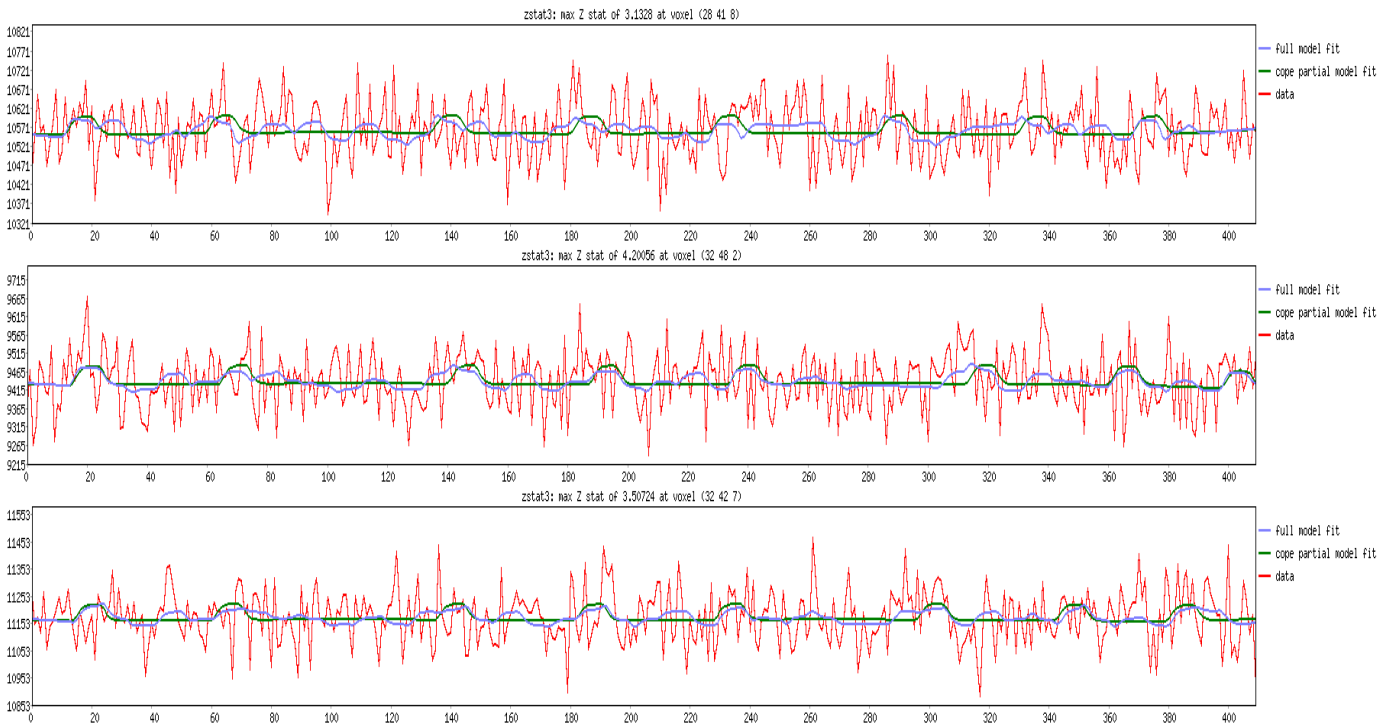


Figure G62.

Examples of Mean Time Series Plot for the left amygdala for the contentment images > neutral images contrast.

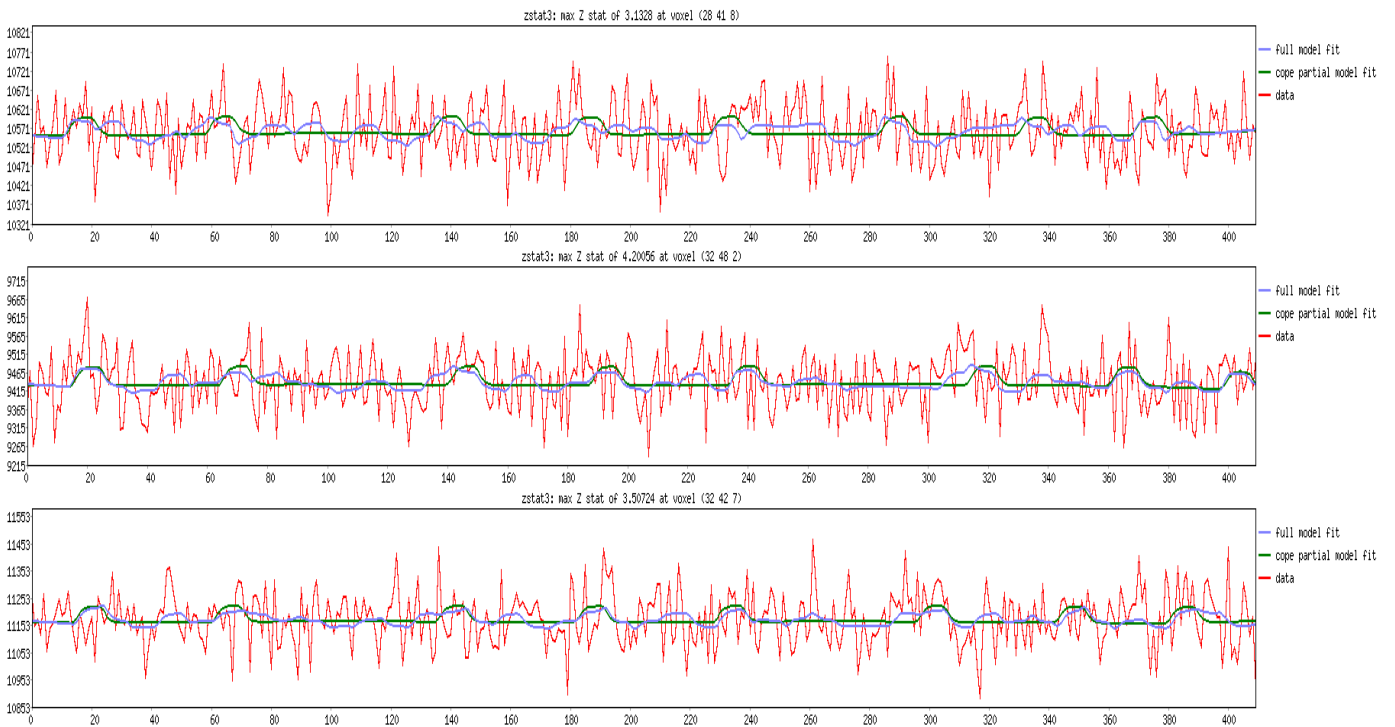


Figure G63.

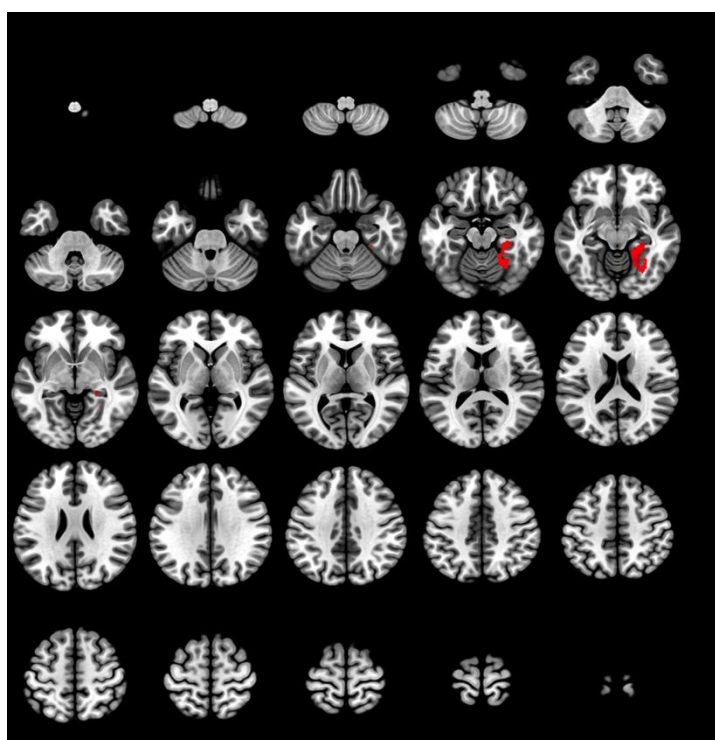
Examples of Mean Time Series Plot for the right amygdala for the contentment images > neutral images contrast.

Table G6.

Coordinates for significant clusters of activation associated with excitement images > neutral images contrast.

Cluster	Voxels	Z-Max	Z-Max X (mm)	Z-Max Y (mm)	Z-Max Z (mm)	Region
1	485	3.7	18	-42	-12	Lingual Gyrus

Note. Reported clusters survived thresholding using clusters determined by $Z > 2.3$ and a (corrected) cluster significance threshold of $p = .05$. Anatomical regions as defined by the Harvard-Oxford Cortical and Subcortical Structural Atlases.



Note. Statistic images were thresholded using clusters determined by $Z > 2.3$ and a (corrected) cluster significance threshold of $p = .05$.

Figure G64.

Group map, excitement images > neutral images contrast.

No clusters of activation survived thresholding for the contentment images > neutrals images and excitement images > neutral images contrast in the student sample (Study One), or for the contentment images > neutrals images contrast in the community sample (Study Two).

