

**Facial affect recognition in young adult offenders:  
Investigating the impact of traumatic brain injury and assessing  
targets for intervention**

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## **Abstract**

Crime and reoffending rates pose a significant societal and economic problem. Traumatic brain injury (TBI) has been associated with higher risk of criminal behaviour and reoffending risk. This project was developed to better understand this association between TBI and criminality and to assess targets for intervention. Here I assess neuropsychological profiles of adolescent and young adult offenders with history of TBI, exploring socioemotional processing as a possible mediator in this effect. Using a novel task, I investigated facial affect recognition and its relation to self-reported TBI across several offending and non-offending samples. The relationship between TBI and facial affect recognition was inconsistent across these studies. Meta-analysing the results suggested there was no clear evidence for deficit in this domain in those with higher severity TBI, in comparison to those without injury. However, the synthesised findings of these studies did suggest strong evidence for increased aggression, delinquency, alexithymia, alcohol and drug use in those with higher dosage of previous injury. Current post-concussion symptomology was a strong predictor of poorer behavioural outcomes. Furthermore, consistent with the wider literature, those recruited from offending populations demonstrated impaired facial affect recognition in comparison to aged-matched, non-offending controls. Building on this, I evaluated the application of a facial affect recognition as a therapeutic intervention for use with these populations. This included a systematic review of current applications and a feasibility study and pilot trial. The trial assessed acceptability and usability of a cognitive bias modification paradigm, for use with a sample of incarcerated violent young offenders. Overall, there are exciting prospects for implementation of strategies of this nature, responding to the need for novel prison interventions. Future high-quality research trials will help determine whether perceptual changes can translate to behavioural outcomes, particularly the alleviation of aggression and antisocial behaviour.

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## List of abbreviations

ADD = Attention deficit disorder

ADHD = Attention deficit hyperactivity disorder

AFC = Alternative forced choice

ASD = Autism spectrum disorder

AST = Attention Switching Task

ATT = attention training tasks

BERT = Bristol emotion recognition task

BJMHS = British Jail Mental Health Screen

CBM = Cognitive bias modification

CD = conduct disorder

CHAT = Comprehensive Health Assessment Tool

CI = Confidence interval

CJS = Criminal Justice System

CRF = case report forms

CTES = Childhood Trauma Events Scale

D-PH = Dunnett's 2-sided post-hoc test

DAI = Diffuse axonal injury

ETI = Early Trauma Self-Report Form

FAR = Facial affect recognition

GCS = Glasgow Coma Scale

HMP = Her Majesty's Prison

LCRC = London Community Rehabilitation Company

LoC = Loss of consciousness

MOT = Motor Screening Task

NOS = Newcastle-Ottawa Scale

OASys = Offender Assessment System

OCD = obsessive compulsive disorder

ODD = oppositional defiant disorder

OGP = OASys General Predictor

OGRS = Offender Group Reconviction Scale

OVP = OASys Violence Predictor

PA = Prolific Academic

PCS = Post-concussion symptoms

PTA = Post-traumatic amnesia

PTI = Youth Psychopathic Traits Inventory

PTSD = Post-traumatic stress disorder

RCT = randomised control trial

RoB = risk of bias

RPCQ = Rivermead post-concussion symptoms questionnaire

RPQ = Reactive Proactive Aggression Questionnaire

RTA = Road traffic accident

RTI = Reaction Time Index

SEE = sensitivity to emotional expressions task

SES = Socioeconomic status

SR-ABM = self-report antisocial behaviour measure

SWM = Spatial Working Memory

TAS = Toronto Alexithymia Scale

TAU = Tel Aviv University

TBI = Traumatic brain injury

UoB = University of Bristol

VR = virtual reality

WASI = Weschler Abbreviated Scale of Intelligence

YOT = Youth offending teams

YPO = Young people with offending behaviour

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# 1 Introduction

## 1.1 Crime and reoffending statistics

Crime poses a significant societal and economic problem. It is a complex and multifaceted construct, with contrasting differences in types of offending, criminal trajectories and incentives that encourage criminal behaviour. Violent crime in particular, is a leading cause of death and disability in older adolescent males (World Health Organization, 2017). The scale of this problem, through direct interpersonal consequences and the wider reaching psychological repercussions on victims and families, led to violence being specified as a global public health concern in 2002 (Krug, D'ahlberg, Mercy, Zwi, & Lozano, 2002). The Office for National Statistics suggests that there has been a rise in theft and higher harm types of violence. This includes a 22% rise in offenses involving knives or sharp instruments, and an 11% rise in firearm incidents in England and Wales in 2017, compared with the previous year (Office for National Statistics, 2018). The increase in knife crime is especially true for youth offenders (under 18 years) and within a year of release from custody approximately 42% of youth offenders have reoffended (Youth Justice Board, 2018). With elevated re-offending rates, and the associated economic burden of £10 to 13 billion for re-offending in England alone, there is a dire need for more effective rehabilitative strategies (Williams et al., 2018).

There is a widely accepted model suggesting criminal involvement typically begins during, and increases across, adolescence; peaking in late adolescence and declining with progression into early adulthood (Sweeten, Piquero, & Steinberg, 2013). This age-crime curve is suggested to be independent of age related differences in economic status and poverty, and has been linked to increased risk-taking tendencies and greater susceptibility to peer influence in adolescence (Shulman, Steinberg, & Piquero, 2013). This is a critical time for intervention, with a distinction made between those who engage in adolescent-limited offending, and those who progress to becoming persistent life-long offenders. It has been suggested that those in the latter group have elevated levels of neuropsychological impairment, difficult temperaments (Moffitt, 1993) and poorer capacity for cognitive maturation (Sigurdsson, Gudjonsson, & Peersen, 2001). Better understanding of persistent life-course

offending profiles, screening and development of effective earlier interventions are needed to tackle the scale of this problem and better identify those at risk for future recidivism.

## **1.2 Neurodisability and vulnerability in the criminal justice system**

Recent evidence suggests there are high rates of neurodisability and mental health issues within the criminal justice system (CJS). A report by the Office of the Children's Commissioner for England (2012) defines neurodisability as:

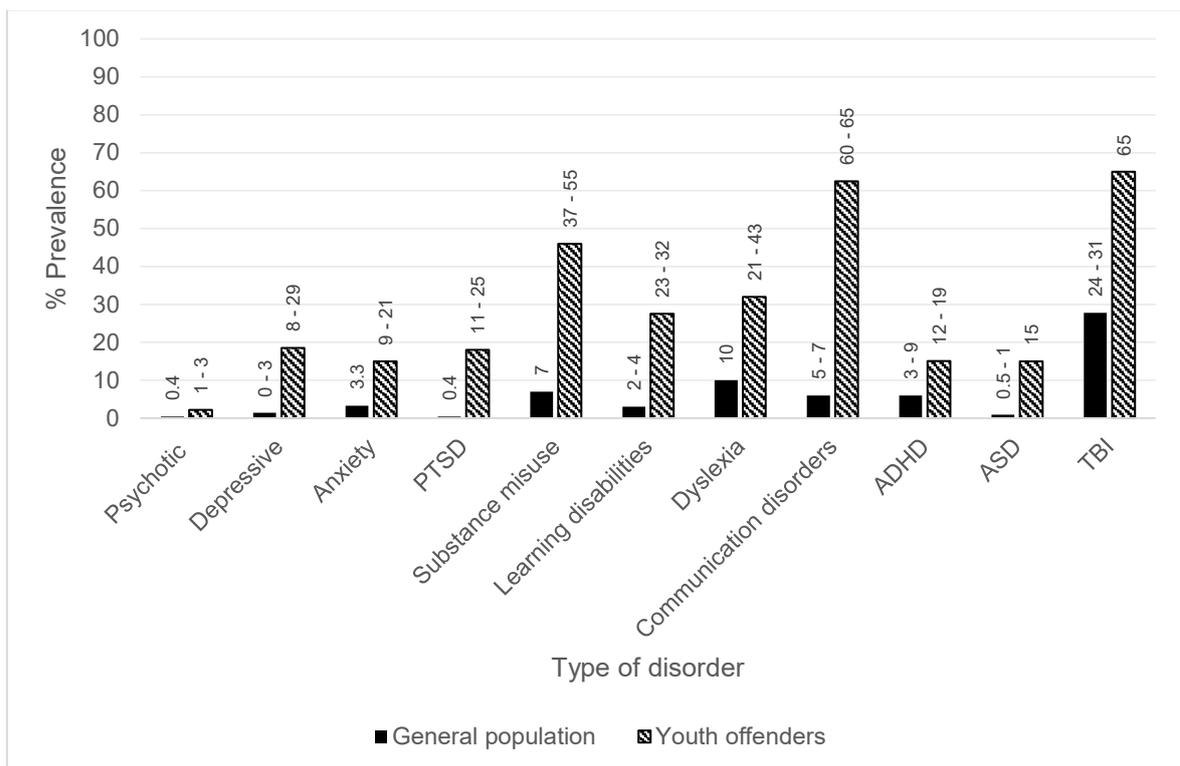
“A compromise of the central or peripheral nervous system due to genetic, pre-birth or birth trauma, and/or injury or illness. This incorporates a wide range of neurodevelopmental disorders, with common symptoms including: communication difficulties; cognitive delays; specific learning difficulties; emotional and behavioural problems; and a lack of inhibition regarding inappropriate behaviour” (Hughes, Williams, Chitsabesan, Davies, & Mounce, 2012, p. 8).

Longitudinal studies indicate that young people with neurodisability are at higher risk for antisocial behaviour which develops into life-course offending trajectories (Chitsabesan, Lennox, Williams, Tariq, & Shaw, 2015). The presence of a neurodisability may affect the ability to engage with rehabilitative interventions due to poor language comprehension, learning difficulties or lack of insight. In addition it may hinder the capacity to effectively navigate the complexities of the CJS processes, including court proceedings and conditions of parole (Chitsabesan & Hughes, 2016).

A comprehensive review of academic papers and government records was conducted to estimate the prevalence of neurodisability for young people within the CJS, compared to the general population. This has been informed by previous work which investigated unmet needs in young offenders, including psychiatric and mental health disorders (Chitsabesan et al., 2006; Fazel, Doll, & Langstrom, 2008). An 'unmet need' is defined as a significant problem requiring some form of intervention which has not been addressed. This concept often captures more psychosocial factors and complex vulnerability than a formal

clinical diagnosis provides (Chitsabesan et al., 2015). Failure to address this need may be due to inadequate screening, poor availability of services or difficulties with service user engagement. A summary of unmet needs and neurodevelopmental disorders is depicted in **Figure 1.1**, adapted from the data presented in Chitsabesan and Hughes (2016). There are particularly high rates of depression, anxiety, post-traumatic stress disorder (PTSD), substance use disorders, learning disability, communication disorders and traumatic brain injury (TBI) in young offending populations in comparison to age matched non-offending counterparts. Recently, high reports of TBI within the CJS and evidence of associated criminogenic profiles, has provoked elevated concern from both academics and policy makers (Chitsabesan et al., 2014; Hughes et al., 2015; Shiroma, Ferguson, & Pickelsimer, 2010).

**Figure 1.1** Prevalence of psychiatric and neurodevelopmental disorders in youth offenders compared to an aged-matched general population sample.



Adapted from Chitsabesan and Hughes (2016, p. 110). Where a prevalence range was given in the original text (e.g. 23 – 32%), the mid-point between the two values has been presented, and the range depicted in the corresponding data labels. ADHD = attention deficit hyperactivity disorder; ASD = autism spectrum disorder.

### 1.3 Traumatic Brain Injury

TBI is a 'major health concern causing a wide range of cognitive and behavioural impairments' (Mansour & Lajiness-O'Neill, 2015). It can give rise to a spectrum of symptoms and psychological deficits in survivors, depending on the nature and severity of the injury. It is a leading cause of death and disability in childhood and young adults, one of the most frequent causes of interruption to childhood development and affects an estimated 10 million people worldwide annually (Dewan, Mummareddy, Wellons, & Bonfield, 2016). Termed 'the silent epidemic' its prevalence is vastly underestimated due to underreporting of injuries, misdiagnosis and complex symptoms which may only become apparent later in the developmental trajectory (Bigler, 2013). A study in 2010 reported 235,000 people hospitalised for TBI each year in the US, with a prevalence estimate of 3.2 million US, and 1.3 million UK citizens living with TBI related disability. This discounts those who fail to be captured through official records (Corrigan, Selassie, & Orman, 2010).

As awareness increases, further research is being devoted to understanding the consequences of injury, of varying causes and severities, on acute and long-term outcomes. However, TBI research still remains dramatically underfunded within the wider group of brain diseases (Sobocki, Olesen, & Jönsson, 2007) in comparison to the associated economic costs, which equate to around £15 billion per year in the UK alone. These costs are, again, likely an underestimation as they do not take into account human costs, such as wellbeing and quality of life (Parsonage, 2016).

#### 1.3.1 Definition and severities

TBI is defined as "an alteration in brain function, or other evidence of brain pathology, caused by an external force" (Menon, Schwab, Wright, & Maas, 2010, p. 1637). Alteration in brain function includes loss of consciousness (LoC), loss of memory prior to or following the event, neurologic deficits (e.g. visual disturbance), and alteration in mental state (e.g. confusion). Clinical manifestations of symptomology may only become apparent after a delay, and this seems to be particularly relevant for neuropsychiatric and

neuropsychological outcomes (e.g. depression, inhibitory control) (Menon et al., 2010). Other evidence of brain pathology includes structural differences as indicated by neuroimaging techniques. 'External force' can include a wide spectrum of causes, but the most common causes of TBI include falls, road traffic accidents (RTA), violence (including fights, firearm and explosion induced blast injuries), falling objects and sports related injuries (A. I. Maas, Stocchetti, & Bullock, 2008). TBI is separate from 'head injury' in that it implicates damage to the brain more specifically, rather than more general damage to the scalp or skull, as can be suggested by the term head injury.

Traditionally, TBI has been defined by whether it is an open injury (such as a penetrating injury arising from a gunshot wound), or a closed injury (such as arising from acceleration-deceleration forces, common in RTA's). There have been, historically a lack of consensus over how to determine TBI and its various forms of severity and psychosocial impact. In general, TBIs tend to be separated into mild, moderate and severe TBI. The Glasgow Coma Scale (GCS) is an universally used clinical tool to assess severity of injury, and uses standard observations of three aspects of patient responsiveness, including eye opening, verbal and motor responding (Teasdale & Jennett, 1974). Mild injury is defined as a score on the GCS of 13 – 15; a moderate injury is defined by a score of 9 – 12; and severe injury is defined by a score of 8 or less (Friedland & Hutchinson, 2013). Period of post-traumatic amnesia (PTA), where the person has no continuous memory of daily events, is also used as an index of severity. PTA within 24 hours from the event of injury considered is mild, PTA between one and six days from the event of injury considered moderate and PTA after 7 days since the event of injury considered severe (Feigin et al., 2013).

Duration of LoC is also used to gauge injury severity and is more common when assessing TBI severity retrospectively. TBI without a LoC, but where the individual experiences being confused or dazed is classified as 'minor, or mild injury without LoC', 'mild injury' is classified as a duration LoC lasting less than 10 minutes, 'complicated mild' injuries encompass those with duration LoC lasting between 10 and 30 minutes, 'moderate injury' includes those with duration LoC lasting between 30 and 60 minutes. 'Severe injuries' include those with a LoC lasting over an hour, and those lasting over 24 hours are classified as 'very severe'. This inclusion of different classification of milder

injuries gives sensitivity to a wider range of injury types and is consistent with European Federation of Neurological Society guidelines (Davies, Williams, Hinder, Burgess, & Mounce, 2012). These severity classification systems can be used in isolation or in combination. In addition, ongoing, or chronic sequelae can be assessed through measurement of current post-concussion symptomology (PCS), often in the domain of cognitive symptoms (such as poor attention or memory) and somatic symptoms (such as dizziness or headaches).

### *1.3.2 Incidence and prevalence*

Incidence is the number of new cases of a disease occurrence during a period of time (e.g. one year), and prevalence is the proportion of the population who have the disease at a point in time. The prevalence and incidence rates of TBI are difficult to determine as many studies use retrospective sampling and are reliant on official records and hospitalisation. It is estimated that around 50 million people worldwide experience a TBI each year, over 90% of which constitute mild injuries (Maas et al., 2017). This estimate omits many milder injuries which are not treated in a hospital setting, or those for which medical assistance is not sought (Andelic, 2013). An important project which addressed this problem was conducted by Feigin et al. (2013) in the Brain Injury Outcomes New Zealand in the Community (BIONIC) study. This was a population based TBI study undertaken between March 2010 and February 2011. They compared incidence rates across rural and urban samples, genders, ages and ethnicities. They used overlapping sources of information including community-based sources such as outpatient clinics and general practitioners, as well as hospitalisations and death certificates. They estimated a prevalence rate of 790 per 100 000 people per year for TBI, with 95% of these (749) fulfilling the classification for mild injuries, corroborating the suggestion that other high-income country estimates had underestimated the true incidence (Corrigan et al., 2010; Tagliaferri, Compagnone, Korsic, Servadei, & Kraus, 2006).

Their results suggested almost 70% of injuries affected children and younger adults (up to age 35 years), with peaks in incidence rates for age groups 5 – 14 years, and 15 – 35 years. Falls and RTAs were the most common cause for each age group respectively. High prevalence of TBI has

also been reported in children 0 – 4 years, attributable predominately to falls and abuse. Injuries below the age of 10 years tend to affect males and females equally, with a stark increase in male injuries after the age of 10 years (Maas et al., 2017). Feigin et al. (2013) also detected a greater risk of moderate-severe injuries in rural compared to urban populations. In the UK ‘serious’ head injury is estimated to have an incidence rate of 52 per 100,000, compared to 12 per 100,000 for ‘severe’ TBI in Australia (Yates, Williams, Harris, Round, & Jenkins, 2006). Yates et al. (2006) reported a rate of 40 per 100,000 for those attending an emergency department with moderate-severe injury, which reflects that of Feigin et al. (2013) with a moderate to severe incidence rate of 41 per 100,000 people.

### *1.3.3 Mechanisms of injury*

Open injuries, such as bullet wounds, tend to result in more focal pathology, with localised damage. Closed injuries tend to result in more diffuse pathology, where a spread of neural damage results from injury. These injuries typically arise from high-speed velocity impact and acceleration-deceleration forces, such as RTA’s or sporting trauma. Due to the anatomical location of the cranial fossa (bones comprising the skull base) and dura mata (membrane enveloping the brain and mediating neural blood flow), movement of frontal and temporal lobes due to impact can create ‘mechanical vulnerability’ for frontotemporolimbic damage (Bigler, 2013). This suggests these neural regions collide against the protruding skull, causing damaging contusions and possible Wallerian degeneration (severing of axonal projections) for medial regions and associated connections (McDonald, 2013). TBI can also result in diffuse axonal injury (DAI). DAI is dependent on inertial forces which deform and ‘shear’ the white matter surrounding neural axons, which becomes more brittle under conditions of severe trauma (Smith, Meaney, & Shull, 2003). DAI following TBI can disconnect large-scale neural networks, leading to network dysfunction and cognitive impairment (Sharp, Scott, & Leech, 2014). The negative effects of DAI have been demonstrated not only for severe TBI’s, but also for moderate and milder injuries. This may be explained by a neural cascade effect, with further

axonal degeneration following the initial neural dysfunction resulting in gradual, progressive impairment (Johnson, Stewart, & Smith, 2013).

#### *1.3.4 Consequences of injury*

Symptoms and consequences of injury vary depending on the type of injury sustained, severity of injury and extent of neuropathology. Ongoing neuropsychological symptomology can account for a greater burden in recovery and for caregivers than the physical symptoms. These include memory problems, attention, executive functioning, behavioural and mood regulation (Fleminger & Ponsford, 2005), processes which are reliant on frontotemporolimbic neural regions. The majority of recovery after TBI takes place in the first two years, but following this prognosis is uncertain. Some will make further recovery and others will deteriorate (Fleminger & Ponsford, 2005). Deficits arising from milder injuries, such as PCS and slower cognitive processing, tend to resolve within one to three months since time of injury (Crowe et al., 2015). Effects of moderate-severe injury tend to be more than three times greater on overall cognitive functioning than that of mild injury (Schretlen & Shapiro, 2003). There are also often physical symptoms such as muscle weakness or slowing of speech, and neuropsychiatric symptoms, such as PTSD, (27% of people with TBI), depression (15 to 33% of people with TBI), and aggression (20 to 49% of people with TBI, depending on criteria used) (Nicholl & LaFrance, 2009).

Sustaining an injury at an earlier time-point, such as during childhood and adolescence can have negative long-term outcomes. This includes a two-fold increased risk of developing a psychiatric disorder later in adulthood (Timonen et al., 2002), and problems with education, employment and quality of life following earlier TBI (Anderson, Brown, Newitt, & Hoile, 2011). A recent Swedish birth-cohort study conducted by Sariaslan, Sharp, D'Onofrio, Larsson, and Fazel (2016) screened 1,143,470 individuals for those who had sustained at least one episode of TBI prior to age 25 years and unaffected siblings. They identified 104,290 participants with a TBI, of which 77% were identified as mild. TBI exposure was associated with elevated risk of impaired adult functioning, for receipt of a disability pension, diagnoses of psychiatric disorders and

hospitalisation, premature mortality, low educational attainment and receipt of welfare benefits. These effects were only mildly attenuated when compared against unaffected sibling controls. Higher risks were associated with those who sustained injury at a later time-point (20 to 24 years old) and there was evidence for a dose-response relationship, with higher injury severity and recurrent injury being associated with poorer outcomes. The authors suggest the inclusion of unaffected sibling controls helps to account for shared genetic and environmental factors, and that their findings are consistent with a causal inference for the effects of childhood TBI on adverse adult outcomes.

## **1.4 Traumatic brain injury and criminal behaviour**

### *1.4.1 Longitudinal cohort studies*

In addition to the adverse outcomes discussed above, there have been a number of large-scale cohort studies which have investigated the associations between earlier injury and later criminal behaviour and convictions. Timonen et al. (2002) investigated the relationship between incidence of TBI with later criminal conviction in the North Finland 1966 birth cohort. Results indicated a 1.7-fold increase risk of criminal conviction following TBI hospitalisation in males. Injury sustained before the age of 12 years was associated with earlier onset of criminality. However, their comparison against population controls did not account for early environmental experience or shared genetic factors. Fazel, Lichtenstein, Grann, and Långström (2011) addressed this and investigated a data-linked Swedish population cohort (also used in Sariaslan et al. (2016)), stratifying experience of a hospitalised TBI by age incurred, severity and diagnostic group. They again incorporated unaffected sibling controls to adjust for familial confounds. Following adjustment, analyses indicated a two-fold increase in risk of specifically violent crime following earlier TBI. This was a reduction from a three-fold increase when investigating the unadjusted predictive value of TBI, emphasising the importance of both TBI and familial factors for predicting violent crime in this population.

Subsequent studies included careful assessment of mediators and confounds. McKinlay, Corrigan, Horwood, and Fergusson (2014) collected

criminal convictions and self-reported delinquency following injury in a New Zealand birth cohort, adjusting for socioeconomic status, early behaviour problems, parental substance abuse problems, pre-existing problems with the child and substance abuse (in a subsection of those who incurred injury later in life), again stratifying by age of injury. Results indicated TBI was significantly associated with increased criminal behaviour, regardless of age at injury or injury severity. These effects remained unchanged after adjusting for pre- and post-injury factors. These findings emphasise the need for further research into consequences of mild injury. The authors suggested that for those incurring injury earlier in life (0 – 5 years) the association was mediated by drug and alcohol dependence. Schofield et al. (2015) investigated consequences of TBI in a retrospective birth cohort in Western Australia, also including sibling controls and concluded the association between TBI and crime was not mediated by psychiatric illness. They concluded their evidence was consistent with a causal relationship between TBI and later criminal convictions, although their observed effect was slightly more modest than that observed in Fazel et al. (2011).

Brewer-Smyth, Cornelius, and Pickelsimer (2015) investigated violent and non-violent criminals using a cross-sectional study, collecting in-depth assessments of early trauma and personality variables. They concluded that whilst TBI predicted criminality, emotional trauma (including childhood sexual and emotional abuse) may play a larger role in predicting violent behaviour than TBI. This emphasises the importance of both early adversity and neurodisability for future risk of criminal behaviour. A recent UK cohort study by Kennedy, Heron, and Munafo (2017) explored earlier TBI and later risk-taking behaviour, including crime, with the inclusion of a negative orthopaedic injury control group. This uses a similar confounding structure without the biological mechanism of brain injury and makes it easier to draw conclusions regarding causative mechanisms. They found associations between TBI and their outcomes of interest, including: alcohol, tobacco and cannabis use, criminal offending and conduct problems. However, the association with criminality was attenuated when compared against the orthopaedic controls. This suggests it may be the presence of an injury, rather than a head injury specifically, which is instrumental in predicting criminality. They also suggested age at injury was an

important factor with differential outcomes depending on the age at which the injury was sustained. Unfortunately, they were unable to obtain a measure of injury severity, limiting the ability to draw conclusions regarding differences between severity groups. They suggested their sample comprised a predominantly mild injury group which may differ in consequences from moderate to severe injuries (more typical of those with hospitalised TBI as recruited in (Fazel et al., 2011; Schofield et al., 2015; Timonen et al., 2002). The attenuation of the association with crime when including negative controls is interesting and suggests there may be other causal factors to acknowledge, such as trait impulsivity and sensation-seeking.

These studies in combination and the longitudinal nature of the designs allows for causal inferences to be made due to the temporal relationship between exposure and outcome (Kennedy et al., 2017). The evidence is fairly consistent in suggesting an association between TBI and later criminal behaviour, but there may be confounding factors such as sensation-seeking, early adversity and the use of alcohol and illicit substances, meaning the direction of causality is continually debated. The severity of injury, age at which the injury was sustained, and number of injuries experienced appears to play an important role in predicting adverse long-term outcomes.

#### *1.4.2 Prevalence of TBI in the criminal justice system*

As mentioned, the prevalence of TBI within the CJS is elevated in comparison to the general population. This is often interpreted as supporting evidence for an association between TBI and criminal behaviour (Williams, McAuliffe, Cohen, Parsonage, & Ramsbotham, 2015). Studies investigating the prevalence of injury within offending populations are effectively summarised by meta-analyses conducted by Shiroma, Ferguson, et al. (2010) and Farrer, Frost, and Hedges (2013), and a systematic review by Hughes et al. (2015). Shiroma et al. (2010)'s meta-analysis synthesised twenty epidemiologic studies of TBI prevalence in adult offending populations and gave an estimated prevalence of 60% of adult offenders having experienced some form of lifetime TBI (95% confidence interval (CI) of 48 to 72%), compared to around 8.5% in the general population (Shiroma, Pickelsimer, et al., 2010). TBI with a LoC was

estimated at a prevalence rate of 50% in offending populations (95% CI of 40 to 60%). Hughes et al. (2015) conducted a systematic review of TBI prevalence in incarcerated juvenile offending populations (under 18 years), synthesising information from ten included studies. They estimated between 50% and 71% of incarcerated young people had experienced some form of head injury, and 16.5% to 49% had experienced TBI with a LoC. They conclude that the reported prevalence is consistently higher in incarcerated young people, compared to community-based offenders and non-offending controls, and the disparity increases with increased severity of injury. Farrer et al. (2013) meta-analysed nine prevalence studies for young offenders, and suggested a prevalence rate of around 30% for TBI with LoC, in line with the estimates suggested by Hughes et al. (2015) with offenders being three times more likely to sustain a TBI compared to non-offending control groups.

#### *1.4.3 Traumatic brain injury and criminogenic profiles*

In addition to higher prevalence of TBI being observed for offending populations, evidence suggests that those who have sustained injury may have divergent criminal profiles compared to those without injury. Williams, Cordan, Mewse, Tonks, and Burgess (2010) found evidence that young offenders with TBI had higher re-offending rates, increased violence in offences in those with repetitive injuries, and higher rates of mental health problems and substance misuse, compared to those without injury. Kenny and Lennings (2007) interviewed 242 incarcerated young offenders in New South Wales and found that presence of a TBI was associated with serious violent offences specifically. This effect was related to the length of the duration of LoC, with those with a LoC for over 10 minutes being at higher risk of serious violent offending. They suggested that the presence of a head injury lowers the threshold for violence in young offenders, increasing levels of disinhibition and reactive aggression. They also suggest that this association may be mediated or exacerbated by alcohol use. Leon-Carrion and Ramos (2003) recruited 49 adult male prisoners from southern Spain and found evidence that both violent and non-violent prisoners showed difficulties with school and education, however only those people with combined education problems and non-treated TBI predisposed people to

violent behaviour. Presence of a TBI has also been associated with increased number of infractions for incarcerated males and females in North Carolina, USA (Shiroma, Pickelsimer, et al., 2010). Perron and Howard (2008) interviewed 720 young offenders in Missouri, USA and their results suggested 18% had experienced a TBI with a LoC elapsing 20 minutes. Those with this level of injury were more likely to be male, have a psychiatric diagnosis, have an earlier onset of criminal behaviour, a higher number of previous convictions and higher risk of lifetime suicidality. An association has also been made between sustaining TBI with a LoC and life-course persistent offending trajectories (Raine et al., 2005).

Presence of a TBI in offenders has also been associated with neuropsychological performance and psychiatric disorders. A UK study conducted by Pitman, Haddlesey, Ramos, Oddy, and Fortescue (2014), used a novel self-report screening measure (the Brain Injury Severity Index) on a sample of 613 adult male prisoners, identifying 103 with TBI for neuropsychological assessment and in-depth structured interviews, compared with a sample of 50 non-injured offending counterparts. They created a TBI severity score by combining the number of injuries against respective injury severities and correlated the presence of an injury and the combined severity score against a range of behavioural, psychiatric and neuropsychological outcomes, using standardised questionnaires and neuropsychological tests. Participants with a higher TBI severity score displayed more problems with memory, aggression, disinhibition and executive function. They also reported higher levels of depression, anxiety and generalised neurocognitive deficit than non-injured counterparts. The neuropsychological outcomes are of interest, however the use of a brief screen for neuropsychological function in this study impairs the ability to explore the specific nature of these deficits in detail. Davies et al. (2012) also utilised a self-report dose-response approach, investigating the influence of frequency and severity on PCS in young male offenders. They found evidence for increased symptomology in cognitive and somatic domains in those with higher severity and frequency of injuries. This effect remained when adjusting for the synchronous increase in hazardous alcohol use with higher dosage of injury. Chitsabesan et al. (2015) used a self-report tool developed for use with young offenders in the UK justice system

(Comprehensive Health Assessment Tool; CHAT) to measure TBI history. They identified 18% (of  $n = 279$  young people) with a TBI related 'need'. This was identified as those with a LoC lasting over 30 minutes, or three or more instances of milder injuries with LoC. In this sample there was also evidence for ongoing PCS, needs relating to alcohol and substance misuse, as well as higher self-harm and suicide risk factors.

These findings in combination build an argument for the complexity of need surrounding individuals within CJS who have experienced a TBI. There seems to be important implications for those with history of untreated injury, especially when injury takes place in childhood and adolescence. There is evidence for a dose-response relationship, with increased symptomology and adverse outcomes for those with higher severity or frequency of injuries. There are also associations with psychiatric health problems, neurocognitive deficit, aggression and disinhibition, drug and alcohol use, as well as more extensive criminal histories, higher risk of reoffending and increased violence in offending behaviour. There is difficulty establishing causation with observational and cross-sectional experimental designs of this nature, however this highlights the comorbidity of TBI with other criminogenic risk factors and emphasises the importance of screening for injury and better understanding of associated profiles in those with identified history of injury.

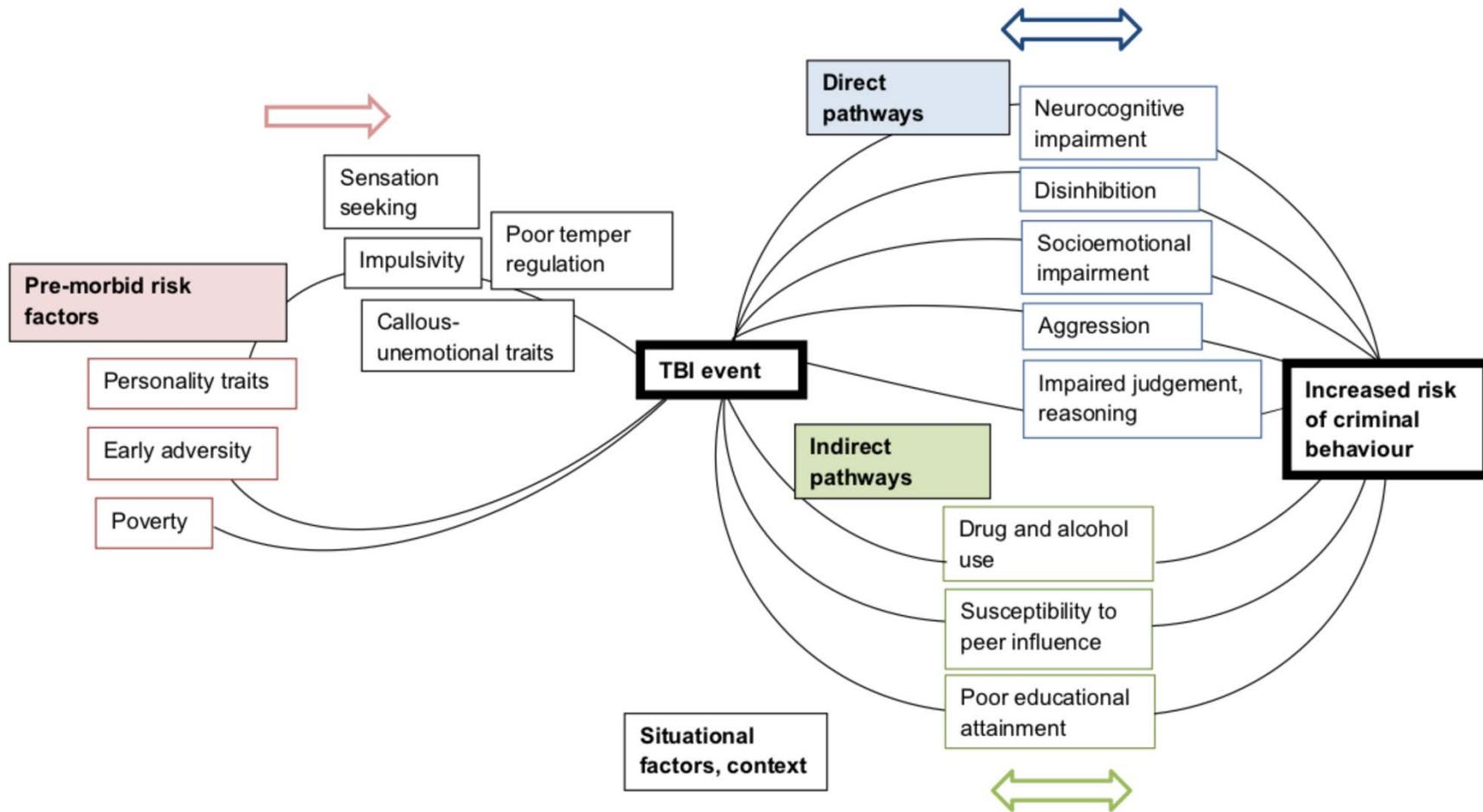
#### *1.4.4 Pathways to criminal behaviour*

It is difficult to pinpoint exact mechanisms which influence criminal behaviour, due to a complex interplay of internal and external factors and dispositions which may elicit a particular behaviour or outcome. Part of this complexity is the aforementioned co-morbidity with other needs and behavioural impairments which may be a consequence of, a precursor to, or mediated by, TBI. The schematic depicted in **Figure 1.2** illustrates possible pathways between TBI and criminal behaviour. This identifies direct and indirect mechanisms which may encourage engagement with criminal behaviour following injury, and pre-morbid factors which could increase the risk of TBI or criminal behaviour, either in combination or in isolation. This model is by no means exhaustive but gives examples of some plausible influential

mechanisms. 'Direct pathways' illustrated here pertain to common neuropsychological outcomes or symptoms of TBI which have logical links with criminal behaviour. This includes general neurocognitive impairment, deficit in socioemotional processing, impaired judgement or reasoning, disinhibition and aggression. Neurocognitive impairment has been linked to early onset and life-course persistent offending in adolescent males (Raine et al., 2005), and socioemotional deficit and disinhibition have been implicated in poorer outcomes regarding treatment engagement and behaviour modification (Fishbein et al., 2006), which can increase risk of future reoffending. Executive function deficits, including disinhibition, impaired judgement and reasoning and understanding consequences of actions have been implicated as a precursors to criminality (Ogilvie, Stewart, Chan, & Shum, 2011), and juvenile offenders with TBI have been found to have higher levels of impulsivity and negative emotionality (Vaughn, Salas-Wright, DeLisi, & Perron, 2014).

Early evidence of difficult temperament, sensation-seeking and aggression in early pre-school years has been linked with childhood delinquency and later serious juvenile offending, as has lower socioeconomic status (SES), neighbourhood disadvantage and poverty, parental neglect and parental abuse (Loeber & Farrington, 2000). In addition, sustaining a TBI may be an artefact of increased risk-taking and impulsivity, either as part of a stable sensation-seeking personality trait or due to adolescent fluctuations. These factors are illustrated by the 'pre-morbid risk factors' in **Figure 1.2**. This suggests there may be pre-existing criminal trajectories in some individuals which are then exacerbated by the presence of a TBI. There may also be indirect pathways by which sustaining a TBI makes you more vulnerable to criminal behaviour. A few examples of these are detailed in the 'indirect pathways' section of **Figure 1.2**. This might include earlier TBI leading to lower educational attainment, and disengagement with the educational system (Ewing-Cobbs et al., 2006; Prasad, Swank, & Ewing-Cobbs, 2017), increasing the risk of engagement with criminal behaviour, or increased vulnerability to negative peer influence following an injury (Grosbras et al., 2007). This could be of particularly importance given the environment the person is in, including contextual factors such as high levels of neighbourhood violence or gang-related crime.

**Figure 1.2** Schematic illustrating direct and indirect pathways to offending following TBI, and influencing factors



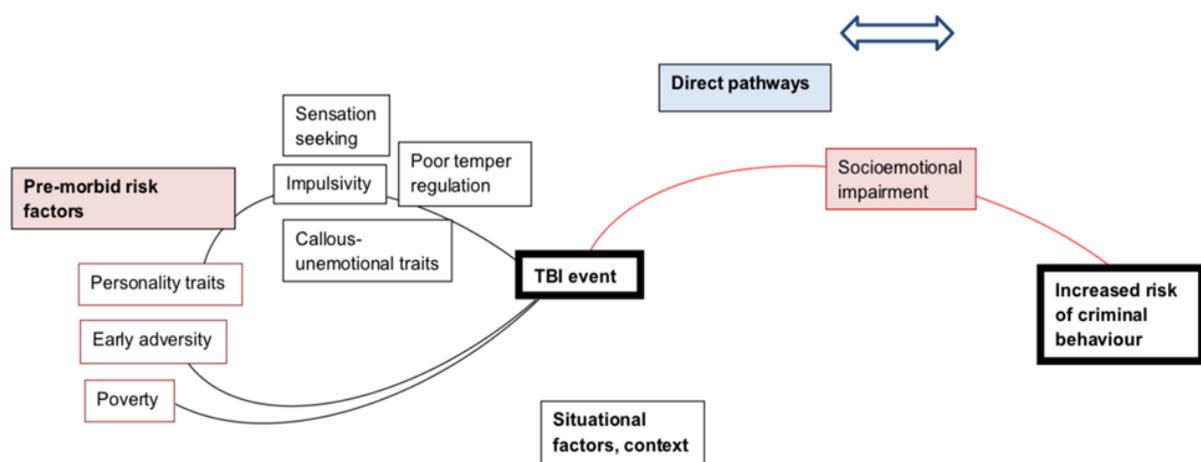
Another factor which may be highly influential within this association, is the use of drugs and alcohol. Longitudinal studies suggest there are increased risks of substance and hazardous alcohol use following TBI, including milder injuries (Kennedy et al., 2017; McKinlay et al., 2014), which increases the risk of criminal behaviour and incarceration (Slade et al., 2008). Situational factors and context are influential at any level in the model and include factors such as cultural attitudes to aggression and delinquency, rural versus urban environments and incentives for criminal behaviour.

As stated, these illustrated mechanisms are by no means exhaustive and many of the pathways outlined here are likely to be bi-directional (illustrated by the corresponding coloured arrows). The potential for reverse causation is apparent in the association between TBI and criminal behaviour, with both the proposed direct and indirect pathways increasing risk for engaging in criminal behaviours and experiencing a TBI. The current literature acknowledges the difficulty in establishing causality and directionality of effects, however suggests evidence points to a more complex influence of TBI on crime, than simply being coincidental with pre-morbid criminal trajectories (Williams et al., 2018).

The pathways outlined above provide suggestions for underlying mechanisms which may mediate this association between TBI and criminal behaviour. However, these suggestions are speculative and currently we lack a comprehensive evidence base detailing the influence of these factors. Better understanding of these pathways and their proportional influence will be valuable in informing preventative strategies to attempt to address this problem and reduce re-offending rates. If there is evidence for a direct effect of TBI on criminal behaviour, with ongoing neuropsychological deficit as a consequence of injury encouraging criminal tendency, then this helps to guide targeted screening and formulation of neurorehabilitative interventions for use with these populations. Within this thesis, I address this need for evidence, by investigating whether there is evidence for direct impairment following TBI, focusing on one of the domains suggested in **Figure 1.2**. Due to the implications of previous TBI with *violent* crime in particular, I decided to investigate impairment in socioemotional processing as a possible mediator in this effect (**Figure 1.3** illustrates this simplified pathway). complex influence of TBI on crime, than simply being coincidental with pre-morbid criminal trajectories (Williams et al., 2018).

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**Figure 1.3** Simplified schematic of proposed pathway between TBI and risk of violent crime



## 1.5 Socioemotional processing as a mediating factor

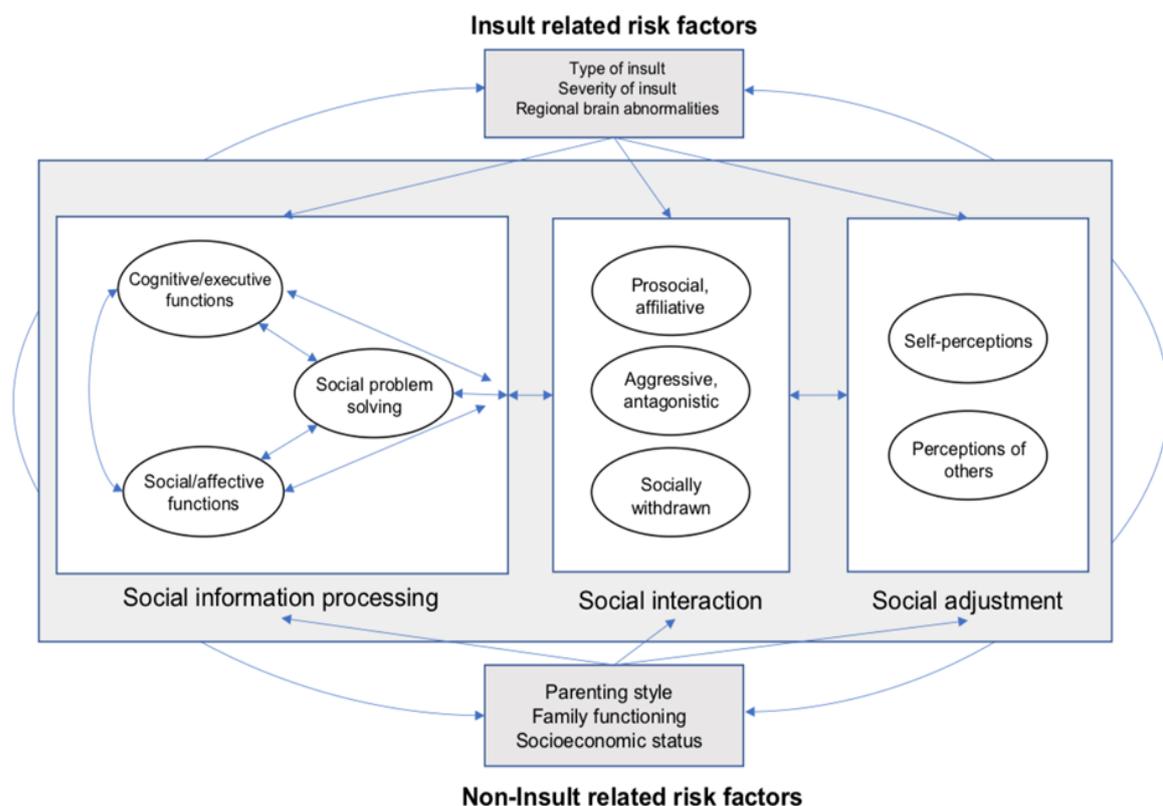
### 1.5.1 Theoretical models of social function

Socioemotional processing is a broad term which encapsulates social cognition and the interpretation and effective navigation of social and emotional information. Socioemotional processing facilitates the wider domain of social function, which encompasses social interaction, social adjustment and social competence (Anderson & Beauchamp, 2012; Rosema, Crowe, & Anderson, 2012). The development of these skills, according to the 'socio-cognitive integration of abilities' model proposed by Beauchamp and Anderson (2010), is governed by brain development and integrity, internal factors (such as personality and temperament) and external factors (such as SES and family dynamics). These influencing factors affect the development of core cognitive abilities including attention and executive functioning, communication abilities and social cognition, which in turn predict social function. Social cognition in itself is also a broad domain, including aspects of 'hot' social cognition, that is, emotion processing including identification of emotions and affective empathy, and 'cold' social cognition, including more deliberate cognitive processes such as theory of mind, cognitive empathy and moral reasoning (McDonald, 2013).

Yeates et al. (2012) develop this model further and propose an integrative multilevel model outlining how different aspects of social functioning interact to achieve social competence, and how this process responds to the event of a TBI. A visual representation of this model is provided in **Figure 1.4**. This includes three related core sections, social information processing (synonymous in this case with socioemotional processing), social interaction and social adjustment. Social information processing encompasses social problem solving, social and affective functions and cognitive and executive functioning. This mainly reflects the rationale of the social information processing model proposed by Crick and Dodge (1994). This suggests separate stages within a social situation, including interpretation of cues, clarification of goals, generation of responses, selection and implementation of response, and evaluation of the outcome of the interaction. The processing of social information, and the ability to problem solve in this way (informed by cognitive and executive functions) informs the subsequent social interaction.

The social interaction, broadly speaking, has been categorised into three main approaches: prosocial or affiliative, aggressive or antagonistic and social withdrawal from the situation. The way in which individuals socially interact in turn corresponds with their social adjustment and competence – the extent to which socially desirable goals are attained, evaluated by perceptions of self or perceptions of others (Yeates et al., 2012). These core components are closely interrelated, and the model is bi-directional. Social functioning can also be affected by environmental risk factors such as parenting style and attachment formation, poverty and SES and early adversity in the home. The experience of a TBI or other brain insult during development can affect any, or all, aspects of this social competence model, indicated by the far-reaching influence of TBI within this depicted figure. In addition, the external injury and non-injury related risk factors are interrelated, with those from adverse family environments and lower SES being at higher risk for sustaining TBI (Amram et al., 2015).

**Figure 1.4** Integrative model of social competence in children with TBI.



Adapted from Yeates et al. (2012) with permission from the authors.

### *1.5.2 Social neuroscience perspectives*

Advances in the sophistication of neuroimaging techniques and neuropsychological testing have led to the identification of neural regions which subserve different aspects of social cognition in the model presented above. Some key neural regions include the amygdala, the temporoparietal junction, the prefrontal cortex, the ventral striatum, the insula and the anterior cingulate cortex (Adolphs, 2001; Rosema et al., 2012). The amygdala, ventral striatum and the orbitofrontal cortex are implicated in the mediation of perceptual inputs and emotional responses, communicating with cortical structures in the creation of internal representations of the social environment. This communication takes place via the anterior cingulate cortex and prefrontal cortex which facilitates executive and higher-order cognitive functions (Adolphs, 2003). The neural development of these regions throughout childhood and adolescence parallels advances in more complex socioemotional processing and social functioning (Richardson, Lisandrelli, Riobueno-Naylor, & Saxe, 2018; Tonks et al., 2009).

Limbic regions and sub-cortical structures (such as the amygdala) tend to develop at a faster rate than cortical structures including the prefrontal cortex. Protracted maturation of frontal cortical structures takes place across late adolescence and early adulthood. This involves synaptic pruning, increased myelination and higher connectivity with subcortical regions. This in turn allows more efficient transmission of information between executive functions such as inhibition control and goal setting, and socioemotional processing (Steinberg, 2007). During early to mid-adolescence, the subcortical limbic regions implicated in the affective components of social processing, such as emotional processing and emotional-regulation, undergo a dramatic increase in dopaminergic activity via the ventral striatum, leading to an increased drive for reward and higher emotional reactivity (Wahlstrom, Collins, White, & Luciana, 2010). This lack of temporal cohesion between the increased need for reward and the maturation of executive neural systems facilitating cognitive functioning, makes adolescents more vulnerable for engaging in risky, thrill-seeking behaviour (Steinberg, 2010). This helps to explain why adolescence is an increased period of impulsivity as immediate goals are often prioritised over long-term outcomes (Chambers, Taylor, & Potenza, 2003). Furthermore, risky behaviours are exacerbated by the presence of peers (Chein,

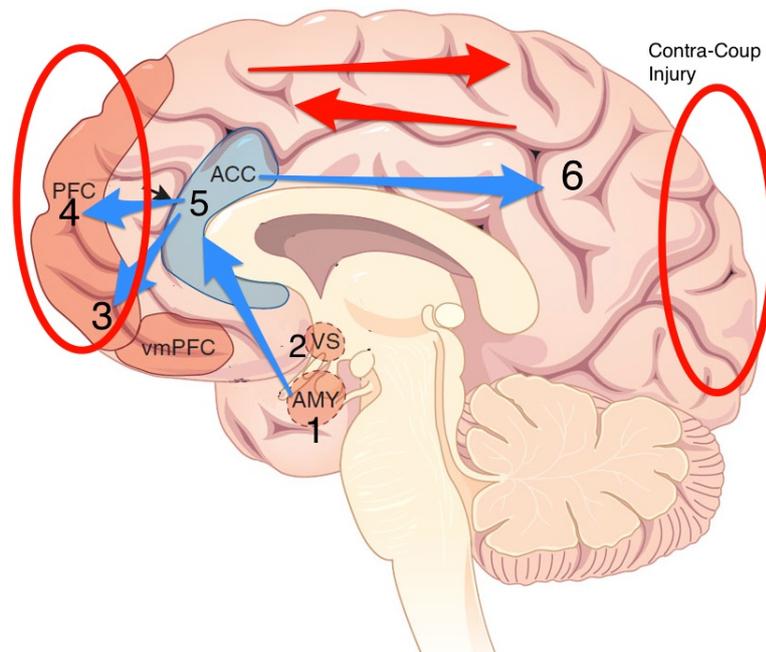
Albert, O'Brien, Uckert, & Steinberg, 2010), helping to explain the pervasive age-crime curve previously mentioned (Shulman et al., 2013). This increases risk for engagement in dangerous and sometimes criminal behaviour such as use of illicit substances, unsafe sex, joy riding and fighting, which conversely increases the risk of sustaining injury, including a TBI.

It has been suggested that regional specialisation of socioemotional neural structures throughout childhood and adolescence is not a modular process but occurs as a function of interactive specialisation. This suggests that the functional development of a specific brain region is determined by its patterns of connectivity to other brain regions, which is dictated by the individual's experiences (M. Johnson et al., 2005). This emphasises the importance of brain networks rather than brain regions in promoting social function. Based on this, the connectivity of the brain, and the integrity of white matter pathways which facilitate this, is considered essential for social brain development (Yeates et al., 2012). These neural regions within the social brain network are highly interconnected, with a high density of projections between cortical and subcortical structures, mediating socio-affective processing and cognitive executive functioning via the anterior cingulate cortex.

### *1.5.3 The social brain and traumatic brain injury*

When damage to the brain is incurred through trauma, the frontotemporal regions of the brain, particularly the frontal and temporal poles, are vulnerable to injury (Bigler, 2007). In addition to this, highly interconnected neural regions are more susceptible to the effects of DAI (McDonald, 2013). This includes structures such as the orbitofrontal and medial prefrontal cortex, the ventral striatum and the anterior cingulate cortex, highlighting the risk of disruption to the socioemotional network as a consequence of TBI. Examples of these regions, their connecting pathways, and mechanisms of injury are depicted in **Figure 1.5**. When damage is sustained to these structures it can have a profound effect on the capacity for socioemotional processing. This in turn has negative implications for subsequent social interactions, social adjustment and social competence (Tonks et al., 2009; Yeates et al., 2007).

**Figure 1.5** Neural regions involved in the socioemotional processing network and injury mechanisms.



1 = amygdala, 2 = ventral striatum, 3 = orbitofrontal cortex, 4 = medial prefrontal cortex, 5 = anterior cingulate cortex, 6 = parietal cortices. Blue arrows indicate areas of high axonal and functional connectivity, red circles and arrows represent areas which are vulnerable to TBI, especially in high-speed velocity trauma. Image modified from Tost and Meyer-Lindenberg (2012), with permissions from Springer Nature.

Injury sustained in childhood and adolescence is suggested to be particularly problematic for long-term socioemotional outcomes. Key factors in relation to this are age at which the injury was sustained and time since injury (Ryan et al., 2014; Yeates et al., 2012). The theory guiding this suggests that injury prior to, or during, important stages in neural development disrupts the formation of these connections at a pivotal stage. Disruption to the development of these networks may cause protracted or prevent subsequent development (Anderson & Moore, 1995). In comparison, injury sustained at a later developmental timepoint or in adulthood, when these networks are more established and resilient, may be less functionally disruptive (Dennis & Levin, 2004). An opposing argument to this suggests that earlier injuries sustained may have more positive outcomes due to greater neuroplasticity allowing greater functional organisation. This was originally proposed in the 1940's

and has had inconclusive supporting evidence (Sariaslan et al., 2016). The relationship between age at injury and outcome is not thought to be linear, but reflects key developmental timepoints in which rapid neural development takes place, in peaks and plateaus (Ryan et al., 2015). The complexity of neural development, the advances in reward-seeking behaviour and the affiliated risk of TBI, highlights adolescence and young adulthood as a critical age group high risk for damage and pervasive symptomology.

In addition to this, age at which outcomes are assessed is also of importance. It has been suggested that some deficits may not become apparent until later stages in socioemotional development, when interactions become more complex and more sophisticated processing is required (Savage, 2009; Tonks et al., 2009). This theory is called “growing into the deficit”, however, the evidence supporting this is also inconsistent (Anderson, Godfrey, Rosenfeld, & Catroppa, 2012). Furthermore, the severity of injury sustained is of importance, with the majority of long-term neurocognitive deficits following childhood TBI arising from moderate and severe injuries, rather than mild injuries (Babikian & Asarnow, 2009). Ryan et al. (2014) found deficit in socioemotional processing, in the recognition of emotion in both visual and auditory domains, was pronounced for a group of children who sustained a severe injury before the age of 7 years. Deficit in these domains was related to frontal pathology and corpus callosum volume, as well as non-injury resilience factors such as SES and family dynamics, such as those identified in the heuristic model detailed in **Figure 1.4**, and the pre-morbid risk factors in **Figure 1.2**.

The association between TBI and poorer socioemotional outcomes has been supported by extensive evidence, demonstrating poorer performance for different measures of social cognition in those with injury, compared to non-injured controls. These effects are most consistently observed in survivors of moderate to severe TBI (see McDonald (2013) for a review of impairments following severe injury). This includes deficits in theory of mind and cognitive empathy (Henry, Phillips, Crawford, Ietswaart, et al., 2006; Ryan et al., 2017; Ryan et al., 2015; Tonks et al., 2008), cognitive flexibility (Milders, Ietswaart, Crawford, & Currie, 2008), detecting social faux pas (Milders, Fuchs, & Crawford, 2003), alexithymia (the experiencing, identifying and describing of emotions) (Henry, Phillips, Crawford, Theodorou, &

Summers, 2006) and affective communication (Borgaro, Prigatano, Kwasnica, Alcott, & Cutter, 2004).

#### *1.5.4 Facial affect recognition and traumatic brain injury*

One of the most consistent findings of socioemotional impairment following TBI, is for the domain of emotion recognition, and particularly facial affect recognition (FAR) (Rosema et al., 2012). The ongoing interest in this component of socioemotional processing stems, in part, from FAR being one of the more overt, and therefore more readily observable aspects of social cognition (as compared to more abstract concepts, such as moral reasoning). However, its predominance also reflects the importance of FAR within social functioning, in guiding subsequent interactions and facilitating development of more complex forms of social processing. FAR has been described as crucial to social reciprocity (Anderson & Beauchamp, 2012), with facial expressions coordinating interactions through their informative, evocative, and incentive function (Matsumoto, Keltner, Shiota, O'Sullivan, & Frank, 2008). The interpretation of expressive cues of facial emotion forms the fundamental stage within Crick and Dodge (1994)'s social information processing model, guiding subsequent interpretation and appropriate responding.

There are numerous ways of assessing FAR, but typically paradigms utilise validated stimulus sets, with images of people displaying facial expressions and the participant is required to identify the presented emotion. These will usually include what have been termed the six basic or 'universal' facial expressions, including: happiness, sadness, fear, disgust, surprise and anger. These have been termed universal expressions, originally by Ekman (1992), as they are thought to be recognised universally, across cultures. Stimuli tend to be displayed in either a static or dynamic format, often requiring a forced-choice response from the participant regarding which emotive expression is being shown. Paradigms used differ in emotions presented, intensity of the emotional expressions (some using morphed stimuli which vary in expressivity), number of overall trials and stimulus presentation time. In terms of measuring accuracy, this often takes the form of the number of times an emotion is correctly recognised, given it is presented (the 'hit rate'), or number of accurate identifications of emotions overall (overall hit rate). Patterns in

errors ('false alarm rates') can also be analysed to investigate whether there are biases present in recognition. Some studies take reaction time into account, investigating which emotions are more readily identified and others stratify by emotional intensity (i.e. investigating which emotions are more easily recognised at lower intensities).

Babbage et al. (2011) conducted a meta-analysis of FAR following TBI. They synthesised effect sizes from thirteen studies, using static stimulus presentation to measure FAR in individuals with moderate to severe TBI. This included 296 adults with TBI, and they concluded estimates of between 13% and 39% experienced deficits in this domain. They extrapolated these rates to global prevalence rates and suggested this equates to around 39 million people worldwide suffering FAR deficit due to TBI (out of a total of 136 million with ongoing TBI related disability). No mention is made regarding specific patterns of emotion recognition deficits in these populations, however they suggest based on previous evidence that there is consensus in that recognition of negative emotions (e.g. fear, sadness, disgust) portrays greater impairment, with positive emotion recognition being preserved in comparison, although this may be an artefact of emotion recognition difficulty (Croker & McDonald, 2005). The majority of research in this area has focused on individuals with moderate to severe injury, however deficits in FAR have also been observed in those with mild injury, both in acute phases and at one-year follow-up (Ietswaart, Milders, Crawford, Currie, & Scott, 2008). For these there was no evidence for selective impairment in expression recognition. Deficits in FAR in those with moderate-severe injury have been linked to lower resting-state functional connectivity (Rigon, Voss, Turkstra, Mutlu, & Duff, 2017), with poorer connectivity corresponding with poorer FAR. Emotion recognition deficits have also been found to span other recognition modalities such as bodily and vocal emotion recognition (Ietswaart et al., 2008; McDonald & Saunders, 2005) and are included within long-term consequences following childhood injury (Ryan et al., 2015).

#### *1.5.5 Traumatic brain injury and social outcomes*

These observed deficits in socioemotional processing appear to translate into poorer social outcomes. Rosema et al. (2012) conducted a review of social function

after childhood TBI and concluded that child and adolescent survivors of TBI have an elevated risk of social dysfunction, with consistent difficulties identified for social adjustment and social cognition. This includes reports of poor self-esteem, loneliness, maladjustment, social isolation and social integration (Knox & Douglas, 2009), in the context of reduced emotional control and aggressive antisocial behaviour in TBI survivors. There is also evidence for increased rates of verbal and physical aggression (James & Young, 2013) and inappropriate sexual behaviour (James, Böhnke, Young, & Lewis, 2015). Based on the model proposed by Yeates et al. (2007) deficits in cognitive, executive and socioemotional functions following TBI may encourage choosing of instrumental over prosocial goals, including aggression and withdrawal, misinterpretation of other's intentions and the production and execution of inappropriate social responses. This may encourage development of antisocial or delinquent behaviour patterns following an earlier injury.

## **1.6 Socioemotional processing and antisocial behaviour**

Poor social processing has been implicated in people with aggressive behaviour, conduct disorder (Dodge & Pettit, 2003; Happé & Frith, 1996), intermittent explosive disorder (Coccaro, Fanning, Keedy, & Lee, 2016) and antisocial and delinquent behaviours (Serin & Kuriychuk, 1994; Spenser et al., 2015). Evidence for this incorporates different aspects of socioemotional processing, including impaired empathetic responding in incarcerated psychopaths (Decety, Skelly, & Kiehl, 2013) and impaired moral judgement in young offending populations. A meta-analysis of fifty studies indicated large effect sizes for impairments in moral reasoning for juvenile offenders. These effect sizes were particularly pronounced for males, older adolescents, incarcerated delinquents and for those with a concurrent psychopathic disorder (Stams et al., 2006). The capacity for FAR in aggressive and antisocial populations, in comparison to normal controls has piqued substantial research interest, with a number of meta-analyses and reviews synthesising these findings (Chapman, Gillespie, & Mitchell, 2018; Dawel, O'Kearney, McKone, & Palermo, 2012; Marsh & Blair, 2008; Wilson, Juodis, & Porter, 2011).

### *1.6.1 Facial affect recognition in antisocial populations*

Marsh and Blair (2008) investigated FAR in antisocial populations, encompassing populations of those who had been objectively selected, classified, or assessed on the basis of a pathology or behaviour defined by antisociality. Antisociality is persistent behaviour that violates the rights and welfare of others or breaks important normative rules. This included twenty studies with a wide spread of different populations, including violent incarcerated individuals with psychopathic traits, patients with frontotemporal dementia, offenders with high functioning ASD, and abusive mothers, with a strong focus on psychopathy. Despite the heterogeneity of populations encapsulated within this definition, they concluded that there was robust evidence for a deficit in the processing of fearful expressions specifically, and to a lesser extent sadness, in those with antisocial tendencies. This finding is used to provide support for the 'Integrated Emotion Systems Model', proposed by Blair (2005), which suggests that accurate identification of fear and sadness in others serves to condition children to avoid the antisocial behaviours which elicit these aversive distress cues. This model suggests that impairment in the recognition of these expressions may affect subsequent moral development and predispose individuals to pervasive antisocial tendencies as a result.

This work was further explored by Wilson et al. (2011) and Dawel et al. (2012) who focused on the construct of psychopathy, delineating this more precisely than had been done in Marsh and Blair (2008). Psychopathy is defined as a disorder which is characterised by persistent antisocial behaviour, with profound deficits in empathy and remorse. Wilson et al. (2011) found evidence for deficit in psychopathic populations across all emotional expressions, with largest effect sizes for sadness and fear. Dawel et al. (2012) took issue with the defining of psychopathy as a unitary construct and attempted to break down the concept into constitute parts. They describe the affective domain (including callous-unemotional traits), and the antisocial domain (including conduct disorder and impulsivity). They also used a more conservative model within the meta-analysis to reduce the rate of type 1 error. Dawel et al. (2012) conclude psychopathy was again associated with impairments across the board of emotions, with stronger effect sizes for fear and sadness. Unfortunately, they were unable to effectively delineate the two constructs as

planned, as for those studies where a distinction was made, psychopathic individuals scored higher in both domains.

A recent review by Chapman et al. (2018) makes the important point that there is an overrepresentation of research investigating psychopathic offenders, which make up around 7% to 9% of the prison population, limiting generalisation to other offenders. They argue that there needs to be greater distinction made between types of offenders (e.g. violent, non-violent, sexual offenders) within this literature. This draws from the observation that different types of antisocial behaviour are likely to have different aetiologies. Seven studies were included in their review, and the evidence suggested that violent offenders are generally less able to recognise negative emotions relative to non-offending controls, and poorer at recognising fear in relation to non-violent offenders. The most consistent findings were for reduced accuracy for disgust, and reduced sensitivity to fear in violent offenders. Violent offenders in general showed reduced sensitivity to emotional expressions, compared to non-violent offenders and non-offending controls.

Important to note within the literature, is the distinction made between recognition biases (the difficulty in recognising some emotions over other) and perceptual biases (an increased tendency to systematically perceive some emotions over others) for emotional expressions. In antisocial or violent populations, there has been interest in whether there is evidence for perceptual biases, particularly for hostile emotions such as anger (Dodge, Price, Bachorowski, & Newman, 1990; Nasby, Hayden, & DePaulo, 1980; Schönberg, Mayer, Christian, Louis, & Jusyte, 2015). In a review of over 2000 anger-prone and aggressive individuals, Mellentin, Dervisevic, Stenager, Pilegaard, and Kirk (2015) suggested there was robust evidence for biased perception, where anger and hostility were perceived from ambiguous and even unambiguous non-hostile expressions. However, the studies investigating this bias within the subsequent Chapman et al. (2018) review, suggest the evidence for this is inconsistent and warrants further investigation.

## 1.7 Facial affect recognition as a target for intervention

Deficit in the domain of FAR has important implications in terms of increased future risk of antisocial or aggressive behaviour. Referring back to the model proposed by Yeates et al. (2012) and depicted in **Figure 1.4**, deficit or bias in the processing of social information may lead to impaired judgement and interpretation of the intentions or reactions of others. This in turn may lead to inappropriate, such as aggressive or antagonistic, responding in order to achieve social goals. This in turn may reduce social adjustment and social competence. Difficulty in the perception of pain or discomfort in others, can make these inhibitory cues less salient, and the repercussions of antisocial behaviour less evident. This may increase the risk of engagement in violent or aggressive behaviour.

Deficits in FAR are common across clinical populations, including populations of people with schizophrenia (Kohler, Walker, Martin, Healey, & Moberg, 2010), ASD (Uljarevic & Hamilton, 2013) and major depressive disorder (Dalili, Penton-Voak, Harmer, & Munafò, 2015), as well as antisocial personality disorders and those with TBI. This observation, combined with the potential benefits of improved functioning in this domain, has led to this capacity being increasingly targeted as an area of intervention and rehabilitation (see Penton-Voak, Munafò, and Looi (2017) for a recent review). Current approaches have included cognitive bias modification (CBM), which attempts to induce changes in perceptual biases (Penton-Voak et al., 2013), repetitive feedback techniques and re-allocation of attentional resources to salient emotive cues (Neumann, Babbage, Zupan, & Willer, 2015; Schönenberg et al., 2014). However, this is an avenue of research which is currently in its infancy. Further investigation is needed to establish whether it is effective, what type of intervention is effective, whether improvements in the domain of FAR are robust and whether this transfers to other behaviours. Furthermore, the acceptability and feasibility of using these interventions with different populations and in different settings should be explored.

## 1.8 Summary

### 1.8.1 Thesis aims and scope

This introductory chapter reviews current evidence and suggests impairment in socioemotional processing following TBI as a possible mechanism in the association between TBI and antisocial or criminal behaviour. Both violence and TBI pose significant societal burdens, and whilst the association between TBI and crime is well established, the underlying mechanisms driving this effect are not well understood. This thesis addresses this gap within the literature. Here I explore the possibility that there is a direct influence of TBI on violent crime, by investigating socioemotional processing as a possible mediator in this effect (illustrated by the model in **Figure 1.3**). I investigate the capacity for FAR as a component of socioemotional processing, in those with and without history of TBI, hypothesising that a history of TBI will be associated with a reduced capacity for FAR. Due to the suggested importance of social information processing in guiding subsequent interaction, adjustment and social competence, I envisaged impairment in this domain would have serious negative consequences for the welfare of the individual. This includes an increased risk of future interpersonal difficulty, aggression and violence.

I explore this further with an investigation of relationships between FAR, aggression and delinquency in populations of people with and without previous criminal convictions. I also investigate wider neuropsychological profiles of those with and without history of injury, to explore whether there were any commonalities in impairment and whether this in turn influenced capacity for FAR. Following the investigation of associations between FAR, TBI and crime, I investigate the implications of this, both theoretically and from an applied standpoint, suggesting possible targets for remedial intervention. This is explored in the latter stages of the thesis, assessing the potential of affect recognition modification as an intervention strategy, to both improve behaviour and reduce antisocial tendencies.

Within this thesis, six main research questions are addressed:

- 1) First, is there evidence for a deficit in FAR in those with self-reported TBI in comparison to those without history of injury, within populations of people with offending behaviour?
- 2) If there is evidence for deficit in this domain, does this relate to different criminogenic profiles or an increased risk of future delinquency?
- 3) Is there evidence for different neurocognitive profiles (as indicated by poorer performance on neuropsychological assessments) for members of offending populations with history of TBI, compared to those without injury? If so, does this impact on their capacity for FAR?
- 4) Are similar relationships between TBI, FAR and antisocial behaviour observed in members of the general, non-offending population, or are any observed effects specific to offending populations only?
- 5) Would interventions targeting the capacity for FAR be effective in reducing antisocial or criminal behaviour?
- 6) Would interventions targeting the capacity for FAR be appropriate for use both with members of these populations and within incarcerated settings?

Regarding the scope of this thesis, here I present evidence from adolescent and young adult samples, with a predominately male participant group. I discuss implications of socioemotional processing more widely, but with a specific focus on FAR as a component of this. Of the neuropsychological assessments conducted, the findings with relevance to FAR ability are discussed within this thesis. I acknowledge that there are other neuropsychological domains vulnerable to TBI and with theoretical links to offending, such as inhibitory control, but it was beyond the scope of this thesis to investigate these mechanisms in detail across these populations. I advocate the importance of supplementing these findings with further research, recruiting a larger group of offenders to allow the stratifying of offence type, inclusion of females, older age adults, alternate components of socioemotional processing and additional areas of neuropsychological functioning.

### *1.8.2 Thesis structure*

To gain new insights into criminal and antisocial behaviour post-TBI, I conducted a selection of experimental research studies and discuss these within this thesis. The first two linked studies (described in Chapters two and three) explore neuropsychological profiles of adolescent and young adult offenders with and without self-reported history of TBI, focusing on FAR ability as a primary outcome of interest (addressing research questions one, two and three). The findings of these studies were inconsistent. Study 1 (adolescent offenders) gave evidence for impairment in FAR in those with substantial TBI, compared to those without, an effect which did not replicate within Study 2 (young adult offenders). Some of the reasons for this discrepancy and additional findings of interest are discussed within these chapters. The third study (described in Chapter four) informs the findings of these first two studies, by investigating FAR in young adult males, via an online platform in a general sample population (addressing research question four). This study investigates differing severities of self-reported injury and explores associations between TBI, FAR and antisocial behaviour. Study 3 gave evidence for increased drug, alcohol use, delinquency and aggression in those with higher dosage of TBI, with no differences between injury groups for FAR and alexithymia. The findings across these three studies are compared and contrasted, in a meta-analytic synthesis of these results and interim discussion (Chapter five). This highlights the importance of screening for PCS and exploring poor overall FAR in offending populations compared to those without history of offending behaviour.

Following this, I shift the focus of the thesis from investigating the influence of TBI on FAR capability, to exploring how knowledge of FAR in these populations can be applied for rehabilitative purposes. I systematically review current approaches, such as cognitive bias modification techniques, attention-orientation strategies and virtual reality embodiment, assessing their efficacy in modifying perception and behaviour (described in Chapter five, addressing research question five). Following this I explore the feasibility of employing a cognitive bias modification intervention for emotive facial expressions, for use in a prison setting, with a sample of violent young offenders (Study 4, described in Chapter six, addressing the sixth research question). Study 3, Study 4 and the review described in Chapter five, were conducted in parallel, meaning findings could not inform the progression of these

studies sequentially. For a reflective summary of the journey of this PhD research and a narrative of author contributions, see **Appendix 1**. The feasibility study (Study 4) was successful in that there were high levels of completion and adherence rates, and the intervention was generally well accepted by participants and staff. Key obstacles to engagement and feasibility was the repetitive nature of the task and an inability to recruit the specified numbers of participants identified in the initial protocol. The results of these research projects are then combined and discussed in response to the research questions outlined above within the general discussion. Here I consider the implications of the findings and provide suggestions for how the knowledge derived from this thesis could be used to inform policy, practice and future research design (Chapter eight).



## **2 Study 1: Traumatic brain injury and facial affect recognition in community young offenders**

### **2.1 Acknowledgements**

This study was conducted by the author as part of a related MSc research apprenticeship in 2013, under the supervision of Prof. Huw Williams. Substantial modifications have been made to this original dataset, including the recruitment of additional participants by Dr Sanna Tanskanan, and subsequent re-analysis of the data by the thesis author. Distinct contributions include the incorporation of additional participants, which included data quality assessment and repeat transcription of the data following previous transcription error in a previous report. In addition to this, linear regression models were chosen for re-analysis in place of ANOVAs, in order to better understand the influence of confounding factors on the predictive value of TBI history. Furthermore, the definition of ‘repetitive mild substantial injury’ was adapted, to include those with three or more instances of mild injury where they had experienced a LoC. This differed from the criteria used in the MSc project which also included those who had experienced mild injury without a LoC within the repetitive mild injury group. The adaption was made with the rationale that self-reported mild injury without a LoC is a more subjective experience and difficult to quantify. Permissions have been granted by the University of Exeter’s Psychology postgraduate board to include the modified dataset within this thesis.

### **2.2 Introduction**

Exploring the hypothesis that socioemotional processing deficit following TBI mediates an association with antisocial behaviour and risk of offending, I investigated FAR in a sample of young people with offending behaviour (YPO), assessing group differences between those with and without history of head injury. I conducted an opportunistic study with a sample of community-based young offenders and young people with antisocial tendencies.

Based on previous methods (Davies, Williams, Hinder, Burgess, & Mounce, 2012), I used self-reported history of TBI using a modified version of the Comprehensive Health Assessment Tool (CHAT) to record lifetime injury. Identifying those with a TBI related need, or 'substantial dosage' of injury (as it shall subsequently be referred to), as those with either an instance of moderate to severe TBI, involving a LoC lasting for 30 minutes or more, or those with repetitive mild injuries (including three or more instances where they had experienced a LoC of any duration) (Chitsabesan, Lennox, Williams, Tariq, & Shaw, 2015). Deriving from the theory and evidence reviewed in the previous section, the following hypotheses were proposed. First, that members of this population who had sustained a substantial dosage of TBI would exhibit poorer performance on a FAR task than those with milder or no injuries (relating to research question one). Second, in those convicted of offences, lower FAR ability would be associated with differential criminal profiles, including increased violence in convictions, earlier onset of offending behaviour, higher frequency of offending and higher risk of reoffending. This second hypothesis corresponds with the second research question for this thesis. These were the primary hypotheses for this study. However, I also conducted exploratory analyses investigating differences in neuropsychological profiles in those with substantial injury, compared to those without (see research question three).

## **2.3 Methodology**

### *2.3.1 Participants and recruitment*

Thirty-five YPO, with an average age of 17 years, were recruited opportunistically through Somerset services in the UK. Twenty-nine were recruited through Youth Offending Teams (YOT) with criminal convictions and six through 'Targeted Youth Support', identified as being at risk for contact with YOT. YOT managers assisted in the identification of eligible participants and with initial contact, providing details of the study. Eight of these participants were collected at a later time-point as part of a subsequent research project and completed a reduced testing battery. Forty aged-matched non-offending controls were collected through local schools, all without history of TBI. Exclusion criteria included having severe learning difficulties, hearing or visual

impairment that would prevent comprehension of tasks, and those identified as 'overly high-risk' to others or themselves (as judged by an offender manager assessment). The YPO were given a five-pound high-street voucher as a reimbursement for their time. Ethical approval was granted by the University of Exeter ethics committee (reference: 2013/289). As this was an exploratory and opportunistic study, power calculations for sample size were not conducted, we aimed to recruit the largest sample possible under available time and resource constraints.

Working with more complex populations and sensitive data, additional ethical considerations were required. It was made very clear that participation was voluntary, that participants could withdraw consent if they changed their minds and that their decision to participate was independent of their involvement with the YOT, with no subsequent consequences for their current sentence. The YOT requested that we rewarded the participants with high street vouchers as opposed to money, as there was a risk that money would be used to purchase drugs and alcohol in the case of some individuals. For any participant who was under the age of 16 years, consent was obtained from their parents or guardians. An additional level of consent was required in order to access criminal histories from 'the Asset' screen, and all data was extracted and fully anonymised within the YOT offices to protect participant confidentiality. As language and comprehension were often poor, study procedures and the various aspects of consent were discussed in detail with the individual prior to their decision regarding participation. Participants were debriefed following the session and if they had any concerns regarding TBI or the content of the study, additional support or information could be sought through their offender managers or the research team.

### *2.3.2 Design and procedure*

An observational case-control design was used. Eligible participants were approached by their YOT managers who introduced the study and provided an information sheet. Consent procedures and testing took place with the researcher (MC) in a single session, taking approximately 45 minutes to 1 hour. Health-related items and neuropsychology testing were administered by

the researcher as literacy and attentional capacity were often poor. Criminal histories were extracted (where available and consent was provided) from criminal records, following the testing session ( $n = 29$ ).

### 2.3.3 *Measures*

#### 2.3.3.1 *Health and demographics screen*

Demographics included age at testing, sex and ethnicity. History of TBI was assessed using the neurodisability section of the CHAT (Chitsabesan et al., 2014)', asking recall of whether a blow to the head causing a LoC or 'dizziness and confusion' had been experienced at some point during their lives. Frequency of injuries, causation and duration of LoC was recorded, as well as age at injury, whether medical attention was sought, and how long they remained in hospital if so. We did not impose any restrictions on severity of head injury or time since injury. This measure was used as it has been developed for use with young people in the UK criminal justice system, and replicates previous methodology used in this area (Davies et al., 2012; Williams et al., 2010). We recorded current PCS using an abbreviated version of the Rivermead Postconcussion Symptom Questionnaire (RPCQ), including eight items measuring cognitive and somatic symptoms and inclusion of the symptom 'fogginess' which has been suggested to have clinical relevance to TBI (King, Crawford, Wenden, Moss, & Wade, 1995).

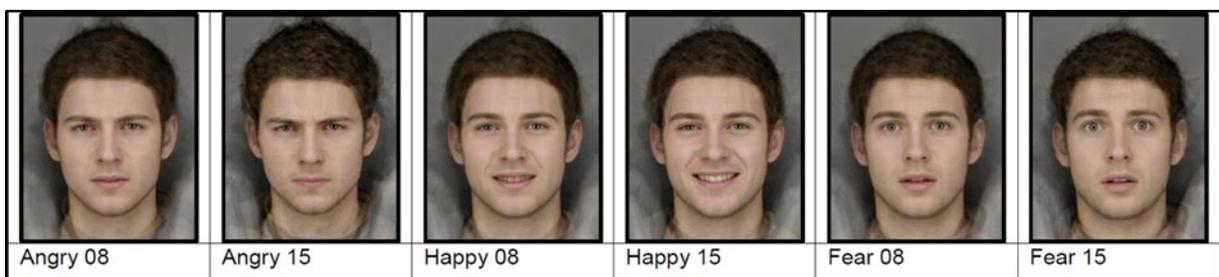
#### 2.3.3.2 *Facial affect recognition*

FAR was measured using the Bristol Emotion Recognition Task (BERT). This is a novel task developed at the University of Bristol, UK, which measures accuracy in identifying emotional content from facial expressions. It uses a linear morph sequence of facial expressions, changing incrementally in expressivity from ambiguous, a composite image of all emotional expressions creating a near neutral expression, to unambiguous, with 100% emotional expression intensity. Prototypical images of each of the expressions were created from twelve European male faces showing each of the six expressions.

Using established techniques, the original photographs were each delineated with 172 feature points, allowing shape and colour information to be averaged across the faces to generate a prototypical ‘average’ expression for each emotion (Tiddeman, Burt, & Perrett, 2001). These images were then manipulated so that the expressivity of emotions varied in incremental stages, with fifteen images presented per expression (90 in total). The emotions included happy, sad, anger, fear, disgust and surprise. See example stimuli at half intensity (stimulus 8) and full intensity (stimulus 15) for anger, happy and fear in **Figure 2.1**.

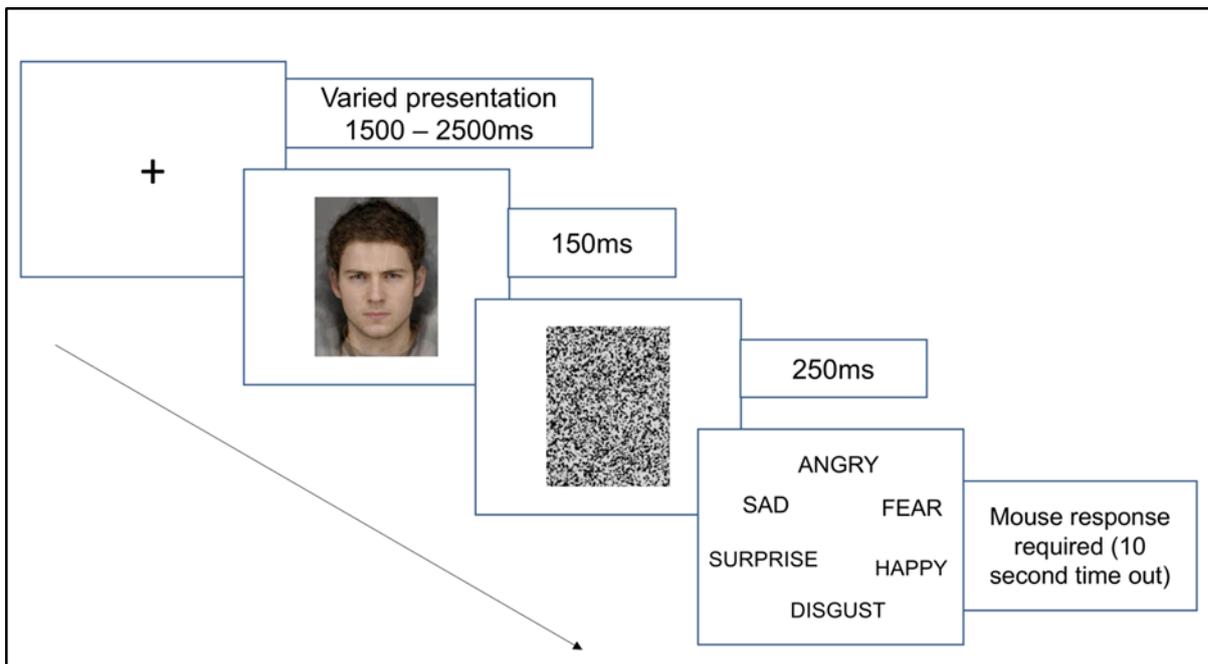
Participants were randomly presented with the 90 facial image trials for 150ms each, preceded by a fixation cross (varying randomly between 1500-2500ms) and followed by a visual mask (250ms) to prevent processing of afterimages. Six expression labels were presented following stimulus presentation and participants were required to select their perceived expression using a mouse response, with a trial time out after 10 seconds. The trial sequence is depicted in **Figure 2.2**. The output provides total expression accuracy score, individual expression accuracy scores (‘hit rates’), and ‘false alarm scores’ for each expression (incorrect selection of expressions, described in greater detail in Chapter five). The task was delivered using EPrime version 2 on a Dell Laptop. A version of this task can be obtained through Cambridge Cognition© (Emotion Recognition Task, <http://www.cambridgecognition.com/tests/emotion-recognition-task-ert>).

**Figure 2.1** Examples of Bristol emotion recognition task stimuli, Study 1.



Stimuli at approximately half intensity (stimuli 8 of 15), and full intensity (15 of 15) are shown for the emotions anger, happy and fear

**Figure 2.2** Example trial from Bristol Emotion Recognition Task, Study 1



Example trial from BERT used in Study 1, including fixation cross, facial stimulus presentation (example displaying anger), visual mask and forced-choice response options

### 2.3.3.3 Neuropsychological assessment

We used the Weschler Abbreviated Scale of Intelligence (WASI) vocabulary and block design sub-tests, for verbal and performance intelligence quotients (IQ) respectively. We did not have sufficient time during the testing session to administer all sub-tests of the WASI and decided to administer the vocabulary and block design sub-tests as key measures of crystallised and fluid intelligence respectively. As measures of executive functioning we used the Trail Making Tests A & B, and the Stroop Task. The Stroop task was included as a measure of inhibitory control and the Trails A & B were included as a measure of processing speed and cognitive flexibility. Furthermore, Trails B is suggested to be a useful predictor of long-term executive functioning outcome after TBI (Tonks et al., 2011). These were all pencil and paper tests and were scored following the completion of the testing sessions. Further details of tasks, reliability and validity information and references can be found in **Table 2.1**.

**Table 2.1** Details of additional neuropsychology testing measures used in Study 1

<b>Neuropsychological Test</b>	<b>Related Process</b>	<b>Details of Test</b>	<b>Scoring</b>	<b>Reliability and Validity</b>
<b>Trail Making Tests A &amp; B</b>	Visual search, scanning, speed of processing, mental flexibility & executive functions (Spreen & Strauss, 1998)	Participants connect 25 'dot' targets, as quickly and accurately as possible. In part A the targets contain numbers (1, 2, 3, etc.) requiring sequential connection, and in part B the targets contain both numbers and letters (1-13, A-L) and the participants must switch between the two modalities (1, A, 2, B, etc.)	Time elapsed on the tests (in seconds). 2 separate scores are obtained for each part of the test. Number of errors made, and interference scores are also recorded.	The TMT's have good construct validity with relation to the proposed related processes (Sanchez-Cubillo et al., 2009) It is said to have good reliability in the general population and also within clinical populations, including those with TBI (Franzen, Paul, & Iverson, 1996)
<b>Stroop Test</b>	Selective attention, cognitive flexibility and processing speed (Howleson, Lezak, & Loring, 2004)	Listed words are presented containing names of four colours printed in different coloured inks to the name displayed (red, green, blue or tan). Two sub-components. Word: participant reads the words printed aloud. Colour: the participant must name the ink colour aloud. The participant is instructed to work through the list (112 items) as quickly and accurately as possible within 120 seconds.	Number of correct responses (colour), time taken to complete (word), interference score and time taken per response.	The Stroop test has been designed for and normed with children, aged 14 years and over. It has excellent test-retest reliability and validity (Strauss, N., Jorgensen, & Cramer, 2005)
<b>Weschler Abbreviated Scale of Intelligence (WASI) Vocabulary Sub-Test</b> (Wechsler, 1999)	Verbal and general intelligence, concept and language development, memory.	Participants are asked to verbally define word meanings, working down a list of 42 items, progressively increasing in difficulty (e.g. item 9. 'Bird', 30. 'Enthusiastic').	Scoring is dependent on the quality of the answer given (0, 1 or 2 points) and the summed scores provide a raw score (then standardized by age).	The WASI has been deemed a reliable and valid measure of general intelligence with reliability coefficients ranging from .92 - .95. It has been normed in clinical populations, including TBI and used with young offending populations (Hayes & O' Reilly, 2013)
<b>WASI Block Design Sub-Test</b> (Wechsler, 1999)	Perceptual organisation, visual-motor coordination & abstract conceptualisation.	Participants are asked to replicate 2D geometric patterns using patterned blocks in a set time period. The test consists of 13 items, again increasing in difficulty with progression.	Scoring is dependent on amount of time taken and is summed and standardized to give an overall score.	

#### 2.3.3.4 *Criminal histories*

These were extracted from the YOT assessment, 'the Asset' (Youth Justice Board, (*Young offenders: assessment using 'Asset'*, 2000)), which is a common assessment profile used across all YOT organisations in England and Wales. It collects background information across a range of different risk factors, summated to create an overall 'risk of reoffending' score. This is used to predict reoffending with 67% accuracy. From this assessment we derived overall risk of reoffending score, primary and additional convictions, number of previous convictions, age of first conviction and whether they had recently used illicit substances. For some of the included participants, this supplementary information was not available (see corresponding *n* in **Table 2.2**).

#### 2.3.4 *Statistical analysis*

I checked for outliers in performance in neuropsychology tests, within groups, using Z values. 'Extreme' outliers (with an absolute value > 3.29), were excluded, and 'probable' outliers (with an absolute value between 2.58 and 3.29) were checked for testing observations that may cast doubt on their validity and warrant exclusion (e.g. distractibility from task) (Field, 2009). The rationale for this was that highly divergent poor performance within experimental groups may indicate a lack of engagement with the task or poor comprehension of task instructions, not identified in the initial assessment phase.

The primary analyses investigated differences between YPO with substantial TBI and YPO with mild or no injury. We used linear regression analyses to assess the association between TBI and overall FAR performance on the BERT. I ran this unadjusted, and then with additional levels of adjustment (sociodemographic, health and neuropsychological performance). I used analysis of variance (ANOVA) to check for between-group differences in background profiling measures and polynomial contrasts to investigate linear trends between TBI severity and PCS.

## 2.4 Results

As recruitment and data collection were pragmatic, here the means (*M*), standard deviations (*SD*) and percentage mean difference (*%MD*) are reported for continuous variables, odds ratios for categorical variables, unstandardized beta values for regression models and 95% confidence intervals (CI) to estimate the magnitude of observed effects (*p*-values are reported in accompanying tables). Rather than reporting results as significant or non-significant, based on the  $p = 0.05$  significance value, here I report a significance value of  $p < 0.001$  as ‘strong evidence’ for an effect,  $p = 0.001$  to  $p < 0.01$  as ‘evidence’ for an effect,  $p = 0.01$  to  $p < 0.10$  as ‘weak evidence’ for an effect and  $p = 0.10$  to  $p < 1.0$  as no clear evidence for an effect.

### 2.4.1 Participants

The YPO sample consisted of 25 males and 10 females, with an average age of 17 years ( $SD = 1$ , range 14 – 19 years) with 32 (91%) of this group of white British ethnicity. The non-offending control group consisted of 6 males and 34 females, with an average age of 16 years ( $SD = 1$ )<sup>1</sup>. See **Table 2.2** for details of criminal histories and health co-morbidity in the YPO sample.

**Table 2.2** Total group background profile, Study 1

Criminal histories	Participants with available data ( <i>n</i> )	Frequencies & range	
Type of crime	29	Violent	19 (65%)
		Non-violent	10 (35%)
Age of first conviction (years)	15		range: 12 - 17
Number of previous convictions	26	1.15 (1.6)	range: 0 - 5
Reoffending risk /48	21	13.6 (4.7)	range: 8 – 23
Recent substance use	29	21	(72%)
Mental health/ neurodevelopmental disorder	21	2	(9.5%)

Means presented, with standard deviations in parenthesis, with the exception of frequency data. Violent crimes were classified as those involving interpersonal aggression. The reported substance use was for alcohol and cannabis. The mental health or neurodevelopmental diagnoses included one Attention deficit hyperactivity disorder, one Asperger’s syndrome.

<sup>1</sup> Ethnicity data for the control group was not collected, 100% originated from the UK and were recruited from a college in the south west of England.

### 2.4.2 Prevalence of traumatic brain injury

Twenty-one participants (60%) reported some form of lifetime head injury. Seventeen participants (49%) reported an injury with a LoC (LoC duration is missing for one case due to an inability to recall, therefore this individual is excluded from the tables presented below and the descriptive statistics). Mean age of most severe injury (as indexed by longest LoC duration) was 11 years ( $SD = 4$ , range: 3 – 17 years), and the mean age of first injury was 9 years ( $SD = 4$ , range: 3 – 14 years). Mean amount of time since most severe injury was 5 years ( $SD = 5$ , range: 0 – 16 years), 43% of the sample took part in the study within 3 years of their most severe injury. See **Table 2.3** for breakdown of injury severities.

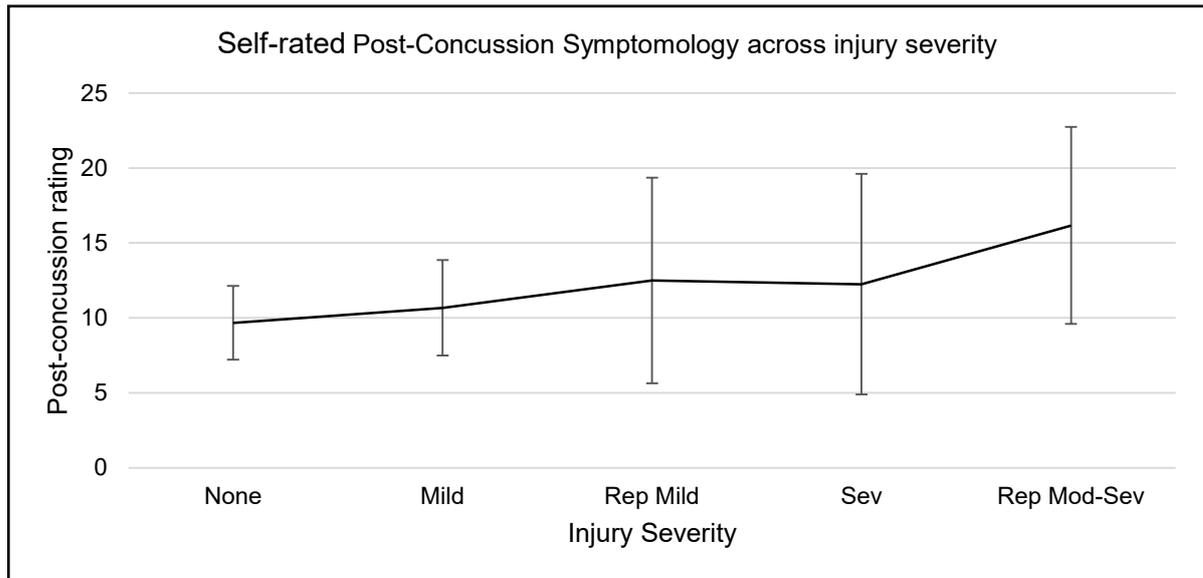
**Table 2.3** Frequency distribution of injury severities, Study 1

TBI Severity	Frequency	Percentage total	Repetitive Injuries (percentage category total)
No history of TBI	14	41.2	0 (0%)
TBI without LoC (dazed & confused)	3	8.8	1 (33%)
Mild TBI (LOC <10 minutes)	8	23.5	2 (25%)
Complicated mild TBI (LOC 10 – 30 minutes)	2	5.9	1 (50%)
Moderate TBI (30 – 60 minutes)	0	0	0
Severe TBI (LOC > 60 minutes)	7	20.6	3 (43%)
Total	34	100	7

Severities of injury reported with longest LoC ( $n = 34$ ) with distribution of repetitive (three or more) injuries. These severity categories are based on distinctions made in previous research (Davies et al., 2012), allowing sensitivity to a wider range of mild injuries that is consistent with European Federation of Neurological Society guidelines.

There was weak evidence for a linear trend between PCS and injury severity, with higher reports of TBI sequela (as indicated by an increased score on the RPCQ) in those with higher dosage of injury (combining duration of LoC with whether repetitive injuries were sustained). Contrast estimate: 4.63, 95% CI: -0.04 to 9.32,  $p = 0.05$ . This is illustrated in **Figure 2.3**.

**Figure 2.3** Post-concussion symptomology, Study 1



Post-concussion symptomology across TBI severity categories, Study 1. +/- 1 95% confidence interval. Rep = three or more repetitive injuries.

I split the sample into two groups, depending on the ‘dosage’ of lifetime injury sustained. This included those with ‘substantial TBI’ (TBI with LoC lasting for 30 minutes or more, or three or more instances of mild TBI with LoC;  $n = 9$ ) and those with no previous history of TBI ( $n = 14$ ) or mild TBI (TBI without LoC, or LoC lasting less than 30 minutes,  $n = 11$ ), (combined  $n = 25$ ). The rationale for a combined ‘mild or no injury’ group was based on evidence that suggests changes in cognitive functioning after non-repetitive mild injury tend to resolve within 1 – 3 months (Schretlen & Shapiro, 2003). I also ran the primary analysis with a three-group model (no injury, mild injury and substantial injury) and did not observe any qualitative difference. Details of these supplementary analyses can be found in the appendices (**Table A1**).

#### 2.4.3 Injury group profiles

Group differences for demographic variables, neuropsychological measures and criminal histories are presented in **Table 2.4**. There were few differences between groups for these measures, with the exception of RPCQ score, with higher PCS reported in those with substantial injury. There was weak evidence for differences in age, with a slightly higher average age in the substantial injury group. There was also weak evidence for difference in

interference score on the Stroop task, with greater interference effects exhibited in the substantial TBI group compared to those with mild or no injury. These findings were exploratory and relate to research question three.

There was no evidence for difference in criminal histories between those with substantial TBI and those with mild or no TBI, as indicated by increased violence in conviction, number of convictions, age of first conviction or risk of reoffending. This corresponded with research question two, and suggested that the hypothesis that those with substantial injury would have differential criminal profiles was unsupported. However, the group sizes for those with TBI were further reduced after excluding those without criminal history data, meaning these results should be interpreted with caution due to limited statistical power.

**Table 2.4** Group profiles, Study 1.

Full dataset ( <i>n</i> = 34)	No or mild TBI ( <i>n</i> = 25)	Substantial (Sub) TBI ( <i>n</i> = 9)	Coefficient (SE) or odds ratio	95% confidence interval	<i>p</i> -value
Age at testing (years)	16.04 (1.21)	16.89 (1.27)	-0.85 (0.48)	-1.82 to 0.12	0.08
Sex (M:F)	18:7	7:2			
Recent drug use (N:Y) (no/mild TBI <i>n</i> = 23; Sub TBI <i>n</i> = 5)*	6:17	1:4	1.41	0.13 to 15.27	1.0
WASI Block Design (/71)	43.96 (9.87)	44.22 (8.93)	-0.26 (3.75)	-7.91 to 7.38	0.95
WASI Vocabulary (/80)	35.52 (10.41)	36.33 (10.67)	-0.81 (4.07)	-9.10 to 7.48	0.84
<b>Reduced Dataset (<i>n</i> = 26) Non TBI (<i>n</i> = 17) TBI (<i>n</i> = 9)</b>					
<i>Rivermead RPCQ score</i> (/32) (no/mild TBI <i>n</i> = 16, sub TBI, <i>n</i> = 8)	10.00 (3.63)	14.13 (5.99)	-4.13 (1.96)	-8.18 to -0.07	0.05
RPCQ Cognitive (/12)	6.31 (2.96)	8.75 (3.92)	-2.44 (1.43)	-5.40 to 0.52	0.10
RPCQ Somatic (/16)	2.88 (2.55)	4.00 (2.07)	-1.13 (1.04)	-3.29 to 1.04	0.29
RPCQ Fogginess (/4)	0.81 (1.17)	1.38 (1.30)	-0.56 (0.53)	-1.65 to 0.53	0.30
Trail-Making A time (s)	36.87 (13.72)	32.77 (7.13)	4.10 (4.92)	-6.06 to 14.26	0.41
Trail Making B errors	2.12 (2.98)	1.89 (2.80)	0.23 (1.20)	-2.26 to 2.73	0.85
Trails Interference Score (B time – A time)	65.25 (37.64)	56.11 (23.14)	9.14 (13.81)	-19.37 to 37.65	0.51
Stroop Word Time (seconds) (Sub TBI group <i>n</i> = 8 for all Stroop output)	71.98 (24.06)	71.02 (21.16)	0.96 (9.95)	-19.63 to 21.55	0.92

Stroop Colour Correct (/112)	81.65 (22.54)	68.25 (21.65)	13.40 (9.55)	-6.36 to 33.15	0.17
Stroop Interference (word correct – colour correct)	27.65 (20.18)	43..50 (21.90)	-15.85 (8.88)	-34.23 to 2.52	0.09
<b>Criminal histories</b>					
Violent crime conviction (N:Y) (no/mild TBI, n = 23, sub TBI n = 5)*	11:12	2:3	1.38	0.19 to 9.83	1.0
Age first conviction (yrs) (no/mild TBI, n = 18, sub TBI n = 4)	14.56 (1.20)	13.75 (1.26)	.81 (0.67)	-0.59 to 2.20	0.24
No. of previous convictions (no/mild TBI, n = 21, sub TBI n = 5)	2.19 (5.86)	2.20 (2.17)	-0.01 (2.70)	-5.58 to 5.56	0.10
Risk of reoffending (no/mild TBI, n = 15, sub TBI, n = 5)	13.80 (4.59)	14.0 (5.52)	-0.20 (2.48)	-5.42 to 5.02	0.94

Beta coefficients displayed with standard error in parenthesis, with the exception of odds ratios for categorical variables. \*Fishers exact test, two-sided significance.

#### 2.4.4 Traumatic brain injury and facial affect recognition

Linear regression indicated that YPO's who had suffered a substantial dosage of TBI were poorer at recognising facial expressions (% accuracies reported) ( $M = 41$ ,  $SD = 7$ ), compared with those with no or mild TBI ( $M = 54$ ,  $SD = 10$ ), supporting our primary hypothesis. Adjustment for sociodemographic, health and neuropsychology variables (see **Table 2.5**) did not attenuate these results. There was weak evidence for the predictive value of vocabulary score (WASI Vocab,  $B = 0.30$ , 95% CI: -0.05 to 0.64,  $p = 0.09$ ), with better vocabulary scores predicting better FAR performance. This supports the hypothesis outlined in research question one.

Individual emotion raw hit rates for YPO's with and without substantial TBI are depicted in **Figure 2.4**. Performance in aged-matched, non-offending controls has been included for comparison. This is to demonstrate individual emotion accuracy in a normative sample and to give an indication of variation across recognition of emotions. This control group has not been included within the primary statistical analysis as they were not matched with the YPO's for SES, gender or IQ but are given here to give a visual illustration of differences in recognition of individual emotions in a non-offending, aged-matched sample.

**Table 2.5** Associations between traumatic brain injury and facial affect recognition overall percentage accuracy, Study 1.

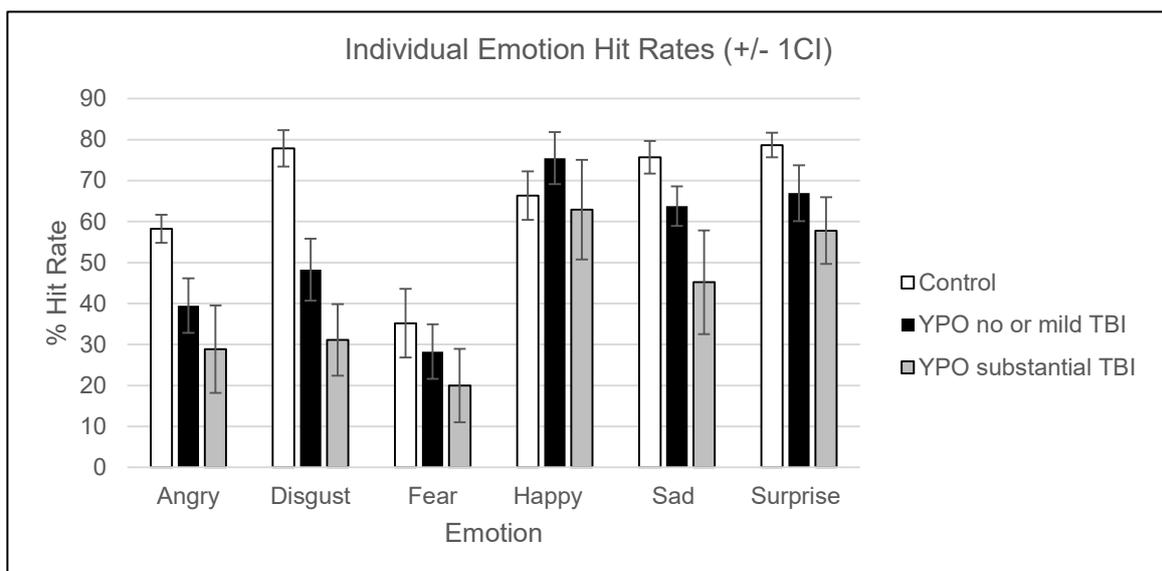
	Unadjusted	Sociodemographic adjusted	Health adjusted	Neuropsychology adjusted
<b>Study 1</b>				
<i>n</i>	<b>34</b>	<b>34</b>	<b>18</b>	<b>25</b>
Unstandardised coefficient	-12.70	-13.18	-14.02	-14.31
95% confidence interval	-20.24 to -5.16	-21.03 to -5.34	-24.72 to -3.33	-23.24 to -5.38
<i>p</i> -value	0.002	0.002	0.01	< 0.003
<i>R</i> <sup>2</sup> ( <i>model p</i> -value)	0.27 (0.002)	0.37 (0.008)	0.42 (0.05)	0.44 (0.04)

The results from unadjusted and adjusted linear regression models are given. Unadjusted gives the associations with substantial TBI only. In Study 1 'Sociodemographic adjustment' includes adjustment for age, gender and verbal IQ (WASI Vocabulary). 'Health adjustment' includes frequent drug use and post-concussion symptomology. 'Neuropsychology adjustment' includes output from the Stroop test (time and interference score), the Trail Making Task (interference) and performance IQ (WASI Block Design).

Running a multivariate analysis with individual hit rate for each of the six emotions as dependent variables, and TBI group status as the between-subjects factor, there was evidence for difference between the substantial injury group and those with no or mild TBI for the emotion sadness (% accuracies reported, *MD*: 19; 95% CI: 7.13 to 30.0,  $p = 0.002$ ), weak evidence for a difference in disgust (*MD*: 17; 95% CI: 2.9 to 31.3,  $p = 0.02$ ) and happiness (*MD*: 12; 95% CI: -0.8 to 25.8,  $p = 0.07$ ). There was no evidence of difference between groups for the additional emotions, and no evidence for an emotion by TBI group interaction. Therefore, these reported differences should be viewed as preliminary and exploratory.

Additional details of associations between FAR, neuropsychological measures and demographic and health measures can be found in the correlational matrices presented in the Appendices (**Figure A1**). There was weak evidence for negative associations between age and measures of IQ (WASI subscales), and increased number of previous convictions with higher age. PCS was associated with decreased overall FAR accuracy and earlier age of first conviction. Poorer overall FAR accuracy was also associated with increased risk of reoffending. Analyses of ‘false alarm rates’ are described in detail in Chapter five, in synthesis with data presented in Chapters three and four.

**Figure 2.4** Individual emotions, Study 1.



Individual emotion raw hit rates, with 95% confidence intervals, Study 1.

## 2.5 Discussion

These results indicate that YPO's with substantial TBI are poorer at recognising emotions compared with YPO's with mild or no injury. There was evidence for higher self-reported PCS in the substantial injury group compared with the mild or no injury group, and weak evidence for greater interference on an executive functioning measure in the substantial injury group. There was no clear evidence of an association between TBI group and differential criminal profiles.

These findings are of interest as they suggest ongoing sequelae in those with a substantial dosage of injury. As the impairment is apparent in a domain with logical pathways to aggression and violent behaviour this may provide a possible target for rehabilitative intervention. However, this was a small scale, preliminary study, with high proportions of higher severity injuries. The prevalence of lifetime head injury (60%) corresponded with similar rates for young offenders, reported in a related systematic review (50% to 71%) (Hughes et al., 2015). However, the proportions of those who experienced TBI with LoC (51%) exceeded both that reported by Hughes et al. (2015) (16.5% to 49%) and in a sample of incarcerated young offenders (41%), measured with an analogous TBI screen to that used within this study (Davies et al., 2012). The elevated discrepancy was greatest for higher severity injuries. Previous studies report a moderate to severe injury prevalence of 8% in incarcerated samples (Davies et al., 2012; Moore, Indig, & Haysom, 2014), defined as experiencing a LoC for 30 minutes or more, this contrasted with the 26% observed within the current sample. There may, therefore, be an over-representation of moderate-severe cases of TBI in this group. Also, as this is an observational study we cannot infer causality or rule out residual confounding (this included for example, levels of pre-morbid aggression and amount of direct interaction with peers).

It is possible that the observed FAR deficits in the substantial TBI group are secondary to generalised neurocognitive impairment which affects engagement with the task, rather than socioemotional impairment specifically. However, the RPCQ identifies more widespread neurocognitive symptoms (such as concentration, memory) and adjusting for this PCS score in the

regression model did not attenuate the predictive value of TBI group status. This suggests that there may be TBI-induced impairment in FAR, independent of generalised neurocognitive impairment, corroborating earlier findings in this field (Tonks et al., 2008). Yim, Babbage, Zupan, Neumann, and Willer (2013) however, suggest that FAR can be predicted by speed of processing, non-verbal memory and verbal memory (as was weakly demonstrated in these results for vocabulary scores). According to their study, FAR tends to be unrelated to measures of executive functioning, which were predominantly used in this current study. Consequently, the included neuropsychology measures may not have been sensitive to deficit affecting task performance.

Furthermore, the 150ms presentation time used within this study was very rapid. This means poorer performance in the substantial TBI group may have been an artefact of slower processing speed. There was no indication of slower general processing in the substantial injury group compared to the mild or no injury group, as conveyed by our neuropsychological measures. However, as these were pencil and paper tasks performance may have been confounded by motor speed (trail making tasks A & B) and executive processes (Stroop task). I decided to explore this further in the subsequent study with increased presentation time, more comprehensive neuropsychological assessment and more precise measures of processing speed.

Individual emotion recognition analysis did not provide clear evidence of deficit in the recognition of specific emotions. However, as these injury groups were small and unbalanced they may have lacked adequate power to detect effects of smaller magnitude. There appeared to be a consistent deficit in the recognition of all emotions in those with substantial TBI compared to those with no or mild injury, with slight variations in effect sizes. Comparing performance across emotions and groups, it appears that the fear stimuli used within this study were difficult to accurately recognise, as evidenced by low accuracy in this emotion across the three experimental groups in comparison to the other included emotions. The stimuli for the emotion 'happy' were of lower difficulty for the YPO samples, as has been observed in previous offending and TBI samples (Chapman, Gillespie, & Mitchell, 2018; McDonald, 2013).

There was no evidence for differential criminal profiles in those with substantial injury compared to those with mild or no injury. Based on previous findings, we hypothesised that there may be greater risk of reoffending or earlier age of first offence in those with higher dosage of injury (Williams et al., 2010). However, the lack of evidence here is difficult to interpret as these individuals were young offenders, with limited criminal histories. We also used official records as proxy measures for alcohol and substance use and mental-health co-morbidity, which may have been outdated or incomplete.

This study was exploratory and preliminary, however if the effects observed are indicative of a real impairment in the FAR domain, this has negative implications for the welfare of the individual. Deficits in FAR could impede detection of emotive state and intention in others, and lead to poor social competence. Emotion perception, even at an implicit level, is suggested to elicit visceral responses with interpretation of expressions helping to reduce limbic arousal (Lang, Greenwald, Bradley, & Hamm, 1993). Impaired recognition may limit the ability to do so, leading to a state of hyperarousal and increased sensitivity to threat, eliciting greater reactivity and possible aggression. This presents a possible target for intervention and rehabilitation, a possibility which I will explore in greater detail in Chapters seven and eight.

Next, I investigated these findings further by conducting a larger-scale, replication study, to examine whether the observed effects in this study were robust. The details of the subsequent study are described in Chapter three.



### **3 Study 2: Traumatic brain injury and facial affect recognition in community young adult offenders**

#### **3.1 Acknowledgements**

This study was conducted in collaboration with the London Community Rehabilitation Company (LCRC), and of note were the efforts of their data manager, Neil Bowen, and the probation officer Steven Kelly in assisting with recruitment. Study co-authors include Ian S. Penton-Voak, Natalia S. Lawrence, Marcus R. Munafò, W. Huw Williams, in the planning stages and Eleanor F. M. Kennedy in assistance with data quality assessments. All co-authors contributed to the drafting of the study manuscript for publication (in preparation). Additional funding was received from the University of Exeter's Open Innovation Fund to assist with data collection.

#### **3.2 Introduction**

Study 2 aimed to replicate and extend the preliminary findings of Study 1. This included recruiting a larger sample of YPO at a later stage in their offending trajectories and incorporating a more comprehensive, computerised neuropsychological battery, including measures of processing speed and memory. I also included questionnaire measures of aggression and personality traits for more in-depth profiling and exploratory purposes, as well as measures of criminogenic risk factors such as early adversity, psychopathy, socio-economic status, substance use and a screen for current and historic mental health issues. Based on the findings of Study 1, an adapted version of the BERT was used (details of this version can be found within the measures section).

A detailed study protocol was pre-registered on the Open Science Framework prior to commencement of data collection (DOI 10.17605/OSF.IO/PFK93). Ethical approval was granted by the University of Exeter ethics committee (reference: 2016/1055), and the study was conducted in accordance with the LCRC research governance standards.

Being a replication study of Study 1, the same hypotheses were retested. This included the hypothesis that members of this population who had sustained a substantial dosage of TBI would exhibit poorer performance on a FAR task than those with milder or no injuries (relating to research question one). Second, in those convicted of offences, lower FAR ability would be associated with differential criminal profiles, including increased violence in convictions, earlier onset of offending behaviour, higher frequency of offending and higher risk of reoffending (corresponding with research question two). Differences in neuropsychological profiles, measures for criminogenic risk and health measures between the two TBI groups were also investigated, using exploratory analyses (see research question three).

### **3.3 Methodology**

#### *3.3.1 Participants and recruitment*

Participants were recruited through the LCRC, a company managing adult offenders, under probation, within the London region. Participants were recruited through the age 18 – 25 male cohort, across the three largest boroughs, Croydon, Hackney and Newham. Senior probation officers conducted eligibility assessment prior to recruitment. Exclusion criteria replicated those of the previous study with the addition of poor language comprehension and being high risk for emotional upheaval due to serious or enduring mental health problems or current life stressors. Participants received a high-street voucher with the value of £10 as a reimbursement for participation, which increased to the value of £20 at a later stage in the study. Participation in the study was recorded by probation officers as 'purposeful activity' within their record of probationary sessions, although it was stressed to the service users that their participation was voluntary, their responses confidential and that their decision regarding participation would not affect their probationary sentence.

Ethical considerations were similar to that of Study 1. However, with the inclusion of additional measures further considerations included: monitoring the participants for signs of fatigue and being aware of emotional reactions that may arise from the more sensitive items (for example, the early trauma

inventory or aggression measure). Participants were pre-warned regarding the sensitive nature of these measures prior to administration. They were advised that they did not need to answer anything they did not feel comfortable with and that all responses were again confidential. Furthermore, asking explicitly about current drug and alcohol use, it was important to reiterate that their answers would have no bearing on their sentence or work within probation. As I included a measure which recorded current undiagnosed mental health issues, if a participant scored over a certain threshold, I would discuss this with them and refer to their probation officer for further support, if appropriate. In the event of confidentiality being breached with concerns regarding risk, this would be discussed with the YPO and documented through the agreed channels (this eventuality did not arise).

An aged-matched non-offending control group were recruited at a later stage following recruitment of the YPO sample, consisting of twelve male university students. This group was collected, as before, for comparative purposes for FAR task performance, and the group size matched that of the substantial injury group. They were tested using the same task version and equipment as used by the YPO in this study and had no history of head injury, criminal history, had no current medication use for mental health diagnoses and reported no substance or alcohol use in the 12 hours prior to testing.

### *3.3.2 Sample size calculation*

Prior to Study 2 commencing, I conducted a power calculation based on the effect sizes derived from Study 1. Power calculations derived from small samples can often overestimate the true effect (Button et al., 2013), so I reduced our effect size derived from Study 1 by a third ( $d = 0.83$  reduced to  $d = 0.55$ ) to accommodate this. Based on this adjusted effect size, and the expected unbalanced distribution of participants between groups (as observed in Study 1), I calculated a group size of  $n = 116$  ( $n = 40$  substantial TBI group,  $n = 76$  no or mild TBI) would be required to achieve 80% power to detect an effect of this size.

### *3.3.3 Design and procedure*

As in Study 1, an observational case-control design was employed. The study involved two sessions. The first took place with the allocated probation officer and included study enrolment, consent and administration of background health and personality questionnaires (taking between 15 and 30 minutes). Probation staff were trained (by MHC & WHW) in research governance procedures, including consenting procedures and data collection techniques prior to data collection. I conducted the second testing sessions, administering the neuropsychological tests and any uncompleted items from the first session (~ one hour).

### *3.3.4 Measures*

In order of administration.

#### *3.3.4.1 Health and demographics screen*

I collected data regarding age, first language, ethnicity, years in education and SES and current or recent substance use (with this assessment repeated at the start of the second testing session). As a measure of SES I calculated relative deprivation of residence from postcodes using the English index of multiple deprivation (2015) (Government, 2015). This was followed with the Brief Jail Mental Health Screen (BJMHS; (Osher, Scott, Steadman, & Robbins, 2004), incorporating an additional question asking whether they had ever received a diagnosis of a neurodevelopmental disorder, the TBI screen adapted from the CHAT and the RCPQ (detailed in Chapter two).

#### *3.3.4.2 Self-report questionnaire measures*

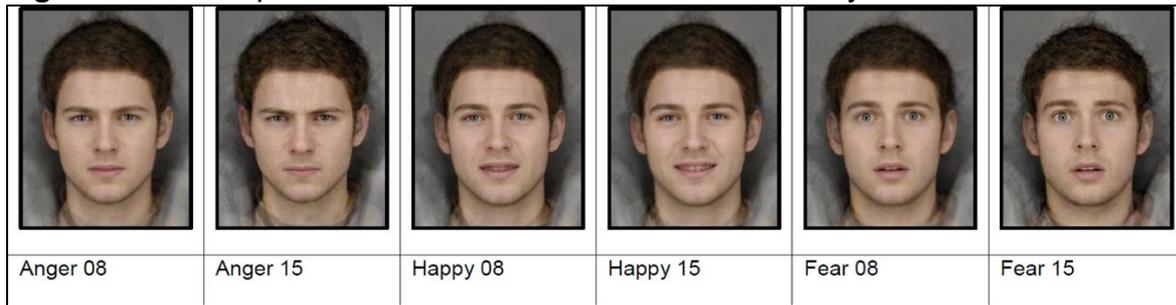
Self-report measures included the Reactive-Proactive Aggression Questionnaire (RPQ; (Raine et al., 2006)); the 20 item Toronto Alexithymia Scale (TAS; (Bagby, Parker, & Taylor, 1994)); the Youth Psychopathic Traits Inventory (PTI; (van Baardewijk et al., 2010)); and an adapted version of the Early Trauma Self Report Form (ETI; (Bremner, Bolus, & Mayer, 2007), derived from Brewer-Smyth, Cornelius, and Pickelsimer (2015). The RPQ was included as the distinction between reactive and proactive forms of aggression is important in helping delineate some of the

mechanisms contributing to aggressive behaviour and the two sub-scales differentiate between these types of aggression. Previous research indicates those with TBI may report more reactive aggression (Dooley, Anderson, Hemphill, & Ohan, 2008). The TAS was included to provide additional insight into affective processing mechanisms, with the assertion that those with TBI may have an acquired 'organic alexithymia'. This includes difficulty identifying and describing emotional states (Henry, Phillips, Crawford, Theodorou, & Summers, 2006). The three subscales of the TAS included: describing emotions; identifying emotions and externally orientated thinking. The PTI was included due to the influence of psychopathic traits in violent behaviour and differential affect recognition (Blair et al., 2004), including the subscales: affective; interpersonal and behavioural psychopathic traits. The ETI was included due to the influence of early traumatic experience in increasing risk of delinquent and aggressive behaviour later in life (Brewer-Smyth et al., 2015). Subscales included physical abuse, emotional abuse and sexual abuse, with an additional item included asking the participant whether they had ever witnessed violence (found to be an important predictor of later violent behaviour).

#### 3.3.4.3 *Facial affect recognition*

FAR was measured using a version of the BERT described in Study 1. This version differed from the previous version in that eight equally spaced images were used per emotion (previously fifteen, using every other image from the original set), giving a trial total of 48 (6 emotions x 8 trials) and in so, creating a shorter version of the task. This version included longer facial stimulus presentation, for 300ms, rather than 150ms, however the visual masks and fixation cross durations were the same as used in Study 1. Five practice trials were also included in this version. Subtle manipulations were made to the stimuli for the emotions fear, disgust and happiness to achieve greater consistency in difficulty across emotions (see **Figure 3.1** for examples of adapted stimuli). Fear and disgust were more prominently delineated, and happiness was less so. The task was delivered using EPrime Version 2 on a touch-screen tablet, to make responding analogous to the other included neuropsychological measures.

**Figure 3.1.** Examples of stimuli used in BERT version Study 2



Stimuli at approximately half intensity (stimuli 8 of 15), and full intensity (15 of 15) are shown for the emotions anger, happy and fear.

#### 3.3.4.4 Neuropsychological assessment

I used the 'Speed and Capacity of Language Processing' test (SCOLP; (Baddeley, Emslie, & Smith, 1992)) to measure verbal comprehension and speed of processing in a linguistic domain. I used the CANTAB Research Suite (provided by Cambridge Cognition©) for computerised neuropsychology, including the tasks: motor screening task (MOT); reaction time index (RTI); spatial working memory (SWM); and the attention switching task (AST). See **Table 3.1** for additional details of these included neuropsychological measures. The CANTAB research suite was chosen as it allowed efficient testing of reaction time, processing speed, executive function, cognitive flexibility and spatial working memory, whilst providing a measure for sensorimotor deficits. Furthermore, it provided a consistent platform on which to complete the tasks, reducing residual confounding. The CANTAB battery has been extensively used and has good reliability. At the time this study was conducted, the developers were also in the process of creating bespoke batteries of tasks depending on the clinical population of interest (including TBI), and the needs of the research study. This allowed careful deliberation of the most effective combination of task variants to most effectively address the research questions within this study.

#### 3.3.4.5 Criminal histories

The Offender Assessment System (OASys) is a computerised assessment system used in England and Wales by prison services and the

**Table 3.1** Details of Neuropsychological Testing Measures used in Study 2.

	<b>Related Process</b>	<b>Details of Test</b>	<b>Scoring</b>	<b>Validity</b>
<b>Cantab: Motor Screening Task (MOT)</b>	Screen for sensorimotor deficits	Coloured crosses are presented on screen, in different locations sequentially. The participant must select the cross on screen as quickly and accurately as possible.	Assesses the participant's speed of responses and accuracy of pointing	No information regarding task validity available.
<b>Cantab: Reaction Time Task (RTI)</b>	Reaction time, movement time and vigilance	Participants must react as soon as a yellow dot appears on screen, releasing a button and pressing the location of the yellow dot. The dot appears either in one location (simple RTI) or one of five locations (5-choice RTI).	Median simple reaction time and median 5-choice reaction time (time taken to release 'button'). Median simple and median 5-choice movement time (time taken to touch stimulus).	The Cantab battery has been extensively used and has good reliability. The RTI has been used previously for people with milder head injuries (Sterr, Herron, Hayward, & Montaldi, 2006), and adolescents with conduct disorder (Lin & Gau, 2017).
<b>Cantab: Spatial Working Memory (SWM)</b>	Spatial working memory and executive function	A number of coloured squares (boxes) are shown on screen. The aim of this test is that, by touching the boxes and using a process of elimination, the participant should find one blue 'token' in each of a number of boxes and use them to fill up an empty column on the right-hand side of the screen. The number of boxes is gradually increased, until it is necessary to search a total of eight boxes.	Between Errors: number of times subject revisits a box in which a token has been found previously. Strategy: number of distinct boxes used by the subject to begin a search for a new token.	The SWM task has been used in previous studies of head injury, for people with both moderate-severe injuries (Salmond, Chatfield, Menon, Pickard, & Sahakian, 2005) and mild head injuries (Sterr et al., 2006). It has also been used previously with young offending populations (Syngelaki, Moore, Savage, Fairchild, & Van Goozen, 2009) and in young people with oppositional defiant disorder (Jiang, Li, Du, & Fan, 2016).

<b>Cantab: Attention Switching Task (AST)</b>	Executive function, providing a measure of cued attentional set-shifting (cognitive flexibility)	A test of the participant's ability to switch attention between the direction of an arrow and its location on the screen and to ignore task-irrelevant information in the face of interfering or distracting events. Some trials display congruent stimuli (e.g. arrow on the right side of the screen pointing to the right) whereas other trials display incongruent stimuli which require a higher cognitive demand (e.g. arrow on the right side of the screen pointing to the left).	Median congruency cost: Difference between median latency of response on congruent versus incongruent trials. Median switch cost: Difference between median latency of response during blocks in which the rule is switching versus assessed blocks in which the rule remains constant.	The use of this task previously is more limited. However, it has been used previously with young adults with sub-concussive trauma (Di Virgilio et al., 2016), and with aggressive children (Rostami et al., 2017).
<b>Speed of Language and Comprehension Processing (SCOLP)</b>	Rate of information processing and verbal intelligence	Two sub-tests. 'Speed of comprehension' measures rate of information processing, requiring participants to read a series of 'silly sentences' and decide if they are true or false (as many as possible in 2 minutes). Whereas the 'spot-the-word' test gives an estimate of verbal intelligence, requiring participants to read word pairs and decide which word is real (no time limit).	Speed of comprehension: number completed in 2 minutes (possible /100), number of errors made. Spot-the-word: number of accurate identifications of real words (/60).	Parallel form reliability was 0.88. It correlates strongly with the National Adult Reading Test. The test is sensitive to the effects of closed head injury, range of drugs and stressors. Norms are available (16 - 65 years) to assess the extent to which comprehension speed deviates from vocabulary.

National Probation Service (employed since 2002). It collects detailed information on a range of background factors, assessing the likelihood of reconviction and risk of serious harm to selves and others. Information for primary and additional offences, number of previous offences, number of incarcerations, number of infractions and age of first offence was extracted. Criminal histories and background risk factors are combined to give 'risk of reoffending' scores. This includes the Offender Group Reconviction Scale (OGRS), which gives a percentage risk score for estimated probability of reoffending between 12 and 24 months. The OASys General Predictor (OGP) and OASys Violence Predictor (OVP) are calculated by combining static predictors from the OGRS and several dynamic factors from the OASys assessment. These give calculated risk of general (non-violent) and violent reoffending, again for 12 and 24 months post-assessment.

### 3.3.5 *Statistical analysis*

A 20% data transcription check was conducted (EFMK) prior to analysis for the hardcopy data to its digital format (an error rate of < 1% was detected). Two researchers independently categorised participants into groups (substantial injury and no or mild injury), based on TBI history (MHC & EFMK). Any for which there was ambiguity regarding severity were referred to a clinical neuropsychologist for assignment (WHW). The statistical analysis replicated that used for Study 1, detailed in Chapter two (see section 2.3.4).

I also conducted additional exploratory analyses, investigating the combined difference in FAR between samples of YPO against age matched non-offending controls, using a linear regression analysis.

## 3.4 **Results**

As in Chapter two, here the means (*M*), standard deviations (*SD*) and percentage mean difference (*%MD*) are reported for continuous variables, odds ratios for categorical variables, unstandardized beta values for regression

models and 95% confidence intervals (CI) to estimate the magnitude of observed effects ( $p$ -values are reported in accompanying tables).

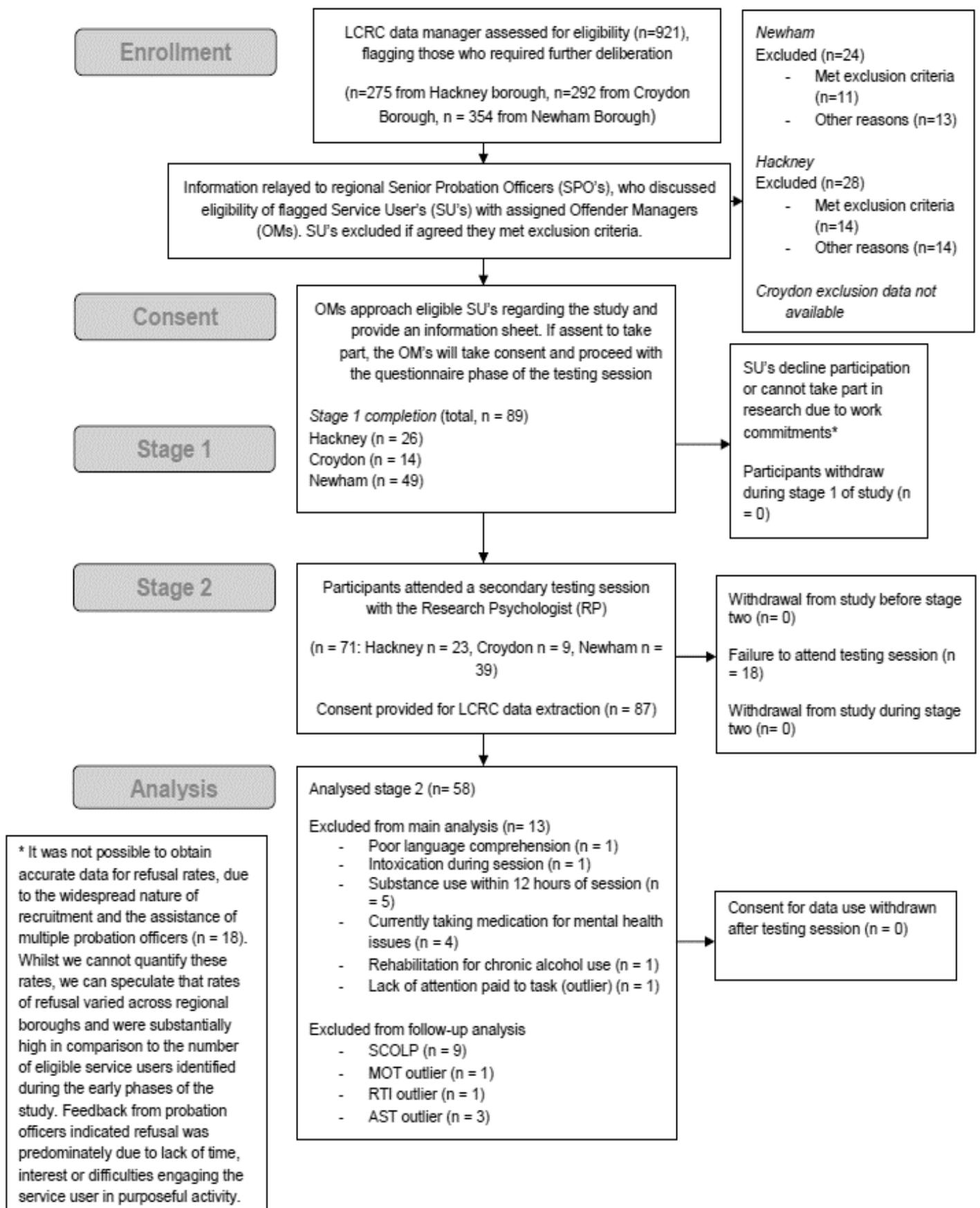
### 3.4.1 Participants

Eighty-nine male YPO were initially recruited into Study 2 and 71 completed both stages of testing. We were unable to recruit the 116 ( $n = 40$  with substantial TBI,  $n = 76$  with no or mild injury) stipulated within our protocol due to recruitment and engagement difficulties. Drop-out between stages of testing and reasons for exclusion are presented in the CONSORT diagram in **Figure 3.2**. Average age was 22 years ( $SD = 2$ ), with a range of 18 to 26 years. The sample was ethnically diverse, with 36% being of Black ethnic origin, 27% of White origin, 24% of Asian origin, and 14% of mixed or 'other' origin. Eighty five percent spoke English as a first language. Mean age at which the participants left education was 17 years ( $SD = 2$ ). The mean percentage deprivation was 19% ( $SD = 10$ ), ranging from 2 – 51% (1% being the most deprived regions of the UK, and 100% being the least deprived). The mean age of the non-offending controls was 21 years ( $SD = 3$ ), 83% were of white ethnic origin. See **Table 3.2** for full sample profile of substance use, mental health and neurodevelopmental co-morbidity and criminal histories.

### 3.4.2 Prevalence of traumatic brain injury

Fifty-seven participants (64%) reported some form of lifetime head injury. Thirty-three participants (37%) reported a head injury with a LoC. For six cases LoC information is missing, either due to omission in responding or an inability to recall. Mean age of most severe injury (as indexed by longest LoC duration) was 17 years ( $SD = 4.5$ , range 3 – 24 years). The mean age of first injury was 14.5 years ( $SD = 5$ , range 3 – 23 years). The average time since most severe injury in the substantial TBI group was 7 years ( $SD = 5$ , range 1 – 16 years), 29% of the sample took part within 3.5 years of their most severe injury. See **Table 3.3** for a breakdown of injury severities.

**Figure 3.2** Recruitment, retention and exclusions, Study 2.



**Table 3.2** Total group background profile, Study 2

Criminal histories		Participants with available data ( <i>n</i> )	Frequencies & range	
Type of crime		72	Violent	34 (47%)
			Non-violent	38 (53%)
Age of first conviction (years)		64	17 (3)	range: 10 – 25
Age of first police contact (years)		63	16 (3)	range: 10 - 24
Number of convictions < 18 years		74	1.5 (1.4)	range: 0 - 5
Number of convictions > 18 years		64	2.2 (2.5)	range: 0 - 10
Reoffending risk OGRS 12 months (%)		65	45 (21)	range: 3 - 89
Reoffending risk OGRS 24 months (%)		65	60 (21)	range: 7 - 94
Reoffending risk OGP 12 months (%)		53	40 (20)	range: 4 - 83
Reoffending risk OGP 24 months (%)		53	53 (21)	range: 8 - 90
Reoffending risk OVP 12 months (%)		50	23 (13)	range: 7 - 74
Reoffending risk OVP 24 months (%)		50	35 (16)	range: 13 - 84
Drug use:				
	Non-user	88	48	(54%)
	Occasion or monthly use		5	(6%)
	Weekly use (<20 units)		7	(8%)
	Daily use		14	(16%)
	> 3 times daily (heavy use)		14	(16%)
Alcohol use				
	Non-user	89	41	(45%)
	Occasion or monthly use		5	(6%)
	Weekly use (<20 units)		33	(37%)
	Daily use		5	(6%)
	Heavy use (>30 units weekly)		5	(6%)
Mental health				
	Score of 3 or more	89	21	(24%)
	Previous hospitalisation		8	(9%)
	Current treatment		9	(10%)
Neurodevelopmental disorder				
	ADHD	83	8	(10%)
	Dyslexia		2	(2%)
	Anxiety		1	(1%)
	OCD		1	(1%)
	Learning difficulty		2	(2%)
	Personality Disorder		1	(1%)
	PTSD		1	(1%)

Means presented, with standard deviations in parenthesis, with the exception of frequency data. Violent crimes were classified as those involving interpersonal aggression, the proportion of violent and non-violent criminal behaviour include previous violent convictions as well as current convictions. Score of three or more on the mental health screen may indicate current symptoms of serious mental health issue and the hospitalisation and treatment refer to mental health related treatment.

There was evidence for an association between PCS and injury severity, with higher reports of TBI sequela (as indicated by an increased score on the RPCQ) in those with higher dosage of injury (contrast estimate: 8.64, 95% CI: 3.48 to 13.80,  $p = 0.001$ ). This is depicted in **Figure 3.3**.

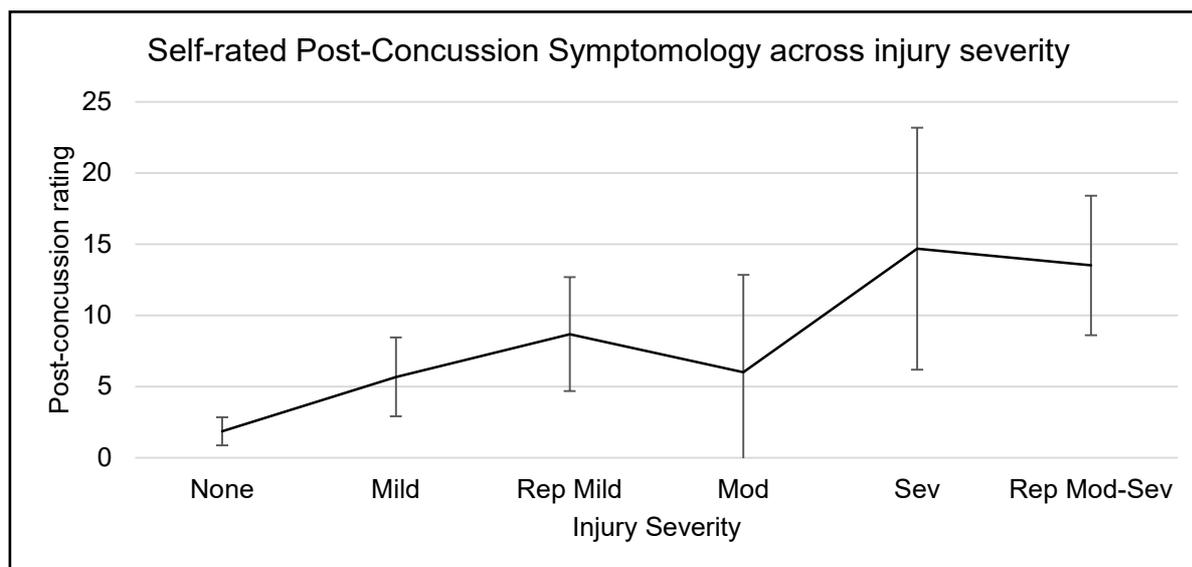
As in Study 1, I split the sample into two groups, based on the 'dosage of lifetime head injury sustained. This included those with 'substantial TBI' ( $n = 14$ ; comprising repetitive mild,  $n = 3$ ; moderate to severe,  $n = 9$ ; repetitive moderate to severe,  $n = 2$ ) and those with no previous history of TBI ( $n = 32$ ) or mild TBI (TBI without LoC, or LoC lasting less than 30 minutes;  $n = 37$ ), (combined  $n = 69$ ). The six without information regarding LoC duration were excluded from categorisation.

**Table 3.3** Frequency distribution of injury severities, Study 2

TBI Severity	Frequency	Percentage total	Repetitive Injuries (percentage category total)
No history of TBI	32	39	0
TBI without LoC (dazed & confused)	18	21	4 (22%)
Mild (LoC < 10 mins)	20	24	7 (35%)
Complicated mild (LoC 10 – 30 mins)	2	2	0 (0%)
Moderate (LoC 30 > 60 mins)	5	6	2 (40%)
Severe (LoC 60 mins to 24 hours)	5	6	4 (80%)
Very severe (LoC > 24 hours)	1	2	0
Total	83	100	18

Severities of injury reported with longest LoC duration ( $n = 83$ ) with distribution of repetitive (three or more) injuries. These severity categories are based on distinctions made in previous research, allowing sensitivity to a wider range of mild injuries that is consistent with European Federation of Neurological Society guidelines.

**Figure 3.3** Post-concussion symptomology, Study 2.



Post-concussion symptomology across TBI severity categories, Study 2. +/- 1 95% confidence interval. Rep = three or more repetitive injuries.

### 3.4.3 Injury group profiles

Following exclusions (with the accompanying reasons detailed in **Figure 3.2**), participants who completed the second stage of the testing session comprised  $n = 46$  in the mild or no injury group and  $n = 12$  in the substantial injury group. Group differences for background variables are reported in **Table 3.4**.

Comparing group means, there was weak evidence for a difference in RPCQ scores, particularly for the cognitive symptoms. Exploratory analyses indicated weak evidence for differences in the 'describing emotions' sub-scale of the TAS, the 'interpersonal' subscale of the PTI and the congruency measure on the AST, suggesting the substantial injury group were more susceptible to increased attentional demands for interfering material. There was no evidence for differences in other domains of neuropsychological functioning. These findings were of relevance to research question three (differences in neuropsychological profiles between TBI groups).

There was also weak evidence for increased risk of *violent* reoffending for the substantial TBI group compared to the mild or no injury group, within both one- and two-years post-conviction. As described in our protocol we ran further exploratory linear regression analyses with violent reoffending risk as the

outcome variable and this difference remained when adjusting for age and SES, see details in **Table 3.5**. This finding related to research question two (differences in criminogenic profiles between TBI groups).

**Table 3.4** Group profiles, Study 2.

	<b>Non-TBI (n = 46)</b>	<b>Substantial TBI (n = 12)</b>	<b>Coefficient (SE) or odds ratio</b>	<b>95% confidence interval</b>	<b>p-value</b>
<b>Demographics</b>					
Age at testing (years)	21.72 (2.0)	22.0 (2.13)	-0.28 (.66)	-1.60 to 1.04	0.67
Deprivation ranking (%)	18.43 (9.52)	21.6 (12.9)	-3.18 (3.33)	-9.85 to 3.49	0.34
Age left school (years)	17.0 (2.49)	16.33 (1.56)	0.67 (0.76)	-0.85 to 2.19	0.38
Verbal IQ (Vocab) /60	39.87 (5.08) (n = 39)	40.0 (5.50) (n = 10)	-0.22 (1.83)	-3.81 to 3.55	0.94
Speed_Comp /100	42.45 (12.93) (n = 40)	44.91 (12.86) (n = 11)	-2.26 (4.40)	-11.10 to 6.58	0.61
<b>Health</b>					
RPCQ Score (/32)	4.30 (5.45)	9.08 (6.93)	-4.78 (1.87)	-8.53 to -1.03	0.01
RPCQ Somatic (/12)	1.54 (2.07)	2.67 (2.39)	-1.12 (0.69)	-2.51 to 0.27	0.11
RPCQ Cognitive (/16)	2.46 (3.46)	5.58 (4.34)	-3.13 (1.18)	-5.49 to -0.76	0.01
RPCQ Fogginess (/4)	0.33 (0.63)	0.83 (1.03)	-0.51 (0.23)	-0.98 to -0.03	0.04
BJMHS Total	1.17 (1.20)	1.33 (1.07)	-0.16 (0.38)	-0.92 to 0.60	0.68
BJMHS 7 (no:yes)	44:2	11:1	2	0.17 to 24.12	0.51
Neurodevelopmental (no:yes)	42:4	9:3	3.5	0.67 to 18.43	0.15
Drug usage (N:INF:W:D)	<b>30:3:3:10</b>	<b>4:0:1:7</b>			
Alcohol usage (N:INF:W:D)	<b>24:2:16:4</b>	<b>3:1:6:2</b>			
<b>Criminal Profile</b>					
Violence (Violent: Non-Violent)	(19:17)	(3:9)	1.77	.43 to 7.31	0.09
Number of court appearances under 18	2.75 (5.17)	4.50 (3.99)	-1.75 (1.64)	-5.05 to 1.55	0.29
Number of court appearances over 18	1.62 (0.18)	3.18 (3.25)	-1.56 (0.81)	-3.20 to 0.08	0.06

Number of court appearances total	4.59 (6.41)	6.91 (5.77)	-2.32 (2.21)	-6.80 to 2.15	0.30
Age of first conviction	16.66 (2.37)	16.36 (3.38)	0.29 (0.95)	-1.62 to 2.21	0.76
Reconviction Scale 1 year (OGRS) /100	42.53 (21.51)	52.64 (24.94)	-10.10 (7.91)	-26.10 to 5.89	0.21
Reconviction Scale 2 years (OGRS) /100	57.07 (22.35)	66.09 (22.57)	-9.02 (7.93)	-25.06 to 7.01	0.24
OASys General Predictor 1 year /100	36.38 (22.44)	45.50 (19.94)	-9.13 (8.19)	-25.82 to 7.57	0.27
OASys General Predictor 2 years /100	48.0 (24.02)	58.30 (19.31)	-10.30 (8.58)	-27.77 to 7.17	0.24
OASys Violence Predictor 1 year /100	18.86 (8.31)	30.0 (20.02)	-11.14 (5.04)	-21.45 to -0.84	0.04
OASys Violence Predictor 2 year /100	29.95 (11.54)	41.90 (22.06)	-11.95 (5.99)	-24.19 to 0.30	0.06
<b>Personality &amp; Background</b>					
RPQ Aggression /46	11.52 (8.73)	15.58 (7.18)	-4.06 (2.74)	-9.55 to 1.42	0.14
RPQ Proactive /24	2.83 (3.84)	4.92 (5.05)	-2.09 (1.33)	-4.76 to 0.58	0.12
RPQ Reactive /22	8.70 (5.47)	10.67 (3.26)	-1.97 (1.66)	-5.28 to 1.35	0.24
TAS Alexithymia /100	50.58 (11.19)	56.33 (10.30)	-5.76 (3.58)	-12.93 to 1.42	0.11
TAS Describe /25	13.3 (4.22)	16.17 (4.80)	-2.83 (1.41)	-5.66 to -0.01	0.05
TAS Identify /35	14.93 (5.99)	16.50 (4.96)	-1.57 (1.89)	-5.35 to 2.21	0.41
TAS External thinking /40	22.31 (4.16)	23.67 (4.27)	-1.36 (1.36)	-4.08 to 1.37	0.32
Psychopathic Traits /72	37.46 (9.57)	43.33 (11.05)	-5.87 (3.21)	-12.30 to 0.55	0.07
PTI Interpersonal /24	12.80 (4.43)	15.67 (4.27)	-2.86 (1.42)	-5.72 to -0.01	0.05
PTI Affective /24	11.74 (3.69)	13.50 (5.30)	-1.76 (1.32)	-4.40 to 0.87	0.17
PTI Behavioural /24	12.91 (3.63)	15.0 (3.91)	-2.09 (1.20)	-4.48 to 0.31	0.09
Early Trauma Inventory /10	2.85 (2.13)	3.83 (1.70)	-0.99 (0.67)	-2.32 to 0.35	0.14
ETI Physical abuse /3	1.52 (1.23)	2.08 (0.79)	-0.56 (0.37)	-1.31 to 0.19	0.14
ETI Emotional abuse /3	0.93 (0.98)	1.33 (0.99)	-0.40 (0.32)	-1.03 to 0.24	0.21
ETI Sexual abuse /3	0.07 (0.33)	0.00 (0.00)	0.07 (0.10)	-0.13 to 0.26	0.50
Witnessed Violence (Y:N)	21:25	7:5	1.67	0.46 to 6.03	0.53
<b>Neuropsychology</b>					
MOT Median latency (ms)	771.46 (181.3)	803.67 (183.60)	32.21 (59.20)	-150.90 to 86.49	0.59

RTI Median Simple RT	277.77 (39.83)	262.27 (40.62)	15.50 (13.42)	-11.39 to 42.39	0.25
RTI Choice RT	316.77 (47.76)	309.21 (52.33)	7.56 (15.53)	-23.54 to 38.67	0.63
RTI Simple movement time	174.50 (66.64)	180.88 (85.84)	-6.38 (22.96)	-52.37 to 39.60	0.78
RTI Choice movement time	216.15 (57.85)	234.50 (65.01)	-18.35 (19.88)	-58.18 to 21.48	0.36
SWM Between errors	12.49 (9.0)	12.25 (10.70)	0.24 (3.04)	-5.86 to 6.34	0.94
SWM Strategy errors	15.69 (3.34)	14.73 (3.52)	.96 (1.14)	-1.32, 3.24	0.40
AST Median Congruency	51.21 (44.51) ( <i>n</i> = 41)	83.08 (40.68) ( <i>n</i> = 12)	-31.88 (14.35)	-60.68, -3.07	0.03
AST Median Switch cost	207.80 (112.49)	173.29 (81.41)	34.51 (34.97)	-35.70, 104.73	0.33

Beta coefficients displayed with standard error in parenthesis, with the exception of odds ratios for categorical variables. For drug and alcohol usage N = Non-user, INF = infrequent (occasion, monthly), W = weekly, D = daily.

**Table 3.5** Associations between traumatic brain injury and risk of violent recidivism

	Unadjusted	Sociodemographic adjusted
<i>n</i>	31	31
Unstandardised coefficient	11.14	9.99
95% confidence interval	0.84 to 21.45	-0.64 to 20.62
<i>p</i> -value	0.04	0.06
<i>R</i> <sup>2</sup> (model <i>p</i> -value)	0.14 (0.04)	0.19 (0.13)

The results from unadjusted (substantial TBI only) and sociodemographic adjusted models (participant age and percentage deprivation ranking).

#### 3.4.4 Traumatic brain injury and facial affect recognition

An unadjusted linear regression model gave no evidence that those with substantial TBI were significantly poorer at FAR (% accuracies reported), (sub TBI *M*: 57.81, *SD*: 12.38; mild or no TBI *M*: 58.29, *SD*: 11.25). This meant the hypothesis outlined in research question one (that those with substantial TBI would have poorer FAR than those with no or mild injury) was unsupported. The adjusted linear regression models gave weak evidence that FAR performance was predicted by verbal comprehension (SCOLP spot-the-word score, *B* = 0.49, 95% CI: 0.14 to 0.85), with higher verbal comprehension predicting higher FAR

**Table 3.6.** Associations between traumatic brain injury and facial affect recognition overall percentage accuracy, Study 2.

	<b>Unadjusted</b>	<b>Sociodemographic adjusted</b>	<b>Health adjusted</b>	<b>Neuropsychology adjusted</b>	<b>Personality questionnaire adjusted</b>
<b>Study 2</b>					
<i>n</i>	<b>58</b>	<b>49</b>	<b>58</b>	<b>50</b>	<b>57</b>
Unstandardised coefficient	-0.48	-0.54	-0.48	-5.01	-0.89
95% confidence interval	-7.93 to -6.98	-8.80 to 7.73	-9.12 to 8.15	-13.04 to 3.02	-8.76 to 6.98
<i>p</i> -value	0.90	0.90	0.91	0.22	0.82
<i>R</i> <sup>2</sup> ( <i>model p</i> -value)	0.00 (0.89)	0.21 (0.12)	0.04 (0.94)	0.41 (0.01)	0.02 (0.89)

The results from unadjusted and adjusted linear regression models are given. Unadjusted gives the associations with substantial TBI only. In Study 2 'Sociodemographic adjustment' includes adjustment for age, verbal IQ (SCOLP), deprivation percentage ranking and age at which the participant left school. 'Health adjustment' includes post-concussion symptomology, frequent drug use, frequent alcohol use, mental health issues, neurodevelopmental diagnosis and experience of early trauma. 'Neuropsychology adjustment' includes output from the Cantab Research Suite (MOT, RTI, SWM & AST). 'Personality questionnaire adjustment' includes the TAS, PTI, and RPQ.

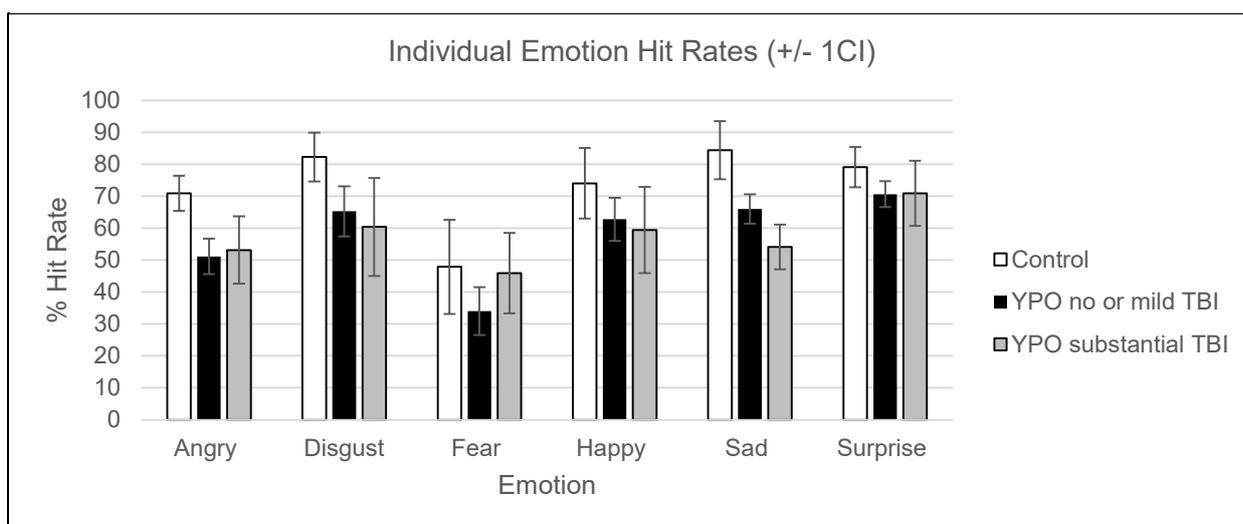
accuracy. There was also evidence for the predictive value of reaction time on FAR (simple RTI score,  $B = 0.11$ , 95% CI: 0.04 to 0.18), with slower 'simple' reaction time (one target), and quicker 'choice' reaction time (responding to multiple targets) being predictive of better FAR performance (choice RTI score,  $B = -0.08$ , 95% CI: -0.13 to -0.02). There was also weak evidence for the predictive value of spatial working memory on FAR performance (SWM between-errors,  $B = -0.33$ , 95% CI: -0.59 to -0.07), with better FAR performance with fewer between-errors (re-visiting a place where a token had already been found). No adjustment (for sociodemographic, health, neuropsychology and personality factors) within the models changed the predictive values of TBI status (see **Table 3.6**).

The primary analysis was also repeated with a three-group model (no injury, mild injury and substantial injury), with no qualitative difference in results. These additional analyses are reported in the appendices (**Table A1**).

As in Chapter two, the raw percentage hit rates for individual emotions are visually represented in **Figure 3.4**, with inclusion of non-offending control performance for comparison. As before, this control group has not been included within the primary analysis as they were not matched for SES and IQ but are included here to give an illustration of performance across emotions in aged-matched non-offending controls. It is apparent that there are no noticeable or consistent differences between YPO's with and without substantial TBI, contrasting with the differences observed previously in Study 1.

Running a multivariate analysis with individual hit rate for each emotion as dependent variables, and TBI group status as the between-subjects' factor, there was evidence for difference between the substantial injury group and those with mild or no injury for the emotion sadness only ( $MD: 12\%$ ; 95% CI: 1.88 to 21.88), with poorer recognition of sadness in the substantial TBI group. However, there again was no clear evidence for an interaction between emotion and injury group, meaning this reported difference should be viewed as preliminary and exploratory.

**Figure 3.4** Individual emotions, Study 2



Individual emotion raw hit rates, with 95% confidence intervals, Study 2.

### 3.4.5 Combined analyses

I also investigated whether the YPO samples included in Study 1 and 2 were poorer at overall FAR, in comparison to the aged-matched non-offending controls, irrespective of TBI status. I combined the datasets and compared the mean percentage accuracy between YPO's against non-offending controls, which indicated poorer FAR performance in those with offending behaviour, compared to non-offending controls. This is in line with expectations, given previous findings suggest poor FAR in populations with antisocial behaviour. The details of the offender status analysis can be found in **Table 3.7**.

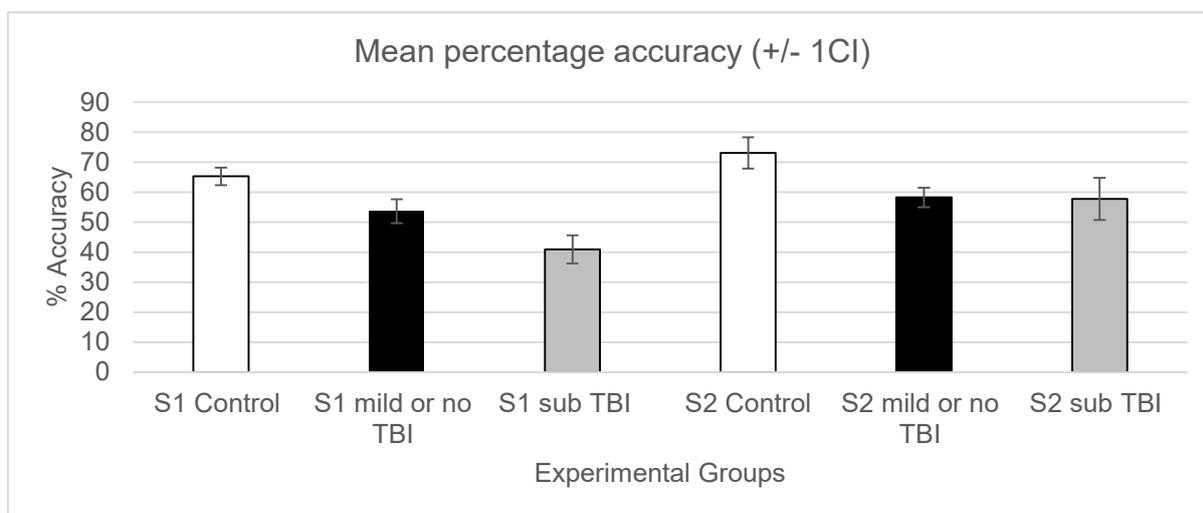
**Table 3.7** Associations between offending status and overall emotion recognition

	Unadjusted	Adjusted
<i>n</i>	144	144
Unstandardised coefficient	-11.82	-24.6
95% confidence interval	-15.6 to -8.0	-34.4 to -14.8
<i>p</i> -value	< 0.001	< 0.001
<i>R</i> <sup>2</sup> (model <i>p</i> -value)	20.9 (< 0.001)	31.6 (< 0.001)

The results from unadjusted (offending status only) and adjusted (for history of substantial injury and study dataset) models.

A visual illustration of overall FAR performance (% accuracies given) across experimental groups and non-offending comparison groups for both studies is given in **Figure 3.5**. There appeared to be higher overall accuracy for participants in Study 2, across groups, compared to Study 1, which may have been due to participant characteristics or stimulus presentation time.

**Figure 3.5** Overall emotion recognition accuracy, Study 1 & 2



Overall percentage accuracies presented for the mild or no injury groups, substantial TBI groups and aged-matched non-offending controls, for Study 1 (S1) and Study 2 (S2). 95% confidence intervals are depicted in error bars.

### 3.4.6 Additional exploratory analyses

There are details of additional exploratory analyses, of which were specified in the pre-registered protocol, which can be found in the appendices. This includes feasibility assessment and correlation matrices (see **Figure A2** & section **A3**) investigating associations between FAR, neuropsychological measures, demographic, health and personality measures. There was evidence for associations between PCS, alexithymia, psychopathic traits, aggression, mental health and early trauma. There was also evidence for associations between related measures, such as neuropsychology measures investigating similar domains and associations between measures of previous criminal behaviour. There was weak evidence for an association between overall FAR

with verbal comprehension and working memory. The feasibility assessment details some of the difficulties encountered in recruitment of eligible service users (recruiting 9% of the total eligible sample), drop-out between sessions one and two (20%) and the reasons for exclusion from the main analysis (often including recent substance use, or comprehension difficulties).

### **3.5 Discussion**

Our primary hypothesis (research question one) in Study 2 was not supported. There was no evidence of a difference in FAR performance between those with substantial TBI and those without. Furthermore, there was no clear evidence of ongoing neuropsychological deficit in those with substantial TBI in comparison with those with mild or no injury, with the exception of weak evidence for poorer performance on the attention-switching task in the presence of interfering material (research question three). There was ongoing sequela in the substantial TBI group with higher reports of PCS, particularly evident for cognitive symptoms, replicating the PCS effect found in Study 1. Differences within self-report questionnaire measures were also observed, with higher levels of alexithymia for the describing of emotions and higher levels of psychopathic interpersonal traits. There were also observed differences in offending profiles, with those who had incurred substantial injury being at a higher risk for violent recidivism than those with mild or no injury, in line with previous literature (research question two) (Fazel, Lichtenstein, Grann, & Långström, 2011; Kenny & Lennings, 2007). However, it should be noted that there is an issue here with uncorrected multiple comparisons for group profile comparisons, therefore these findings should be interpreted as preliminary.

### **3.6 General discussion**

#### *3.6.1 Comparisons between studies*

Given the substantial decrease in FAR performance found in Study 1 and the well-replicated effect of TBI on FAR in the literature (Babbage et al., 2011), it was surprising not to find support for our primary hypothesis in Study 2. As

discussed, this may be explained by a high proportion of severe injuries observed in Study 1 generating an expected effect of TBI on impaired performance, particularly when the tasks used (BERT) required a quick response. However, despite the Study 2 substantial TBI group having a lower proportion of severe injuries, we still expected to detect a deficit, even if the magnitude of the effect size was reduced in comparison to Study 1. However, there was no evidence for this in the young adult sample. To better understand whether this finding indicates a spurious result in Study 1, a lack of sensitivity in the task used in Study 2, insufficient power to detect effects or conversely, a lack of effect within the Study 2 sample it is important to consider differences in methodologies.

One explanation is that the YPO sampled in Study 1 had experienced a particularly high severity of TBI at a closer time-point than found in our young adult YPO's in Study 2. The time elapsed since most severe injury was slightly longer in the young adult (Study 2) sample, and they tended to have a later age of both first and most severe injuries compared to the adolescent YPO (Study 1) sample. This might suggest that the TBI-related impairment had resolved with a longer time since injury in Study 2. Alternatively the deficit observed in Study 1 may be attributable to the developmental time period in which the injury was sustained. Ryan et al. (2014) suggested that sustaining an injury before an important neurodevelopmental stage may disrupt subsequent development and elicit more enduring impairment. It is possible that the participants in Study 1 experienced injury prior to, or during, an important stage in neural development. This may have produced more pronounced impairment in FAR compared to the older participants in Study 2. If those in Study 2 experienced injury when these neural systems were already more established and less vulnerable, it's likely they endured less FAR related deficit as a consequence.

It is also important to consider study sample characteristics, differing in age, area of residence and ethnicity. There is some evidence that FAR ability improves linearly across childhood, adolescence and young adulthood (Lawrence, Campbell, & Skuse, 2015; Thomas, De Bellis, Graham, & LaBar, 2007). Greater variability in FAR performance at a younger age may have made the Study 1 individuals more sensitive to TBI related FAR impairment. Study 1's YPO derived from rural residences and town dwellings, whereas the Study 2

YPO sample derived from a highly urban setting. It is plausible that different mechanisms encourage criminal behaviour in urban versus rural settings (Atav & Spencer, 2002) or that differing levels of interpersonal exposure may influence FAR ability.

It is also possible that changes in task parameters – the Study 2 BERT included less trials overall, and longer stimulus presentation time (300ms, rather than 150ms) – may have made the task less sensitive to deficits. Indeed, performance seems to have improved across the Study 2 groups following the increase in presentation time, as we might expect (see **Figure 3.5**), and reaction time (as measured by the RTI) predicts performance on the 300ms Study 2 BERT. This suggests that the previous effect may have been an artefact of processing speed. However, there is no evidence of reduced processing speed in either Study 1 or 2's substantial TBI sample compared to those with mild or no injury, which limits our ability to attribute the discrepancy between findings to this explanation. There also seems to be differences in the predictive value aspects of reaction time on FAR. Simple reaction time (responding to one target only) is negatively associated with FAR performance, which may suggest quick responding can result in greater errors (false alarms). Choice reaction time (with multiple targets) however, was positively associated, with quicker response predicting better performance. Further research comparing performance between those with and without TBI on these two BERT presentation times would be helpful in establishing whether changes in presentation times influenced the outcome of these two studies.

There was no clear evidence for impaired or differential neuropsychological processing in those with substantial TBI in comparison to those with mild or no injury. The only exception to this, was weak evidence for greater susceptibility to interfering material in those with substantial injury. This was indicated by a greater interference score on the Stroop task in Study 1 and this effect was replicated by the congruency score on the attention-switching task (AST) in Study 2. This suggests that those with substantial injury struggled with increased attention demands in the presence of incongruent or interfering stimuli. This should be investigated further in future studies to determine if the effect is robust and whether this has further implications for informing our understanding of the association between TBI and criminality.

In terms of individual emotions, we did observe evidence for a reduction in hit rates for the emotion sadness specifically for those with substantial injury, across both studies, and weak evidence for lower hit rates for disgust and happiness in the substantial TBI group in Study 1, which was not replicated in Study 2. The failure to replicate the effect for disgust and happiness in Study 2 may reflect the weakness of the effect initially. In addition, the subtle changes made to these emotive stimuli to make difficulty more consistent across emotions in Study 2 may have attenuated these initial differences. It is of interest that the deficit in the identification of sadness replicated, however as stated, these results are preliminary and not supported with an interaction effect between emotion and group therefore these effects may not be robust.

Whilst no difference in FAR was observed in those with and without substantial TBI in Study 2, the combined analysis indicated poorer FAR for both groups of offenders, in comparison with non-offending controls, regardless of TBI status. This should be investigated further in future, with more closely matched non-offending controls. However, these findings are in line with previous research (Chapman, Gillespie, & Mitchell, 2018; Marsh & Blair, 2008), and suggests FAR training as a possible intervention for antisocial or delinquent behaviour in these population (Penton-Voak et al., 2013; Schönenberg et al., 2014).

### *3.6.2 Study limitations*

There are important limitations to be acknowledged. First, despite efforts to gain the specified sample size ( $n = 116$ ) for Study 2, this was not feasible. This was due to limited resources available and difficulties engaging members of this population (see the feasibility analysis within the Appendices (**A4**) for more detail). Following exclusions, the sample size of those with substantial injury was small and this reduced statistical power, hindering the ability to draw conclusions regarding ongoing deficits in this population. Future replication of these efforts in a multi-site, longitudinal study would be advantageous for recruiting greater numbers and achieving greater balance across experimental groups.

Second, there may have been a recruitment bias in the respondent group for these studies. It is possible that those who were not recruited or decided not to participate comprised YPO with more complex injuries and needs, giving an unrepresentative sample of the offending population. Third, it is difficult to assess validity of self-report data. Inaccurate reporting may have arisen due to confidentiality issues for drug, alcohol use and sensitive items, lack of comprehension on some more complex questionnaire items, or memory difficulties (especially for the recall of trauma). However, whilst it may be argued that hospitalisation and medical records would be a more objective means of identifying TBI history, this would underestimate the majority of injuries that go unreported, consequently omitting many milder injuries. Furthermore, the self-report personality questionnaires appeared sensitive to TBI related impairment in this sample. It may be that these measures provide insight into more complex constructs and behavioural difficulties than can be encapsulated by more exacting neuropsychological tests and experimental paradigms.

It is also necessary to consider the complications of measuring 'offending behaviour' as a unitary construct. It would be beneficial to stratify different types of offending behaviour when assessing the influence of injury (O'Rourke, Templeton, Cohen, & Linden, 2018). Here I've focused predominately on socioemotional processing and its correspondence with violent crime in particular, however, we recruited opportunistically a group of YPO with both violent and non-violent convictions. Whilst there was no evidence for higher proportion of violent offending in those with injury, we observed a higher risk for future violent crime in the Study 2 substantial injury sample. Within this particular probationary setting, 'very high risk' violent individuals are referred to a different organisation within the National Probation Service. Therefore, it is interesting that we observed a relationship with increased risk of violent crime, even in lower risk samples. As mentioned, it would be beneficial in future studies to recruit an aged-matched non-offending control group which is also well-matched for SES and IQ, to investigate the influence of offending history on FAR with tightly matched controls. There is also a difficulty inferring causality with cross-sectional designs of this nature, for which longitudinal experiments are more appropriate (see Chapter eight for a more detailed discussion).

### **3.7 Summary**

These studies in combination are of importance within the field of TBI and offending behaviour as despite difficulties we managed to recruit and furthermore, engage, over a hundred adolescents and young adults at a pivotal stage in their offending trajectories. This provided detailed assessment and neuropsychological profiling of those with TBI. The discrepancies between studies and sample profiles illustrates the complexity and heterogeneity of both offending behaviour and consequences of injury, emphasising the need for investigation on a much larger scale. It is interesting that, whilst we did not observe clear evidence for neuropsychological deficits in the second TBI sample in the domain of FAR, injury was associated with self-reported interpersonal problems, interference effects for incongruent material and importantly, with increased risk of violent recidivism. This suggests that there is an association between TBI and criminal behaviour, but, of course, it is mediated by complex risk factors (Williams et al., 2018; Williams, McAuliffe, Cohen, Parsonage, & Ramsbotham, 2015). This emphasises the need for better screening, allocation of resources and management of individuals with TBI within the justice system to help reduce risk of recidivism – social and economic cost savings could be substantial.

### **3.8 Future directions**

It is beyond the scope of this thesis to conduct a subsequent definitive study of a sufficient magnitude with young people within offending populations, but I envisage this study will be informative in providing guidance for future research. If a future study with sufficient power provides evidence for ongoing neuropsychological and FAR impairment in those with higher dosage of injury, it would be interesting to explore this further. What remains to be seen is whether the association between TBI and crime are only present in those with pre-morbid criminal tendencies, exacerbating pre-morbid behaviours by reducing protective factors. By recruiting individuals from justice systems, with previous convictions or cautions for criminal behaviour, we are predominately identifying those who are at higher risk for future recidivism. However, presence of TBI may also encourage tendencies towards aggression or delinquency in those

without previous offending histories, influencing risk of initial contact with the criminal justice system.

To investigate this further, I conducted the next study on a non-offending sample from the general population to examine the effects of TBI on FAR. A second aim of the following study was to more formally compare the effects of different presentation times to inform the interpretation of results from S1 and S2. Furthermore, I investigated whether TBI and FAR ability was related to behavioural measures of aggression, delinquency, alexithymia and current health. The details of this study (Study 3) are described in Chapter four.



## **4 Study 3: Assessing the relationship between self-reported traumatic brain injury, facial affect recognition and antisocial behaviour in a general population sample.**

### **4.1 Acknowledgements**

This study was conducted in collaboration with Andy Woods, developer of the online platform 'Xperiment', and his assistance with the programming of the measures for use in an online format was greatly appreciated. Study co-authors include Ian S. Penton-Voak, Natalia S. Lawrence, Andrew L. Skinner and Andy T. Woods in the planning stages of the study and Lydia Cook in her assistance with data quality assessments and recruitment. Zara Bernard assisted in the initial piloting of the task and study procedure, Dr Bobby Stuijzand advised on power calculations and the charity 'Headway' assisted with advertisement and recruitment. All co-authors contributed to the drafting of the study manuscript for publication (in preparation). Additional funding was received from the University of Exeter's Open Innovation Fund to assist with data collection.

### **4.2 Introduction**

This study builds on the theory and the findings of the studies described in the previous chapters, by investigating similar mechanisms and associations between self-reported injury, antisocial behaviour, and FAR. In this study, however, I recruited a sample of young adult males from the general population, rather than those identified on the basis of previous antisocial behaviour (in the form of criminal convictions). This aimed to inform the discrepant findings of TBI effects on FAR in Study 1 and 2, giving clearer insight into the mechanisms driving this effect, if it exists. I rationalised that if evidence for an association between TBI, FAR and measures of antisociality and delinquency was observed in members of the general non-offending population, then this gives a more robust theoretical framework from which to extrapolate to offending populations with more complex needs. If, however, we observed evidence for FAR

impairment in those with TBI, without any translation to antisocial behaviour, this could suggest that the pre-morbid risk factors (as suggested in **Figure 1.2**) play a vital role in the association between TBI and later criminal behaviour. This study addresses research question four, 'are similar patterns of effects between TBI, FAR and antisocial behaviour observed in members of the general, non-offending population (see section 1.8.1).

In addition to investigating these mechanisms in a general population sample, I also examined the influence of adapting stimulus presentation time on subsequent performance, using similar presentation times to the 150ms and 300ms employed in the previous studies. This helped establish whether the increased presentation time used in Study 2, may have made the task less sensitive to subtler deficits in those with greater dosage of injury.

Here I investigate whether there is a deficit in overall FAR in young adult males with differing severities of self-reported lifetime TBI, compared to age-matched controls without history of TBI. Using the same FAR task as used within studies 1 & 2 (the BERT), adapted for delivery in an online format. I decided to use an online format as this enabled greater access and extensive screening of these populations. This in turn aided recruitment of appropriate sample sizes for statistical comparisons between groups. Furthermore, delivery of the BERT in an online format had been successful previously (Attwood et al., 2017). I used the same self-reported TBI screen as used in Studies 1 & 2 (the CHAT) to aid consistency and comparisons across samples. Stimulus presentation time was manipulated to explore whether this accounted for inconsistencies in findings between Studies 1 & 2. I also investigated whether poorer socioemotional processing is associated with higher reports of aggression, delinquency and, in line with Study 2, alexithymia. Alexithymia was included as previously those with substantial TBI reported greater difficulty in the description of emotions relating to the self, and to provide greater insight into affective processing mechanisms.

A detailed study protocol was pre-registered on the Open Science Framework prior to the commencement of data collection (DOI 10.17605/OSF.IO/2EC4N). Ethical approval was granted by the University of Exeter ethics committee (reference: 2016/1303).

## 4.3 Methodology

### 4.3.1 Participants and recruitment

I recruited young adult males, aged 16 to 35 years old, from the general population. Participants were predominately identified and recruited through an online crowd-sourcing platform (see section 4.3.4 for details). We (MC & LC) also advertised for participants through social media (including Facebook and Twitter), head injury charities, sports clubs and societies and by displaying hard-copy advertisements and flyers in public places. Additional inclusion criteria included being able to speak English fluently. Exclusion criteria included: currently receiving treatment for a mental health condition, uncorrected visual impairment and consumption of alcohol or illicit drugs in the twelve hours prior to testing. Initially, I aimed to recruit two injury groups, those with substantial injury based on the criteria used previously (an instance of head injury with a LoC lasting over 30 minutes or 3 or more instances of head injury with LoC lasting less than 30 minutes), and those with no history of head injury. There were two conditions of the task, long presentation time and short, and I aimed to allocate equal numbers of those with and without injury to each condition.

### 4.3.2 Sample size calculation

Based on the findings of Study 1, group differences between those with and without substantial TBI, indicated an effect size of  $d = 1.44$  for difference in overall emotion recognition. Again, employing the rationale that small scale studies can overestimate effect sizes by up to a third (Button et al., 2013), I reduced this effect size to  $d = 0.96$  (0.40 effect size  $F$ ).

Using this modified effect size, the sample size needed for a two-way ANOVA, interaction effect (three numerator degrees of freedom), four evenly split groups (TBI group X presentation time), with a power of 95% was calculated as  $n = 112$  males (28 per group). I determined that a sample of this size (substantial TBI  $n = 56$ , no TBI  $n = 56$ ) should provide 100% power to detect an effect of this magnitude, and 95% power to detect a medium to large effect size of  $d = 0.63$ . Within these samples I specified that  $n = 28$  were

assigned to the 'long' stimulus presentation condition (305.1ms), and  $n = 28$  to the 'short' stimulus presentation condition (152.6ms).

#### *4.3.3 Additional injury groups*

Originally, I decided to recruit those with and without substantial injury as the primary groups of interest, and then recruit an opportunistic additional 'mild' injury group for exploratory purposes (detailed in the study protocol). As initial screening was more extensive than originally anticipated, I extended this additional recruitment from one to two mild injury groups to allow greater differentiation between milder injuries. The first mild injury group included individuals who had experienced at least one TBI with LoC for less than 10 minutes ('mild TBI'), and the second included individuals who had experienced at least one TBI lasting between 10 and 30 minutes ('complicated mild TBI'). This builds on evidence which suggests that there may be greater ongoing cognitive deficit in those with complicated mild injuries in comparison to those with milder injuries (Borgaro, Prigatano, Kwasnica, & Rexer, 2003). Complicated mild injury is typically defined as a 'mild TBI, with an accompanying brain lesion or depressed skull fracture' (Williams, Levin, & Eisenberg, 1990), however in the absence of diagnostic imaging data, we categorized mild and complicated mild based on loss of consciousness duration, as observed in previous studies (Davies, Williams, Hinder, Burgess, & Mounce, 2012). For these additional exploratory groups, I also aimed to recruit  $n = 56$  per group, so that group sizes were matched across injury severities. These additional groups were also further equally sub-divided into stimulus presentation time conditions.

#### *4.3.4 Design and recruitment procedure*

This study used a between-subjects, two-factor (substantial injury versus no injury; short stimulus presentation versus long stimulus presentation), observational case-control study. The primary outcome measure was overall FAR accuracy on the online version of the BERT.

The platform 'Prolific Academic' (PA) is an online crowd-sourcing platform tailored for research (see <https://prolific.ac>). The platform can create bespoke screens for researchers recruiting specific populations. I requested a head injury screener, asking "have you ever had an injury to the head that's caused you to be knocked out and/or dazed and confused for a period of time (e.g. from a fall, blow to the head or a road traffic accident)?"<sup>2</sup>. Following this a short eligibility survey was launched, directed at members of the PA participant pool who fit our eligibility criteria (male, aged 16 to 35 years, English as a first language, answering 'yes' to the head injury screening question). The eligibility survey asked about history of head injury in greater detail based on the items included in the CHAT. I also included a pre-screening criterion identifying those with an approval rate of 90% or more on PA to try and promote greater reliability in respondents. This could arguably bias the sample, however, as researchers are strongly advised to only reject a submission with appropriate cause, this approval rate criteria includes 97% of the participant pool on this platform and therefore should not hinder generalisability of findings.

The first head injury eligibility survey was launched in November 2016 and then then re-launched at future time-points to capture new and active users (five studies run in total, over a period of 18 months). The survey was hosted on the platform 'Bristol online surveys' (<https://www.onlinesurveys.ac.uk>). The survey asked questions regarding the frequency of injuries, cause of injuries, age at injury, duration of LoC (if LoC occurred), whether medical attention was sought, and the duration of the hospital visit if so. The participants also completed the short version of the Rivermead Post-Concussion Symptoms Questionnaire (RPCQ) (as used in Study 1 & 2) at this time-point. Advertisements circulated outside of PA directed participants either directly to this questionnaire, or to the lead researcher (MC) for additional study details. Participants recruited for the non-injured control group were recruited in the

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<sup>2</sup> An additional screen was launched at a later time point in the study which asked more specifically 'have you ever had an injury to the head *that has caused you to be knocked out* for a period of time (e.g. from a fall, blow to the head or a road traffic accident)?'. This was to help tailor the recruitment and reduce the number of respondents who had experienced a head injury without a LoC.

same way, except those who responded 'no' to the head injury history screening question were targeted.

Based on the responses of this eligibility survey, participants were categorised into those with 'minor injury' (head injury with no LoC), 'mild injury' (head injury with LoC lasting less than 10 minutes, on fewer than three occasions), 'complicated mild injury' (head injury with LoC lasting between 10 and 30 minutes, on fewer than three occasions), and 'substantial injury (head injury with LoC lasting over 30 minutes, or three or more instances of head injury with LoC, for any duration). These participants were then either contacted directly and invited into the study (non-PA), or recruited through PA, using their custom 'whitelist' feature. This feature enables the researcher to specify which participants within the PA participant pool will receive the study advert, using their PA subject identifiers.

Exclusion based on current treatment for mental health disorders, recent drug or alcohol use, or uncorrected visual impairment took place after the participants had been recruited and completed the study. This was done in an attempt to reduce potential dishonesty regarding these items, as we believed participants may be less likely to disclose this health information if it meant they could not subsequently take part and receive reimbursement as a consequence. It is unlikely that the same issues apply regarding the shorter head injury eligibility questionnaire, as responses within this could equally be used for inclusion as well as exclusion on subsequent studies and no reference was made to future studies in the initial questionnaire description. There was a higher risk of dishonesty regarding previous head injury for those who responded directly to external (non-PA) advertisements. However, as the advert detailed a 'small financial reimbursement' (of £2.50), we regarded this to be a relatively low risk as a consequence. Different versions of the full study (administered through the Xperiment platform: <https://www.xpt.cloud>) were used for PA and non-PA users. The full study was advertised as an 'emotion recognition study' rather than a 'head injury research study' to reduce demand characteristics. I aimed to recruit additional participants to replace those who had been excluded based on our criteria, and rather than excluding outright I ran the analysis unadjusted and adjusted for the presence of an unmedicated mental health disorder or neurodisability.

### 4.3.5 Measures

#### 4.3.5.1 Traumatic brain injury screen

Replicating that used within Study 1 and 2 (as derived from the neurodisability section of the CHAT; (Prathiba Chitsabesan, Lennox, Williams, Tariq, & Shaw, 2015) I adapted this for delivery in an online format. This included asking about presence and frequency of injuries initially, followed by a detailed page per reported injury asking causation, duration of LoC and further details regarding medical assistance. As mentioned, the RPCQ was also administered following the CHAT items, within the eligibility questionnaire, and then repeated by all participants during the main experiment itself (i.e. at the time of FAR assessment), allowing comparisons of post-concussion symptomology to non-TBI related symptoms in non-injured controls.

#### 4.3.5.2 Facial affect recognition measure

Participants completed the short version (48 trials, 8 per emotional expression) of the BERT. The emotional stimuli were randomly presented for either 152.55ms (in the short presentation condition), or 305.10ms (in the long presentation condition). As before, the facial affect stimuli were preceded by a fixation cross and followed by a visual mask to prevent processing of afterimages. These presentation times were chosen following the recommendation that specifying stimulus presentation times as multiples of 16.95ms in online research promotes more accurate temporal presentation, based on LCD monitor screen refresh rates (Woods, Velasco, Levitan, Wan, & Spence, 2015). The same alternative forced choice response option was used following stimulus presentation, and stimuli were derived from the male, Caucasian stimulus set (replicating that used in Study 1 & 2). Full-intensity practice trials were also included in this version. The stimuli set was that used in Study 2 and depicted in **Figure 3.1**.

#### 4.3.5.3 *Self-report personality questionnaires*

Participants completed the Reactive Proactive Aggression Questionnaire (RPQ), the Toronto Alexithymia Scale (TAS) (both detailed in Chapter 3), and a self-report antisocial behaviour (SR-ABM) (Riopka, Coupland, & Olver, 2015). The SR-ABM is a 28-item questionnaire requiring binary yes/no responses for delinquent or criminal acts, ranging in seriousness and separable into 'rule violations' and 'serious antisocial behaviour' subscales, and was found to have good concurrent validity with self-report psychopathy sub-scales and attitudes towards criminal behaviour in a sample of university undergraduates (Riopka et al., 2015).

#### 4.3.6 *Study procedure*

Participants were recruited using the procedure outlined in section 4.3.4. PA users were reimbursed £0.50 for completion of the head injury eligibility questionnaire (approximately 5 minutes completion time). For those who were eligible and chose to participate in the full study, they were provided with a link which directed them to an external website (Xperiment). They were then provided with an information sheet and were required to indicate whether they provided consent to participate in the study. They were also informed that they could exit the browser window if they did not wish to take part, and indeed, this option was available to them at any point during the experiment if they wished to withdraw. Within the programme, participants were randomised to either the short or long presentation version of the BERT task. They completed this following consenting procedures and preliminary exclusion criteria.

The BERT took approximately 5 – 7 minutes to complete, depending on the assigned condition and participant's speed of response. Following completion of the BERT, participants were presented with an information page which detailed the progression to the self-report questionnaire measures, with a warning regarding items of a more sensitive nature. Participants were asked to complete the self-report questionnaire measures in the following order: RPQ, SR-ABM, TAS & the RPCQ. Subsequently, participants were presented with a debrief page and were informed the study had ended. PA users were provided

with a completion hyperlink which signaled to the PA platform that the study had ended, and they were eligible for financial reimbursement. Non-PA users contacted the researcher upon completion of the study, and payment was arranged via paypal or online transfer. Participants were paid £2.50 at the beginning of the study for their participation in the full study, and this increased to £5 to encourage recruitment at later stages of the study.

#### *4.3.7 Statistical analysis*

A 20% data transcription check was conducted by an independent researcher (LC) on all study data prior to analysis. Error rate was < 1%. I checked for outliers in FAR performance using box-plots and Z-values. 'Extreme' outliers (with a Z value of > 3.29) were excluded, and 'probable outliers' (Z value of between 2.58 and 3.29), were identified, and the analysis was run with and without these participants to check for qualitative differences in results. I used histograms to check normality assumptions.

Using linear regression models, both unadjusted and adjusted for age, years in education, mental health or neurodisability co-morbidity and recent substance use (within the past month), I investigated the effect of TBI on overall FAR. I also ran a two-way ANOVA on overall FAR score, investigating the main effects and interaction effects for TBI group (substantial TBI versus no TBI), and presentation time condition (short versus long presentation).

Secondary analyses included assessment of differences between those with and without TBI for scores on RPQ, SR-ABM, TAS and health-related items. Using ANOVA's, I checked for differences between TBI groups by investigating the main effect of injury group for the demographic variables and self-report measures. These main effects were explored further using polynomial contrasts and Dunnett's 2-sided post-hoc tests (D-PH) to investigate differences for injury groups compared to controls, with chi-squared analysis for categorical variables.

I conducted exploratory analyses investigating whether there is a relationship between overall FAR score and scores on the RPQ, SR-ABM and

TAS, using linear regression models, both unadjusted and adjusted for the presence of TBI.

I also investigated the effect of TBI severity on overall FAR accuracy. This compared the performance of the no injury, mild injury, complicated mild injury and substantial injury groups, and following this, sub-divided the substantial injury group into severities (repetitive mild, moderate and severe) for a separate analysis, to investigate whether any observed impairment would be confined to those with more severe injuries.

## 4.4 Results

### 4.4.1 Recruitment and participants

#### 4.4.1.1 Head injury history screening

In total, I assessed  $n = 1294$  people for history of head injury, through PA and advertisement responses, using the eligibility questionnaire. Of these,  $n = 62$  were excluded due to reports of no previous head injury or being over the age of 35 years,  $n = 25$  were excluded as they could not estimate their LoC duration,  $n = 63$  were excluded due to suspected spam responding for one of the questionnaire hyperlinks<sup>3</sup>, and  $n = 17$  were screened as part of an affiliated sub-study on females with history of head injury. This left a total of  $n = 1127$  young adult males reporting a history of head injury, screened for inclusion in this study. Of these,  $n = 444$  (39%) reported a head injury without a LoC;  $n = 525$  (47%) reported injuries which we classified as 'mild' (with LoC lasting less than 10 minutes);  $n = 69$  (6%) reported injuries which we classified as 'complicated mild' (with LoC lasting between 10 and 30 minutes) and  $n = 89$  (8%) reported injuries which were classified as 'substantial' (with LoC elapsing 30 minutes or experiencing head injuries with LoC on at least three separate occasions).

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<sup>3</sup> The suspected 'spam' responses were all received within a short period of time, with similar formatting of email addresses and similarities in open responses on the head injury history questionnaire.

#### 4.4.1.2 Full study recruitment

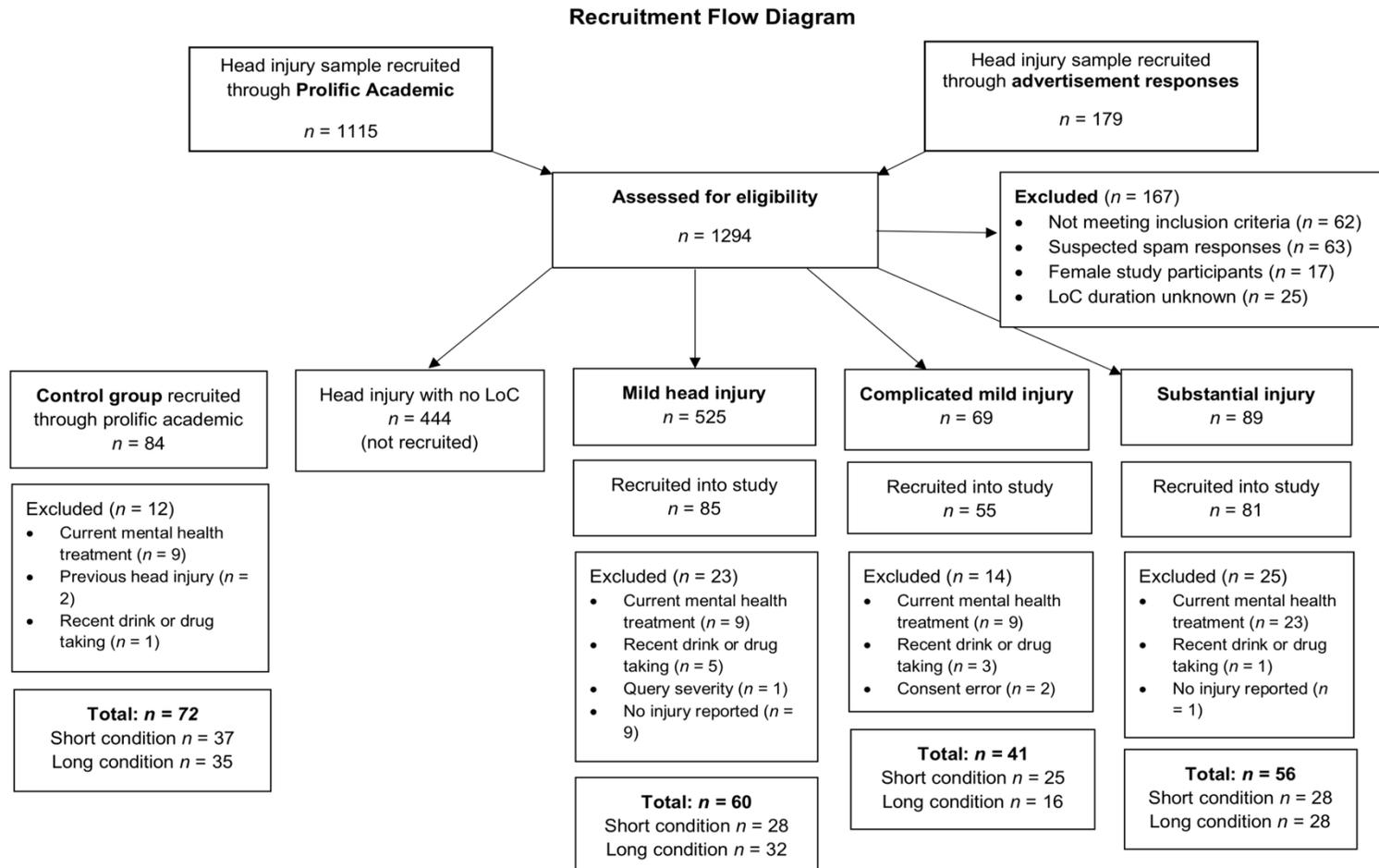
Identifying those who fit the eligibility criteria, an additional  $n = 84$  were recruited as non-injured controls through PA ( $n = 12$  subsequently excluded);  $n = 85$  were recruited into the mild injury condition ( $n = 23$  excluded);  $n = 55$  were recruited into the complicated mild injury condition ( $n = 14$  excluded); and  $n = 81$  recruited into the substantial injury condition ( $n = 25$  excluded). See **Figure 4.1** for a breakdown of recruitment across groups and reasons for exclusion.

This gave a total participant group of  $n = 229$ , with four groups including: non-injured control ( $n = 72$ ; short condition  $n = 37$ ; long condition  $n = 35$ ), mild injury ( $n = 60$ ; short condition  $n = 28$ ; long condition  $n = 32$ ), complicated mild injury ( $n = 41$ ; short condition  $n = 25$ ; long condition  $n = 16$ ) and substantial injury ( $n = 56$ ; short condition  $n = 28$ ; long condition  $n = 28$ ). I over-recruited the control and mild injury groups to compensate for imbalances due to some preliminary errors with the randomisation command within the programme. In addition, I did not manage to recruit the specified sample size for the complicated mild injury group due to time and resource constraints. The imbalance between study conditions within the complicated mild group may compromise power for this sample. However, I did not perceive this to be problematic as the recruitment for this group was opportunistic and for exploratory purposes.

#### 4.4.2 Full sample characteristics

After preliminary exclusions there was a group size of  $n = 229$ , young adult males, average age 27 years ( $SD = 5$ ), ranging from 16 to 35 years. The majority of the sample originated from the UK (50%), or the US (38%) with the remaining 12% originating from countries including: Australia, Belgium, Belarus, Bermuda, Canada, Hong Kong, Italy, Ireland, Kenya, Lebanon, Nigeria, New Zealand and 'Africa' (country not specified). They all reported fluency in English. In terms of education level, 12% had no qualifications or attended high school only, 26% achieved A-levels or a college diploma, 3% held an associate degree, 40% held an undergraduate degree, 15% held a post-graduate qualification and 4% held, or were training towards a doctorate. We converted level of highest qualification held to years in education (with 19 years being

**Figure 4.1.** Recruitment flow diagram for online study



the highest awarded for a doctorate qualification), and the full sample had a mean of 15 years in education ( $SD = 2$  years). Twenty-one (9%) reported a neurodevelopmental disorder. Of these, four reported a speech impediment, two reported dyslexia, two reported dyspraxia, five reported ADHD, two reported attention deficit disorder (ADD), five reported ASD and one person reported a mild aphasia.

Fifty-two participants (23%) reported consuming more than seven alcoholic drinks per week (e.g. more than seven pints of lager or seven glasses of wine), and these individuals were classified as ‘heavy drinkers’. Twenty-six participants (11%) reported using illicit drugs in the previous month, and these individuals were classified as ‘drug users’. Ten participants (4%) reported having consumed alcohol in the 12 hours prior to the experiment, however when questioned further regarding this they reported having one alcoholic drink the previous evening and felt completely sober at the time of testing. We retained these participants as a consequence. Any participants in the wider group who did not confirm this, or who had consumed alcohol at a closer time point were excluded from the groups (as detailed in the previous stage).

#### 4.4.3 Injury group differences

Differences between injury groups are presented in **Table 4.1**, with accompanying information regarding whether there was statistical evidence for a main effect of injury group.

**Table 4.1** Group differences between different injury severities

Measure	Control ( $n = 72$ )	Mild injury ( $n = 60$ )	Complicated mild injury ( $n = 41$ )	Substantial injury ( $n = 56$ )	Evidence for group main effect
Age at testing (yrs)	27.44 (5.18)	26.18 (4.62)	26.39 (5.13)	27.55 (4.94)	$F_{(3,225)} = 1.16, p = 0.33$
Age at first injury (yrs)		15.49 (4.97) ( $n = 59$ )	15.54 (6.45)	16.51 (5.26) ( $n = 55$ )	$F_{(2,152)} = 0.59, p = 0.56$
Age at most severe injury (yrs)		17.02 (5.43)	16.71 (6.75)	19.88 (5.20)	$F_{(2,154)} = 4.93, p = 0.008$
Time since most severe injury (yrs)		9.18 (5.88)	9.68 (6.86)	7.70 (5.08)	$F_{(2,154)} = 1.57, p = 0.21$
Years in education	15.01 (2.24)	14.62 (1.89)	15.17 (1.76)	15.13 (1.78)	$F_{(3,223)} = 0.89, p = 0.45$
Neurodevelopmental (Y:N)	6:66	6:54	4:37	5:51	Fisher's exact = 0.28, $p = 0.99$
Heavy drinking (Y:N)	6:66	14:46	6:35	26:30	$\text{Chi}^2 = 28.0, p < 0.001,$

Drug use (Y:N)	2:70	10:50	2:39	12:44	Fisher's exact = 14.5, $p = 0.002$ ,
RPQ Total (/46)	8.71 (5.67)	10.43 (6.58)	11.34 (6.12)	11.63 (6.28)	$F_{(3,225)} = 2.87, p = 0.04$
RPQ Proactive (/24)	1.58 (2.55)	2.48 (3.10)	2.66 (2.92)	2.95 (3.21)	$F_{(3,225)} = 2.60, p = 0.05$
RPQ Reactive (/22)	7.13 (4.23)	7.95 (4.03)	8.68 (4.17)	8.68 (4.20)	$F_{(3,225)} = 1.93, p = .13$
SR-ABM (/28)	2.39 (2.66)	5.60 (5.30)	4.95 (5.10)	8.04 (5.83)	$F_{(3,225)} = 15.19, p < 0.001$
SR-ABM Serious (/13)	0.29 (0.90)	1.43 (2.14)	1.27 (2.43)	2.23 (2.64)	$F_{(3,225)} = 9.67, p < 0.001$
SR-ABM Rule breaking (/15)	2.10 (2.10)	4.17 (3.57)	3.68 (3.17)	5.80 (3.69)	$F_{(3,225)} = 14.98, p < 0.001$
TAS Total (/100)	49.44 (11.64)	50.92 (14.26)	51.78 (10.43)	52.05 (12.92)	$F_{(3,225)} = 0.55, p = 0.65$
TAS Identify (/35)	15.58 (6.0)	16.92 (7.42)	17.63 (6.19)	17.64 (6.81)	$F_{(3,225)} = 1.33, p = 0.26$
TAS Describe (/25)	13.11 (3.95)	13.62 (4.47)	13.83 (4.39)	14.46 (4.53)	$F_{(3,225)} = 1.06, p = 0.37$
TAS External (/40)	20.75 (4.55)	20.38 (5.20)	20.32 (4.56)	19.95 (4.83)	$F_{(3,225)} = 0.30, p = 0.83$
RPCQ Total (/32)	5.93 (4.66)	7.15 (6.0)	10.28 (6.27)	10.16 (6.20)	$F_{(3,217)} = 8.33, p < 0.001$
RPCQ Somatic (/16)	2.22 (1.66)	2.75 (2.30)	3.75 (1.94)	3.52 (2.26)	$F_{(3,217)} = 6.64, p < 0.001$
RPCQ Cognitive (/12)	3.06 (2.86)	3.60 (3.51)	5.33 (4.11)	5.54 (3.96)	$F_{(3,217)} = 6.56, p < 0.001$

Injury group means are given with standard deviations in parenthesis. Means, SD's and mean effect reported for continuous variables, with frequency data reported for categorical variables. Results of Chi Squared tests are reported for continuous variables, except in circumstances where there is a cell count of less than 5, in which case Fisher's exact is reported.

There were no observable differences for age at testing, years in education or distribution of neurodevelopmental diagnoses between groups. There was also no difference observed for age of first injury<sup>4</sup>, or time since most severe injury. There was, however, evidence for a difference between groups for age at which most severe injury was sustained (ranging between 5 and 33 years), with the substantial group being older on average than the mild and complicated mild injury groups (see **Table 4.2** for pairwise comparisons).

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<sup>4</sup> Two participants gave answers as 'being children' for age at first injury and were excluded from this comparison as a more specific age estimate could not be obtained.

Chi squared analysis indicated strong evidence for a different distribution of heavy drinkers across injury groups than expected, with a higher distribution of heavy drinkers in the substantial injury group and less heavy drinkers in the control group. There was also evidence for a differential distribution of recent drug users than expected, with again, higher numbers of recent users in the substantial injury group and lower numbers in the control group.

There was weak evidence for a main effect of injury group on self-reported aggression (RPQ total), with higher scores for the injury group compared to the control group. There was evidence for a linear trend, with increasing aggression scores with increased injury severity. This was replicated for the proactive subscale, with larger scores in the substantial injury group compared to the non-injured controls, and a linear trend in the same direction. There was no evidence for a main effect of group for the reactive aggression subscale, however there was weak evidence for a linear trend, with increasing reactive aggression with injury severity.

There was strong evidence for a main effect of injury group on self-reported delinquency (SR-ABM total), with post-hoc analyses giving evidence for a difference for all injury groups compared to the non-injured controls. The difference was largest for the substantial injury group compared to the controls and there was strong evidence for a linear trend, indicating higher self-reported delinquency with increasing injury severity. This was replicated for the serious antisocial behaviour subscale, and the rule violations subscale.

There was no evidence for a main effect of TBI group on alexithymia score, or for differences of the injury groups against the non-injured controls, or evidence of a linear trend. This was also the case for the identifying emotions subscale, with the exception of the linear trend, for which there was weak evidence (increased alexithymia traits with increased TBI severity). This pattern of results was also observed for the describing emotions sub-scale, and there was no evidence of difference between groups for the externally orientated thinking sub-scale.

There were 8 missing data points for the RPCQ measure that was taken during the time of testing, due to a programme error at the earlier stages of data collection (seven mild and one complicated mild participant). There was strong

evidence for a main effect of injury group on post-concussion symptomology (PCS), with post-hoc analyses indicating differences between the complicated mild and substantial injury group compared to controls, corroborated by strong evidence for a linear trend (increased PCS with increased TBI severity). This pattern of effects was replicated for the somatic symptoms subscale, and the cognitive symptoms subscale. See **Table 4.2** for details of post-hoc analyses, point estimates and confidence intervals.

**Table 4.2** Post-hoc analyses for Study 3 group differences and polynomial contrasts

Measure	MD	SE	P-value	95% CI
<b>Age of most severe injury (Bonferroni)</b>				
Sub TBI versus Mild TBI	2.86	1.06	0.02	0.28 to 5.43
Substantial TBI vs Comp Mild TBI	3.17	1.18	0.02	0.32 to 6.02
Linear trend			0.008	0.54 to 3.51
<b>Aggression total (RPQ)</b>				
Sub TBI vs control	2.92	1.10	0.02	0.31 to 5.52
Comp Mild TBI vs control	2.63	1.20	0.08	-0.23 to 5.49
Mild TBI vs control	1.73	1.08	0.27	-0.83 to 4.28
Linear trend			0.006	0.61 to 3.71
<b>Proactive aggression (RPQ)</b>				
Sub TBI vs control	1.36	0.52	0.03	0.12 to 2.61
Comp Mild TBI vs control	1.08	0.57	0.16	-0.29 to 2.44
Mild TBI vs control	0.90	0.51	0.20	-0.32 to 2.12
Liner trend			0.01	0.21 to 1.69
<b>Reactive aggression (RPQ)</b>				
Sub TBI vs control	1.55	0.74	0.10	-0.21 to 3.32
Comp Mild TBI vs control	1.56	0.81	0.15	-0.38 to 3.49
Mild TBI vs control	0.83	0.73	0.55	-0.90 to 2.55
Liner trend			0.02	0.15 to 2.25
<b>Delinquency (SR-ABM)</b>				

Sub TBI vs control	5.65	0.85	< 0.001	3.63 to 7.66
Comp Mild TBI vs control	2.56	0.93	0.02	0.35 to 4.77
Mild TBI vs control	3.21	0.83	< 0.001	1.24 to 5.19
Liner trend			< 0.001	2.45 to 4.84
<b>Serious antisocial behaviour (SR-ABM)</b>				
Sub TBI vs control	1.94	0.37	< 0.001	1.07 to 2.81
Comp Mild TBI vs control	0.98	0.40	0.04	0.02 to 1.93
Mild TBI vs control	1.14	0.36	0.005	0.29 to 1.99
Liner trend			< 0.001	0.75 to 1.78
<b>Rule violations (SR-ABM)</b>				
Sub TBI vs control	3.71	0.56	< 0.001	2.38 to 5.04
Comp Mild TBI vs control	1.59	0.61	0.03	0.13 to 3.04
Mild TBI vs control	2.07	0.55	0.001	0.77 to 3.37
Liner trend			< 0.001	1.59 to 3.17
<b>Alexithymia (TAS)</b>				
Sub TBI vs control	2.61	2.23	0.52	-2.69 to 7.91
Comp Mild TBI vs control	2.34	2.35	0.67	-3.48 to 8.15
Mild TBI vs control	1.47	2.19	0.85	-3.73 to 6.67
Liner trend			0.23	-1.21 to 5.09
<b>Identifying emotions (TAS)</b>				
Sub TBI vs control	2.06	1.18	0.21	-0.75 to 4.87
Comp Mild TBI vs control	2.05	1.28	0.28	-1.03 to 5.14
Mild TBI vs control	1.33	1.16	0.54	-1.42 to 4.09
Liner trend			0.07	-0.13 to 3.21
<b>Describing emotions (TAS)</b>				
Sub TBI vs control	1.35	0.77	0.20	-0.47 to 3.18
Comp Mild TBI vs control	0.72	0.84	0.74	-1.29 to 2.72
Mild TBI vs control	0.51	0.75	0.85	-1.28 to 2.30
Liner trend			0.08	-0.12 to 2.04
<b>Externally orientated thinking (TAS)</b>				
Sub TBI vs control	-0.80	0.86	0.69	-2.84 to 1.23
Comp Mild TBI vs control	-0.43	0.94	0.95	-2.67 to 1.80

Mild TBI vs control	-0.37	0.84	0.95	-2.36 to 1.63
Liner trend			0.37	-1.76 to 0.66
<b>Post-concussion symptomology (RPCQ)</b>				
Sub TBI vs control	4.23	1.02	< 0.001	1.81 to 6.65
Comp Mild TBI vs control	4.34	1.13	< 0.001	1.67 to 7.02
Mild TBI vs control	1.22	1.03	0.52	-1.24 to 3.68
Liner trend			< 0.001	2.09 to 4.98
<b>Somatic PCS (RPCQ)</b>				
Sub TBI vs control	1.30	0.36	0.001	0.43 to 2.16
Comp Mild TBI vs control	1.50	0.40	0.001	0.55 to 2.46
Mild TBI vs control	0.53	0.37	0.35	-0.34 to 1.41
Liner trend			< 0.001	0.57 to 1.60
<b>Cognitive PCS (RPCQ)</b>				
Sub TBI vs control	2.48	0.63	< 0.001	0.97 to 3.99
Comp Mild TBI vs control	2.27	0.70	0.004	0.60 to 3.94
Mild TBI vs control	0.55	0.64	0.75	-0.98 to 2.08
Liner trend			< 0.001	1.15 to 2.95

Mean differences (MD) and standard errors (SE) reported, alongside probability values and 95% confidence intervals. All post-hoc analyses report Dunnett 2-sided tests, comparing injury groups against non-injured controls, with the exception of age at most severe injury (Bonferroni post-hoc tests used, as comparisons against controls could not be used in these instances).

#### 4.4.4 Emotion recognition analysis

Three 'probable' outliers were identified within groups (Z scores between 2.58 and 3.29; one from the control group, one from the mild injury group and one from the substantial injury group), for overall FAR accuracy. Histograms revealed the data to be normally distributed.

##### 4.4.4.1 Linear regression models

I ran an unadjusted linear regression model investigating the effect of TBI group on overall FAR accuracy (combined hit rate across the six emotions). There was no evidence that history of TBI predicted FAR accuracy for any of the injury severities (control group  $M = 30.43$ ,  $SD = 6.37$ ; mild injury  $M = 29.0$ ,

$SD = 7.06$ ; complicated mild injury  $M = 30.0$ ,  $SD = 6.37$ ; substantial injury  $M = 30.34$ ,  $SD = 5.43$ ). I then ran an adjusted model, including the predictors age, years in education, neurodevelopmental diagnoses, drug use in previous month and heavy alcohol use (see **Table 4.3**). There were no qualitative changes to the predictive value of injury status after adjusting for these variables.

**Table 4.3** Linear regression models for traumatic brain injury severity and overall facial affect recognition accuracy

	No injury versus mild injury	No injury versus complicated mild injury	No injury versus substantial injury
<b>Unadjusted</b>			
<i>n</i>	229		
Constant (SE)	30.41 (0.74)		
Unstandardised coefficient	-1.43	-0.43	-0.09
95% Confidence interval	-3.62 to .76	-2.88 to 2.02	-2.32 to 2.14
p-value	0.20	0.73	0.94
R <sup>2</sup> (model p-value)	0.01 (0.58)		
<b>Adjusted</b>			
<i>n</i>	227		
Constant (SE)	33.14 (3.89)		
Unstandardised coefficient	-1.69	-0.58	-0.20
95% Confidence interval	-3.94 to 0.57	-3.02 to 1.87	-2.58 to 2.19
p-value	0.14	0.64	0.87
R <sup>2</sup> (model p-value)	0.05 (0.23)		

Linear regression models for full sample ( $n = 229$ ), 2 participants excluded from adjusted regression model ( $n = 227$ ) due to lack of clarity for years in education. Unadjusted includes severity of TBI groups only, adjusted includes demographic and health variables (age, years in education, neurodevelopmental diagnosis, use of drugs in previous month and heavy alcohol consumption).

There was weak evidence for the predictive value of age at testing, with a reduction in BERT accuracy with an increase in age ( $B = -0.15$ ,  $SE = 0.09$ ,  $p = 0.08$ , 95% CI = -0.32 to 0.02). Another variable predictive of FAR accuracy was neurodevelopmental co-morbidity, with a reduction in FAR accuracy with the presence of a neurodevelopmental disorder ( $B = -3.40$ ,  $SE = 1.45$ ,  $p = 0.02$ , 95% CI = -6.6 to -0.53). In our pre-registered protocol, I specified that we would run the analysis with and without those with a co-morbid, unmedicated neurodevelopmental disorder ( $n = 21$ ). There were no qualitative differences between the regression models when excluding these participants. I also ran the analysis with and without the presence of the three ‘probable’ outliers, and

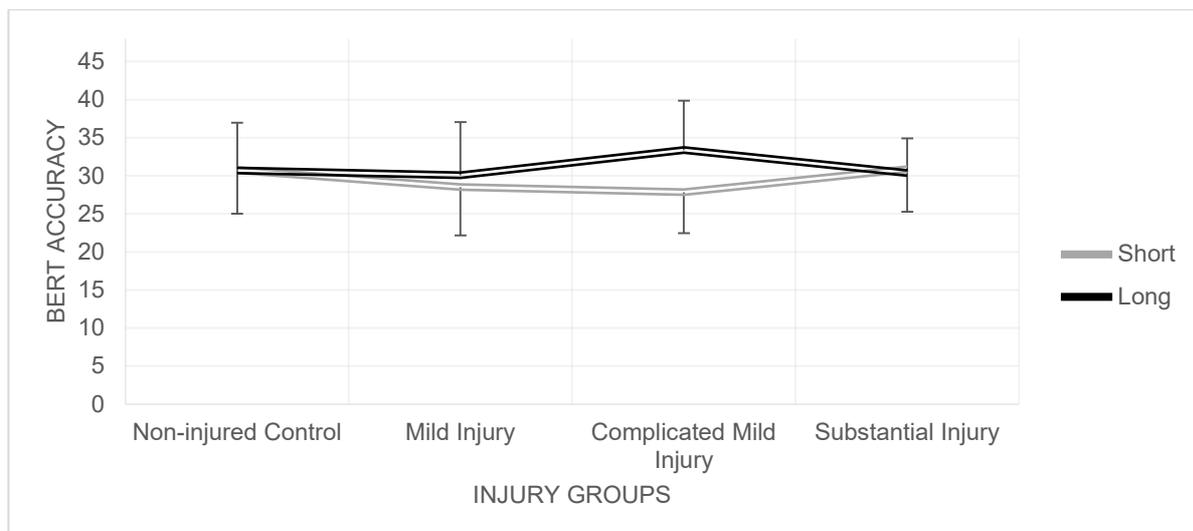
again did not find any qualitative difference in results. As a result, these participants have been retained in the sample for the subsequent analyses. The details of these analyses can be found in the appendices (see section **A5**, **Tables A2** and **A3** respectively).

These results suggest that our primary research question within this study was not supported, there was no evidence for poorer performance on the BERT task in those who reported a substantial dosage of TBI in comparison to non-injured, aged-matched controls. This was also true for the milder injury severity groups. These findings are of relevance to research question four within the overarching research questions for this thesis (see section 1.8.1).

#### 4.4.4.2 *Presentation time manipulation*

Running a two-way ANOVA, with injury group and presentation time as independent variables, we found no significant main effect of injury group ( $F_{(3,221)} = 0.82, p = 0.49$ ), or presentation time (short presentation condition,  $M = 29.62, SD = 5.85$ ; long presentation condition,  $M = 30.32, SD = 6.82$ ;  $F_{(3,221)} = 1.98, p = 0.16$ ). There was, however, weak evidence for an interaction effect ( $F_{(3,221)} = 2.55, p = 0.06$ ). The interaction effect appears to be driven by an improvement in accuracy in the complicated mild condition, for the longer presentation time ( $M = 33.38, SD = 6.47$ ), compared to the shorter presentation time ( $M = 27.84, SD = 5.39$ ), with weak evidence for a difference between presentation time groups that was not observed for the other injury groups ( $t_{(229)} = -2.51, p = 0.01, 95\% CI = -11.74$  to  $-1.40$ ). Given that this effect was not replicated in the other injury groups, and that the overall complicated mild injury group size was smaller with greater group imbalance, we suggest this result be interpreted tentatively. See **Figure 4.2** for a visual representation.

**Figure 4.2** Overall FAR accuracy across presentation times and injury groups



Mean overall FAR accuracy for the short and long stimulus presentation time conditions, across injury groups. Error bars represent standard deviations.

#### 4.4.5 Exploratory analyses

##### 4.4.5.1 Self-report measures and FAR

The pre-registered study protocol specified additional exploratory analyses, which included investigating the relationship between aggression, self-reported delinquency and alexithymia on overall FAR accuracy. To investigate this, I ran linear regression analyses assessing the influence of these variables on FAR accuracy, both unadjusted and adjusted for the presence of TBI (substantial versus non-injured control). There was weak evidence that the models explained a proportion of the variance. The only variable which predicted overall FAR accuracy was alexithymia score, with an increase in alexithymic traits leading to a reduction in overall FAR accuracy. Adjusting for the presence of a substantial TBI did not affect these results. See **Table 4.4** for details of these models.

**Table 4.4** Linear regression models for self-report measures on overall FAR accuracy

	Aggression (RPQ)	Delinquency (SR-ABM)	Alexithymia (TAS)	Post-concussion symptoms (RPCQ)
<i>n</i>	221			
<b>Unadjusted</b>				
Constant (SE)	35.31(1.78)			
Unstandardised coefficient	-0.06	0.15	-0.10	-0.03
95% Confidence interval	-0.22 to 0.10	-0.03 to 0.33	-0.18 to -0.03	-0.20 to 0.13
p-value	0.45	0.11	0.006	0.68
R <sup>2</sup> (model p-value)	0.05 (0.02)			
<b>Adjusted</b>				
<i>n</i>	221			
Constant (SE)	35.32 (1.79)			
Unstandardised coefficient	-0.06	0.14	-0.10	-0.04
95% Confidence interval	-0.22 to 0.10	-0.05 to 0.32	-0.18 to -0.03	-0.20 to 0.13
p-value	0.47	0.15	0.006	0.65
R <sup>2</sup> (model p-value)	0.05 (0.02)			

Linear regression model for the influence of aggression, delinquency, alexithymia and post-concussion symptomology on FAR accuracy, adjusted and unadjusted for presence of a substantial TBI.

#### 4.4.5.2 Substantial injury severity breakdown

As stipulated in the study protocol, I ran a sub-analysis, separating the substantial injury group into sub-groups, based on severity. This included: repetitive mild (LoC for any duration under 30 minutes, on three or more occasions,  $n = 23$ ); moderate (LoC for 30 to 60 minutes,  $n = 13$ ); severe (LoC for 60 minutes to 24 hours,  $n = 13$ ); and very severe (LoC lasting over 24 hours,  $n = 7$ ). The rationale for this was to investigate whether there may be more pronounced effects in those with higher injury severity, compared to the repetitive mild group. The results of these analyses can be found in the appendices (see section **A5, Table A4**). There was no clear evidence for differences between these sub-groups, with the exception of weak evidence for differences in the aggression measure (higher scores for the moderate injury group, for the proactive subscale in particular) and the cognitive PCS sub-scale (with a lower symptom score for the severe injury group). As these groups were small and unbalanced, and the evidence for any differences weak, conservative

interpretation of these findings is advised. These results suggest that the decision to group the substantial injury group based on the specified LoC severity indicators (i.e. repetitive mild, moderate to very severe), was appropriate in this sample.

#### 4.4.5.3 *Age at injury and time since injury*

I ran exploratory analyses to assess relationships between BERT performance and injury parameters. Across the combined sample there was no evidence for an association between age at which most severe injury was sustained and overall FAR accuracy ( $r = -0.11$ ,  $p = 0.19$ ). There was weak evidence for an association between FAR overall accuracy and age at which first injury was sustained ( $r = -0.14$ ,  $p = 0.07$ ), with decreasing FAR performance with increasing age at first injury. There was no evidence for an association between time since injury and overall FAR accuracy, ( $r = 0.03$ ,  $p = 0.73$ ). It has been suggested that sustaining a severe injury at an earlier age may lead to more enduring symptoms. As a consequence, I also investigated these associations within injury groups to investigate whether effects were present for those with substantial injuries. There was no evidence of an association between FAR accuracy and age of first injury, regardless of injury severity. There was weak evidence for an association between FAR accuracy and age at which worst injury was sustained, for the substantial TBI group only ( $r = -0.25$ ,  $p = 0.06$ ), with decreasing FAR accuracy for those who were older at the time of their most severe injury. This finding is in opposition with the theory detailed above. This might be explained by elevated symptoms in those with more recent injuries, as those in the substantial TBI group were older on average at the time at which most severe injury was sustained (19.9 years). However, there is no evidence for an association between time since most severe injury and FAR accuracy in the substantial injury group, which negates this explanation ( $r = 0.20$ ,  $p = 0.13$ ).

#### 4.4.5.4 Aggression, antisocial behaviour and post-concussion symptomology

I investigated whether the differences observed between injury groups for the RPQ, SR-ABM and RPCQ could be explained in part by heavy alcohol or recent drug use. To examine this, I ran a linear regression model for the total outcomes for each measure as outcome variables, TBI groups as predictors, and the models were run unadjusted (TBI groups only) and adjusted (for drug and alcohol use). The results of these analyses are presented in **Table 4.5**.

I observed weak evidence for a difference between non-injured controls and complicated mild injury group for the aggression measure, and stronger evidence for a difference between the substantial injury group and non-injured controls, observing higher aggression scores in those with injury. However, when adjusting for drug and alcohol use, these differences were attenuated, with only weak evidence remaining for an effect of injury on aggression in the complicated mild injury group. There was also weak evidence that heavy drinking and drug use predict aggression scores (heavy drinking,  $B = 1.80$ ,  $p = 0.09$ , 95% CI = -0.25 to 3.86; recent drug use,  $B = 2.45$ ,  $p = 0.07$ , 95% CI = -0.18 to 5.08), with increased aggression in those classed as heavy alcohol or recent drug users. This suggests that the differences observed between those with and without injury in self-reported aggression, may be mediated by drug and alcohol use.

I observed strong evidence for a difference between non-injured controls and the mild and substantial injury groups, and evidence for a difference between the complicated mild and non-injured controls for the antisocial behaviour measure (with higher scores for antisocial behaviour in those with injury). When adjusting for the influence of drug and alcohol use, the evidence for differences between these groups remained, with strong evidence for difference in the substantial injury group in particular. There was evidence that drug and alcohol use also predicted antisocial behaviour (heavy drinking,  $B = 2.08$ ,  $p = 0.008$ , 95% CI = 0.55 to 3.62; recent drug use,  $B = 3.57$ ,  $p < 0.001$ , 95% CI = 1.61 to 5.53), with higher reports of antisocial behaviour in those with heavy drinking or drug using tendencies.

I also observed strong evidence for a difference between non-injured controls and the complicated mild and substantial injury groups for PCS, with higher reports of symptomology in the injury groups. The differences observed were not affected when adjusting for drug and alcohol use, which did not predict PCS.

**Table 4.5** Linear regression models for injury group effects on self-report measures

	No injury versus mild injury	No injury versus complicated mild injury	No injury versus substantial injury
<b>Aggression (RPQ total) <i>n</i> = 229</b>			
<b>Unadjusted</b>			
Constant (SE)	8.71 (0.73)		
Unstandardised coefficient	1.73	2.63	2.92
95% Confidence interval	-0.39 to 3.84	0.26 to 5.00	0.76 to 5.08
p-value	0.11	0.03	0.008
R <sup>2</sup> (model p-value)	0.04 (0.04)		
<b>Adjusted</b>			
Constant (SE)	8.49 (0.72)		
Unstandardised coefficient	1.12	2.47	1.77
95% Confidence interval	-1.02 to 3.25	0.13 to 4.81	-0.52 to 4.06
p-value	0.30	0.03	0.13
R <sup>2</sup> (model p-value)	0.07 (0.006)		
<b>Antisocial behaviour (SR-ABM total) <i>n</i> = 229</b>			
<b>Unadjusted</b>			
Constant (SE)	2.39 (0.56)		
Unstandardised coefficient	3.21	2.56	5.65
95% Confidence interval	1.58 to 4.85	0.73 to 4.39	3.98 to 7.31
p-value	< 0.001	0.006	<0.001
R <sup>2</sup> (model p-value)	0.17 (< 0.001)		
<b>Adjusted</b>			
Constant (SE)	2.12 (0.54)		
Unstandardised coefficient	2.40	2.36	4.19
95% Confidence interval	0.81 to 3.99	0.61 to 4.10	2.48 to 5.89
p-value	0.003	0.008	< 0.001
R <sup>2</sup> (model p-value)	0.25 (< 0.001)		
<b>Post-concussion symptoms (RPCQ total) <i>n</i> = 221</b>			
<b>Unadjusted</b>			

Constant (SE)	5.93 (0.67)		
Unstandardised coefficient	1.22	4.34	4.23
95% Confidence interval	-0.82 to 3.26	2.13 to 6.56	2.23 to 6.23
p-value	0.24	< 0.001	< 0.001
R <sup>2</sup> (model p-value)	0.10 (< 0.001)		
<b>Adjusted</b>			
Constant (SE)	5.85 (0.67)		
Unstandardised coefficient	0.85	4.28	3.73
95% Confidence interval	-1.23 to 2.92	2.07 to 6.49	1.58 to 5.87
p-value	0.42	< 0.001	0.001
R <sup>2</sup> (model p-value)	0.12 (< 0.001)		

Linear regression model for the influence of TBI group status on self-reported aggression, antisocial behaviour and post-concussion symptomology. Models are unadjusted (injury groups only) and adjusted for the recent drug use and heavy alcohol use.

#### 4.5 Discussion

The aim of the current study was to assess FAR ability in a sample of general population, young adult males, with differing severities of self-reported TBI. I explored the relationships between history of TBI, FAR and a series of self-reported measures of aggression, self-reported delinquency (antisocial behaviour) and alexithymia. This study addressed the fourth research question outlined in the introductory chapter ‘are similar patterns of effects between TBI, FAR and antisocial behaviour observed in members of the general, non-offending population’ (see section 1.8.1). Given that the findings between Studies 1 and 2 were discrepant in relation to these variables, rather than assessing similarity here the primary research question was whether members of this population with substantial TBI would have poorer FAR and whether this translated to increased aggression and self-reported delinquency.

The results of this study did not provide support for a deficit in overall FAR accuracy, as measured by performance on the BERT, in those with self-reported history of TBI compared to non-injured controls, meaning the primary hypothesis was unsupported. This was true for those with more severe injuries, in the ‘substantial injury’ group and also for our exploratory milder injury groups. In addition to this, there was no evidence of a difference between injury groups in the accompanying socioemotional measure, the alexithymia questionnaire (measuring difficulty in identifying and describing emotions, and externally

orientated thinking). I did, however, observe higher post-concussion symptomology, higher proportions of heavy alcohol and recent drug use, increased scores for aggression and antisocial behaviour in the substantial injury group compared with the non-injured controls.

#### *4.5.1 Traumatic brain injury and facial affect recognition*

It is interesting that we did not observe an effect of TBI history on FAR ability in this sample, given that deficit in socioemotional processing following a TBI is frequently reported in the literature. This difference may be linked to TBI severity. Prior observations of deficit were seen for individuals with severe TBI's more specifically (McDonald, 2013), with impairments investigated in the domain of FAR by a multitude of studies for sufferers of both acute and chronic TBI. A meta-analysis of these studies estimated a large effect size of impairment for those with TBI in relation to non-injured controls, suggesting approximately 39% of people with moderate to severe TBI suffer deficits in the domain of FAR (Babbage et al., 2011). Whilst definitions of what constitutes a 'severe' TBI differs across the literature, it is often agreed that sustaining a TBI with a LoC over 60 minutes in duration satisfies this criteria (Chitsabesan & Hughes, 2016). It may be argued that having a combined 'substantial' injury group, as detailed in this study, comprised of individuals with and without 'severe' injuries, may have compromised statistical power to detect these effects. However, sub-group analyses of differing injury severities within the substantial injury group did not indicate any differences for those with 'severe' (over 60 minutes LoC), or 'very severe' (over 24 hours LoC) compared to those with repetitive mild or moderate severity injuries, or indeed, the mild or no injury groups. The group sizes of those with 'severe' to 'very severe' injury in this study ( $n = 20$ ), was comparable to earlier studies which did find evidence of a deficit in FAR (Allerdings & Alfano, 2006; Knox & Douglas, 2009).

McDonald (2013) discusses some of the issues with generalising these deficits in samples of people with TBI, with reference to the heterogeneity of injury pathology and the confounding nature of neurocognitive ability – suggesting that these estimates proposed by Babbage et al. (2011) may be over-inflated. Ryan et al. (2014) investigated long-term consequences for

socioemotional processing after a paediatric TBI and their results suggested vulnerability for deficit in FAR was also more apparent for those with severe injuries, rather than moderate or mild injuries. They also found that poorer emotion processing was associated with frontal pathology (as compared to non-frontal and temporal pathology) and volume of the posterior corpus callosum. One of the difficulties measuring injury severity with retrospective self-report, as used in this study, is the inability to qualify these injuries with official medical records or to investigate evidence for pathology as indicated by presence of radiological or neurological abnormalities. It may be that the injuries reported by the individuals in our sample did not cause chronic damage to these influential neural regions, sparing ability in this domain as a result.

Other important factors previously mentioned, are time since injury and age at injury. It may be argued that a lack of observable deficit in our TBI samples could be due to the measurement of retrospective lifetime injury, yielding those in chronic stages of injury for whom socioemotional symptoms may have dissipated. However, we did not find evidence that time since injury was associated with FAR, which argues against this. In addition, studies have found emotion recognition deficits following TBI in acute-care (Green, Turner, & Thompson, 2004) and more chronic stages of recovery in adults comparable to that included in our sample, including 7 years average time post-injury (Spell & Frank, 2000); 5 years (Knox & Douglas, 2009) and at long-term follow-up following paediatric injury (average 16 years, Ryan et al., 2014).

As mentioned in Chapter one & Chapter three, injury sustained during childhood or adolescence is thought to be particularly problematic for long-term social outcomes (Yeates et al., 2012). We did not find evidence that those with earlier age of first, or most severe injuries had poorer FAR ability. As previously mentioned, this might be explained by the synchrony of injury with developmental stages. In Ryan et al. (2014)'s study, age of first injury included those with injuries between 1 and 7 years old, compared to the average 15 to 16 years old reported in our study, so it is possible that the majority of our participants had injuries occurring after these key developmental time-points when socioemotional skills are more established. There is some discrepancy in the literature as to when these critical stages occur, indeed, there is likely to be individual variation. However, a review by Tonks et al. (2008) suggests some of

the key stages for socioemotional development typically take place around age 3, age 10-11 (for understanding of intent and reading emotions in others), and age 14, reflecting neurological changes in the structure of neural regions subserving these functions.

The age ranges for initial injury observed here replicates that of those sampled in Study 2 (young adult offenders), who were on average 14 to 15 years old at time of first injury. The young offender sample in Study 1, however, were younger at age of first injury, being around 9 years old on average. This may help to explain discrepancies in findings between studies and I will investigate this further in the meta-analyses in Chapter five. Furthermore, there was weak evidence to suggest those in the substantial injury group who were *older* at time of most severe injury (average age 19 years) had poorer FAR. This is perplexing, suggesting that those with more recent injuries may have more pronounced symptoms. If this observed effect was explained by the theory that injury recency may produce greater impairment, we would expect to see this effect replicated in time since injury (with greater impairment with shorter time since injury), which was not observed. However, it is possible here that the measure of time since injury is confounded with the inclusion of milder injuries at a more recent time point.

The changes in presentation time between Study 1 and 2 did not explain differences between these studies as suggested in the Chapter three discussion, as there was no evidence of an interaction effect in the current study between presence of substantial injury and injury presentation time on FAR ability. This leads to the conclusion that the discrepant findings between studies 1 & 2 were unlikely to arise due to changes made to the BERT stimulus presentation time in Study 2. These combined findings suggest that deficit in FAR following injury may be more complex and nuanced than is portrayed by the current literature and is likely to be a function of injury severity, area and type of pathology and developmental stage at time of injury.

#### 4.5.2 TBI, aggression and antisocial behaviour

The association between TBI status, self-reported aggression and self-reported antisocial behaviour, independent of FAR, is interesting. There was strong evidence for a linear trend for PCS, antisocial behaviour and evidence for a trend in aggression, all increasing with higher reported injury severity. There were also higher observed proportions of recent drug users and heavy alcohol users in those with substantial injury compared to non-injured controls. The increase in aggression, particularly proactive aggression, observed in those with higher severity of injury was attenuated when heavy drinking and drug use were adjusted for in the analysis. Higher risk of substance use and hazardous alcohol use are commonly reported after TBI, including after milder injuries (Kennedy, Heron, & Munafo, 2017; McKinlay, Corrigan, Horwood, & Fergusson, 2014). It is difficult to establish causation, as many individuals have substance abuse problems prior to experiencing a TBI. Evidence also suggests those who experience a TBI are at higher risk of establishing a substance abuse problem for the first time following an injury (Corrigan, Rust, & Lamb-Hart, 1995), suggesting a double mechanism of risk. This evidence supports one of the suggested pathways illustrated in Chapter one, that the association between TBI and criminal behaviour may be mediated by increased risk of drug and alcohol use following injury.

This assertion is supported by the findings of Kennedy et al. (2017) where adjustment for substance use in their statistical model alleviated the observed association between TBI and later criminality. However, the influence of drugs and alcohol on criminality was not replicated in this sample. Here, TBI remained a strong predictor for antisocial and delinquent behaviour following adjustment for these variables. However, an important methodological difference between this study and that of Kennedy et al. (2017)'s was their inclusion of negative, orthopaedic controls. Their findings suggest that the association between TBI with delinquent and antisocial behaviour may be an artefact of increased risk-taking or sensation seeking in those with injury compared to non-injured controls, pre-disposing individuals to delinquency and higher risk of injury. Future inclusion of a negative injury control group would be helpful in clarifying this in our current sample. However, it is also worth considering that even if the relationship between TBI and delinquency observed

in this sample is confounded by premorbid risk-taking and impulsivity, this doesn't necessarily explain the linear trend observed between injury severity and antisocial behaviour. Pre-morbid risk-taking tendencies may predispose you to higher risk of injury generally, but it doesn't assume that the injuries sustained will be of a greater severity. This was not assessed in Kennedy et al. (2017), who categorised all histories of TBI as 'mild injuries' and used criminal convictions as the crime-outcome measure. It may be that the inclusion of higher injury severities and measures of more general antisocial behaviour and delinquency made this study more sensitive to detect effects of TBI on behaviour, independent of substance use.

#### *4.5.3 Study limitations*

There are important limitations to acknowledge in this study. Primarily, issues arise from conducting this research in an online format. Online research does not have the same element of experimental control as conducting laboratory-based experiments affords, and it is difficult to ensure participants are attending to and completing the task at optimal levels without the presence of confounding distractors. To adjust for this, I screened for outliers which may have suggested poor attendance to task, however this would only identify those with very poor engagement and increases the risk of excluding those who legitimately struggled with the task for alternate reasons. There is a possibility that the responses regarding TBI history or other health measures were inaccurate, and there is no opportunity to validate these against more objective measures. In addition, having the participants complete the study in one session remotely makes it difficult to follow-up on any missed items or to seek clarification in responses, as many participants fail to respond to follow-up emails. In addition, recruiting from PA and placing many advertisements in university settings may have given a sample where the participants had higher education level, and SES than is typically observed in the general population.

As participants were recruited internationally, we were unable to include an accurate measure of SES, which is an important factor to consider in relation to TBI and measures of delinquency. In addition, I did not include a question asking whether those with injuries had completed any rehabilitation following

injury, which may have included rehabilitation in a socioemotional domain, affecting performance on the task. In future, I would address this, and adjust for this in the analysis.

#### 4.5.4 *Future research*

If replicating a study of this nature in future, I would advocate the inclusion of a negative orthopaedic control, to assess the influence of having sustained an injury generally on the outcome measures, compared with those sustaining head injuries more specifically. It would be interesting to investigate whether the effects observed here, replicate in a general population sample with a more objective means of assessing TBI history (i.e. using hospital and medical records, qualified with structural changes using imaging methods). It would also be interesting to assess those included on a wider battery of socioemotional tasks, including more complex social vignettes, dynamic social stimuli, emotion recognition in vocal prosody, etc.) to see whether the lack of observable difference between groups spans wider domains of social processing. Knox and Douglas (2009) observed that their patients with TBI were worse at recognising dynamic facial expression stimuli only, rather than static stimuli. It may be that the use of static stimuli in these studies reduced sensitivity for deficits in these individuals.

It would be advantageous to replicate this study, with an additional measure of inhibitory control or risky decision making. Impulsivity has been linked with self-reported delinquency and earlier onset of offending behaviour (Carroll et al., 2006), and poorer inhibition control has been associated with both premediated and reactive aggression in delinquent youth (Zhang, Wang, Liu, Song, & Yang, 2017). This would not address the question of causation, as it would be difficult to determine whether deficits in inhibition control were premorbid, but it would help to establish whether any association between TBI and aggression or delinquency was moderated by deficits in this domain. To address the question of causality, it would be beneficial to assess these neuropsychological domains in a longitudinal cohort study, and assess whether these are affected following TBI, and if so, whether this corresponds with later

risk of antisocial or delinquent behaviour (see Chapter eight for a more detailed discussion of future research suggestions).

#### 4.5.5 *Summary*

In summary, there is no clear evidence for impairment in FAR, for those with history of self-reported TBI in this general population sample. There was also no evidence of increased alexithymic traits following TBI. However, there was increased self-reported aggression, delinquency, PCS and higher proportions of recent drug use or heavy alcohol use in those with injury, with discrepancies increasing with increasing injury severity. This association between TBI and criminal tendency may be due to an alternate neuropsychological consequence of TBI not measured here, pre-morbid tendencies - possibly towards risk-taking and impulsivity, or secondary to other criminogenic risk factors, such as substance abuse, poverty, peer influence and SES.

Given that three analogous studies have been conducted, utilising comparable versions of the BERT and the same assessments for TBI history and PCS, I decided to combine these samples and investigate trends using meta-analytic techniques to address questions relating to perceptual biases, PCS and age at injury. The results of these are described in Chapter five.



## **5 Assessing the relationship between self-reported traumatic brain injury and facial affect recognition in adolescents and young adults with and without offending histories: a mini-meta analytic approach.**

### **5.1 Introduction**

As detailed at the end of Chapter four, given that three analogous studies have been described in the previous chapters using comparable measures for TBI and FAR, I have combined these sets of data to provide more robust estimates of effects. Here I will use a set of 'mini' meta-analyses to address research questions pertinent to all three studies and the wider thesis. This includes research question one, two and four (see section 1.8.1). Mini meta-analyses use the same logic as meta-analyses, but can be conducted on as few as two studies and aim to combine conceptually comparable results into an overall effect size (Goh, Hall, & Rosenthal, 2016). This can give stronger evidence for the replicability of a research question and better precision for effect estimates.

First, I will detail combined analyses for overall FAR between those with substantial TBI compared with non-injured matched controls, second I explore emotion recognition differences between groups for the individual emotions included within the FAR measure (fear, anger, sadness, happiness, disgust and surprise), including hit rates (the number of times an emotion was correctly identified when it was presented), false alarm rates (the number of times an emotion was incorrectly selected) and unbiased hit rates (a measure of correct identifications as a proportion of the number of times an emotion was selected overall). This is helpful for exploring whether there is any evidence for biases in recognition (differential proportions of hit rates across emotions), perceptual biases (differential proportions of false alarm rates across emotions) and to gauge an unbiased measure of accuracy (i.e. were individuals hit rates for an

emotion higher solely because that emotion was selected more frequently overall)<sup>5</sup>.

Following this, I investigate in greater detail associations between injury characteristics relating to age at which injuries were sustained and time since injury on overall FAR, to inform the earlier theory and discussion on age at injury on subsequent impairment. I also present analysis of combined associations between post-concussion symptomology (PCS) and overall FAR, as well as associations between PCS and additional measures, including reoffending risk, aggression and alexithymia.

Lastly, I present mini meta-analyses of emotion recognition between offenders and non-offending controls, including individual emotion recognition analysis to investigate whether there are biases in perception for those with offending tendencies compared to those without.

## **5.2 Methodology and results**

### *5.2.1 Facial affect recognition and traumatic brain injury*

The overall FAR outcome measure included the proportion of correct hits out of the possible total for a given measure. In Study 1, this was out of 90 trials and in Study 2 & 3 this was out of 48 (shortened version). Here I compare those with substantial injury ( $n = 77$ ), against those with no previous history of head injury ( $n = 109$ ). This combines samples from the three studies detailed in Chapters two to four, selecting those with no history of head injury (excluding those with mild injuries), from the wider samples.

To produce a combined effect size using a fixed-effects approach in which the mean effect size was weighted by sample size, following the guidance provided by Goh et al. (2016), first I calculated Cohen's  $d$  for each sample using the following formula for unequal group sizes:

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<sup>5</sup> False alarm rates and unbiased hit rates have not been analysed or discussed until this point in the interest of concision and due to the individual studies being underpowered to draw valid conclusions

$$d = \frac{t(n1 + n2)}{\sqrt{df} \sqrt{n1n2}}$$

Following this, I converted  $d$  to  $r$  using the formula detailed below. In this formula  $P$  refers to the proportion of the sample in one group (number of those with substantial TBI divided by the total sample), and  $Q$  refers to the proportion of the sample in the other group (number of those without history of TBI divided by the total sample size):

$$r = \sqrt{\frac{d^2}{d^2 + \frac{1}{P * Q}}}$$

Then I transformed the  $r$  values using a Fisher's  $z$  transformation for normalisation (creating  $r_z$ ), before combining the  $r_z$  values from the three samples meta-analytically using the following formula (converting them back to  $r$  following this to aid interpretation):

$$\text{Weighted } \bar{r}_z = \frac{\sum([N - 3]r_z)}{\sum(N - 3)}$$

Following this, I calculated a summary  $p$ -value using the combined  $Z$  value. The combined  $Z$  value is calculated using the formula below:

$$Z \text{ combined} = \frac{\text{Mean } r_z}{SE}$$

The characteristics of the study samples and results of the mini-meta analysis are presented in **Table 5.1**. The overall effect size was considered small

(magnitude of  $r$  typically classified as small ( $r = 0.1$ ), medium ( $r = 0.3$ ) or large ( $r = 0.5$ ) (Cohen, 1992)), and there was no evidence for combined difference between groups for FAR ability between those with substantial TBI compared to non-injured controls ( $p = 0.17$ ). This meant the primary hypothesis that those with substantial TBI would be poorer at overall FAR in comparison to those without injury, was unsupported.

**Table 5.1** Mini meta-analysis for TBI status and overall FAR

<b>Study sample characteristics</b>					
	<i>N</i>	<i>TBI vs No TBI</i>	<i>Mean Age (SD)</i>	<i>Offending status</i>	
Study 1	23	9:14	16.48 (1.20)	Youth offender	
Study 2	34	12:22	21.85 (2.19)	Adult offender	
Study 3	128	56:72	27.49 (5.06)	Non-offending	
<b>Results of mini-meta analysis</b>					
	<i>t</i>	<i>df</i>	<i>p</i>	<i>Cohen's d</i>	<i>r</i>
Study 1	2.34	21	0.03	1.05	0.46
Study 2	0.20	32	0.84	0.07	0.04
Study 3	0.09	126	0.93	0.02	0.01
Mean <i>r</i> (95% CI)	0.07 (- 0.08 to 0.22)				
Combined Z	0.94 (0.17)				

One-tailed significance calculated for combined Z,  $r_z$  converted back to  $r$  to aid interpretation (not Fisher Z transformed).

### 5.2.1.1 Individual emotion recognition analysis

The meta-analytic summaries of study effect sizes are presented for individual emotion hit rates (**Table 5.2**), individual emotion false alarm rates (**Table 5.3**) and individual emotion unbiased hit rates (**Table 5.4**). For full details of these analyses please see the detailed tables presented in the appendices (section **A6**, **Table's A5, A6 & A7**). These analyses do not map directly onto the overall thesis research questions and are exploratory. They are of relevance in that specific biases in perception or recognition of emotions may be influential in encouraging aggressive or antisocial behaviour (see literature review in section 1.6).

### 5.2.1.1.1 Individual emotion hit rate

Individual emotion hit rate is the number of times an emotion is correctly identified, when it has been presented. In Study 1, the emotion hit rates are out of a possible 15 per emotional expression, and in Study 2 & 3 emotion hit rates are out of a possible 8 per emotional expression. All the hit rates for the six emotions combined make up the overall FAR score. Here the only emotion with consistently lower hit rates was disgust.

**Table 5.2** Results of mini-meta analysis for individual emotion hit rates and TBI status

<b>Anger</b>	
Mean $r$ (95% CI)	0.01 (-0.14 to 0.15)
Combined $Z$ (p-value)	0.09 (0.93)
<b>Disgust</b>	
Mean $r$ (95% CI)	0.15 (0.00 to 0.29)
Combined $Z$ (p-value)	2.02 (0.04)
<b>Fear</b>	
Mean $r$ (95% CI)	0.01 (-0.14 to 0.16)
Combined $Z$ (p-value)	0.15 (0.88)
<b>Happy</b>	
Mean $r$ (95% CI)	-0.01 (-0.15 to 0.14)
Combined $Z$ (p-value)	-0.09 (0.93)
<b>Sad</b>	
Mean $r$ (95% CI)	0.03 (-0.12 to 0.18)
Combined $Z$ (p-value)	0.39 (0.70)
<b>Surprise</b>	
Mean $r$ (95% CI)	0.05 (-0.10 to 0.19)
Combined $Z$ (p-value)	0.65 (0.52)

2-tailed significance calculated for combined  $Z$ ,  $r_z$  converted back to  $r$  to aid interpretation (not Fisher  $Z$  transformed). Negative values for  $r$  denote better performance for those with TBI compared to non-injured controls.

### 5.2.1.1.2 Individual emotion false alarm rate

Individual false alarm rate is the number of times an emotion is incorrectly selected, when it is not presented. This equates to the total number of times that emotion is selected overall, minus the number of correct hits for

that emotion. Here there is weak evidence that disgust was incorrectly selected more frequently than the other emotions in those with TBI.

**Table 5.3** Results of mini-meta analysis for individual emotion false alarm rates and TBI status

<b>Anger</b>	
Mean r (95% CI)	-0.02 (-0.17 to 0.13)
Combined Z (p-value)	-0.24 (0.81)
<b>Disgust</b>	
Mean r (95% CI)	-0.13 (-0.27 to 0.02)
Combined Z (p-value)	-1.70 (0.09)
<b>Fear</b>	
Mean r (95% CI)	0.03 (-0.12 to 0.17)
Combined Z (p-value)	0.37 (0.71)
<b>Happy</b>	
Mean r (95% CI)	-0.05 (-0.19 to 0.10)
Combined Z (p-value)	-0.61 (0.54)
<b>Sad</b>	
Mean r (95% CI)	-0.03 (-0.18 to 0.12)
Combined Z (p-value)	-0.39 (0.70)
<b>Surprise</b>	
Mean r (95% CI)	0.06 (-0.09 to 0.20)
Combined Z (p-value)	0.73 (0.47)

2-tailed significance calculated for combined Z,  $r_z$  converted back to  $r$  to aid interpretation (not Fisher Z transformed). Negative values for  $r$  indicate those with TBI have scored higher (making more false alarms, corresponding with greater inaccuracy), than non-injured controls.

#### 5.2.1.1.3 Individual emotion unbiased hit rate

As mentioned earlier, it is useful to supplement raw hit rates and false alarm rates with an unbiased hit rate to obtain a more accurate measure of accuracy. Here I've used the following formula for an unbiased hit rate ( $H_u$ ), proposed by Wagner (1993):

$$H_u = \frac{a^2}{b * (a + c)}$$

In this equation,  $a$  denotes the individual emotion hit rate,  $b$  denotes the total number of times a stimulus from that emotion category was presented, and  $c$  denotes the number of false alarms within that emotion category. For example, if an individual correctly identifies the emotion anger three times (three

hits), and also incorrectly selects anger twice (two false alarms), in a version of the task where a stimulus displaying an angry emotion is presented 15 times in total, this would give a  $H_u$  of 0.12. This measures the joint probability that a stimulus category is correctly identified, when it is presented, and that a response is correct, when it is used (value ranging between 0 and 1). This gave evidence that those with TBI were poorer at recognising the emotion disgust only, relative to those without TBI.

**Table 5.4** Results of mini-meta analysis for individual emotion unbiased hit rates and TBI status

<b>Anger</b>	
Mean $r$ (95% CI)	0.01 (-0.14 to 0.16)
Combined $Z$ (p-value)	0.16 (0.87)
<b>Disgust</b>	
Mean $r$ (95% CI)	0.18 (0.04 to 0.32)
Combined $Z$ (p-value)	2.44 (0.01)
<b>Fear</b>	
Mean $r$ (95% CI)	0.05 (-0.10 to 0.19)
Combined $Z$ (p-value)	0.65 (0.52)
<b>Happy</b>	
Mean $r$ (95% CI)	0.04 (-0.11 to 0.19)
Combined $Z$ (p-value)	0.53 (0.60)
<b>Sad</b>	
Mean $r$ (95% CI)	0.08 (-0.07 to 0.22)
Combined $Z$ (p-value)	1.05 (0.29)
<b>Surprise</b>	
Mean $r$ (95% CI)	0.04 (-0.11 to 0.18)
Combined $Z$ (p-value)	0.51 (0.61)

2-tailed significance calculated for combined  $Z$ ,  $r_z$  converted back to  $r$  to aid interpretation (not Fisher  $Z$  transformed). Negative values for  $r$  denote better performance for those with TBI compared to non-injured controls.

Combining the results of individual emotion recognition performance, across these three studies it appears that the only evidence for a robust difference in those with substantial TBI compared to those with no injury, is for the emotion disgust. This includes poorer emotion hit rate, weak evidence for higher false alarm rate, qualified further with strong evidence for a small to medium effect of poorer recognition in those with injury using the unbiased hit rate. There was no clear evidence of differences in recognition of other emotions as a consequence of substantial head injury.

### 5.2.1.2 Facial affect recognition and injury characteristics

Combining datasets gives greater statistical power to detect effects. Using mini-meta analytical techniques I analysed whether there was an association between age at first injury, age at most severe injury and time since injury on overall FAR, comparing those with substantial injury from studies 1, 2 & 3. The characteristics and results in **Table 5.5**. Again, these exploratory analyses do not directly respond to the research questions outlined in Chapter one but are included to inform the debate generated by the research findings of the previous three chapters.

There was no clear evidence of a relationship between FAR performance and injury characteristics in those with history of substantial TBI, across the three studies.

**Table 5.5** Mini meta-analysis for injury characteristics and overall FAR

<b>Study sample characteristics</b>			
	<i>N</i>	<i>Mean Age (SD)</i>	<i>Offending status</i>
Study 1	9	16.28 (1.31)	Youth offender
Study 2	12	22.0 (2.13)	Adult offender
Study 3	56	27.55 (4.94)	Non-offending
<b>Results of mini-meta analysis</b>			
	<i>Age at first injury</i>	<i>Age at most severe injury</i>	<i>Time since most severe injury</i>
Study 1	-0.07	-0.01	-0.14
Study 2	-0.03	0.11	0.05
Study 3	-0.18	-0.25	0.20
Mean <i>r</i> (95% CI)	-0.15 (-0.37 to 0.09)	-0.18 (-0.40 to 0.05)	0.15 (-0.09 to 0.37)
Combined <i>z</i> (p-value)	-1.25 (0.21)	-1.53 (0.13)	1.26 (0.21)

Correlations between age at injuries/time since injury and overall FAR combined, with  $r_z$  converted back to  $r$  to aid interpretation (not Fisher Z transformed). 2-tailed significance calculated for combined Z. Correlations for substantial injury group from each study only.

### 5.2.1.3 Facial affect recognition and post-concussion symptomology

In addition, I investigated the associations between post-concussion symptomology (PCS) (as measured using the RPCQ and its respective sub-

scales), and overall FAR, to determine whether ongoing symptomology was a better predictor of FAR than TBI history status. For Study 1 this includes those recruited with offending histories only, but for Study 2 we also collected PCS from non-injured, non-offending controls, and in Study 3, non-injured controls as a comparison to gauge general non-TBI symptomology (e.g. difficulties with concentration, headaches) which may be captured by the RPCQ.

There was evidence for poorer overall FAR in those with higher overall PCS symptoms, which appeared to be driven by greater symptomology in the cognitive domain, with small effect sizes. See **Table 5.6** for meta-analysis of group characteristics and results. Details of separate analyses, investigating these effects with injured participants only, and non-injured participants, can be found in the appendices (section **A6**, **Tables A8 & A9**). This suggested the effects observed here were restricted to those with injury-related symptoms only (i.e. not present in non-injured controls).

**Table 5.6** Mini meta-analysis for post-concussion symptoms and overall FAR

<b>Study sample characteristics</b>			
	<i>N</i>	Mean Age (SD)	Offending status
Study 1	25	16.98 (1.27)	Youth offender
Study 2	70	21.63 (2.17)	Adult offender & control
Study 3	221	27.10 (4.95)	Non-offending adults
<b>Results of mini-meta analysis</b>			
	<i>PCS total</i>	<i>PCS somatic</i>	<i>PCS cognitive</i>
Study 1	-0.49	-0.15	-0.52
Study 2	-0.06	0.05	-0.10
Study 3	-0.10	-0.08	-0.13
Mean <i>r</i> (95% CI)	-0.12 (-0.23 to -0.01)	-0.06 (-0.17 to 0.06)	-0.16 (-0.26 to -0.04)
Combined <i>z</i> (p-value)	-2.15 (0.03)	-1.0 (0.32)	-2.73 (0.01)

Correlations between age at injuries/time since injury and overall FAR combined, with  $r_z$  converted back to  $r$  to aid interpretation (not Fisher Z transformed). 2-tailed significance calculated for combined Z. RPCQ score from main study testing session used for Study 3, 8 data-points missing due to technical error.

### 5.2.2 Post-concussion symptomology and measures of reoffending risk, aggression & alexithymia

There was greater variation in measures used to assess antisocial or aggressive behaviours, however there were some comparable measures used across studies that I will synthesise here. This includes risk of reoffending score (general) in studies 1 & 2 and the aggression measure (RPQ) in studies 2 & 3. The alexithymia measure (TAS) was also used in both Study 2 and Study 3 and will be included here. Here I investigate the associations between PCS and measures of antisocial behaviour and alexithymia. See **Table 5.7** for meta-analysis group characteristics and results.

The combined evidence suggests that there is no clear link between PCS and re-offending risk. However, it gives strong evidence for an association between higher PCS and self-reported aggression and alexithymia, with medium to large effect sizes. Exploring this further for the delinquency measure in Study 3 only, there was also strong evidence for an association between higher PCS and higher self-reported delinquency and antisocial behaviour ( $r = 0.30, p < 0.001$ ). As detailed in section 5.2.1.3, these analyses were repeated, separating those with TBI and those without history of injury. These effects replicated for both those with and without history of injury (see appendices, section **A6**, **Tables A10 & A11**), which suggests these effects may not be TBI specific.

**Table 5.7** Mini meta-analysis for post-concussion symptoms and additional measures

<b>Study sample characteristics</b>			
	<i>N</i>	Mean Age (SD)	Offending status
Study 1	19	16 (1.15)	Young offenders
Study 2 (OGRS)	41	21.56 (2.03)	Young adult offenders
Study 2 (RPQ & TAS)	70	21.63 (2.17)	Young adult offenders and controls
Study 3	221	27.10 (4.95)	Non-offending adults
<b>Results of mini-meta analysis</b>			
	Re-offending risk	Aggression (RPQ)	Alexithymia (TAS)
Study 1	0.23		

Study 2	0.02	0.44	0.44
Study 3		0.46	0.36
Mean <i>r</i> (95% CI)	0.08 (-0.18 to 0.34)	0.46 (0.36 to 0.54)	0.38 (0.28 to 0.47)
Combined <i>z</i> (p-value)	0.61 (0.54)	8.30 (< 0.001)	6.74 (< 0.001)

Correlations between age at injuries/time since injury and overall FAR combined, with  $r_z$  converted back to  $r$  to aid interpretation (not Fisher Z transformed). 2-tailed significance calculated for combined Z. Reoffending risk data not available for whole sample in Study 1 or 2, due to missing data in justice records. OGRS at 1 year used for reoffending risk in Study 2. PCS not collected for non-offending controls in Study 1.

### 5.2.3 Emotion recognition and age

It has been suggested that age at testing can affect emotion recognition, with differential emotion recognition in children compared to adolescents and adults (Thomas, De Bellis, Graham, & LaBar, 2007), and younger adults compared to older adults (West et al., 2012). In an exploratory analysis, I investigated whether there was an association between age and overall FAR across the three samples, irrespective of offending status and TBI status. The characteristics and results of this analysis are presented in **Table 5.8**. There was no clear evidence of a relationship between overall FAR performance and age at testing, across the three studies.

**Table 5.8** Mini meta-analysis for age at testing and overall FAR

Study sample characteristics			
	<i>N</i>	Mean Age ( <i>SD</i> )	Offending status
Study 1	75	16.45 (1.03)	Adolescents
Study 2	70	21.63 (2.17)	Young adults
Study 3	229	26.95 (4.98)	Young adults
Results of mini-meta analysis			
	Age at testing		
Study 1	0.07		
Study 2	-0.02		
Study 3	-0.09		
Mean <i>r</i> (95% CI)	-0.05 (-0.15 to 0.06)		
Combined <i>z</i> (p-value)	-0.87 (0.38)		

Correlations between age testing and overall FAR combined, with  $r_z$  converted back to  $r$  to aid interpretation (not Fisher Z transformed). 2-tailed significance calculated for combined Z.

#### 5.2.4 Emotion recognition and offending behaviour

As discussed at the end of Chapter three, there appeared to be an effect whereby those recruited from justice system organisations, with a history of criminal convictions, had poorer performance on the FAR measure, in comparison with non-offending controls. The study characteristics and meta-analytical results of these combined effects are presented in **Table 5.9**. Meta-analysing these results gave strong evidence for a large effect size, with offenders performing worse than aged-matched controls on the BERT. The outcome of this analysis has relevance for the fifth thesis research question: ‘would interventions targeting the capacity for FAR be effective in reducing antisocial or criminal behaviour?’, suggesting this is a justifiable and important avenue to explore further. In addition, I investigated this by analysing combined effect sizes for individual emotion recognition, exploring whether there was presence of biases in responses, and re-visiting the influence of TBI on FAR within these populations (research question one).

**Table 5.9** Mini meta-analysis for offending status and overall FAR

<b>Study characteristics</b>						
	<i>N</i>	<i>Offender vs controls</i>	<i>Mean Age (SD)</i>		<i>Offending status</i>	
Study 1	75	35:40	16.45 (1.03)		Youth offender	
Study 2	70	12:58	21.63 (2.17)		Adult offender	
<b>Results of mini-meta analysis</b>						
	<i>N</i>	<i>t</i>	<i>df</i>	<i>p</i>	<i>Cohen's d</i>	<i>r</i>
Study 1	75	6.36	73	< 0.001	1.56	0.61
Study 2	70	4.25	68	< 0.001	1.37	0.46
Mean <i>r</i> (95% CI)	0.54 (0.41 to 0.65)					
Combined <i>Z</i>	7.16 (< 0.001)					

2-tailed significance calculated for combined *Z*, *r<sub>z</sub>* converted back to *r* to aid interpretation (not Fisher *Z* transformed).

### 5.2.4.1 Individual emotion recognition

#### 5.2.4.1.1 Individual emotion hit rate

Using the same approach as detailed previously, combined effect sizes between the two studies gave strong evidence for poorer emotion recognition in offenders compared to controls, as evidenced by individual emotion hit rate. The results indicated medium to large effect sizes for all included emotions except fear, for which there was weak evidence for poorer performance in offenders, and happy, for which there was no evidence of difference. See **Table 5.10** for a summary of results. Detailed analyses can be found in the appendices (see section **A5, Table's A12, A13 & A14**).

**Table 5.10** Results of mini-meta analysis for individual emotion hit rates and offending status

<b>Anger</b>	
Mean $r$ (95% CI)	0.54 (0.41 to 0.65)
Combined $Z$ (p-value)	7.11 (< 0.001)
<b>Disgust</b>	
Mean $r$ (95% CI)	0.58 (0.46 to 0.68)
Combined $Z$ (p-value)	7.82 (< 0.001)
<b>Fear</b>	
Mean $r$ (95% CI)	0.18 (0.02 to 0.34)
Combined $Z$ (p-value)	2.15 (0.03)
<b>Happy</b>	
Mean $r$ (95% CI)	0.01 (-0.15 to 0.18)
Combined $Z$ (p-value)	0.17 (0.87)
<b>Sad</b>	
Mean $r$ (95% CI)	0.48 (0.34 to 0.59)
Combined $Z$ (p-value)	6.11 (< 0.001)
<b>Surprise</b>	
Mean $r$ (95% CI)	0.36 (0.20 to 0.49)
Combined $Z$ (p-value)	4.39 (< 0.001)

2-tailed significance calculated for combined  $Z$ ,  $r_z$  converted back to  $r$  to aid interpretation (not Fisher  $Z$  transformed). Negative values for  $r$  denote better performance for those with offending behaviour compared to non-offending controls.

#### 5.2.4.1.2 Individual emotion false alarm rate

Investigating biases in incorrect selections by meta-analysing false alarm rates for individual emotions across study 1 & 2, indicated strong evidence that offenders were more likely than non-offending controls to incorrectly select

disgust, fear and happy emotions, with medium effect sizes. No difference in incorrect selections was observed for anger, sadness and surprise. The results are summarised in **Table 5.11**.

**Table 5.11** Results of mini-meta analysis for individual emotion false alarm rates and offending status

<b>Anger</b>	
Mean $r$ (95% CI)	-0.13 (-0.29 to 0.04)
Combined $Z$ (p-value)	-1.54 (0.12)
<b>Disgust</b>	
Mean $r$ (95% CI)	-0.32 (-0.46 to -0.16)
Combined $Z$ (p-value)	-3.90 (< 0.001)
<b>Fear</b>	
Mean $r$ (95% CI)	-0.38 (-0.51 to -0.23)
Combined $Z$ (p-value)	-4.71 (< 0.001)
<b>Happy</b>	
Mean $r$ (95% CI)	-0.26 (-0.41 to -0.10)
Combined $Z$ (p-value)	-3.17 (0.001)
<b>Sad</b>	
Mean $r$ (95% CI)	-0.00 (-0.17 to 0.16)
Combined $Z$ (p-value)	-0.05 (0.96)
<b>Surprise</b>	
Mean $r$ (95% CI)	-0.07 (-0.23 to 0.10)
Combined $Z$ (p-value)	-0.79 (0.43)

2-tailed significance calculated for combined  $Z$ ,  $r_z$  converted back to  $r$  to aid interpretation (not Fisher  $Z$  transformed). Negative values for  $r$  indicate those with offending behaviour have scored higher (making more false alarms, corresponding with greater inaccuracy), than non-offending controls.

#### 5.2.4.1.3 Individual emotion unbiased hit rate

Calculating the unbiased hit rate as detailed in section. 5.2.1, the synthesis of the study effect sizes for Study 1 & 2 indicated strong evidence for impaired performance for recognition of all emotions except happiness, in offenders compared to non-offending controls. The effect sizes were largest for the emotions anger and disgust, with medium to large effect sizes for sadness, fear and surprise, and weak evidence for a small effect size for impairment in recognition of the emotion happiness. See **Table 5.12** for a summary of these analyses.

**Table 5.12** Results of mini-meta analysis for individual emotion unbiased hit rates and offending status

<b>Anger</b>	
Mean <i>r</i> (95% CI)	0.56 (0.43 to 0.66)
Combined <i>Z</i> (p-value)	7.38 (< 0.001)
<b>Disgust</b>	
Mean <i>r</i> (95% CI)	0.64 (< 0.001)
Combined <i>Z</i> (p-value)	8.99 (< 0.001)
<b>Fear</b>	
Mean <i>r</i> (95% CI)	0.33 (0.17 to 0.47)
Combined <i>Z</i> (p-value)	4.04 (< 0.001)
<b>Happy</b>	
Mean <i>r</i> (95% CI)	0.19 (0.02 to 0.34)
Combined <i>Z</i> (p-value)	2.25 (0.02)
<b>Sad</b>	
Mean <i>r</i> (95% CI)	0.38 (0.23 to 0.51)
Combined <i>Z</i> (p-value)	4.66 (< 0.001)
<b>Surprise</b>	
Mean <i>r</i> (95% CI)	0.38 (0.23 to 0.51)
Combined <i>Z</i> (p-value)	4.68 (< 0.001)

2-tailed significance calculated for combined *Z*, *r<sub>z</sub>* converted back to *r* to aid interpretation (not Fisher *Z* transformed). Negative values for *r* denote better performance for those with offending behaviour compared to non-offending controls.

#### 5.2.4.2 Overall FAR in offenders with and without TBI

Lastly, I repeated the mini-meta analysis detailed in **Table 5.1**, this time including only those with convictions for offending behaviour, comparing overall FAR in those with substantial TBI or no history of TBI (excluding those with mild injuries). Again, there was no clear evidence for impairment in those with substantial TBI compared to those without TBI, across the two samples. Find details of this mini-meta analysis in **Table 5.13**.

**Table 5.13** Mini meta-analysis for TBI status and overall FAR in offending populations

<b>Study sample characteristics</b>					
	<i>N</i>	<i>TBI vs No TBI</i>	<i>Mean Age (SD)</i>	<i>Offending status</i>	
Study 1	23	9:14	16.48 (1.20)	Youth offender	
Study 2	34	12:22	21.85 (2.19)	Adult offender	
<b>Results of mini-meta analysis</b>					
	<i>t</i>	<i>df</i>	<i>p</i>	<i>Cohen's d</i>	<i>r</i>
Study 1	2.34	21	0.03	1.05	0.46
Study 2	0.20	32	0.84	0.07	0.04
Mean <i>r</i> (95% CI)	0.22 (- 0.06 to 0.46)				

Combined Z	1.57 (0.11)
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Two-tailed significance calculated for combined Z,  $r_z$  converted back to  $r$  to aid interpretation (not Fisher Z transformed).

### 5.3 Discussion

Within this chapter I have used meta-analytical techniques to synthesise effect sizes from the first three studies described in the preceding chapters. This was to address research questions relating to TBI, FAR and antisocial behaviour (see research questions one, two and four in section 1.8.1). The results from numerous analyses are presented here, therefore I will summarise and discuss these in turn.

#### 5.3.1 Facial affect recognition and traumatic brain injury

Combined comparisons between those with substantial TBI and matched controls without injury, for overall FAR ability, gave no clear evidence for a difference between these groups in the domain of FAR. This helps conclude that the effects observed within Study 1 failed to replicate across different samples with comparable severity of TBI history, and analogous measures of FAR. This was also true when the findings from offending samples (Studies 1 & 2) were synthesised separately, meaning the hypothesis outlined in research question one was unsupported. Furthermore, this suggests that there were not clear differences observed in relation to this effect in those with offending histories in comparison to non-offending counterparts (Study 3), confirming that similar patterns of effects between TBI and FAR were observed between samples (research question four). This implies that the effect size originally observed in Study 1 may have been overinflated or spurious, as can often be the case with small sample sizes (Button et al., 2013). As mentioned previously, this suggests that FAR impairment following TBI may be less common, or subtler than is suggested by the current literature. Further research into consequences of lifetime TBI in the domain of socioemotional processing and FAR is needed.

Investigation of these abilities in those with milder severities, across different ages and injury timespans would be informative. The majority of

research reported in this area concentrates on those with severe injuries, although the meta-analysis conducted by Babbage et al. (2011) did combine effects from studies including those with both moderate and severe injuries. Knox and Douglas (2009) suggest that patients with severe injuries may be more socially isolated than those with moderate or milder injuries, which may exacerbate effects of FAR deficit. Effects may be attenuated in those with milder lifetime history of TBI who do not experience similar levels of absence from work or social events.

Studies in this area often advocate the targeting of this domain for therapeutic intervention using training (Hopkins, Dywan, & Segalowitz, 2002; Ietswaart, Milders, Crawford, Currie, & Scott, 2008). Based on our findings, careful screening and identification of those with pronounced and chronic FAR deficits is advised when formulating treatment approaches and identifying those suitable for intervention. Effective screening strategies were adopted by Neumann, Babbage, Zupan, and Willer (2015) when identifying eligible participants for their FAR training randomised control trial (RCT) (for example, having impaired FAR at least one SD below controls on a standardised measure of FAR pre-testing, which remained consistent over time prior to the intervention being administered). Replication of their, or a similar approach when considering the use of FAR training for those with TBI in clinical settings is recommended.

#### *5.3.1.1 Individual emotion recognition*

An unexpected finding which emerged when investigating individual emotion recognition, combined across these studies, was that those with substantial injury exhibited differential impairment for the recognition of disgust, which was not observed for other emotions. This was detected for raw hit rate, unbiased hit rate, and to a lesser extent, in false alarm rates. Evidence has suggested that the recognition of disgust can be selectively impaired when an individual suffers damage to the insula and putamen, which appear to be implicated in the recognition of this particular emotion, but not others (Calder, Keane, Manes, Antoun, & Young, 2000). These are deep subcortical structures, but it is possible that diffuse injury could affect the transmission and functional

capacity of these regions in individuals with TBI. Furthermore, selective impairment of disgust recognition has also been observed for individuals with obsessive compulsive disorder (OCD, (Daros, Zakzanis, & Rector, 2014), which may suggest this emotion is more difficult to recognise or vulnerable to deficit in the presence of neurodisability.

The impairment for the recognition of the emotion sadness in those with injury across study 1 & 2 (described in Chapter three, section 3.6.1) was not replicated in the combined analysis. This might suggest that the previous observations were not robust, or alternatively, that the effect was present in individuals with TBI recruited from offending populations, rather in those with TBI generally. Differential impairment in the recognition of the emotion sadness in individuals with TBI was also reported by Spikman et al. (2013), who suggested impaired recognition of the emotion sadness may serve a useful marker for those with problems that interfere with successful social reintegration. This derives from their finding that impaired recognition of sadness was associated with increased behavioural problems, which has relevance to those with history of offending behaviour. Deficits in the recognition of sadness may fail to inhibit aversive or antisocial behaviour in the perpetrator and lead to these behaviours becoming more ingrained (Blair, 2005). In addition, investigating causes and contexts of injury may be informative in differentiating some of these findings. For example, does the recognition of sadness or disgust have more relevance for survivors of injury sustained through interpersonal conflict, such as fights or abuse, compared to survivors of non-conflict injury sustained through, for example, sports or RTA's? These suggestions are speculative, however future research investigating these effects would be beneficial.

Impairment in the recognition of specific emotions is not typically reported after TBI, although there are reports of increased difficulty in the recognition of 'negative' emotions (typically sadness, fear, disgust and anger) (Crocker & McDonald, 2005; Hopkins et al., 2002; Jackson & Moffat, 1987; Spikman et al., 2013). This may be due to happiness being an easier emotion to identify generally, and typically the only 'positive' emotion included within FAR measures of this nature. However, as a consequence any interventions designed to target FAR for use with individuals with TBI are recommended to

incorporate a greater proportion of negative affect emotions than positive (Radice-Neumann, Zupan, Babbage, & Willer, 2007). However, studies reporting a specific deficit in the recognition of disgust after TBI are uncommon. It would be interesting to synthesise wider findings of studies in this area meta-analytically and explore recognition of individual emotions in those with injury compared to non-injured controls to investigate whether this is a consistent effect. This would inform the earlier work of Babbage et al. (2011) who focused on overall FAR only, rather than individual emotion recognition. Furthermore, as the studies reviewed in earlier studies used a variety of FAR tasks which employed different stimulus sets (often derived from the Ekman faces database), it would be useful in future to validate the stimuli used within the BERT against these more traditional, and typically unmorphed emotive stimuli to determine whether patterns in emotion recognition are confounded by the stimulus set used.

#### *5.3.1.2 Injury characteristics and facial affect recognition*

Knox and Douglas (2009) note the importance of accounting for time since injury when investigating FAR deficits after TBI, because, as detailed in Green, Turner, and Thompson (2004), abilities of those with chronic or acute TBI are likely to differ due to factors such as functional reorganisation or the ability to use compensatory strategies. Here we did not find any evidence that time since most severe injury influenced FAR ability when the results of the three studies were combined. Neither did we find an association between age at most severe injury, or age at first injury and overall FAR. These effects are interesting to explore in relation to theories of neurodevelopment and socioemotional processing ability; however, it should be acknowledged that the three studies described in the preceding chapters are not well placed to investigate these effects conclusively. A definitive study requires more objective measures of TBI history, with accompanying radiographic data and carefully selected participants with variation in age at injury for comparison. Despite the lack of evidence for an effect observed here, I believe, based on the reviewed theory and previous evidence, that this may be an important influential factor

and advocate consistent measurement and reporting of this in future studies in this area, to enable greater potential for comparisons across samples.

#### *5.3.1.3 Post-concussion symptomology and facial affect recognition*

When meta-analysing effect sizes for associations between PCS and overall FAR across the three studies, results indicated evidence for a small effect where increased PCS was associated with poorer FAR. Investigation of sub-scales of this measure indicated this appeared to be driven by cognitive symptoms especially (including the items poor memory, poor concentration, confusion, and difficult recalling everyday events). In the analyses presented in **Table 5.6** I included both those with injury and non-injured controls, to investigate whether general difficulties in these domains related to FAR ability. Upon observing this effect, separate analyses (see **Appendix A6**) suggested there was no qualitative change in combined effects for PCS with overall FAR when excluding non-injured controls, and in the separate analysis for non-injured controls these observed effects were not present. This suggests that ongoing symptoms deriving from earlier injury were influential in FAR ability.

#### *5.3.2 Post-concussion symptomology and measures of reoffending risk, aggression & alexithymia*

In addition to the observed effects for FAR, these combined analyses also indicated there was strong evidence that presence of PCS was related to increased alexithymia, aggression and (Study 3 only), self-reported delinquency. There were no observed effects for PCS and reoffending risk. Repeating the subsequent analyses detailed above (see **Appendix A6** for details), there was again no qualitative difference when those without injury were excluded. However, in those without injury there appeared to be similar effects for PCS and the aggression measure, and weak evidence for an association between alexithymia and PCS (of a smaller magnitude). No effect was observed for delinquency in those without injury.

This interesting, as it suggests that ongoing symptomology is associated with poorer outcomes, related to socioemotional processing and antisocial behaviour. However, given the replication of some of these effects in non-injured controls it is difficult to determine whether this derives from consequences of TBI, or reflect increased poorer outcomes in those who suffer cognitive or somatic symptoms more generally. These individuals may suffer symptoms in these cognitive domains through general neurocognitive deficit, or due to co-occurring symptomology as a consequence of a co-morbid disorder, independent of earlier TBI. This may also be true for the observed association described in 5.3.1.3 between PCS and FAR, however being an effect of smaller magnitude investigation in the non-injured samples may have failed to detect the effect seen in those with injury due to reduced statistical power.

Whether due to injury, or non-injury factors, this finding is of importance. First, even though these symptoms can be experienced from non-trauma aetiologies, they are commonly associated with, and frequently observed following TBI. Experiencing PCS symptoms in combination, for an extended duration, has been termed 'post-concussive syndrome' and has been estimated to affect 50 – 80% of individuals within 3 months of a mild TBI, with 15% reporting symptoms following a year post-injury (Satz et al., 1999). Second, it suggests that the decision to compare individuals based on TBI severity may have reduced sensitivity to detect effects. Injuries are heterogenous in their effects and long-term consequences, and there might be wide variation within injury severity groups in terms of experienced symptoms and subsequent recovery. Using LoC duration as a means of measuring severity and grouping on this basis is a rudimentary measure. These findings suggest that estimates of effects could be strengthened if a composite measure of TBI severity and related ongoing symptomology was used to define injury severity groups. It is interesting that these PCS effects were observed for the socioemotional processing measures, alexithymia and FAR, where an effect was not observed as a function of TBI severity in Study 3, or (with the exception of a weak effect for alexithymic interpersonal traits) Study 2. Perhaps the use of this measure is more sensitive and has greater relevance for socioemotional processing than severity of previous TBI. The findings for aggression and delinquency corroborate those described for TBI severity in Study 3 (with both increased

PCS, or increased TBI severity being associated with increased aggression and delinquency). The effects were not replicated for reoffending risk; however, this may reflect the complex and multifaceted nature of these risk composites, and that in this mini-meta analysis, two different reoffending risk measures were combined which may have introduced additional noise into the data.

These results are correlational, therefore hindering our ability to make causative inferences regarding mechanisms underlying these associations. However, one theory which may help explain these effects is that of ego depletion. This theory suggests that the capacity for self-control or will-power draws from a limited pool of mental resources, which can become depleted. This may be through effortful executive tasks such as decision-making or self-regulation, or resource depletion due to fatigue or illness, impairing subsequent performance in these cognitive domains (Baumeister, Bratslavsky, Muraven, & Tice, 1998). Experiencing elevated or frequent PCS such as poor memory, concentration and confusion, may mean that these individuals have to devote more mental energy to cognitive tasks further depleting this energy source as a consequence. This may reduce the capacity for subsequent decision-making or self-regulation processes, through this reducing self-control. This could have negative implications for behaviours with antisocial consequences, such as aggression or delinquency. Indeed, a number of studies have investigated ego depletion as a consequence of sleep deprivation, and suggest that increased ego-depletion leads to increased unethical behaviour and delinquency in workplace settings (Barnes, Schaubroeck, Huth, & Ghumman, 2011), due to reductions in meta-cognition and self-control.

An important limitation to note in relation to this finding, is the reliance in these studies on subjective, self-report measures. The PCS, the aggression, the delinquency and the alexithymia measures all use a self-report comprising a number of items for which the participant has to rate along a Likert scale. The effects observed here may be an artefact of skewed responding where individuals who are more likely to report more severe PCS, are also more likely to report more extreme responses for items relating to aggression, delinquency and alexithymia. The evidence for an association between FAR and PCS contrasts with this assertion, as the FAR measure was more objective and did not rely on self-report. Despite this, it would be beneficial in future to investigate

whether these effects replicate, using supplementary objective measures, such as aggression diaries completed by a carer or close family member and a more extensive battery of socioemotional processing tasks.

### *5.3.3 Facial affect recognition and offending populations*

For the final analyses, I moved away from the investigation of TBI history specifically and investigated FAR in the samples recruited from justice organisations based on their offending histories (Studies 1 & 2). Their performance was compared against the aged-matched non-offending controls detailed within these corresponding chapters. As mentioned previously, these controls were matched only on age and not having any previous history of TBI, therefore they are not ideal comparisons in regard to IQ, SES and in Study 1, gender, and as such these results should be interpreted as preliminary. The analyses gave strong evidence, with a large effect size, for poorer FAR in those with offending histories compared to non-offending controls. These effects were observed across the board of emotions, however the evidence for deficit in the recognition of happiness was much smaller in magnitude (as is commonly typical in the FAR literature) and was only present in the unbiased hit rate analysis.

Interestingly, the emotion most commonly reported as impaired in this population, fear, was not strongly observed in this study. Evidence for impairment in hit rates was weak, participants were more likely to incorrectly select it than other emotions, but in terms of unbiased hit rates, the largest effects were for the recognition of anger and disgust. The differential impairment for fear was initially reported in a meta-analysis by Marsh and Blair (2008), and corroborated by the findings of Wilson, Juodis, and Porter (2011). However, these studies placed a strong focus on the dimension of psychopathy as a proxy for antisociality. Subsequent meta-analyses which have attempted to delineate participant characteristics more clearly based on this feature, have found evidence for pervasive deficit across a broader range of emotions (including happiness and surprise). There is a disproportionate focus on psychopathy within this field, and recent evidence has suggested when you move the focus from psychopathy, and categorise offenders based on offence

type (i.e. violent or non-violent), there is evidence for a general FAR deficit in violent offenders, including the emotions anger, disgust and fear (Chapman, Gillespie, & Mitchell, 2018). Indeed, this is an important distinction to make, as certain emotions may have more relevance based on offending sub-type. Sadness and fear may have more relevance for violent, proactive crimes, as are typically affiliated with psychopathy, whereas difficulty recognising anger and disgust, as observed here, may have more relevance for general antisocial behaviour. For example, use of drugs or petty theft is more likely to elicit anger or disapproval, conveyed in expressions of disgust in an observer, than fear *per se*. It may be the case, that the inclusion of both violent and non-violent offenders in these studies has identified markers for general delinquency, rather than typical patterns relating to violence.

In addition to this, I did not observe evidence for a hostile attribution bias from these meta-analytic estimates. Typically, this would be evidenced by a retained capacity to recognise anger in relation to other emotional expressions, or an increased tendency to incorrectly select anger (as conveyed by false alarm rates). This finding contrasts with the findings of a systematic review by Mellentin, Dervisevic, Stenager, Pilegaard, and Kirk (2015) who found convincing evidence for some form of biased perception pattern across 21 experiments on angry or aggressive individuals. However, as we did not recruit based on an individual's violence or aggression this may explain why we did not observe a hostile attribution bias. Future studies which make a clearer distinction between types of criminal behaviour, in particular violent, non-violent and sexual offences, would be helpful in confirming whether these observed patterns in recognition are typical in these populations.

#### *5.3.4 Recommendations for practice*

Based on these findings and their implications, the following recommendations for practice are proposed. First, for individuals within the CJS, whether in addition to current health and needs assessments, or upon initial entry, screening of TBI history and ongoing related symptomology should be assessed. The full version of the CHAT, from which our TBI measure derived, is currently being used with all service users within the youth justice

system, however, this has not yet been replicated for the adult services. The use of a composite measure, of both previous lifetime injury and PCS may be helpful to identify those with more complex behavioural problems, who have greater vulnerability for recurrent future engagement with the CJS. This supports recommendations made by Williams et al. (2018).

Careful monitoring and assessment of those with injury extends beyond those within the CJS, and also applies to young people and young adults within the general population who have sustained a TBI. The second recommendation is to identify individuals at risk following an injury, including those categorised as 'mild', and to provide assessments of social functioning, substance misuse or other risky-behaviours, as well as monitoring engagement with their education or occupation over time. This would be to help identify and support those for whom maladaptive behaviour patterns emerge or amplify following a TBI and to help alleviate these behaviours or encourage alternative strategies to prevent them becoming ingrained. This may help to reduce initial contact with the CJS.

Finally, one of the strongest and most consistent effects observed within these analyses, and frequently reported within the wider literature, is the impairment in FAR in those with offending behaviour, compared to non-offending controls. There are discrepancies in the precise patterns of impairment, and as stated, further comparisons are needed against tightly-matched controls. However, the magnitude and consistency of this effect points to this domain as a possible target for intervention for use with offending populations and within the CJS. As differential processing in those with TBI within the CJS, in the domain of FAR, was not observed, I do not propose this be directed only at those with injuries but extend this possibility of intervention for use with the wider offending population. However, due to the high proportion of TBI and other forms of neurodisability reported within the CJS, it would be beneficial if tailored interventions in this domain were also suitable for use with service-users with identified neurodisability-related need (i.e. in terms of language accessibility and attentional demands).

### 5.3.5 Summary

Here I synthesised data from studies 1, 2 & 3 in a series of mini meta-analyses to address questions relating to TBI and FAR, PCS and additional measures of socioemotional processing and antisocial behaviour. Overall there was no clear evidence for an overall deficit in FAR in those with substantial TBI compared with non-injured controls. However, there was evidence for differential impairment for the emotion disgust compared to the other emotions, in those with substantial injury and weak evidence for an association between increased PCS and poorer FAR. PCS was also associated with increased aggression, delinquency and alexithymia. It is difficult to determine whether these reported PCS derive from earlier TBI or non-injury aetiology, but this points to important targets for future screening and assessment, to identify those with more complex behavioural profiles. There is consistent evidence for poorer FAR in those with offending behaviour in comparison with non-offending controls, across emotions except for recognition of happiness. As a consequence, I propose that targeting this domain for intervention in individuals with offending behaviour, may be beneficial in reducing maladaptive behaviour and improving social functioning.

Given that the application of FAR training as a behavioural intervention is a relatively new endeavour, across different populations with FAR deficit, I explore this possibility further in Chapter's six and seven. In Chapter six a systematic review is described, synthesising studies which have used FAR training with individuals with antisocial or aggressive behaviour, addressing research question five: are interventions targeting this domain effective at reducing antisocial behaviour? In Chapter seven, I describe a pilot and feasibility study conducted for a novel FAR training intervention, for use with violent offenders in a prison setting. This addresses research question six: would FAR interventions be appropriate for use with members of these populations, in incarcerated settings?



## **6 Facial affect recognition training interventions for antisocial and aggressive populations: a systematic review**

### **6.1 Acknowledgements**

This study was conducted in collaboration with Prof. Marcus R. Munafò, Prof. Ian S. Penton-Voak, Dr Gemma Taylor and Dr Michael N. Dalili, who contributed to the planning stages and screening of studies for inclusion and risk of bias. I would also like to acknowledge the assistance of our subject librarian, Sarah Herring for her expertise regarding search strategy formulation. All co-authors contributed to the drafting of the study manuscript for publication (in preparation).

### **6.2 Introduction**

As detailed at the end of Chapter five, here I describe the findings of a systematic review investigating the current use of FAR interventions for antisocial and aggressive populations. This review was conducted in parallel with the feasibility study and pilot trial described in Chapter seven and was designed to inform the future development of a FAR training intervention, for use with young people within the CJS. In the literature review in Chapter one, I present evidence describing FAR impairments within a variety of clinical populations, including TBI, schizophrenia, ASD and MDD. Targeting of this domain as a viable therapeutic intervention has become more popular, using training tasks and feedback techniques to improve FAR in populations where this ability is often impaired. These approaches aim to improve social functioning and wellbeing in the recipient as a consequence of improved FAR (Neumann, Babbage, Zupan, & Willer, 2015; Penton-Voak, Munafò, & Looi, 2017).

Based on the observation that offending, or antisocial populations tend to exhibit poorer FAR, I decided to explore whether this would also be a viable

intervention target for members of these populations. Here, antisocial behaviour is broadly defined here as behaviour which is likely to cause harassment, alarm or distress to one or more persons, whereas aggression is defined as feelings of anger or antipathy resulting in hostile or violent behaviour - constituting a form of antisocial behaviour. Development of a FAR training programme for use as an intervention tool, would aim to reduce aggressive behaviour through more positive or accurate interpretations of an individual's environments and interactions.

To inform this process, I initially sought to derive a more comprehensive synthesis of current studies investigating the use of FAR training approaches with aggressive or antisocial populations. I anticipated that there would be variety in the approaches used, including stimuli sets, populations targeted and outcome measures. Based on this I planned to qualitatively analyse the results only at this stage. Future quantitative meta-analyses of the findings would be considered if enough comparable studies were yielded. This chapter addresses the fifth thesis research question, 'would interventions targeting the capacity for FAR be effective in reducing antisocial or criminal behaviour?' (see section 1.8.1). The protocol for this review was registered on PROSPERO in December 2017 (CRD42017084391).

### *6.2.1 Study objectives*

This review aimed to:

1. Identify studies reporting the use of FAR training to reduce aggression or improve social functioning in people with antisocial or aggressive behaviour, with appropriate comparators.
2. Identify paradigms used and intervention parameters, including behavioural outcome measures and proposed active mechanisms.
3. Summarise the evidence that various intervention paradigms have an impact on relevant behavioural outcomes.

## 6.3 Methodology

### 6.3.1 Literature search

#### 6.3.1.1 Search strategy

The review was conducted according to PRISMA guidelines (<http://prisma-statement.org>). Electronic databases including: MEDLINE (PubMed), PsycINFO, Web of Science, CENTRAL and EMBASE were searched for relevant studies. I also searched clinical trial registries for unpublished or ongoing studies, as well as the databases CINHALL and PsycINFO for grey literature sources. These include dissertations and theses which may have included details of unpublished studies. I searched for relevant review articles and scanned the reference lists of these and the included studies to identify any additional relevant studies not yielded within the database searches. I also contacted authors of the included studies with enquiries regarding unpublished studies. All years were included, up to March 2018. I aimed to identify studies published in English.

The following search terms were used for the population of interest (MeSH terms highlighted in **bold**): **crime** OR **antisocial personality disorder** OR aggress\* OR **conduct disorder** OR antisocial. The following search terms were used for the intervention of interest: emotion recognition training OR facial affect recognition OR facial emotion recognition OR emotion recognition OR behaviour modification OR cognitive bias modification OR **social perception**. Population and intervention terms were combined using the Boolean operator 'AND'. I decided to include search terms for the population of interest and the intervention only, reflecting the exploratory nature of this review with the aim of maximising inclusivity. Variations of this search strategy were used for the additional databases, encompassing the search terms listed (or with controlled vocabulary database equivalents) and additional key text words. An example of the search strategy for MEDLINE (PubMed) is included within the appendices (A7). Search results were extracted, stored and managed in EndNote X8.

### 6.3.1.2 *Study selection*

Studies yielded by the database searches and reference lists were uploaded to Covidence and screened for eligibility following removal of duplicates. In the first stage of screening, studies were excluded if there was no mention of emotion recognition, facial expressions, or antisocial behaviour within the title or abstract. Following exclusion of irrelevant studies from the titles and abstracts, the remaining full-texts were screened for eligibility. Reasons for exclusion were recorded at this stage. A 100% eligibility assessment was conducted by two review authors independently (MC & MD) at both the title and abstract and full-text screening stages. Discrepancies were resolved by reaching consensus through discussion.

Inclusion criteria included: randomised or non-randomised control trials, or observational study designs; studies published in English; populations described as aggressive or antisocial (including those holding convictions for aggressive behaviour, or within a clinical population defined by aggressive behaviour such as conduct disorder, antisocial personality disorder, intermittent explosive disorder), or qualified as aggressive/high risk for violence using behavioural assessment; any age; any intervention attempting to modify FAR ability; a no treatment/training group or use of a 'sham' training condition as the intervention control; emotion recognition ability as an outcome measure and ideally a behavioural outcome relating to antisocial behaviour or social functioning; any study setting.

Exclusion criteria included: Animal (non-human) studies; review articles; FAR training within a larger battery of anger management or social functioning interventions where FAR improvement was not the primary outcome; emotion recognition training in primarily non-FAR modalities (e.g. training in recognition of intent in social scenarios or recognition of emotive vocal prosody); pharmaceutical interventions; studies where the target populations were characterised by serious psychiatric disorders (including, but not limited to: bipolar disorders, schizophrenia, paranoid and other psychotic disorders, major depressive disorders, pervasive developmental disorders, eating disorders and anxiety disorders) not defined by aggressive or antisocial behaviour. I did not

exclude studies where co-morbid disorders may have been present<sup>6</sup>, rather I identified and excluded studies who recruited on the basis of a psychiatric disorder.

### 6.3.2 *Data extraction*

I completed the data extraction and a 10% extraction check was conducted by the second review author (MD). Pre-specified data was extracted from each study and recorded in the data extraction spreadsheet. This included study characteristics, participant characteristics, type of antisocial behaviour, control group characteristics, intervention characteristics and the type of outcome data provided.

### 6.3.3 *Risk of bias and study quality*

For randomised control trials (RCT) the Cochrane risk of bias (RoB) tool (Higgins et al., 2011) was used to assess RoB and for non-randomised studies quality was assessed using the Newcastle-Ottawa Scale (NOS; Wells et al., 2016). Two researchers (MC & MD) assessed all included studies independently during the data extraction phase<sup>7</sup>. The Cochrane RoB tool examines a range of methodological domains for potential bias (including blinding, selective reporting, inadequate randomisation), giving a rating of 'low', 'high' or 'unclear' for each. The highest risk rating given is used as the overall risk outcome for the study. The NOS assesses eight items, within three broader quality domains including: selection of study groups; comparability of study groups; and ascertainment of exposure or outcome of interest. For judgements of high-quality methodology within the domains, a star is awarded, and each study can score up to a maximum of nine stars.

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<sup>6</sup> For studies where participants had co-morbidities present, I extracted information regarding this to present in the narrative synthesis.

<sup>7</sup> With the exception of one article co-authored by MD. Second assessment completed by GT

## 6.4 Results

### 6.4.1 Study selection

**Figure 6.1** outlines the search process using a PRISMA flow diagram. The initial search yielded 2548 articles, excluding duplicates. Fifty-seven of these articles were identified for full-text review, of which 46 were excluded. The reasons for exclusion are detailed in **Figure 6.1**. Ten articles were identified for extraction, and one ongoing trial was also identified. Within these ten articles there were details of eleven separate studies (two studies were included within one of the articles). During extraction, a study was excluded from the outcome synthesis due to incorrect study design (lack of comparator), which prevented assessment of study quality. Eleven studies were described in terms of characteristics and ten were synthesised in relation to their outcomes. This included five grey literature sources. A list of included studies and details of the ongoing trial can be found at the end of this chapter.

### 6.4.2 Study characteristics

Of the eleven studies the majority were RCT's, with three non-randomised studies. Studies were published between 2012 and 2018 (or were currently in preparation for publication). See **Table 6.1** for a detailed summary of study characteristics.

This synthesis contains information relating to  $n = 405$  antisocial individuals who received some form of FAR training,  $n = 341$  matched antisocial counterparts who received a control or sham version of the intervention, or no training (treatment as usual; TAU) and  $n = 62$  controls without history of antisocial or violent behaviour, who received the intervention or were used for comparison of performance on outcome assessments. Discrepancies between these values and those detailed in **Table 6.1** derive from the use of multiple comparators in the study described in Schöenberg et al. (2014). The main comparison group for Schöenberg et al. (2014) (detailed in **Table 6.1**) is a matched group of violent offenders who took part in a different variant of FAR training. The performance on the main outcome of interest (FAR performance on a separate task) for both sub-groups of offenders was also compared

**Figure 6.1** PRISMA flow diagram depicting the search process

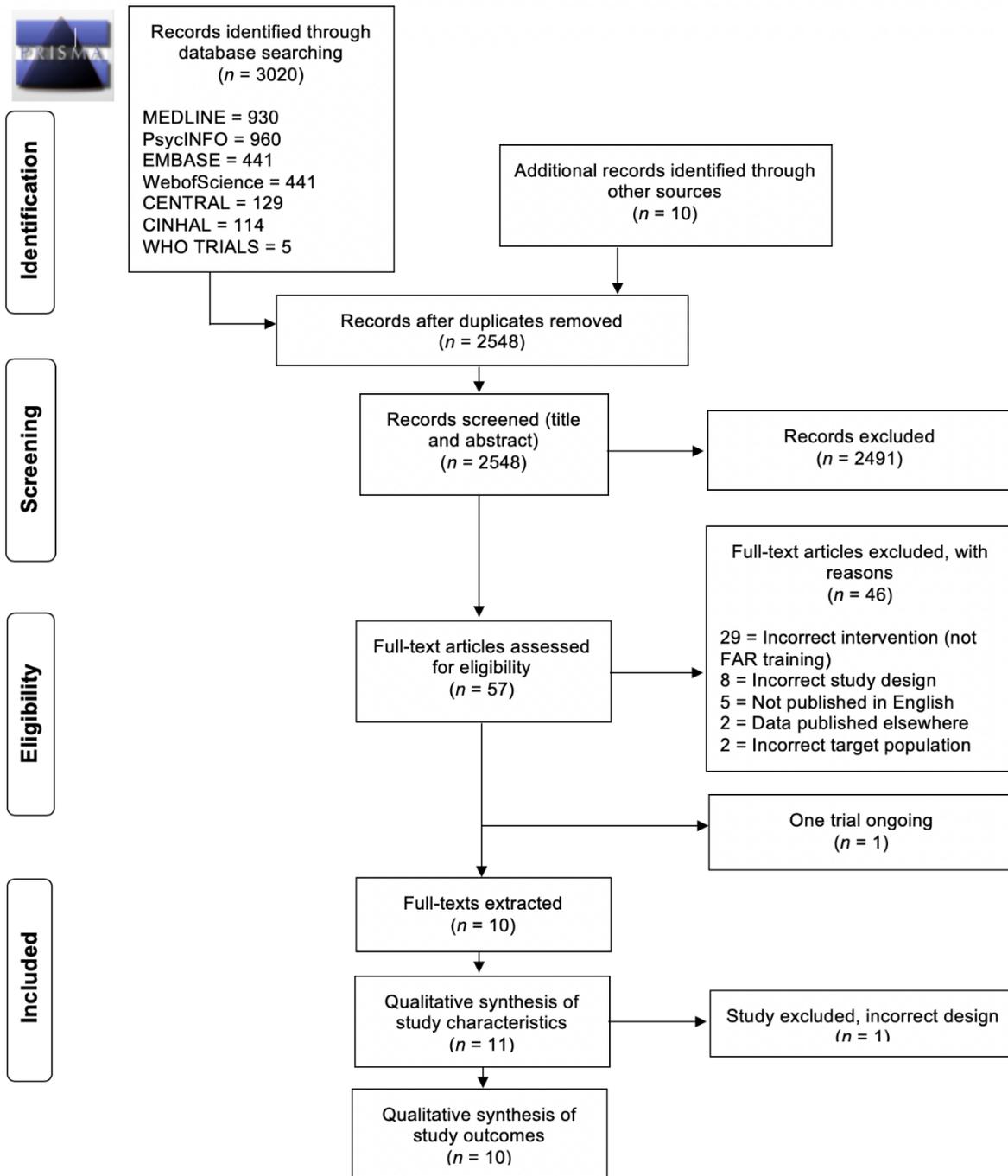


Diagram adapted from Moher, Liberati, Tetzlaff, and Altman (2009)

**Table 6.1** Study characteristics for all studies included in the data extraction phase

Author	Year	Location	Study design	N (cases)	N (controls)	Controls	Antisocial behaviour	Definition	Age group	Age Cases	Age controls	% Female Cases	% Female Controls	Education	IQ	Psychopathic	Comorbidity
Dadds	2012	Australia	RCT	87	109	Matched	Behaviour management problems	Diagnosed by clinician	Children	10.4 (2.4)	10.6 (2.8)	28	22	Not stated	Matched	Unclear	Yes, no major neurological or physical illness
Heimstra (a)	In prep	Netherlands	RCT	36	34	Matched	Clinically referred aggression	Affiliation w/ school	Children & early adolescents	11.9 (1.0)	11.4 (1.0)	0	0	Matched	Not stated	Matched	Yes, details unclear
Heimstra (b), Study 1	In prep	Netherlands	RCT	28	31	Matched	Clinically referred aggression	Affiliation w/ school	Children & early adolescents	11.6 (range: 9.4 - 13.0)	11.0 (range: 9.1 - 14.0)	0	0	Matched	Not stated	Not stated	Yes, details unclear
Heimstra (b), Study 2	In prep	Netherlands	RCT	43	32	Matched	Clinically referred aggression	Affiliation w/ school	Children & early adolescents	11.6 (1.0)	11.0 (1.1)	0	0	Matched	Not stated	Not stated	Yes
Hubble	2015	UK	Non-randomised trial	24	26	Matched	Offending general	Criminal conviction	Adolescents	16.08 (1.2)	16.35 (1.2)	0	0	Not stated	Matched	Matched	Not stated
Kuin	In prep	Netherlands	RCT	45	41	Matched	Offending general	Criminal conviction	Adults	37.3 (11.0)	41.9 (11.6)	0	0	Unclear	Unclear	Not stated	Unclear; No serious psychiatric disorders in previous 3 months
Maoz	In prep	UK & Israel	RCT	77	79	Matched	High trait anger	State anger expression inventory threshold	Young adults	21.85 (CI: 21.1 - 22.56)	22.55 (CI: 21.75 - 23.35)	62.5	63.8	Matched	Not stated	Not stated	Not stated
Penton-Voak	2013	UK	RCT	23	23	Matched	High trait aggression, high risk of crime	Affiliation w/ Youth Offending Team	Adolescents	13.22 (0.28)	13.48 (0.35)	28% across whole group	28% across whole group	Not stated	Not stated	Not stated	Not stated
Schönenberg	2014	Germany	RCT & Case-control	22	22	Matched	Violent offenders	Criminal conviction	Adults	34.86 (11.09)	35.77 (9.77)	0	0	Matched	Not stated	Unclear	Unclear; No schizophrenia or IQ disability
Seinfeld	2018	Spain	Case-control	20	19	Non-aggressive	Domestic violence offenders	Criminal conviction	Adults	38.75 (8.52)	35.95 (10.63)	0	0	Matched	Not stated	Not stated	Yes, no epilepsy
Stoddard*	2016	USA	Open-pilot training trial	14		No control	Disruptive mood dysregulation disorder	Diagnosed by clinician	Adolescents	13.4 (2.8)		57					Yes, no MDD, psychosis, ASD, PTSD, substance use, head trauma, mania, IQ disability

Affiliation w/ school within 'definition' refers to a specialist school for children with chronic behavioural problems. DMDD = Disruptive mood dysregulation disorder, characterised by abnormally angry or irritable mood, with inappropriate behavioural outbursts. MDD = Major depressive disorder; ASD = Autism Spectrum Disorder; PTSD = Post traumatic stress disorder. \*Study not included in narrative synthesis of outcomes or final study count due to lack of comparison group.

against non-offending controls ( $n = 43$ ) who did not complete any form of FAR training intervention.

Antisocial or aggressive populations detailed within these studies included five samples of people with offending behaviour, who had either been convicted of crimes (four studies) or had been referred to offending services as they were high risk for criminal behaviour (one study). Two of these recruited violent criminal populations specifically, and the remaining three included those with more general offending behaviour (inclusive of violent crime). Of the remaining studies, five studies recruited individuals with behaviour management disorders or clinically referred aggressive behaviour. One study recruited members of the general population with high trait anger. Of those with offending behaviour, their aggression or antisociality was qualified by their convictions or CJS affiliation. Those with behaviour management problems were qualified by assessment and diagnosis from clinical professionals, or affiliation with a specialised education service for children with severely disruptive behaviour. Those with high trait anger were identified using the validated State-trait anger expression inventory (STAXI-2) (Spielberger, 1999).

Of these eleven studies, four included studies of children and young adolescents, three recruited adolescents specifically, and four recruited adult populations. Comparison groups were well matched based on age, and for any studies where discrepancies arose, age was adjusted for in the analysis. Four of the eleven studies included females, with the remaining studies recruiting male participants only. In general, included studies measured and matched comparison groups by either education level, or IQ. Penton-Voak et al. (2013) is an exception, where matching on this basis is not mentioned, and for Kuin, Masthoff, Nunnink, Munafò, and Penton-Voak (in prep) it is unclear as to whether the differences in education reported are qualitatively different. Few of the included studies measure for psychopathic traits, and of those that do, only two of the studies appear to be matched on this domain. Dadds, Cauchi, Wimalaweera, Hawes, and Brennan (2012) categorises participants based on presence of callous-unemotional traits, however the frequencies of those dichotomised as having high or low callous-unemotional traits for different training conditions are not provided. Schönenberg et al. (2014) measured offenders psychopathic traits using the psychopathic personality inventory

revised (PPI-R) (Lilienfeld & Widows, 2005), however the differences between the antisocial groups are not reported, and this measure is not used in the non-offending controls.

There was a high prevalence of co-morbid health disorders within the included populations. Six studies refer to the presence of comorbidity generally, five exclude based on co-morbidities (including serious psychiatric conditions such as schizophrenia, psychosis, mania and major depressive disorder (MDD) in previous 3-6 months; epilepsy; major neurological illness). Two refer to excluding based on intellectual disability, although a further two studies exclude based on 'insufficient language comprehension' which may encapsulate those with intellectual disabilities (Schönenberg et al., 2014; Seinfeld et al., 2018). Stoddard et al. (2016) are the most comprehensive in their exclusions, and exclude based on euphoric mood, manic episodes, a six-month history of MDD, post-traumatic stress disorder (PTSD), conduct disorder (CD), psychosis, autism spectrum disorder (ASD), those with chronic or active medical conditions, psychoactive substance use in previous two months, history of head trauma, current psychotropic medication use and an intelligence quotient score of less than 70. Within **Table 6.1** 'unclear' in the comorbidity column relates to those who mention exclusion of particular psychiatric diagnoses, but with no measurement of additional health comorbidities. For those who screen for comorbid health disorders (without excluding on this basis), it's suggested that co-morbidity of ADHD, oppositional defiant disorder (ODD), CD, anxiety and depression, ASD and MDD are common (Dadds et al., 2012; Heimstra, de Castro, & Thomaes, in prep-a, in prep-b; Stoddard et al., 2016).

#### *6.4.3 Risk of bias and study quality*

The RoB assessments for RCT's are summarised in **Table 6.2**. For all included studies with RCT design, the RoB was judged to be either 'High' (Dadds et al., 2012), or 'Unclear'. The rationale for 'high risk' judgements for Dadds et al. (2012), derived from the quasi-randomisation procedure used to assign treatment groups, and an inability to blind participants to the intervention or 'treatment as usual' group. For the studies judged as having 'unclear risk' this commonly derived from insufficient information provided regarding

randomisation, blinding and allocation procedures, a lack of a pre-registered study protocol to assess selective reporting, or insufficient information regarding participant drop-out.

Non-RCT study quality assessments are summarised in **Table 6.3**. In the majority of domains, methodology used was judged to be of high quality, reflected in the affiliated scoring. In some instances, the judgement domain was not applicable with the study methodology used (denoted with 'X'). However, some studies gave insufficient detail regarding recruitment of study controls and ascertainment that they did not have history of violent or antisocial behaviour. Furthermore, as studies were selective in their recruitment and did not always provide reasons for exclusion, findings may not be generalisable to wider offending or antisocial populations and risk of selection biases in recruitment is elevated.

#### *6.4.4 Intervention characteristics*

There were several FAR interventions detailed within the included studies. This included: cognitive bias modification (CBM), attention training tasks (ATT), sensitivity to emotional expressions (SEE) tasks, virtual reality (VR) embodiment, and more comprehensive, holistic interventions which combined different strategies to train FAR. See **Table 6.4** for a detailed summary of interventions used, their paradigm parameters and FAR outcome measures.

##### *6.4.4.1 Cognitive bias modification paradigms*

As mentioned briefly in Chapter one, CBM builds on attribution theory, suggesting that some individuals may have perceptual or cognitive biases which affect the way they interpret their surroundings (for example, being more likely to interpret ambiguous emotional expressions as hostile). Modification techniques aim to manipulate this bias by giving adapted feedback, encouraging a shift in perception away from the maladaptive bias and towards more positive or adaptive interpretation. The majority of studies included within

**Table 6.2** Risk of bias assessment for randomised control trials

COCHRANE RoB Tool	Random sequence generation	Justification	Allocation concealment	Justification	Blinding of participants and personnel	Justification	Blinding of outcome assessment	Justification	Incomplete outcome data	Justification	Selective reporting	Justification	Overall
<b>Dadds</b>	High risk	Quasi-randomised, based on participant birthdate	High risk	Randomisation based on participants birthdate	High risk	Intervention versus treatment-as-usual	High risk	Unblinded; completed by parents and teachers	Low risk	No difference in drop-out between the two conditions, intention-to-treat analysis	Unclear risk	No published study protocol or registration	<b>High risk</b>
<b>Heimstra (a)</b>	Unclear risk	No description of randomisation procedure	Unclear risk	Allocation concealment not described	Unclear risk	Teachers blinded, but no indication of whether blinding was effective. Unclear whether experimenter was also blinded.	Low risk	Mainly objective outcome measures or ratings completed by blinded teachers	Unclear risk	70 of 87 participants completed the study (80.5%), but sensitivity analyses and drop-outs by arm not reported	Unclear risk	No published study protocol or registration	<b>Unclear risk</b>
<b>Heimstra (b), Study 1</b>	Unclear risk	No description of randomisation procedure	Unclear risk	Allocation concealment not described	Unclear risk	Subjects and teachers blinded, no assessment of whether blinding effective or mention of experimenter blinding	Low risk	Mainly objective outcome measures or ratings completed by blinded teachers	Unclear risk	59 of 78 participants completed the study (75.6%) but drop-outs by arm not reported	Unclear risk	No published study protocol or registration	<b>Unclear risk</b>
<b>Heimstra (b), Study 2</b>	Unclear risk	No description of randomisation procedure	Unclear risk	Allocation concealment not described	Unclear risk	Subjects and teachers blinded, no assessment of whether blinding effective or mention of experimenter blinding	Low risk	Mainly objective outcome measures or ratings completed by blinded teachers	Unclear risk	75 of 87 participants completed the study (86.2%) but drop-outs by arm not reported	Unclear risk	No published study protocol or registration	<b>Unclear risk</b>
<b>Kuin</b>	Low risk	Use of a randomisation tool	Unclear risk	Allocation concealment not described	Low risk	Use of blinded computer codes to inform task condition, neither participants or trainer were made aware of condition (double-blind)	Unclear risk	Described as double-blind but blinding of outcome assessor not described	Low risk	90% and 83% completed by intervention and controls, due to prison transfer or release	Unclear risk	No published study protocol or registration	<b>Unclear risk</b>
<b>Maoz</b>	Unclear risk	No description of randomisation procedure	Unclear risk	Allocation concealment not described	Unclear risk	Blinded, but method of blinding and whether effective not described	Unclear risk	Blinding procedures not described	Low risk	Missing outcome data balanced in numbers across intervention groups, with similar reasons for missing data	Unclear risk	No published study protocol or registration	<b>Unclear risk</b>

<b>Penton-Voak</b>	Unclear risk	No description of randomisation procedure	Unclear risk	Allocation concealment not described	Unclear risk	Blinded, but method of blinding and whether effective not described	Low risk	Completed by staff members of the youth programme who were blind to the participants training condition	Unclear risk	Intention-to-treat used, drop-out not reported by arm, reasons for drop-out not detailed	Unclear risk/Low risk	No published study protocol or registration, however all main outcomes reported	<b>Unclear risk</b>
<b>Schönenberg (RCT)</b>	Unclear risk	No description of randomisation procedure	Unclear risk	Allocation concealment not described	Unclear risk	Participants and experimenters blinded, but method of blinding and whether effective not described	Unclear risk	Blinding procedures not described	Low risk	No drop out, complete dataset	Unclear risk	No published study protocol or registration	<b>Unclear risk</b>

Highest risk of bias score received dictates overall judgement. Higher scores mean higher risk of bias.

**Table 6.3** Study quality assessment for non-randomised studies

Newcastle-Ottawa Scale	Case selection	Justification	Representative of cases	Justification	Selection controls	Justification	Definition controls	Justification	Comparability age	Justification	Comparability education	Justification	Ascertainment exposure	Justification	Ascertainment case controls	Justification	Non-response Rate	Justification	Overall
<b>Hubble</b>	a (*)	Based on conviction, recruited through youth offending team	b	Recruited via caseworkers, recommended suitable participants (possible selection bias)	a (*)	Drawn from the same community as cases	X	Controls same definition as cases, but non-randomised design. High risk of bias.	a (*)	Groups comparable in terms of age	a (*)	IQ used as measure of educational ability, well matched	a (*)	Based on conviction, recruited through youth offending team	a (*)	Yes, same ascertainment used for both groups	a (*)	No participants dropped out from the study	7
<b>Schönenberg (case-control)</b>	a (*)	Based on conviction	b	Only violent, psychopathic male offenders	a (*)	Recruited from institute database	b	Assume no previous violent history, but no explicit mention	a (*)	Not well matched, but adjusted for in outcome	a (*)	Groups comparable in terms of education	a (*)	Based on criminal records	b	Not same ascertainment for controls	a (*)	No drop-out in any group described	6
<b>Seinfeld</b>	a (*)	Based on conviction, sentenced to domestic violence intervention programme	b	17/37 not eligible based on exclusion criteria or due to missing data. Potential for selection bias.	a (*)	Recruited via advertisement in the community	a (*)	No history of domestic violence, carefully screened for history of violence or dysfunctional relationships	a (*)	Groups comparable in terms of age	a (*)	Groups comparable in terms of education	a (*)	Based on conviction, sentenced to domestic violence intervention programme	a (*)	Yes, not affiliated with intervention programme and carefully screened for violence	X	Unclear, numbers or losses to follow-up not stated	7

X – judgement not appropriate. (\*) = star awarded for best quality, summated to generate overall score. Higher score means higher study quality rating.

**Table 6.4** Characteristics of facial affect recognition training interventions

Author	Year	Intervention	Intervention validated	Stimuli set	Stimuli validated	Type of stimuli	Morphed?	Presentation Time	Response Option	Accessible	Primary FAR outcome measure	Type of Stimuli	Morphed	Presentation time	Response option	Data available?
Dadds	2012	Holistic	Yes	Created for purpose	Yes	Dynamic	No	Unclear	Variable	Yes	FACES accuracy	Static	No	2000ms	6AFC	Not stated
Heimstra (a)	In prep	CBM	No	Created for purpose	No	Static	Yes	500ms	2AFC	Not stated	Attribution threshold					Not stated
Heimstra (b) Study 1 & 2	In prep	CBM	No	Created for purpose	No	Static	Yes	500ms	2AFC	Not stated	Attribution threshold					Not stated
Hubble	2015	Holistic	No	Pennsylvania Emotion Recognition Test	Yes	Static	No	No limit	Variable	Not stated	Facial Emotion Recognition measure accuracy	Static	Yes	Not stated	6AFC	Yes
Kuin	In prep	CBM	No	Karolinska Directed Emotional Faces, composite images used	No	Static	Yes	150ms	2AFC	Not stated	Attribution threshold					Not stated
Maoz (TAU)	In prep	CBM	No	NimStim stimuli set	No	Static	Yes	200ms	2AFC	Not stated	Attribution threshold					Not stated
Maoz (UoB)	In prep	CBM	No	Karolinska Directed Emotional Faces, composite images used	No	Static	Yes	150ms	2AFC	Not stated	Attribution threshold					Not stated
Penton-Voak	2013	CBM	No	Karolinska Directed Emotional Faces, composite images used	No	Static	Yes	150ms	2AFC	Not stated	Attribution threshold					Not stated
Schönenberg	2014	ATT	No	Rodbound Faces Database	Yes	Static /Dynamic	Yes	1000ms	Direction arrow (2AFC)	Not stated	Intensity score on 'morphing' task	Static /Dynamic	Yes	500ms	Button press as soon as identified (% intensity); 6AFC	Not stated
Schönenberg	2014	SEE	No	Rodbound Faces Database	Yes	Static /Dynamic	Yes	1000ms	Direction arrow (2AFC)	Not stated	Intensity score on 'morphing' task	Static /Dynamic	Yes	500ms	Button press as soon as identified (% intensity); 6AFC	Not stated
Seinfeld	2018	VR Embodiment	No	Created for purpose	Pilot study validation	Dynamic	n/a	n/a	n/a	Not stated	Face-Body compound test accuracy	Static	No	100ms	2AFC (happy-angry; happy-fear)	On request
Stoddard*	2016	CBM	No	Karolinska Directed Emotional Faces, composite images used	No	Static	Yes	150ms	2AFC	Not stated	Attribution threshold					Not stated

For Moaz (in prep) there are two variants of the task: TAU = Tel Aviv University; UoB = University of Bristol. CBM = Cognitive bias modification; (Schönenberg) ATT = Attention training task; SEE = Sensitivity to emotional expressions task; VR = virtual reality. AFC = alternative forced choice, with the associated number denoting the number of alternative choices. The grey highlighted sections correspond with FAR outcomes encompassed within the intervention (same parameters apply)

this review adopted this approach, building on earlier work conducted by Penton-Voak et al. (2013), and adopting either the same or analogous paradigms (Heimstra et al., in prep-a); (Heimstra et al., in prep-b); (Kuin et al., in prep); (Maoz et al., in prep); (Stoddard et al., 2016).

Penton-Voak et al. (2013) generated prototypical happy and angry composite images, by combining photographs of twenty male individuals (derived from the Karolinska Directed Emotional Faces database) showing happy and angry emotions. These were then morphed to create a 15-image linear sequence changing incrementally from unambiguously happy to unambiguously angry, with ambiguous composites between the two expressions in the sequence mid-point. The intervention involved a baseline phase, requiring the participant to make a dichotomous judgement as to whether the face was happy or angry, calculating an individual's threshold balance-point. This was followed by a training phase giving explicit feedback as to whether the response was correct or incorrect. The training condition gives adjusted feedback, attempting to shift participant responses away from hostility biases towards the positive end of the spectrum. In the control version unadjusted feedback is given, reflecting the individual's original baseline threshold without any attempt to manipulate participant response. Following training, the threshold balance-point is recalculated to investigate whether there is threshold shift from baseline. See Chapter seven for a detailed description of this task version.

Stoddard et al. (2016) employed the same intervention as used in Penton-Voak et al. (2013), described above. (Heimstra et al., in prep-a; in prep-b) used a similar intervention format, with 15-equally spaced images across a linear morph sequence, with a novel stimulus set creating composite images from nine images of boys, aged 10 – 15 years old, (subsequently morphed), to reflect the population of interest within their studies. Heimstra et al. (in prep-a) also created an additional linear morph sequence, morphing from anger to fear (rather than anger to happiness), which they used in an attempt to modify biases in perception away from hostile attributions, whilst simultaneously increasing sensitivity to fearful expressions. Kuin et al. (in prep) used the adult male stimuli set (as used in Penton-Voak et al. (2013); (Stoddard et al., 2016)) but modified the task slightly, presenting more ambiguous expressive stimuli

more frequently, and incorporating non-verbal feedback cues into the training trials to aid comprehension (green ticks and red crosses). Maoz et al. (in prep) included two versions of the intervention, one used at the University of Bristol (UoB) site, which replicated that detailed previously (Penton-Voak et al., 2013; Stoddard et al., 2016), and one used at Tel Aviv University (TAU). The TAU version used morphed images generated from stimuli from the NimStim set (Tottenham et al., 2009), including female faces, a slightly longer duration of presentation for facial stimuli and modified parameters for a visual mask which followed stimulus presentation. All CBM studies measured their primary outcomes as changes in threshold balance-points (attribution balance points) following training, utilising the same stimuli as in the training phase of the tasks.

#### *6.4.4.2 Attention training task*

ATT's draw from the theory that some individuals may have poorer FAR due to an inability to effectively attend to emotional expressions or facial features. The intervention attempts to address this by directing attention, either explicitly or implicitly, to specific regions of the face. This approach has been used previously with other clinical populations, including people with schizophrenia (Marsh et al., 2010; Russell, Chu, & Phillips, 2006) and ASD (Begeer, Rieffe, Terwogt, & Stockmann, 2006).

The 'Mind reading' programme is an interactive, systematic guide to emotions (Golan & Baron-Cohen, 2006), developed for use with people with ASD. It employs strategies to direct attention in combination with video clips and voice recordings to provide cues and aid identification of affective expressions, tailored for different developmental stages. Dadds et al. (2012) used this holistic programme with the children recruited in their study. Schönenberg et al. (2014) employed an ATT with a sub-set of violent offenders, using an implicit dot-probe task which directed participant's attention to fearful facial expressions at 75% intensity. Participants in Schönenberg et al. (2014) completed four weekly sessions (length of time taken not specified), and were tested on an analogous morphing task following completion of the intervention to assess improvement in FAR. Participants in Dadds et al. (2012), also completed four sessions, lasting 90 minutes each (however the time-frame between sessions is unclear). Dadds

et al. (2012) compared FAR in those in the 'mind reading' intervention group against a group who received treatment-as-usual, post-intervention, using a validated FAR measure (Dadds, Hawes, & Merz, 2004).

#### *6.4.4.3 Sensitivity to emotional expressions task*

A modified version of the ATT task, the SEE task, was administered to the other sub-set of violent offenders included within the Schönenberg et al. (2014) study. This version attempted to improve sensitivity for subtler emotional cues by gradually reducing the expressivity of emotional expressions across training sessions. This strategy was also employed in the training used in Hubble, Bowen, Moore, and van Goozen (2015), again adopting a more holistic approach, including attentional direction, explicit feedback techniques, mimicry of emotional expressions, and graded difficulty at later stages in training through reduction in cue expressivity. This was a FAR orientated sub-section of a wider emotion recognition training programme, developed for people with severe TBI (Neumann et al., 2015), and was delivered over 2-3 sessions in the space of two weeks (approx. 2 hours total). Hubble et al. (2015) measured FAR outcome using a separate FAR measure (detailed in Bowen, Morgan, Moore, and van Goozen (2014)).

#### *6.4.4.4 Virtual reality embodiment*

VR embodiment is a novel approach, which uses immersive VR technology to create a virtual scenario where, in the case of Seinfeld et al. (2018), the male participant embodies a female avatar. Within this study the VR scenario then involved the participant experiencing both verbal and physically abusive behaviour from a virtual male aggressor. This included emotional taunting, throwing of a physical object with intimidating intent, and invasion of the female avatar's personal space. This intervention was designed for use with male perpetrators of domestic violence and was constructed to relate specifically to that population, enabling the perpetrators to take the perspective of their female victims and better recognise their emotive facial expressions. The participants took part in one single session. The effect of the intervention

on offenders and controls was measured using a FAR face-body paradigm, administered prior to and following the VR experience. This involved creation of congruent and incongruent bodily and facial emotional expressions. Participants were required to give a forced-choice response for the emotion displayed by the face (happiness versus fear; happiness versus anger) and told to ignore the bodily emotion.

#### *6.4.5 Primary outcomes, facial affect recognition*

##### *6.4.5.1 Cognitive bias modification*

As the majority of included studies employed similar CBM paradigms, these have been synthesised and compared in relation to their primary outcome of interest - attribution threshold shift on the task following training - for those receiving the active intervention in comparison to those in the control condition. There was variation in reported outcomes between studies, with some omitting average means and indices of statistical variation, and others omitting any measure of statistical variance, obscuring computation of effect sizes. However, as all CBM studies used a continuum of 15 equally spaced images from which to derive an attribution threshold (balance-point), this allowed conversion of the scores to comparable proportions of pre- and post- training attribution thresholds. Available means, and mean differences are reported in **Table 6.5**. Indices of variation are reported where available, and results of statistical models investigating evidence for these effects are also reported, with details of adjustment for confounding factors. Maoz et al. (in prep) in addition to their training paradigms included a different version of the post-training assessment, with novel stimuli from the NimStim set to assess near transfer of training effects to new facial stimuli. These results are also reported within **Table 6.5**.

**Table 6.5** Primary FAR outcomes for CBM interventions

Study	Pre-training threshold	Post-training threshold	Pre-control threshold	Post-control threshold	Post-training threshold vs control (0 - 1)	Adjusted?	Reported experimental condition effect	No. of sessions
Heimstra (a) anger	0.52	0.4	0.49	0.47	0.10 (adj)	Baseline attribution age	Model change with addition of condition predictor: R <sup>2</sup> change of 0.13 (F <sub>(3, 66)</sub> = 10.62, <i>p</i> < 0.001). Training condition shift: β = -0.37, <i>t</i> <sub>(67)</sub> = 3.54, <i>p</i> < 0.01	3
Heimstra (a) fear	0.59	0.64	0.62	0.58	-0.06 (adj)	Baseline attribution; age	Training condition shift: β = 0.23, <i>t</i> <sub>(67)</sub> = 1.92, <i>p</i> = 0.06	2
Heimstra (b) Study 1	0.49	0.31	0.49	0.5	0.20 (adj)	Baseline attribution	Model change with addition of condition predictor: R <sup>2</sup> change of 0.44 (F <sub>(2, 56)</sub> = 59.13, <i>p</i> < 0.001)	5
Heimstra (b) Study 2	0.51	0.4	0.5	0.52	0.11 (adj)	Baseline attribution; age	Model change with addition of condition predictor: R <sup>2</sup> change of .12 (F <sub>(3,71)</sub> = 25.15, <i>p</i> < 0.001)	3
Kuin	0.46	0.2	0.46	0.43	0.25 (adj) (95% CI: 0.19 to 0.31)	Baseline attribution; age; IQ; moderator age X condition)	Post-train 95% CI -4.6 to -2.8, <i>p</i> < 0.001, intervention group only	5
Maoz	0.55 (95% CI: 0.53 to 0.57)	0.40 (95% CI: 0.38 to 0.43)	0.56 (95% CI: 0.54 to 0.58)	0.56 (95% CI: 0.54 to 0.59)	0.15	No	Main effect of condition: F <sub>(1, 148)</sub> = 35.44, <i>p</i> < 0.001, η <sup>2</sup> <sub>p</sub> = .19; training group shift: <i>t</i> <sub>(76)</sub> = 14.57, <i>p</i> < .001, Cohen's <i>d</i> = 1.70, control group shift: <i>t</i> <sub>(76)</sub> = 0.57, <i>p</i> > 0.25 ( <i>d</i> not given)	2
Maoz (near transfer)	0.55 (95% CI: 0.54 to 0.57)	0.46 (95% CI: 0.44 to 0.48)	0.56 (95% CI: 0.54 to 0.57)	0.57 (95% CI: 0.55 to 0.59)	0.11	No	Main effect of training Condition F <sub>(1, 148)</sub> = 26.57, <i>p</i> < 0.001, η <sup>2</sup> <sub>p</sub> = 0.15; training group shift, <i>t</i> <sub>(38)</sub> = 7.41, <i>p</i> < 0.001, Cohen's <i>d</i> = 1.20 and <i>t</i> <sub>(37)</sub> = 3.85, <i>p</i> < 0.001, Cohen's <i>d</i> = 0.64 for the TAU and UoB task versions, respectively	2
Penton-Voak					0.28 (SE: 0.08)	No	<i>b</i> = 4.22, SE = 1.23, <i>t</i> <sub>(36)</sub> = 3.33, <i>p</i> = 0.003	4

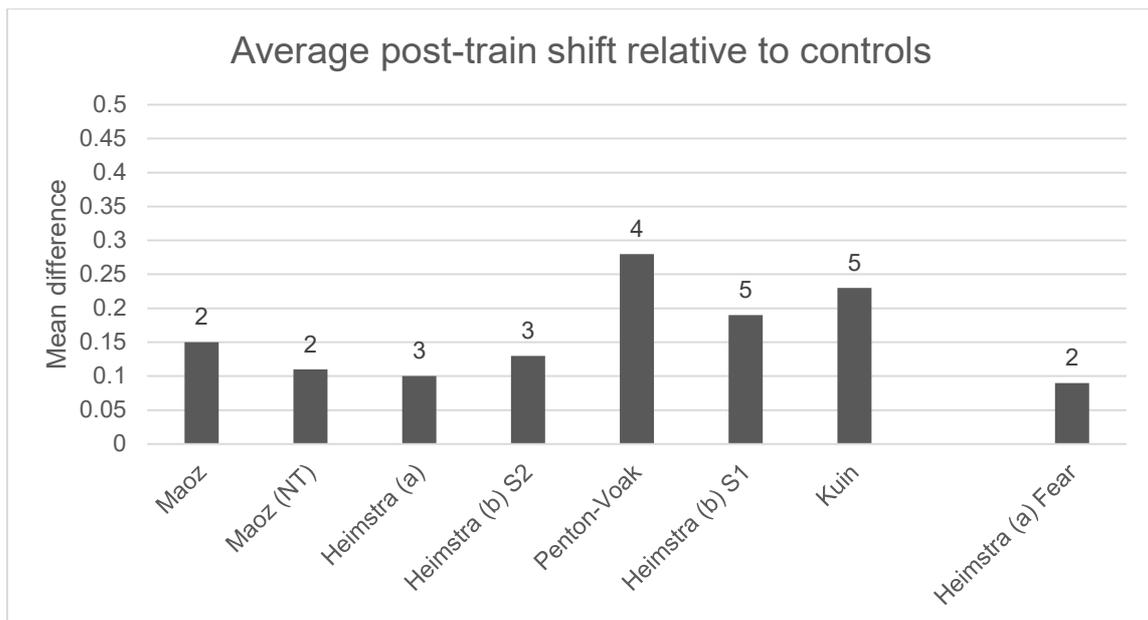
Threshold mean differences between training and controls are presented on a scale between 0 – 1 (converting raw scores /15, and % responses). These values are derived directly from adjusted regression models (adj) if provided, converted from unstandardized beta values or calculated from the provided means. Measures of variation are reported where provided (95% CI = 95% confidence intervals; SE = standard error). The original scores for Kuin (in prep) have been inverted to represent the proportion of ‘anger’ responses (rather than ‘happy’ responses), corresponding with the other presented studies.

For all studies, a shift towards identification of ambiguous faces as happy over angry is reported, indicated by reduced mean proportion of anger responses following training in the intervention group compared to those in the control condition. The exception to this, is in the Heimstra et al. (in prep-a) study, which attempted to train participants to be more sensitive to fearful facial expressions (see ‘Heimstra (a) Fear’ in **Figure 6.2**). They report weak evidence for a small increase in proportion of ‘fearful’ responses in the training group, compared to controls. The relative mean difference’s in proportion of anger (or fear) responses are presented in **Figure 6.2**. Based on the reported *p*-values, evidence for a modifying effect of CBM training on threshold responses is strong, with a reduction in hostile attributions in favour of positive attribution (*p* < 0.001 – *p* < 0.01) and weak evidence for an effect on fearful attributions (*p* < 0.1 - *p* > 0.05). There appears to be variation in the magnitude of these effects, although this should be verified in future using standardised mean differences. In addition, studies varied in the number of training sessions received.

Comparing mean difference by number of training sessions gave evidence for a linear trend ( $p = 0.006$ , 95% CI = 0.05 to 0.15), with increasing threshold score differences (i.e. greater shift towards positive attribution) in those who received a higher number of training sessions.

One study (Kuin et al., in prep) included an additional follow-up assessment to investigate whether any changes in threshold shift were maintained. They assessed participants at a 6-week period following training and found a maintained shift in the training group relative to controls of 0.17 (0 – 1 scale), with a reduction of 0.08 in mean difference from the 5-weeks previous. This suggested the effects of the intervention were maintained over a longer time period.

**Figure 6.2** Mean difference in threshold shift for training group relative to controls



Scores are presented on a scale between 0 and 1, with larger mean difference in post-training threshold scores indicating greater modification of attribution biases. Studies are presented in order of number of administered sessions (depicted as data labels). NT = Near Transfer.

#### 6.4.5.2 Non-CBM FAR outcomes

Dadds et al. (2012) measured overall FAR accuracy on the Family and Child Experiences Survey (FACES), an established measure of FAR where participants are asked to identify the emotion (happy, sad, angry, fearful, disgust or neutral) from static stimuli presented on a computer monitor. They

found no evidence that those in the FAR intervention group showed any improvement in overall FAR accuracy at the 6-month follow up, in relation to those in the treatment-as-usual group.

Hubble et al. (2015) measured FAR accuracy post-training using the 'facial emotion recognition task (as used in Bowen et al. (2014)). They found evidence for interaction effects between time (baseline and post-training), condition (intervention versus controls) and emotion (happy, sad, angry, fearful, disgust). They explored this further with factorial ANOVA's, and found strong evidence for an interaction between group and time, in that those in the training condition showed improvements in accuracy for fear ( $F_{(1, 48)} = 13.00, p = 0.001, \eta^2 = 0.17$ ) and sadness ( $F_{(1, 48)} = 14.30, p < 0.001, \eta^2 = 0.23$ ) at post-training relative to baseline, in comparison with controls. There was also weaker evidence for an effect of improved anger recognition ( $F_{(1, 48)} = 10.13, p = 0.003, \eta^2 = 0.17$ ), all with medium to large effect sizes. There was no evidence for these interaction effects for happiness, or disgust).

Schönenberg et al. (2014) created a specialised morph task to measure outcome FAR, including the emotions happy, sad, angry, fearful, disgust and surprise, presenting the emotional stimuli at different expression intensities. The percentage intensity required for accurate identification of emotions was averaged, and these averages were compared between baseline and post-intervention. Mean difference was compared across three experimental groups, with reduced intensity post-training indicating improved performance. The groups included violent offenders assigned to the SEE intervention, violent offenders assigned to the ATT and non-offending controls (CTL), who did not receive an intervention but were used to adjust for repetition effects. The difference scores were analysed with a 6 (emotion: happy, angry, fearful, sad, disgusted, surprised)  $\times$  3 (group: SEE, ATT, CTL) repeated-measures ANOVA. Post-hoc analyses revealed weak evidence that the SEE group exhibited improved performance (with lower intensity stimuli for accurate judgements) following training, compared to the ATT group ( $p < 0.05$ ) and the CTL group ( $p < 0.10$ ), with no difference in performance post-training between the ATT group and CTL's. There was no evidence for an interaction of group by emotion, suggesting that improvement following training was consistent across all emotions. Effect size estimates were not provided. The authors concluded that

the SEE training only led to increased sensitivity for subtle emotional cues and was effective in improving FAR accuracy at lower expressive intensities on a novel task.

Seinfeld et al. (2018) measured FAR accuracy following the VR intervention using a dichotomous judgement task. They used signal detection to create a sensitivity index and a response criterion to measure SEE and response bias respectively. They used Bayesian analysis of linear models, modelling the difference between pre- and post-intervention, with condition (violent offender versus non-violent control) as an independent factor. Findings indicated that offenders substantially improved their recognition of fearful female facial expressions (posterior probability (PP) = 0.99) but remained worse in the recognition of anger from female facial expressions (PP = 0.90), compared to non-offending controls. These effects were not replicated for analogous expressions in male stimuli. Their results also suggested that the intervention reduced a baseline tendency in the offenders to classify both male (PP = 0.96) and female faces (PP = 0.83) as happy, rather than fearful, with no changes in bias for classification of angry faces.

#### *6.4.6 Behavioural outcomes*

Secondary behavioural outcomes were also assessed in these studies. To compare across these studies, outcomes have been categorized by type of behaviour or wellbeing index. This includes: aggression; anger and hostility; clinical symptomology; crime data and other aspects of social cognition. Schönenberg et al. (2014) and Seinfeld et al. (2018) did not report additional outcome measures and are not included within this section.

##### *6.4.6.1 Aggression*

Heimstra et al. (in prep-a) used social scenario vignettes to measure hostile attribution and aggressive response both pre and post-intervention. Participants reported how they would respond in an ambiguous scenario and responses were coded for aggression by independent researchers. They found no evidence for changes in aggressive response following the intervention for

either group. Heimstra et al., in prep-b, Study 1 measured subjective reactive and proactive aggression, aggregated with a teacher report of aggressive behaviour. In addition, they found no evidence for an effect of training condition on aggressive behaviour, observing decreases in aggressive behaviour for both the training and control group ( $F_{(1,18)} = 6.37, p = 0.02$ , and  $F_{(1,26)} = 10.38, p = 0.003$ , respectively). The study author's concede that issues with missing teacher reports may have affected outcome accuracy in this instance. Heimstra et al., in prep-b, Study 2 used a 'survivor' procedure to measure real-time aggression. Participants responded to ambiguous social interactions in a simulated social-media platform, and dictated monetary reward received by other players. Responses were coded by independent researchers for presence of aggression, and amount of reward money withheld. No evidence for an effect of the training condition was found for either outcome measure.

Kuin et al. (in prep) used two measures for aggressive behaviour, one being a weekly self-report, measuring verbal aggression, physical aggression, hostility and anger. The second was a validated aggressive behaviour scale completed by members of staff on a weekly basis, prior to and up to six weeks following training. There was no clear evidence for an effect of training on the self-report or staff-reported outcome measures. This contrasts with the findings of Penton-Voak et al. (2013), who also used self- (daily) and staff-reported (weekly) measures of aggressive behaviour. They completed these prior to and for two weeks following training. They found strong evidence that the training reduced staff-rated aggressive behaviour after two weeks compared to those in the control condition,  $b = -2.40, SE = 0.67, t_{(39)} = 3.77, p = 0.001$ , which was replicated for the self-reported aggression measure,  $b = -4.74, SE = 1.26, t_{(27)} = 3.61, p = 0.001$ . Maoz et al. (in prep) measured direct and displaced retaliation using an ultimatum game but did not observe a reduction in direct retaliatory behaviour in the training group in comparison to controls. Both groups retaliated in response to unfair play, regardless of training condition. They did however, observe weak evidence for an effect of training on 'displaced retaliation'. Those in the training group gave fairer offers to innocent players in comparison with those in the control condition,  $F_{(1, 148)} = 3.93, p = 0.05, \eta^2_p = 0.03$ .

#### 6.4.6.2 *Anger and hostility*

Heimstra et al. (in prep-a) found no evidence for modified hostile attribution in the social scenario vignettes between intervention groups. This was assessed by asking the reasons and corresponding intentions for a hypothetical behaviour and coding responses for hostile attribution. Heimstra et al. (in prep-b, Study 2) assessed state anger post-training using validated measures. They found no evidence for difference between groups, despite observing a hostile attribution bias in those with higher pre-training state anger ( $r = -0.34, p = 0.003$ ).

Staff-reported measures used in Kuin et al. (in prep) provided no evidence for reduced irritation or anger post-training in the training group compared with the controls, corroborating the lack of evidence for self-reported reductions in anger, irritability or hostile perceptions in both the validated and created-for-purpose measures. There was also no clear evidence for reductions in trait anger post-intervention, as indicated by the validated scales used in Maoz et al. (in prep).

#### 6.4.6.3 *Clinical symptomology*

Dadds et al. (2012) measured the effects of the intervention using the Strengths and Difficulties Questionnaire (Goodman, 1997) at 6 months follow-up. They found evidence for a three-way interaction between time (pre- and post-training), treatment condition and callous-unemotional traits (high, low). FAR training was associated with a decrease in conduct problem scores in comparison with the treatment-as-usual group, and those with high callous-unemotional traits, who did not receive the FAR intervention, showed increased conduct problems at 6-months ( $d = 0.26$ ).

#### 6.4.6.4 *Crime data*

Hubble et al. (2015) were the only study to investigate offending behaviour using crime related data. They investigated all crimes committed six months following the intervention. Adjusting for baseline differences from the

mean, the training group showed weak evidence for reductions in re-offending severity  $B = -0.35$ ,  $z = -2.07$ ,  $p = 0.04$ , which was not observed in the control group. There was no difference between groups in offence frequency, or time taken to reoffend.

#### 6.4.6.5 *Social cognition*

Dadds et al. (2012), included a measure of cognitive and affective empathy, and reported evidence for a three-way interaction between time (pre- and post-intervention), condition (training versus control) and callous-unemotional traits (high versus low). Those with high callous-unemotional traits in the intervention group showed improvements in affective empathy in comparison to the treatment-as-usual group. There was no evidence of interactions for the cognitive empathy scale. Kuin et al. (in prep) included a measure of pro-social behaviour within the staff-report measure but found no evidence of increased pro-social behaviour post-intervention in comparison with controls.

## 6.5 Discussion

In this review I sought to identify studies using FAR training for people with antisocial behaviour. I investigated the range of intervention strategies used and their parameters and summarised the effects that these interventions have had on relevant behavioural outcomes. Eleven studies were identified, with an additional ongoing trial and ten of these were included in the outcome synthesis. Of these, six adopted a CBM paradigm, three used more holistic approaches and attention strategies and one used VR embodiment. Whilst there were discrepancies between studies, FAR training tended to be effective at improving or modifying FAR. However, translation to improvement in secondary outcomes was less consistent, and some of the reasons for this will be explored here.

First, there was a limited number of eligible studies identified within this review. Of those which had been published following peer-review, these were relatively recent (the earliest being published in 2012). This reflects the novelty

of applied FAR theory for use with antisocial or aggressive populations, and the infancy of experimental research in this area. The increase in research attention may reflect advances in emotion recognition technology and social psychophysics. This allows researchers to more accurately portray emotive states, and manipulate these for therapeutic benefit (Jack & Schyns, 2017). The use of immersive VR to treat individuals with violent behaviour is an exciting example of this and it will be interesting to observe how this develops in future.

CBM was the most common intervention strategy observed in this review, with some more holistic approaches in use or in development. There was also evidence of repurposing of FAR training programs which were originally designed for use with other clinical populations, for use with aggressive or antisocial individuals. The applicability of FAR training as a clinical tool is currently under review (Bordon, O'Rourke, & Hutton, 2017; Golan & Baron-Cohen, 2006; Neumann et al., 2015; Penton-Voak et al., 2017). In future, it would be pragmatic to assess current use of established FAR programmes across clinical populations and to make comparisons regarding their efficacy to inform intervention design. However, the identification of simpler intervention strategies, such as the CBM, ATT and SEE tasks described here, is informative in that they help elucidate effective components within these training programmes. The majority of the interventions described here incorporated some aspect of FAR training using morphed stimuli with different levels of expressivity and graded difficulty across the paradigms. It may be important to capitalise on this aspect of training in future interventions as this appears to be effective in training sensitivity for subtler emotions.

There is compelling evidence for using CBM to alter perceptual biases. For all included studies which utilised a CBM procedure, strong evidence was observed indicating a positive shift in perception following training, for the intervention group compared with controls. The use of a tight experimental control here (with all aspects of the control intervention kept the same, bar the modification element), presents a convincing account that CBM is effective at manipulating perception of FAR, across stimulus sets, ages of participants, types of antisocial behaviour and in the presence of co-morbid health disorders. There is preliminary evidence that this attributional shift transfers to novel stimuli, and that the effects can be maintained after a period of 6-weeks. The

findings presented here suggest that there may also be additional gains with repetitions of training sessions. However, this should be investigated empirically as studies investigating CBM for depressive symptoms suggest that effects are most pronounced between the first two training sessions, but may plateau with subsequent administrations (Penton-Voak et al., 2018).

Evidence for the ability of non-CBM interventions to manipulate FAR is less consistent, however still promising. This likely reflects the greater variation in experimental paradigms and outcome measurement. Dadds et al. (2012) did not find evidence that those in the treatment group showed improvements in FAR compared to those receiving treatment-as-usual, whereas Hubble et al. (2015) found improvements following training in the intervention group, for specific emotions only (sadness, fear and anger). This was not replicated in Schönberg et al. (2014), who observed improved sensitivity for all included emotions. Seinfeld et al. (2018) again, found improvements in recognition for specific emotions (fear in females), but this was limited by the inclusion of fear, anger and happiness only within outcome measures, rather than the wider selection of emotions included in the other non-CBM studies. An important factor to consider here is that post-intervention FAR was assessed at a much closer time-point in the studies which did indicate improvement (Hubble et al., 2015; Schönberg et al., 2014; Seinfeld et al., 2018), compared to Dadds et al. (2012) who reassessed their participants at 6-months follow-up. It may be that improvements in FAR are not maintained over a longer follow-up period (i.e. months rather than weeks) and this should be established in future studies with longitudinal assessments.

In response to the primary research question, 'are interventions targeting the capacity for FAR effective in reducing antisocial or criminal behaviour', it seems modifications in FAR as a result of training do not necessarily translate to improvements in behavioural or emotional outcomes relating to aggression and hostility. Within the CBM literature the evidence is sparse. In these reviewed studies, only Penton-Voak et al. (2013) observed reductions in aggression, and in Maoz et al. (in prep) for displaced retaliation. It is interesting that the effects observed in Penton-Voak et al. (2013) were not replicated in Kuin et al. (in prep), who used analogous self-report measures. One explanation for this discrepancy could be that Kuin et al. (in prep) recruited

incarcerated males, whereas Penton-Voak et al. (2013) recruited young people in the community. Incarceration may result in more structured routine with less variation and greater interpersonal restrictions, which may reduce observable lower-level aggression or antipathy. The observation for an effect on displaced retaliation rather than direct retaliation (being less likely to punish innocent players, rather than unfair players) in Maoz et al. (in prep), may suggest that the benefits are subtle, with overt conflict overriding the benefits of CBM training.

However, it is also interesting to note that the holistic approaches adopted by Dadds et al. (2012) and Hubble et al. (2015) translated to improved clinical and crime related outcomes at a 6-month follow-up period, with reductions in clinical symptomology and re-offending severity respectively. As this was not moderated by FAR ability, Dadds et al. (2012) suggest that the interaction with carers and intervention staff during FAR training may have been therapeutically beneficial (slightly increased in comparison to the treatment-as-usual group), rather than FAR changes *per se*. It could also be argued that as intervention groups in Hubble et al. (2015) were not randomly allocated, this increases risk of selection bias within the intervention group. It is possible that those deemed more appropriate to participate in the FAR intervention were also those who were more compliant with YOT interventions. In turn this could have affected the observed reduction in offence severity at the 6-month follow-up. Conversely, benefits of FAR training may take time to manifest. The adaption of ingrained cognitive schemata, via perceptual modifications, in turn translating to behavioural change, is likely a subtle and prolonged process. This concurs with previous researching investigating CBM for individuals with depression. The antidepressant effects of CBM on depressed mood are suggested to occur after a delay, succeeding the initial bias modification (Lang, Blackwell, Harmer, Davison, & Holmes, 2012).

### *6.5.1 Future directions*

To better understand the efficacy of these interventions and their active mechanisms, further research is required. A RCT with appropriate intervention comparisons, accompanied by evidence of effective randomisation, blinding and selection of controls to minimise risk of bias would be beneficial. This could

help determine whether modifications in FAR are sustainable and translate to reductions in feelings of anger and hostility, and maladaptive behaviour. Based on the findings presented here, I advocate the importance of thorough screening for individual differences that may affect intervention suitability, including baseline FAR, presence of biases and callous-unemotional traits. In addition, screening for co-morbidity is paramount, given differential emotional processing observed for other clinical populations (whether for exclusion or adjustment in analysis). Furthermore, a diagnosis of TBI, ASD, MDD or a disorder that affects attentional capacity (e.g. ADHD, substance use disorders) may be influential in determining how receptive an individual would be to FAR training. However, if excluding on the basis of co-morbidity, researchers should not be overly stringent. Co-morbid disorders are common, and exclusion on this basis may lead to unrepresentative sampling. Adjustment in analyses is a preferable alternative.

### *6.5.2 Summary*

It remains to be seen whether FAR training can effectively modify behaviour in individuals with antisocial or aggressive tendencies. However, the receptibility of FAR to training is encouraging and transcends age groups, types of antisocial behaviour and therapeutic setting. The use of novel interventions, and particularly immersive VR is an exciting prospect and it will be interesting to see how applications in this field develop with technological advances. Future research should aim to minimise RoB using randomised designs and tighter experimental control. This combined with greater consistency across studies in choice of outcome measures, and longer follow-up duration will help better establish the efficacy of these interventions.

The execution of a RCT should be carefully planned, especially when working with populations who are typically difficult to engage. This will help to minimise RoB and promote scientific and methodological rigour. With this aim, I planned a feasibility study and pilot trial for a definitive RCT, testing the CBM intervention employed in Penton-Voak et al. (2013), for use with young people with violent behaviour, in a prison setting. The details of this study are described in Chapter seven.

## 6.6 Included studies

- Dadds, M. R., Cauchi, A. J., Wimalaweera, S., Hawes, D. J., & Brennan, J. (2012). Outcomes, moderators, and mediators of empathic-emotion recognition training for complex conduct problems in childhood. *Psychiatry Research*, 199(3), 201-207.
- Heimstra, W., de Castro, B. O., & Thomaes, S. (in prep-a). *Improving emotion attribution in children with aggressive behavior problems using cognitive bias modification*.
- Heimstra, W., de Castro, B. O., & Thomaes, S. (in prep-b). *Reducing Aggressive Children's Hostile Attributions: A Cognitive Bias Modification Procedure*.
- Hubble, K., Bowen, K. L., Moore, S. C., & van Goozen, S. H. (2015). Improving Negative Emotion Recognition in Young Offenders Reduces Subsequent Crime. *PLoS One*, 10(6), e0132035. doi:10.1371/journal.pone.0132035
- Kuin, N. C., Masthoff, E. D. M., Nunnink, V. N., Munafò, M. R., & Penton-Voak, I. S. (in prep). *Changing perception: A randomized controlled trial of facial emotion recognition training in order to reduce anger and aggression in violent offenders*.
- Maoz, K., Dalili, M. N., Adler, A. B., Sipos, M. L., Bliese, P. D., Quartana, P. J., . . . Bar-Haim, Y. (in prep). *Increasing positive interpretation of ambiguous faces reduces displaced interpersonal retaliation*.
- Penton-Voak, I. S., Thomas, J., Gage, S. H., McMurran, M., McDonald, S., & Munafò, M. R. (2013). Increasing recognition of happiness in ambiguous facial expressions reduces anger and aggressive behavior. *Psychological Science*, 0956797612459657. doi:10.1177/0956797612459657
- Schönenberg, M., Christian, S., Gaußer, A.-K., Mayer, S., Hautzinger, M., & Jusyte, A. (2014). Addressing perceptual insensitivity to facial affect in violent offenders: first evidence for the efficacy of a novel implicit training approach. *Psychological medicine*, 44(05), 1043-1052. doi:10.1017/s0033291713001517
- Seinfeld, S., Arroyo-Palacios, J., Iruetagoiena, G., Hortensius, R., Zapata, L. E., Borland, D., . . . Sanchez-Vives, M. V. (2018). Offenders become the victim in virtual reality: impact of changing perspective in domestic violence. *Scientific Reports*, 8(1), 2692. doi:10.1038/s41598-018-19987-7
- Stoddard, J., Sharif-Askary, B., Harkins, E. A., Frank, H. R., Brotman, M. A., Penton-Voak, I. S., . . . Leibenluft, E. (2016). An Open Pilot Study of Training Hostile Interpretation Bias to Treat Disruptive Mood Dysregulation Disorder. *J Child Adolesc Psychopharmacol*, 26(1), 49-57. doi:10.1089/cap.2015.0100

Ongoing trial: Schönenberg, M. Emotion recognition training in antisocial violent offenders with psychopathic traits. Started December 2017. University Hospital, Tuebingen; German Research, Foundation. Details can be found here: <https://clinicaltrials.gov/ct2/show/NCT03382808>



## **7 A feasibility study and randomised pilot trial for a cognitive bias modification intervention for use with incarcerated young males with violent behaviour**

### **7.1 Acknowledgements**

This study was conducted in collaboration with Her Majesty's Prison (HMP) service, Parc, in Bridgend, South Wales. Co-authors include Prof. Ian S. Penton-Voak and Prof. Natalia S. Lawrence, who supervised the project, Prof. Marcus R. Munafò and Prof. W. Huw Williams, who contributed to the planning stages, Dr Lucy A. Biddle, who contributed to the qualitative aspects of the study, Eleanor F. M. Kennedy who conducted data-quality checks and Robert Gardiner who assisted with the management of the study within the prison. This is currently being prepared for manuscript submission and all co-authors will be consulted prior to this. Additional funding was received from the University of Exeter's Open Innovation Link Fund, the University of Exeter's post-graduate support fund, and in part by the Medical Research Council and the University of Bristol (MC\_UU\_12013/6).

### **7.2 Introduction**

Violent crime has been specified as a public health concern and development of new interventions addressing this problem are needed. The previous chapter reviewed the applicability of FAR interventions to address aggressive or antisocial behaviour. Other reviews of interventions designed to reduce aggression include a Cochrane review of randomised control trials, which indicated moderate effectiveness in 61% of trials. This review suggested that interventions utilising social skills training rather than aggression inhibition training were more successful (Mytton, DiGuseppi, Gough, Taylor, & Logan, 2006). This corroborates an earlier review synthesising interventions used for serious juvenile offenders (Lipsey & Wilson, 1998). This review suggested that the most effective interventions for use within institutional settings were interpersonal skills training and behaviour modification in a family-style group

setting. There have been encouraging results in relation to interventions targeting general reactive aggression, but the effectiveness of these for use with violent offending populations is less consistent (see McGuire (2008) for a comprehensive review). This may be due in part to the difficulty quantifying aggression and violent behaviour, and also in conducting controlled intervention studies to gauge efficacy within institutional settings.

Part of the difficulty in administering intensive psychosocial interventions within prison and community settings is the additional strain this can put on available institutional resources and the associated economic costs. Resource considerations when delivering interventions include: available time within the sentence to complete the intervention, training and availability of staff and physical space restrictions. In addition to this, the high presence of neurodisability within the CJS may make it difficult for some individuals to engage with interventions that are reliant on language, communication skills, and insight into the triggers and consequences of one's own behaviour. Due to this, I have explored options for lower-intensity behavioural interventions, encompassed within the domain of interpersonal skills training, that may be appropriate for use in a prison setting and which make lower demands in terms of language capacity and behavioural insight.

Building upon the findings of the systematic review described in the preceding chapter, I explored the potential of the CBM paradigm, initially described in Penton-Voak et al. (2013), and replicated in a selection of the other included review studies (Heimstra, de Castro, & Thomaes, in prep-a, in prep-b; Kuin, Masthoff, Nunnink, Munafò, & Penton-Voak, in prep; Maoz et al., in prep); Stoddard et al. (2016), targeting hostile attribution biases in FAR. I wanted to explore whether this intervention would be appropriate and acceptable for use within a prison setting. Furthermore, I wanted to examine whether a definitive RCT to test effectiveness intervention effectiveness in this setting would be feasible. Whilst the translation of this CBM intervention to behavioural outcomes is variable, as detailed in Chapter six, the consistency in shifting of perceptual bias is encouraging and warrants further investigation on a larger scale. In addition to this, this approach is automated, can be administered without extensive training and is relatively self-contained. If effective in reducing aggressive behaviour or promoting prosocial behaviour, it has potential to

provide an economical method to reduce societal costs of violent and aggressive behaviour in young people.

A definitive RCT to address the question of this intervention's effectiveness in reducing aggression has been designed, for adolescent and young adult offenders in an incarcerated setting. Power analyses for the full-scale study have suggested recruitment of  $n = 400$  participants is necessary to provide 80% power to detect a sample size of  $d = 0.4$  (a difference of 2.3 points on the staff rating scale; effect sizes derived from Penton-Voak et al. (2013)). Part of the difficulty in testing intervention effectiveness for use within CJS organisations is that due to the aforementioned resource restrictions, and the constraints of the daily routine within prison settings, it can be challenging to execute experimental studies (McGuire, 2008; O'Rourke, Templeton, Cohen, & Linden, 2018). As this planned study is large-scale, requiring repeated testing in an unpredictable environment with complex populations, it is important to first test feasibility. This will enable us to address the questions of whether a definitive trial should be done, and how it should be done if so. To address these questions, I designed a feasibility study and pilot trial for the full-scale definitive RCT. This also addresses the sixth research question outlined in the introduction (section 1.8,1), 'would interventions targeting the capacity for FAR be appropriate for use with members of these populations and within incarcerated settings?', especially in relation to the acceptability of the intervention by participants and prison staff.

### *7.2.1 Study objectives and feasibility criteria*

The primary objectives of this study were:

1. To determine whether it is feasible to run a full-scale definitive RCT testing the effectiveness of a novel FAR training intervention in a population of violent offenders in a prison setting.
2. To pilot the procedures and materials required to do so.

Following recommended guidelines proposed by Eldridge et al. (2016), I outlined the pilot and feasibility criteria prior to conducting the study (protocol pre-registered on the Open Science Framework, DOI

10.17605/OSF.IO/U29QQ). These criteria derived from those suggested by Bowen et al. (2009) to assess feasibility success and Thabane et al. (2010) to assess pilot study success. There is some overlap between these criteria, but they cover the broad domains of (primarily feasibility): acceptability, demand, implementation, practicality, adaption, integration, expansion and efficacy; and (primarily pilot trial): process, resources, management and scientific rigour. I used a mixed-methods approach to address these questions, using qualitative methods to address questions relating to acceptability, demand, practicality, integration and aspects of expansion, process, resources and management.

I outlined criteria for success, informing whether this pilot trial should progress to a definitive trial. This helped establish whether the proposed process of recruitment and adherence to the intervention phase was achievable in a prison setting. I specified recruitment of  $n = 40$  into the study, with a minimum of 80% of this sample ( $n = 32$ ) completing four sessions of emotion recognition training within ten days, and at least 80% completing all four weeks of the behavioural assessment diaries as a minimum criterion for feasibility success.

Secondary objectives were to collect baseline characteristics, including health measures and neuropsychological assessment of participants to provide a detailed profile of this population. This was important as certain characteristics (for example, presence of neurodisability or high ratings of callous-unemotional traits) may mediate the effectiveness of the intervention, and furthermore, we wanted to better understand the profiles of these populations to inform future study design.

Ethical approval was granted by the University of Exeter's ethics committee (reference number: 2016/1290) and the National Offender Management Service (reference number: 2016-270).

## **7.3 Methodology**

### *7.3.1 Participants*

Participants were recruited into the study from the Young Offenders Institute (YOI) at HMP Parc, United Kingdom, between February and March 2017. Inclusion criteria included: being aged 15 to 25 years; having a recorded offence(s) (current or previous) of non-sexual violence (this included homicide, manslaughter, wounding, affray, actual bodily harm, grievous bodily harm, common assault and robbery), or having a recorded incidence of violence or aggression whilst incarcerated; having adequate sentence time before discharge to allow for baseline aggression measure, intervention, and institutional follow-up and having capacity to give informed consent. Exclusion criteria included: having poor language comprehension or learning difficulty which would impede understanding of task instructions; having uncorrected visual impairment which would impede performance on computer-based tasks; were non-compliant with the study (including intoxication) and being at risk of emotional upheaval or undue stress as a consequence of participation (which included those with serious and enduring mental health problems).

### *7.3.2 Study setting and recruitment*

HMP Parc is a male, category B (closed, moderate to high security) local prison situated in South Wales, United Kingdom. The YOI is a separate unit within the prison which houses prisoners under the age of 18 years, both convicted and on remand. At the time of testing, the YOI unit had capacity to house 64 young offenders and had separate resources including building space and intervention staff compared to the adult units within the prison.

HMP YOI Parc staff who were familiar with the prisoners screened and identified individuals who met the inclusion criteria, using prison records. Following this, the same member of staff (RG) approached eligible individuals, providing details of the study and making enquiries as to whether the individual would be interested in taking part. For those who did express an interest, an appointment was made to meet with the researcher (MC) who provided a full study information sheet, discussed study details with the individuals and

obtained informed, written consent. For those who were under the age of 16, consent was obtained from their caregiver, via the HMP prison staff.

We aimed to follow the same recruitment procedure in the adult unit, with the original plan of recruiting  $n = 20$  males under 18 years from the YOI and  $n = 20$  young adults (18 – 25) from the adult unit as I felt this would be an appropriate sample size to gain insight into intervention feasibility and study acceptability in each unit. Unfortunately, it was not possible to recruit participants from the adult unit at the time the study was conducted, due to insufficient staff resources meaning we recruited participants from the YOI only.

### *7.3.3 Study design and procedure*

I conducted a parallel-group, randomised controlled pilot trial. An equalisation randomisation of 1:1 was used. Following eligibility checks and preliminary discussion with HMP Parc staff, I met individually with the young offenders to discuss the study in greater detail, and if they were eligible they provided consent and were enrolled into the study. Following this, the baseline testing procedure took place with my administration of measures and neuropsychological assessment. Following completion of baseline assessment, HMP Parc staff arranged to deliver the intervention and administer outcome behavioural diaries (described in section 7.3.4).

Participants were randomly allocated to either 'condition one' or 'condition two', using anonymised participant ID's and pre-assigned coded tablets (labelled by ISPV) to blind myself and the prison staff to the participant's allocated condition. Anonymised subject ID's were alternately allocated to either condition, giving approximately equal numbers of participants assigned to each condition. The staff then retained this allocation on a hardcopy study form which they used to help inform themselves of allocated conditions (again, labelled 'condition one' and 'condition two'). The intervention was administered a total of four times to each participant over a duration of four to ten days. In Penton-Voak et al. (2013) this intervention was administered four times over a period of five days, aiming for completion on consecutive days. However, in this study I extended this time period to allow for possible disruptions in the intervention schedule. The time of day the participant received the intervention varied

between administrations but took place between the hours of 08:00 and 16:00 during a weekday.

The intervention was delivered within the YOI building where the young offenders take part in educational sessions, and on occasion within external areas (such as the office within the carpentry workshop, or the participant's cell if they were between scheduled activities). The intervention was administered on a one-to-one basis, in a room or area where there were no other people present (to minimise distraction), and it was administered and supervised by either a member of YOI intervention staff, or a YOI prison officer. The YOI intervention staff member received individual training on how to use the equipment and deliver the intervention prior to the intervention phase of the study. Subsequently they delivered this training themselves to an additional YOI prison officer who assisted in the intervention administration. Participants were instructed that they would take part in a digital intervention as part of a wider research study, where they would receive emotion recognition training and monitor their behaviour throughout the duration of the study.

Behaviour diaries were administered the week before the intervention, the week during the intervention and two weeks following the completion of the intervention. They were administered by HMP Parc staff who managed the weekly collection and re-issuing of diaries. A member of HMP Parc staff who was familiar with the participant and who had regular contact over the space of the week was designated to complete the corresponding staff-rated behaviour diary for that participant. Where there were inconsistencies in ratings or participant contact, HMP Parc staff communicated internally to ensure diaries were completed.

Following completion of the intervention and behavioural diaries, I met with the participants again individually, to debrief them and invite them to take part in a semi-structured interview. This was designed to assess aspects of intervention and study feasibility. These interviews contained both open questions for qualitative analysis, and closed questions for quantitative analysis. I also interviewed available members of staff who were involved in delivering the intervention. For the open questions, I would probe with supplementary questions following responses and non-verbal prompts to encourage elaboration. I used a pre-determined list of questions and topics and asked the

same questions in the same manner for each participant. Participants and staff were also given the option to add any comments of interest not incorporated within the interview questions. The interview questions and topics are included within the appendices (see section A8). Interviews were recorded with a Dictaphone and took place within the YOI offices.

### 7.3.4 Measures

#### 7.3.4.1 Emotion recognition training intervention

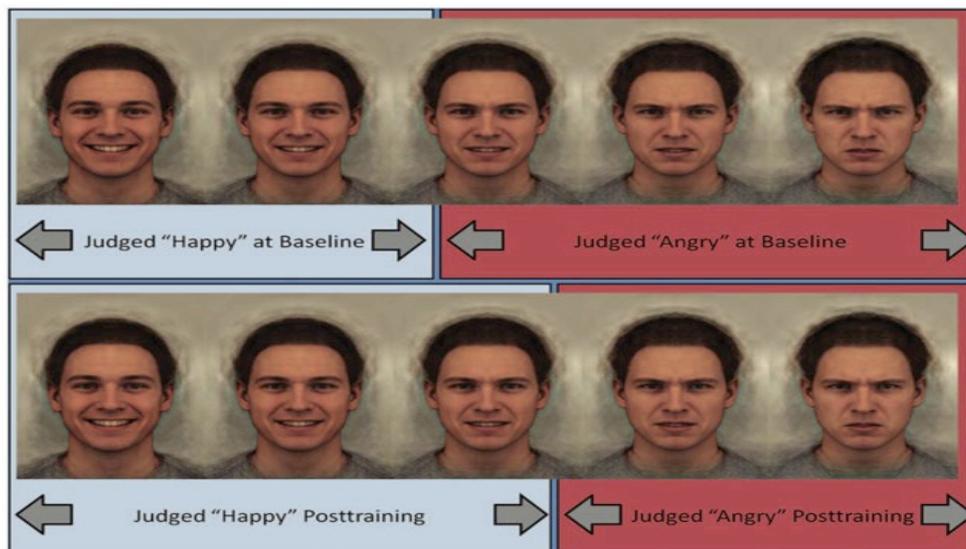
The intervention used within this study replicates that used by Penton-Voak et al. (2013) and is described in Chapter six, but will be described again here in greater detail for clarity. This intervention attempts to modify hostility biases in perception. Prototypical happy and angry composite measures were generated from twenty male faces showing a happy facial expression and the same individuals showing an angry facial expression. These prototypical images were used as endpoints for a generated linear morph sequence consisting of images changing incrementally from unambiguously happy to unambiguously angry, with emotionally ambiguous images in the middle. Fifteen equally spaced images were used as experimental stimuli in this task (see **Figure 7.1** for example stimuli).

The baseline and test phases of the task consisted of 45 trials, with each stimulus from the morph sequence presented three times. These images were presented in a random order for 150ms, preceded by a fixation cross (1,500 – 2,500ms which was randomly jittered). Stimulus presentation was followed by a mask of visual noise (150ms) and then a prompt asking the participant to respond (a two-alternative forced-choice judgment of whether a face was happy or angry). The responses on the baseline task were used to obtain a simple estimate balance point at which each participant was equally likely to perceive happiness or anger.

The training phase was similar to baseline and test phases, except that feedback was provided following the participant's response. In the training condition, feedback was directly based on the participant's baseline balance point, shifted two morphed steps towards the happy end of the continuum. This

meant that the two images closest to the balance point that previously would have been classified as angry at baseline were considered happy for the purposes of feedback. The control condition did not shift the balance point, and gave feedback based on the participant's own original responses. Each face on the fifteen-face continuum was presented twice (randomised presentation) within each block. Six training blocks were delivered for a total of 180 training trials. Following the training phase, each balance point was again calculated, using the same method as the baseline (the test phase). This was to test for modification in perception of ambiguous emotional responses following training. See **Figure 7.1** for a visual representation of this process. The training took approximately 20 to 25 minutes to complete in each session.

**Figure 7.1** Illustration of stimuli used and balance point manipulation in FAR training intervention.



Stimuli morph from happy (far left) to angry (far right), with adjusted feedback occurring around the ambiguous mid-point stimuli (based on individual balance-point). Image obtained from Penton-Voak, et al. (2013). Increasing recognition of happiness in ambiguous facial expressions reduces anger and aggressive behaviour. *Psychological Science*, 24(5), p.3.

The intervention programme was delivered using E-prime 2.0 Pro, on Windows Connect, 8" Tablets. There were four tablets available for intervention delivery, two with the active training condition version, and two with the control condition. The control condition was delivered in an identical way to the training condition, with the only difference between the two being the manipulated

feedback on the training trials. We marked the tablets with coloured stickers to differentiate the two conditions.

#### *7.3.4.2 Aggression behaviour diaries*

*Self-report behaviour diary.* As in Penton-Voak et al. (2013) participants were required to complete an aggressive behaviour diary. The self-report behaviour diary, developed by McMurrin (2007), has been modified for use in an adolescent and young adult population. The diary covers six categories of aggressive behaviour including: looking at someone in an aggressive way; being verbally aggressive; showing aggression but not touching them (e.g. slamming doors); hitting, kicking or punching someone; and using someone; and using something as a weapon against someone. It required participants to tick the corresponding category if the behaviour occurred during that day. Each diary contained seven days, the participant was encouraged to complete them each day, and a new diary was re-issued weekly.

*Staff-report behaviour diary.* Again, as used in Penton-Voak et al. (2013), the same six categories were included in the staff-report behaviour diary, for use by HMP Parc staff, who were blind to the intervention condition to which participants were allocated. Staff were required to make a judgement about how often that participant displayed each of the behaviours over the preceding week, on a scale of 0 (never occurred) to 100 (present all the time). These scores were averaged over the six categories.

#### *7.3.4.3 Baseline profiling*

The baseline profiling included within this study replicates that detailed within Study 2 in Chapter three. This includes the health and demographics screen (including the TBI measure, substance use, mental health and neurodevelopmental disorders and PCS), the aggression measure, the alexithymia measure, the psychopathic traits measure and an early trauma screen. I decided to use a different early trauma screen in this study, as in

Study 2 I felt the Early Trauma Self-Report (ETI) form used asked questions which may have been regarded as too sensitive given the context of the interview session. Instead I used the Childhood Trauma Events Scale (CTES), which is a survey assessing six categories of traumatic experience (death, divorce, sexual abuse, violence, illness or other) (Pennebaker & Susman, 1988). I included an additional question asking whether they had 'witnessed violence towards others, including a close family member' (derived from Brewer-Smyth, Cornelius, and Pickelsimer (2015)). The scale assesses the level of trauma caused by these events (scale 1 – 7), and amount that they confided in others at the time (scale 1 – 7). This was asked for events occurring before the age of 17, and for incidents occurring within the last 3 years (adult participants only).

I also included the short version of the BERT, used in Study 2, with the original presentation time of 150ms, Cantab research suite (Provided by Cambridge Cognition®), including the RTI, SWM and AST, and the SCOLP as the verbal intelligence quotient.

### *7.3.5 Protocol modifications and intervention fidelity*

Some changes to the procedural pre-registered protocol were required, occurring after the feasibility study and pilot trial commenced. This included exclusion of the CTES from baseline assessment. As mentioned above, through the experience of administering these measures, I decided asking questions of such a personal and sensitive nature was not justified by the aims of the current study and was considered invasive, despite the change in measure from the ETI to the CTES. Therefore, I removed the CTES from subsequent testing. I was also unable to collect criminal histories for the participants, as originally planned. This was due to a lack of authorisation for access to participant criminal histories to allow criminal profiling for the purposes of the feasibility study and pilot trial. Staff members made eligibility judgements regarding previous violent offences or aggressive infractions to counteract the need for this information. If this trial progresses to the future definitive RCT, permissions for access should be re-visited as profiling and subgroup analysis based on type and severity of crime would be of interest. As mentioned, the initial protocol

specified that we would aim to recruit equal numbers of participants from the YOI and adult unit, but this was not possible due to insufficient staff resources in the adult unit (see section 7.4.4 for further details of study termination).

Adherence to the protocol was assessed by through conducting a data check on the completed participant data for dates of intervention administration and the weekly behaviour diaries, to confirm these corresponded with the timeframes stipulated within the protocol. The interviews with the involved staff members were also used to derive details of how the intervention was executed and managed, and this helped to ascertain intervention fidelity. Individual task performance was checked in case of any unusual patterns in responses which might suggest a lack of engagement with the task (e.g. a very low or very high balance point across sessions with very little, or very large variation).

The only additional protocol modification that I am aware of, was the introduction of 'exclusives' as incentives for participation by the HMP Parc staff. This occurred for a selection of participants, but it was not specified exactly which participants received these. Exclusives are items which cannot be purchased from the prison shop (such as a particular brand of shower gel or confectionary).

### *7.3.6 Feasibility and pilot trial assessment*

Prior to starting the feasibility study and pilot trial I decided upon feasibility and pilot criteria and methods of assessing these (see section 7.2.1). Part of the initial feasibility assessments lay within the early discussions with HMP Parc, regarding their policies on research, what we envisioned the study would involve and the estimated time-frame. The feasibility and pilot assessments discussed here relate to those that took place within the pilot trial itself and subsequent interviews, rather than the pre-planning process.

Methods used to address each feasibility and pilot trial objective are summarised in **Table 7.1**. For the questions addressed using the semi-structured interview, these predominately are encapsulated within the qualitative analysis, summarised using narrative descriptions in the qualitative results section. For items assessed using quantitative methods, including

recruitment rates, degree of execution (task completion), group profiles and effect size estimates, these are reported using descriptive statistics, reporting frequency count data, or point estimates with 95% confidence intervals. There were no changes to pilot trial assessments or measurements after the trial commenced.

### *7.3.7 Qualitative analysis of interview data*

Following completion of the semi-structured interviews, all audio files were transcribed into a digital format. I used a thematic approach to analyse the qualitative data from the open answer responses, which involved generating themes and codes from three transcripts initially (two participants, one staff member). This process was carried out independently by two researchers, with the second being an experienced qualitative researcher (LB). Both researchers derived a separate coding framework, which were compared at a subsequent time-point, resolving any areas of difference through discussion. Following this, the agreed coding framework was applied to the transcripts, adjusting for any new themes that emerged during the process. Once all the transcripts had been coded, the finalised coding framework and three unfamiliar transcripts were supplied to the second-coder (LB) who coded these transcripts independently using the provided framework. These independently-coded transcripts were then compared with the initial coding (completed by MC), and further discussion took place to resolve any areas of discrepancy. Following this, the finalised coding framework was re-applied to all transcripts.

**Table 7.1** Feasibility and Pilot criteria with methods of assessment

Area of focus	Outcomes of interest	Assessment	Interview Question
<i>Feasibility criteria</i>			
<b>Acceptability of intervention</b>	Satisfaction	Staff & participant interview	Overall, would you say you were satisfied with the intervention? Rate your satisfaction on a scale (0 – 100)
	Intent to continue use	Staff and participant interview	If you had the option to continue using this intervention within your unit, would you do so?
	Perceived appropriateness	Staff and participant interview	Do you feel this intervention was appropriate for use within a prison setting?
<b>Demand</b>	Fit within organisational culture	Staff interview	Do you think this intervention would fit amongst the behavioural interventions currently being used by HMP Parc?
	Perceived +/- effects on organisation	Staff interview	Do you feel that the intervention had positive or negative effects on the participants, or the unit?
	Actual use	Numbers of participants full/partial completes	
	Perceived demand	Staff interview	Do you think there's a need for more aggressive behaviour interventions within the prison? Do you think there's a need for more behavioural interventions similar to the intervention used here?
<b>Implementation</b>	Degree of execution	Numbers of participants full/partial completes. Number of times each participant completed the training (/4)	
	Success or failure of execution	More than 80% fully completed the training and 80% behaviour diary entries	
	Amount, type of resources needed to implement	Number of staff members/intervention staff needed. Number of days/hours needed to deliver the intervention and follow-up measures	

		Number of tablets used	
<b>Practicality</b>	Factors affecting implementation ease or difficulty	SSI staff, and researcher observation (see process criteria in pilot section)	What do you think helped implement the intervention? Did anything make it easier/harder to do this? (e.g. efficiency of the tablets, training of staff, clarity of instructions and measures).
	Efficiency, speed, or quality of implementation Positive/negative effects on target participants	Time taken to complete all baseline testing, training and follow-up assessments Staff interview, participant interview	Staff: Do you think the intervention had any +/- effects on the participants Participants: Do you think this intervention had any +/- effects on you?
	Ability of participants to carry out intervention activities	Number of intervention training tasks completed, % of baseline tests completed, exclusions due to lack of comprehension	
	Cost analysis	Detailed breakdown of study costs incurred	
<b>Adaption</b>	Degree to which similar outcomes are obtained in a new format Process outcomes comparison between intervention use in two populations	Effect size comparison with similar sample from previous study See above	
<b>Integration</b>	Perceived fit with infrastructure	Staff interview	Do you think this intervention could be easily integrated into the current aggression reduction intervention programmes?
	Perceived sustainability	Costs of using equipment/time and staff resources – would there be other needs (software programme licencing?)	
<b>Expansion</b>	Costs to organisation and policy bodies	If expanded to full-scale RCT, what would be the costs incurred, based on those incurred for the feasibility?	
	Fit with organisational goals and culture	Based on the responses in the staff interviews for fit within HMP Parc's organisational goals and culture – would	

	Positive or negative effects on organisation	this apply on a larger scale, in prisons across the country? If replicated on a larger scale, would this put a significant burden on the HMP Parc staff? Judge based on staff demand/time taken.	
	Disruption due to expansion component	Staff interview	Based on your experience of the feasibility study, do you think replication on a larger scale within HMP Parc would cause disruption to the current programmes within the prison?
<b>Limited efficacy</b>	Intended effects of program on key intermediate variables	Behavioural aggression diary ratings. Change in balance point on happy-angry continuum.	
	Effect size estimation	Effect size estimation from mean difference in behavioural diaries	
	Maintenance of changes from initial change	Will changes in the amount of time given to deliver the intervention (10 days rather than 5 days), or the follow-up period, affect the efficacy for the full-scale RCT? Will these changes from the feasibility study be carried forwards?	
<i>Pilot trial criteria</i>			
Process	Recruitment rates	Number of participants recruited into the study (from number eligible)	
	Refusal rates	Number of service users approached regarding the study who decided not to participate	
	Failure/success rates (see Bowen implementation)	More than 80% fully completed the training and 80% behaviour diary entries	
	(Non)compliance or adherence rates	Were there any reports of non-compliance or adherence rates (% total)?	
	Is it obvious who meets and does not meet the eligibility requirements?	Staff interview	Did you find it easy to recruit using the pre-determined recruitment criteria? Was it obvious who met these criteria?

	Are the eligibility criteria sufficient or too restrictive Understanding of the questionnaires or data collection tools	Staff interview. Number of YOI eligible SU's. Staff interview, participant interview	Were the eligibility criteria sufficient or too restrictive? How did you find the behaviour questionnaires and other data collection tools? Did you understand the instructions, or did you think they lacked clarity?
	Do the answers given on the questionnaires match the format provided (e.g. multiple response, no answer, unanticipated answers)	Analysis of participant response forms, how many missed items, or items that cannot be used? Any areas lacking clarity?	
<b>Resources</b>	Length of time taken to fill out study forms Determining capacity  Process time  Is the equipment readily available when it is needed? What happens when it breaks down or gets stolen/broken?  Can the software used for capturing data read and understand the data? Does the organisation do what it has committed to do?  Do investigators have time to perform the tasks they committed to doing?	Keep record of time taken to complete baseline testing. How many participants can be seen per day, with the resources provided? (Baseline and intervention) How long does it take to test $n = 40$ participants? (baseline and intervention) Staff interview  Staff interview  Eprime checks: suitable data capture for BERT 6AFC/BERT intervention and RTI Description of HMP Parc input for this study and assess whether this has been adhered to following completion (and reasons for non-adherence). Assessment for baseline and intervention Staff interview	Is the equipment readily available when it is needed? Did you have any additional issues with the technical equipment? Did it break/stop working/not save properly?  Did you feel you had adequate time to perform the tasks you committed to doing (recruitment, administering intervention, behaviour diary reminders).

	Are there any capacity issues at each participating centre?	Staff interview	Are there any capacity issues in your unit? E.g. difficulty finding space to run the intervention on multiple people at one time.
<b>Management</b>	What are the challenges that participating centres have with managing the study?	Staff interview	What challenges did you encounter with managing the study?
	Was there enough room on the data collection forms for all of the data received?	Check individual CRF forms	
	Any problems with transcription?	Independent data transcriber to check, any discrepancies?	
	Can data from different sources be matched?	Second rater for staff-reported behaviour (n = 4)	
	Do the data show too much, or too little, variability?	Check range and standard deviations of outcome measure	
<b>Scientific</b>	Is it safe to use the study intervention?	Staff interview	Would you consider this intervention safe to use?
	Do participants respond to the intervention?	See below; participant interview	
	What is the estimate of the treatment effect?	Difference in balance-points post-training between those in the control condition and the active training condition	
	What is the estimate of the variance of the treatment effect?	Standard deviation of above	

## 7.4 Results

### 7.4.1 Participants and recruitment

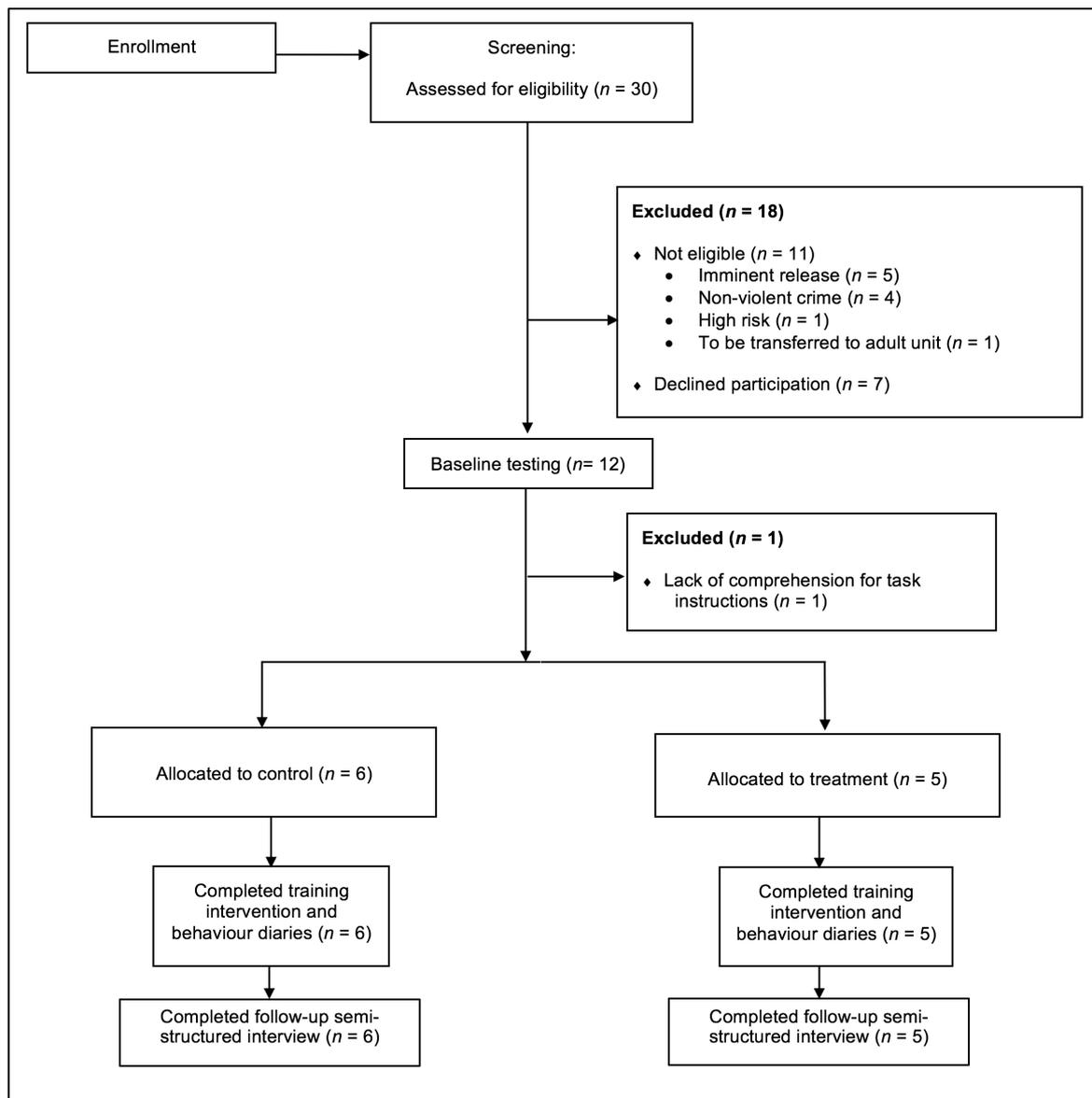
At the time this study was conducted, there were 30 young people in the YOI. This was reported as lower than usual by prison staff as the unit has a capacity for 64 individuals, although no additional reason was provided for this. All 30 young people were assessed for eligibility. Nineteen (63%) were identified as eligible and of these, twelve were recruited into the study. This gave a recruitment rate of 63% and a refusal rate of 37%. Ten participants were over the age of 16 years, and provided their own consent, two participants were under the age of 16 years and parental consent was obtained on their behalf by prison staff. One participant was excluded from the sample due to poor task comprehension, leaving a group size of eleven. These eleven were randomly allocated to conditions, with six in the control condition and five in the treatment condition. All eleven participants completed baseline assessment (100%), all four training sessions (100%) and the follow-up semi-structured interviews (100%). See the CONSORT diagram in **Figure 7.2** for a visual representation of the recruitment process and reasons for exclusion.

### 7.4.2 Degree of execution

In terms of completion rates, there were three missing data-points from the behaviour diaries. We aimed to collect four weeks of behaviour diaries, both self and staff rated prior to and following the intervention. Two of the baseline diaries were not collected (for participants 309 and 311) as participants attended a court case that week and were not present. One of the participant intervention diaries was also missing (participant 311), however no explanation was given for this omission. This gave a 96.6% collection rate for the behaviour diaries.

Within the baseline assessment, all participants completed the health screening, the 6AFC BERT and the CANTAB neuropsychology. One participant did not complete the TAS and the PTI due to lack of time. This gave a 98.5% completion rate for the baseline assessment. All eleven participants completed four sessions of FAR training however one data file was corrupt and could not

**Figure 6** CONSORT Flow diagram of randomised pilot trial



be recovered for analysis (307, session 1). This gave a data retention rate of 97.7%.

Originally, I specified recruitment of  $n = 40$  into the study, with a minimum of 80% of this sample ( $n = 32$ ) completing four sessions of emotion recognition training within ten days, and at least 80% completing all four weeks of the behavioural assessment diaries as minimum criteria for feasibility success. We recruited 55% of the total number of young people we aimed to recruit originally ( $n = 20$ ), and 27.5% of the total sample size we aimed to recruit. This meant the pre-determined success criterion was not met for sample size. However, the

criteria for intervention implementation and data collection was met, with rates exceeding 80%.

### *7.4.3 Resources*

#### *7.4.3.1 Staff*

There were five members of HMP staff involved in the implementation of the study, and one researcher (MC). This included one key staff member, who managed and co-ordinated the study (RG), and four additional members of staff who were selected to complete the staff-rated aggression behaviour diaries. One of these additional staff members had a more prominent role in organising and collecting the diaries and was later interviewed (NC). The manager of the YOI and a staff member from the adult interventions team were also involved in the initial planning of the study but did not implement the study directly.

#### *7.4.3.2 Equipment*

Four digital tablets were used to deliver the intervention, two per condition (with the training pre-loaded and tablets blinded prior to administration). One of these was identified as faulty in the earlier stages of the study and subsequently was not used, however this was not deemed of consequence, as the intervention was delivered on three tablets without issue.

#### *7.4.3.3 Case report forms*

The case report forms (CRF's) and measures used for the study were described as clear and easy to use. There were no errors or problems reported with the inputting of data into the CRF's, although one form (staff checklist) was not used, except retrospectively by the researcher, therefore this measure was superfluous. Feedback for the behaviour diaries indicated that it would be more helpful to provide space to record the dates of each day (previously labelled day one to seven). More explicit feedback in terms of how to complete the form (e.g.

using ticks to denote when the behaviour has occurred) would also be helpful as there was some variability in completion styles.

#### *7.4.3.4 Time*

The feasibility study and pilot trial took 6 months to complete, from the preliminary meetings at HMP Parc (December 2016) to the completion of the semi-structured qualitative interviews (May, 2017). Study preparations took approximately two months (January to February, 2017). Eligibility assessments took one week (February 27<sup>th</sup> – March 3<sup>rd</sup>), baseline assessments took one further week (March 6<sup>th</sup> – 10<sup>th</sup>). Behaviour diaries were collected from early April till mid-May, and the intervention was administered in line with these – taking one week (April 20<sup>th</sup> – 27<sup>th</sup>). The debriefing and semi-structured interviews took place in one week (May 15<sup>th</sup> – 19<sup>th</sup>). It took approximately ten weeks from baseline testing to the completion of the behaviour diaries. Eligibility assessments, intervention delivery and behaviour diary management were coordinated by HMP Parc staff in conjunction with other commitments (approximately 4.5 hours per participant). Baseline testing took on average one hour, and the study intervention took approximately 25 minutes per session (a precise record of timings was not kept). Based on this, on average four participants could be seen in one day for baseline testing, and eight for intervention completion. However, it was rare to be able to deliver the intervention to more than four participants in one day, due to the time taken to organise delivery and the prison scheduling.

#### *7.4.4 Termination*

The feasibility study and pilot trial ended due to time and resource restrictions. All eligible participants were recruited within the YOI unit, however when we tried to replicate this process in the adult unit it became apparent this would not be feasible due to restrictions on staff numbers and time. This was in part due to the large numbers of adult prisoners within the prison (over 1000 individuals), and the constrained reach of the intervention team assigned to them. Following further meetings with HMP Parc staff, we decided to

incorporate the intervention in a different procedural format – by administering it during an intervention session within a pre-established programme.

Unfortunately, this was also unsuccessful. HMP Parc staff from the adult intervention team provided the following statement explaining the reasons for this:

*“We have had staff shortages, meaning we have had to attempt to engage the group members that we are working with rather than being able to recruit anyone else. We have been having difficulties over the last few months with our programmes and maintaining motivation levels. We have had a number of non-completers on our programmes, meaning we are struggling with our targets. We have been trying to review the reasons for this to establish some understanding. It seems that the increase in substance use around the estate has impacted on motivation levels to engage and we have been battling at times to keep group members on the programme. Due to these issues, they have been very reluctant to engage in anything other than what they see as mandatory. Also, due to operational issues in the establishment and an increase in incidents, we have been struggling to start group sessions on time. This means that by the end of the session they are keen to leave as they may have been waiting around for a few group members. This also doesn't help to maintain their motivation to complete any additional work”. – Staff, adult unit intervention team.*

HMP Parc as an organisation were very engaged and committed with the research process and completed all agreed study responsibilities efficiently and to a high standard. Inability to continue the study in the adult unit was not a reflection of poor co-operation or effort on the part of HMP Parc staff, but unavoidable situational factors outlined above.

#### *7.4.5 Cost analysis*

I estimate total expenditure to be around £1330 for this study. This includes £225 on travel, £230 on equipment (including four digital tablets costing £40 each), £640 on nearby accommodation (for 8 nights), £100 CRF printing costs and £135 on sustenance and sundry.

##### *7.4.5.1 Sustainability and expansion*

The costs above are based on time and costs incurred to recruit and run the intervention on eleven participants. If we collected the full sample of  $n = 40$  participants, I estimate another five weeks would have been required to complete testing (three weeks baseline testing and study management, two weeks for debriefing and semi-structured interviews). Based on the above, the costs incurred for the additional visits would be £2200 (accommodation, travel and sustenance). This would bring the total to £3530. There would be no additional costs for equipment and resources, providing four tablets would be sufficient for a group size of  $n = 40$ .

If this was expanded for the full-scale RCT, with the sample size of  $n = 400$  as originally proposed and if conducted in the same format, the costs would be approximately £27,400 (estimated 60 weeks of testing: 40 weeks for baseline, 20 weeks for debrief, data collection and quality checks, £440 estimate per week; £1000 printing costs). It would also account for 1800 HMP Parc staff hours, based on the estimates provided, equating to 30 hours per week (discounting researcher hours, equating to approximately 2250 hours at 37.5 hours per week). Additional tablets would be required (suggested ten) and based on the performance of those used in this study, I would advise buying more sophisticated equipment (approximately £100), equating to an additional £1000 (£28,400 total).

## 7.4.6 Quantitative analyses

### 7.4.6.1 Sample characteristics

Basic demographic and health information, and neuropsychological test performance are presented for the eleven participants in **Table 7.2**. The average speed of comprehension is in the 25<sup>th</sup> percentile for their associated age group, and the average verbal comprehension for this sample is within the 5<sup>th</sup> percentile for their age group, suggesting their verbal comprehension is very poor as indicated by normative values. Neurodisability rates are high (approximately 45% of the sample had some form of previous TBI and diagnoses of neurodevelopmental disorders) with higher proportions of heavy drug and alcohol use than observed in the young adult sample described in Chapter three (Study 2). Higher rates of self-reported aggression were observed in the current sample than seen in the young adult sample (Study 2), which is logical given these individuals were selected on the basis of violent histories. Alexithymia and psychopathic traits were comparable to the Study 2 sample, and performance on the overall FAR measure was similar to that observed in the non-injured young offender group described in Chapter two (Study 1) (average performance around 53% accuracy, compared to 52% in the current sample). The current sample had slightly slower simple reaction and movement times than observed previously, comparable spatial working memory, and were quicker to respond on average in the attention-switching task.

**Table 7.2** Profile of young offending participant sample

	Young offenders ( $n = 11$ )
<i>Demographics</i>	
Age at testing (years)	16.1 (0.70), range 15 to 17
Age left school (years)	13.64 (1.14), range 12.5 to 16
Speed of comprehension (SCOLP) (/100)	43.91 (6.63)
Verbal IQ (vocabulary; SCOLP) (/60)	36.27 (4.10)
<i>Health</i>	
Alcohol use (N:W:H)	4:4:3
Drug use (N:W:D:H)	2:1:1:7
Mental health current symptoms (BJMHS) (/6)	1.18 (1.17)

Neurodevelopmental disorder (no:yes)	6:5
Traumatic brain injury (no:yes)	6:5
Post-concussion symptoms (RPCQ) (/32)	7.45 (3.98)
<i>Personality and background</i>	
RPQ Aggression (/46)	20.27 (9.17)
TAS-20 Alexithymia (/100)	53.60 (8.28)
PTI Psychopathic traits (/72)	42.80 (7.73)
Participant-rated aggression baseline (/42)	4.18 (6.12)
Staff-rated aggression baseline (/100)	16.44 (16.14)
<i>Neuropsychology</i>	
BERT 6AFC emotion rec accuracy (/48)	24.91 (4.68)
BERT training pre-balance point (/15)	7.10 (1.37)
RTI Median Simple RT (ms)	283.27 (40.92)
RTI Choice RT (ms)	320.82 (4.29)
RTI Simple movement time (ms)	201.59 (38.14)
RTI Choice movement time (ms)	228.05 (54.41)
SWM Between errors	13.0 (8.64)
SWM Strategy errors	16.09 (2.30)
AST Median Congruency (ms)	36.96 (60.75), range -48.0 to 169.0
AST Median Switch cost (ms)	126.86 (71.32), range 26.0 to 261.5

Means presented with standard deviations in parenthesis. For drug and alcohol use, N = never, W = weekly, D = daily, H = heavy user (3 or more times daily for drug use or in excess of 30 units per week for alcohol use). Negative values for the attention switching task (AST) indicate faster responding on incongruent trials.

#### 7.4.6.2 Intervention outcome estimates

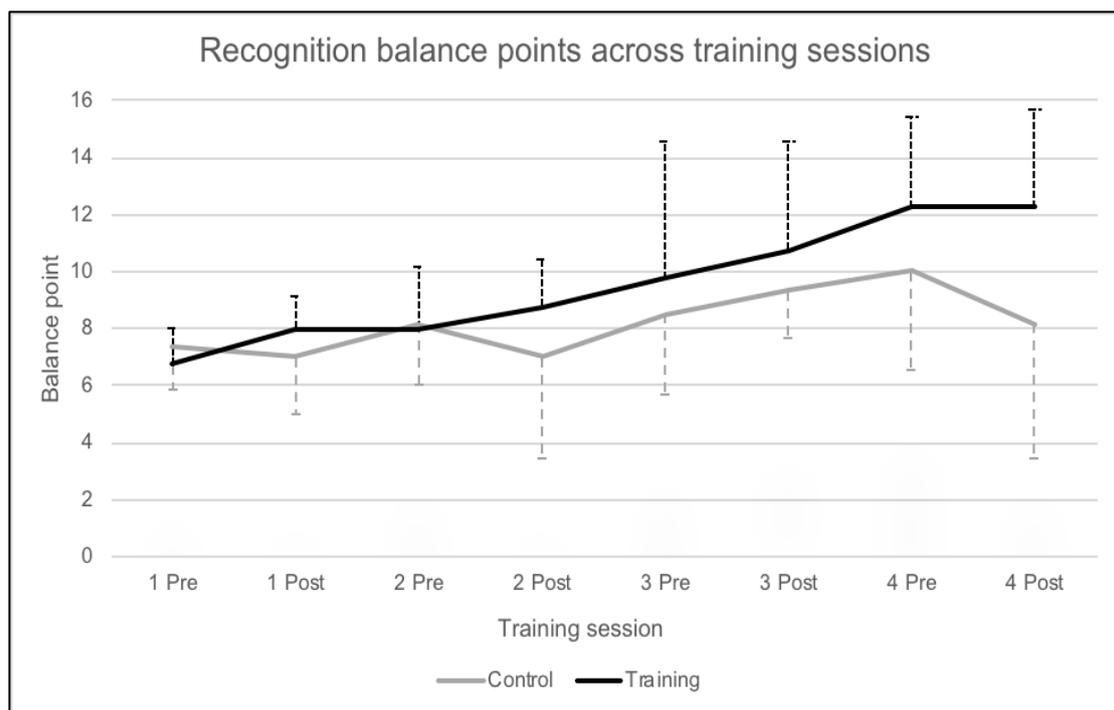
**Figure 7.3** depicts the recognition balance-point on the FAR training task across intervention sessions, for the control and active training group. I expected to see an increase in balance point over sessions in the active training but not control group. This was for both the pre- and post-training assessments as participants would be expected to show enduring shifts in bias over time.

As stated in the protocol, I investigated shift in balance points between the pre-training balance point in session one, and the post-training balance point in session four, for those in the control condition compared to the active training condition. I removed one participant from the training condition (307) prior to analysis, due to data loss for the initial session, and comments regarding their inaccurate responding in the qualitative interviews. These

estimates are based on very small numbers with considerable variability, therefore it is inadvisable to use these estimates to inform power calculations for a definitive trial.

Comparing the total shift in balance points, between the pre-training balance point in session one and the post-training balance point in session four, there is a modest shift in the balance point in the training condition, in comparison with the control condition, towards the happy end of the continuum,  $b = 4.67$ ,  $SE = 2.23$ ,  $95\% CI = -0.49$  to  $9.82$ . This beta coefficient is similar to that seen in previous YOT samples ( $b = 4.22$ ,  $SE = 1.23$ , (Penton-Voak et al., 2013)).

**Figure 7** Recognition balance point across intervention sessions



Average balance-points are depicted, with standard deviations depicted in error bars. Pre-refers to the pre-training balance point at the beginning of the session, and post refers to the post-training balance point calculation. The numbers represent the session number (1 – 4). This figure does not include the data for participant 307.

This intervention procedure differs from that detailed in Penton-Voak et al. (2013) in that there was a longer time period available in which to deliver the intervention (ten days, as opposed to five). In actuality, all participants

completed the intervention within seven days, which included a two-day break over the weekend. It appears this adaption is unlikely to compromise intervention effectiveness, and advocate maintaining this change in future research to allow for greater flexibility within the intervention schedule. Upon closer inspection of the data there appeared to be greater variation in responses for the fourth session compared to the initial sessions, for both the control and training groups (S1 post-training, control:  $M = 7.0$ ,  $SD = 2.0$ ; training:  $M = 8.0$ ,  $SD = 1.16$ ; S4: post-training, control:  $M = 8.17$ ,  $SD = 4.71$ ; training:  $M = 11.60$ ,  $SD = 3.29$ ). This may suggest more noise and less consistency in responding in the later sessions, or alternatively that the intervention was more effective for some participants than others, resulting in greater variation in later sessions.

In terms of reducing aggressive behaviour, as indicated by the staff-rated and self-rated behaviour diaries, the training did not appear to have an effect. This was true for scores one-week post training (staff-rated aggression:  $b = 0.82$ ,  $SE = 20.5$ ,  $95\% CI = -46.40$  to  $48.04$ ; self-rated aggression:  $b = 2.0$ ,  $SE = 2.90$ ,  $95\% CI = -4.70$  to  $8.70$ ), and for two-weeks post training (staff-rated aggression:  $b = -9.02$ ,  $SE = 18.75$ ,  $95\% CI = -52.25$  to  $34.21$ ; self-rated aggression:  $b = 2.92$ ,  $SE = 2.56$ ,  $95\% CI = -2.98$  to  $8.81$ ). Positive beta values represent an increase in aggression, whereas negative beta values represent decreased aggression scores in the training group compared with the controls (scored as a percentage in staff diaries, and as frequency counts in participant diaries). I also had two members of staff independently rate behaviour for 25% of the sample, for the intervention week. There was a positive correlation between the two sets of ratings,  $r = 0.81$ .

#### 7.4.7 Qualitative analysis

Semi-structured interviews were conducted with all eleven participants who completed the intervention and two members of staff who were involved in managing and administering the intervention (one a member of intervention staff and one prison guard). The interviews varied in length, taking on average 6 minutes for the participants (ranging from 3.5 minutes to 11.5 minutes). This is considered short for a qualitative interview and may reflect the closed nature of

some of the interview items and a reluctance to elaborate on responses on the part of the interviewees. The staff interviews were longer in duration, taking on average 27 minutes. All interviews were conducted and transcribed by the same researcher (MC). An independent 10% data transcription check was conducted prior to analysis.

For the open question responses, thematic analysis was conducted for the transcribed interviews, and following discussion between the independent coders (MC & LB), the finalised coding framework was agreed. The finalised key qualitative codes included: acceptability (desire to continue using), evoked feeling or emotions, factors affecting adherence or engagement, suggestions for improvement, active mechanisms, factors affecting management and integration, factors affecting intervention delivery, assessment of change, evaluation of intervention, data validity concerns and method of administration. These will be discussed individually in turn. A visual illustration of the coding framework is provided in **Figure 7.4**.

There were no clear differences in the nature of the comments made between those in the active training condition and those in the control condition.

#### *7.4.7.1 Acceptability*

All participants and staff members were asked if they would continue using the intervention, should they have the option to do so. In many cases, the response comprised a yes or no answer, however some elaborated further when prompted. Out of the eleven participants, six reported that they would keep using the intervention, giving the rationale that it was something to do, that it kept their minds occupied and that it was helpful for them. One participant suggested they would continue to use the behavioural diaries, but not the FAR training component as it was too time consuming, and another suggested they might continue to use the intervention, but that the training could be quite frustrating. Three participants reported that they would not continue to use the intervention, because it was boring, not applicable to them, or overly repetitive. One staff member, who works as a prison interventions officer, reported that they would use the intervention provided some alterations were made to make

the task less repetitive. This reflected the opinion of the second staff member who said they would not choose to continue to use the intervention, due to its repetitive nature.

**Figure 8** Thematic coding framework derived from qualitative analysis



#### *7.4.7.2 Evoked feeling or emotion*

A common theme that emerged for participant responses were comments regarding evoked feelings or emotive responses experienced when using the intervention, or staff observations of evoked feelings in those taking part. These evoked feelings or emotions tended to fall into two broader valence sub-codes. Negative emotions reported by the participants included anger and

frustration with the repetitiveness of the intervention and were reported by five (just under half) of the participants.

*“And sometimes, like obviously me I ain’t got enough patience like, so I just get angry (muffled), know what I mean, cause it’s actually like the same faces like all over again”, pt. 307, training.*

The positive emotions reported related to happiness, being occupied and stimulated when completing the intervention and were reported in around a third of the participants.

*“Just that, I feel happy innit, that’s it. Kept me busy init. Like it’s better than most of the education time”, pt. 312, control.*

Staff member observations of feelings and emotions felt by participants tended to fall within the negative sub-category, noting feelings of disinterest and frustration.

#### *7.4.7.3 Evaluation of intervention*

Staff and participants offered evaluation of the intervention, both overall and with specific reference to the FAR training and diary components. These included perceived value, acceptability, ease of use, safety and experience of using. These themes emerged most prominently in reference to the FAR training component, and slight variations emerged for the behavioural diary component, including forgetting and reminders, subjective issues and monitoring of behaviour.

#### 7.4.7.3.1 Facial affect recognition training evaluation

Two participants made comments relating to their perceived value of the intervention, expressing doubt in the effectiveness of the intervention, or its utility in real-life situations.

*“I don’t know, personally I don’t think it will work but, um; It’s just um, it’s just paperwork. Little games and that on the tablet, it’s not, it’s not going to change my mindset or anyone’s mindset, I don’t feel”,* pt. 305, control

Ease of use commentary relating to the intervention generally and FAR training more specifically was very positive. I incorporated a quantitative component here, asking participants and staff to rate the difficulty (or perceived difficulty) on a scale from one to ten, with one being the easiest and ten being the most difficult. The average score across the group was two. All those interviewed (participants and staff), referred to the training being ‘easy’ or ‘very easy’ and ‘straightforward’. All reported being able to understand task instructions and the staff indicated that they understood the premise and rationale of the study in addition to this. The highest difficulty rating (five) provided the accompanying comment that the speed of presentation made the FAR training more difficult.

*“Cause sometimes it’s difficult, you can hardly see the faces it just pops up and pops out quick it’s a second only, you know what I mean?”,* pt. 312, control

The ease of the intervention and the fact that nearly all reported finding the FAR training to be repetitive may have led to the recurrent comment (participants and staff) that the training was considered ‘long’ (three interviewees) or ‘boring’ (five interviewees).

*“but you know like the tablets a bit boring like, do you know what I mean? It’s the same thing all the time”*. pt. 308, control.

*“So, it does become a bit repetitive and I think it’s just generally the clientele we’re dealing with, the age group we’re dealing with they do find it like a bit boring”* – Staff, NC.

Out of the ten interviewees (participants and staff) who were asked, eight said that they felt four times was an acceptable number of intervention sessions in which to complete the training. However, one member of staff stated that he considered this to be the limit.

*“The only other thing that might have an effect was again, it was about the repetition over and over again that would make it a little bit difficult, it could have made it difficult if it was longer than four sessions, it would have been – you know it’s going to drop substantially then – Staff, RG. Commenting on participant engagement.*

Both staff members reported that they considered the intervention safe to use. Nine of the participants and both members of staff reported that they considered the intervention appropriate for use within a prison setting. One participant commented that they did not think it appropriate as they doubted it would be effective, and another stated that they did not know. This suggests that interventions targeting FAR would be appropriate for use with violent young people, in a prison setting (research question six, see section 1.8.1).

An additional theme which emerged in relation to the FAR training was the acceptability or preference for the use of tablet technology. This was mentioned by three participants and a member of staff and will be discussed in greater detail in a following section (see ‘method of administration’). There was also some general overlap within the evaluation section in relation to the relevance of the intervention for certain individuals. This is explained in greater detail in ‘factors affecting adherence and engagement’.

#### 7.4.7.3.2 Behaviour diaries evaluation

Four participants and one member of staff commented that the behaviour diaries were easy to use (in addition to the FAR training component). Three questioned the personal relevance of the diaries, in relation to their not having displayed any aggressive behaviour and therefore having nothing to report. Two made comments regarding how useful they found the diaries, in that the diary helped them to monitor their aggressive behaviour. Two indicated issues with remembering to complete the diary and having to retrospectively complete it. The need for reminders was also commented on by a member of staff who reported needing to re-issue diaries which had been misplaced in some cases. Conversely, the other member of staff reported little need for issuing daily reminders or difficulty with collection, stating:

*“To be honest I didn’t have any problems collecting the paperwork in from the lads, they sort of, every Thursday if I was in on the Wednesday or the Tuesday, I’d say I’ll come and collect the papers on the Thursday morning when I’m in. Next time I work on the unit with them, straight away they’d come out with their breakfast – oh there’s the paper” – Staff, NC*

Other staff comments in reference to the diaries included them being difficult to coordinate and manage (see ‘factors affecting management and integration’), that they need to be made more relevant to the behaviour of this particular age group (see ‘suggestions for improvement’) and that scoring on a scale of 1 to 100 within the staff diaries could lead to confusion and inconsistency between staff members.

#### 7.4.7.4 Factors affecting adherence or engagement

Seven participants and both staff members described factors that affected adherence to the intervention, in both positive and negative directions. These factors fell into four main categories including: personal relevance, assigned value, context and repetition.

#### 7.4.7.4.1 Personal relevance

The topic of personal relevance was mentioned by approximately a third of the participants, who questioned the relevance or the suitability of the intervention for them. Three participants referred to an inability to report aggressive behaviour due to a lack of aggression.

*“Yeah like, obviously there was nothing that for me, cause obviously I know I got it [the intervention] for like a good four weeks, like 5 weeks but when I was getting it like, them days like, if I had this before when I’ve come in jail, would have been different, I probably would have filled up a whole page, every day, but obviously like, since I started like a couple of months after I don’t get angry the way I used to.”*, pt. 307, training.

It was also suggested by a participant that the intervention was not suitable for their age group and it would be more appropriate for a younger population, which may have caused disengagement with the intervention. This was echoed by a member of staff who stressed the importance of making the intervention appropriate to the level of learning. Whilst feedback indicated overall that the task was easy, it may have been too easy in some cases and considered patronising.

#### 7.4.7.4.2 Assigned value

Assigned value of the study, with the perception that the research was meaningful and informative may have improved engagement due to interest in the intervention and a wider understanding of the value of research. This was expressed by one participant.

*“Cause it’s something to do isn’t it? Like studies and that for university. Just to help and stuff innit, do you know what I mean, helping like future and that so don’t mind doing it like”* – pt. 308, control

#### 7.4.7.4.3 Context

Adherence also related to factors which were specific to the context in which this study was conducted. A recurring comment for two participants was an interest or willingness to take part in the study as it was something to do and provided stimulation. This suggests that the engagement may be a consequence of lack of variation in the prison routine and may not be replicated in a non-prison setting. Another participant referred to the novelty of the intervention, as being different to the usual paperwork format of the current prison interventions.

The presence and frequency of reminders provided by the intervention staff for completion of training and behaviour diaries was also mentioned by two interviewees (one staff, one participant), suggesting reminders may have improved adherence. An important consideration in relation to context was in how the training was integrated with the prison schedule. This was mentioned frequently by staff and on occasion by participants. Different educational programmes are given different value by service users, with some being much more popular than others (for example cooking, gym and carpentry). If the intervention interfered with a preferred activity, this could reduce engagement. However, if the intervention was arranged outside of these activities or in lieu of other interventions then participants would be more receptive.

*“So it was literally we’d go round and pop them out of education or catch them when they came back from the gym that’s generally the hardest part is getting them when they’re in a lesson that they like, they don’t want to come out and do that so then you try to rearrange a day I could be on an early, so then I’m handing over to someone else to catch up with them =” – staff, NC.*

*“Yeah I don’t mind it innit, do you know what I mean? It got me out of my class like half the time my class was boring like do you know what I mean, so I didn’t mind getting out and doing it like, innit... I done it once, came out of my cell once cause I’d just finished gym and ah, went in my cell like, went to shower and then the gov came and got me so that was alright like do you know what I*

*mean going up to my cell for a bit longer. But other times it was out of education likely, so.” pt. 308, control.*

#### *7.4.7.4.4 Repetition*

The repetitiveness of the task (as mentioned in section 7.4.7.3.1) also emerged as a factor that may affect adherence. This was frequently noted by members of staff and participants.

*“I think there was a positivity, especially at the beginning. I think because it was the same thing and the same task repeated over and over again I think that was um, the biggest impact about people being reluctant to um, engage” – Staff, RG*

*“If you’re doing it every day, it’s like four times like, so you’ve gotta do that once every week its and it’s the same thing like more time people will just get bored of it where (1) I’m not saying I done this but time where you gotta just press something, like [Gestures repetitive pressing of the tablet without attention paid to the task] till it finishes. And then, yeah, it does get boring if you’re doing it like four times a week and that”, - pt. 307, training.*

#### *7.4.7.5 Method of administration*

There was overlap between this code, factors affecting adherence and engagement and intervention evaluation, however the main sub-themes that emerged within this section included: use of tablets, intervention format (including number of completed sessions, repetition within the training and speed of presentation), success of blinding, assessment of behaviour diaries and instruction comprehension.

#### 7.4.7.5.1 Tablet technology

The use of tablet technology to deliver the intervention was met with positive evaluation and approval. Around half of the participants and both staff members referred to the use of tablets during the interview, with six commenting on the preference for tablets due to the novelty of the intervention platform.

*“Yeah, cause usually it’s all like paperwork and stuff and it gets kind of boring but it’s a change obviously, people want the change sometimes innit. So not many people want to go and do an intervention if it’s just the paperwork and stuff so, with a tablet it makes it a bit more fun if you know what I mean”* pt. 306, training.

Another participant commented that the tablets were beneficial as an alternative to writing. The novelty of the interactive element of the intervention may have been useful in retaining the interest of participants, whilst traditional pen and paper format used in typical interventions may cause disengagement.

*“Cause like, its more of a thing where obviously if you had the faces and you had to write it down there’s people that like don’t like writing or doing anything to do with writing so”* pt. 307, training

Members of staff also made positive appraisals in relation to the interactive element, the simplicity of the platform, and the portability of the tablets.

*“I think using technology would be a good idea, it’s different from being sort of sat down in a room – I imagine it’s (intervention staff name) talking and asking questions, things like that [gestures tablet] if you’re actually using something*

*interactive and things like that I think you'd keep the boys stimulated a bit more"*  
– NC, staff

*"Yeah I think it makes it a bit more interesting for them. Um, in here they seem to sort of slip away from technology and such so I think, its sort of a novelty, to be honest, they like novelties"* NC, staff

*"No training required actually there were, apart from the bugs that we encountered, one or two bugs there were no issues they were straightforward to implement. It was really straightforward".* RG, staff.

Within this code, aspects of the FAR training itself were also discussed. This included the willingness to complete the training four times (see the 'evaluation' code for additional detail), the repetitive aspect of the training (see 'factors affecting adherence or engagement) and the speed of the stimuli presentation (see 'data validity concerns'). Comments relating to the diaries reflect those described in the 'behaviour diary evaluation' sub-code, and clarity of task instruction (see 'evaluation' code).

#### *7.4.7.6 Data validity concerns*

Any comments made during the interviews that alluded to problems with the study procedure or methodology, which could impede the validity of collected data were included within this code. Issues observed included the format of the intervention, inaccurate responding, inconsistencies in staff contact and possible issues with blinding.

One participant made a comment which suggested the task manipulation may not have been subtle enough, leading him to believe there was an error in the task.

*“And then I think, I think there’s something wrong as well cause sometimes even though the guy like obviously I seen like, the person is angry and then you press happy says correct”* pt. 307, training

Another suggested there may have been an issue in the randomisation command.

*“Cause mostly, on most of them like if it’s just one thing it’s always straight happy or it’s straight angry you don’t really think like happy, angry, happy, angry there’s just either, there’s like twenty happy and then its starts doing happy and angrys think like that. That’s what I clocked onto”* pt. 309, control.

Two participants made comments relating to the quick stimuli presentation speed, suggesting obscured recognition for some participants.

*“Cause they all look the same as well. Like when it’s flashing quick it just looks the same like. Don’t have a clue (laughs)”* pt. 308, control

There may also have been some inaccurate responding on the emotion recognition task in the later trials or towards the end of the session for one or a minority of the participants. This was suggested by one of the participants and both members of staff and was related to levels of boredom and repetition.

*“On one case, they weren’t really paying attention to the images and they were just pressing the er, thing so, yeah”* Staff, RG.

There were also data validity concerns in relation to the retrospective completion of behaviour diaries (see ‘behaviour diaries evaluation section’).

Ideally participants should complete the diaries daily, or staff weekly, for more accurate behavioural observations.

Other issues that were flagged by staff was the inconsistency in members of staff rating the behavioural diaries. Difficulties emerged in the identification of staff members who had been in contact frequently with the participants during the observation time-frame and in the collation of information across the week when there were changes in appointed staff or absences (see 'factors affecting management and integration').

*"The hardest thing I think, was erm, obviously cause I don't work every day, I'm not sort of seeing the boys behaviour every day. So other officers were involved and were all sort of like, um, liaise with each other if we don't see each other via email, so so and so's been OK the last few days I've been in, so. That's how we've been gathering data. And we didn't know which officers were involved in it, well we did know, we did all the names like that, but when officers were on duty at any given time and things. So, that was the hardest part really. Sort of just all collating all the information that we had over a 7 day period"* Staff, NC.

Another concern was that the staff-blinding may not have been effective. Both members of staff claimed to know which condition the participants had been allocated to, despite these being anonymised as condition one and two by the researcher (also blinded) during the allocation stage. The conditions were renamed as 'training' and 'control' by the prison staff during the intervention to make it easier to differentiate the conditions, and these were later confirmed as accurate labels by the researcher during the analysis stage. There were however, no data validity concerns regarding this in relation to the participants. No participant reported any awareness of their assigned condition, or the knowledge that two separate conditions existed.

*"(Did you know which was which?) (MC)*

*Oh definitely, yeah yeah um, it was important for me to be as clear as possible because we just put the tape on, initially we just put the tape on there to indicate, mm, for me I just wanted to write it down not only for my benefit um, but also for my colleagues benefit so they could not make any mistakes (OK, and so you knew exactly which one was the active training?) (MC)*

Yes, yeah”, Staff, RG

#### *7.4.7.7 Suggestions for improvement*

Predominately, suggestions for intervention improvement were directed at alleviating the repetitive nature of the task. This included: reducing the number of sessions overall; shortening the task itself, including less trials within each session; and reducing the frequency within which the task was administered, for example, administering it only once per week, but for a longer overall duration.

Additionally, three participants and one member of staff suggested making the task more varied and interesting by incorporating additional stimuli depicting different actors, the introduction of female facial stimuli and introducing greater variation in emotions and features.

*“Just more expressions like innit, do you know what I mean? Cause it’s just the same ones. Cause they all look the same as well”. pt. 308, control*

*“Change the faces a bit, the boys would probably appreciate some female faces on there”, - Staff, NC.*

In regard to behavioural observations and recording aggressive behaviour, staff members made some helpful suggestions. This included keeping track of aggressive behaviour using the prison documenting system, P-NOMIS over a longer time period for more objective observations. They also suggested adapting the current diary measure to make it more relevant to this particular age group, as some behaviours categorised as being aggressive,

could also be interpreted as being 'mischievous' or 'cheeky' in the current sample, making the staff and self-reporting element of this measure quite subjective. They also suggested including the dates on the diaries, instead of 'day 1 – 7' as it currently reads.

#### *7.4.7.8 Assessment of change*

I asked all the participants during their interviews whether they felt the intervention had any positive or negative effects on them. All eleven participants answered no to this question. I also asked whether they thought the way they interacted with their peers had changed, or whether their levels of aggression had changed. Half the group reported that they did not think they had changed in these respects, and the others reported that they felt they had. There was no clear pattern to suggest those who observed improvements were limited to the training condition (out of the five participants assigned to active training three reported positive effects and two reported no change). The reported changes from the intervention group included: being different with the other young people on the unit and getting into less fights (304, training); learning to let things slide and control themselves a little bit more (307, training); reading faces a little bit better (311, training). The reported changes from those in the control group included: looking at what they were doing wrong and having more awareness (309, control); and getting on with everyone on the unit, with a '10%' reduction in levels of aggression following training (312, control).

I also asked members of staff whether they had observed any positive or negative effects on the participants or within the unit. One member of staff reported that he did not observe any change in relation to attitudes to violence, but in terms of negative effects he did observe boredom in some participants towards the end of the training (staff, NC). The other staff member reported positive change in some of the participants, observing that they seemed more focused on their behaviours (staff, RG).

#### 7.4.7.9 Active mechanisms

Several participants described mechanisms by which they thought the intervention might modify behaviour. These fell into two main types. First, three participants commented specifically on modifications or improvements in FAR. One suggested that engaging in the FAR training may improve this skill and aid with the interpretation of intent.

*“Like, say that obviously if you’re arguing with someone then seeing that and doing that (gestures to task) you might be able to like, be able to read their body language easier and that”* pt. 301, control.

Another two participants, both within the training condition, implied the intervention could work by drawing their attention to facial expressions, when usually they would not be aware of them, or thinking about them.

*“I dunno cause you don’t really think about feel[ings] in it – its not one of those things you think about. But when you do like – cause I got loads of them wrong. I was thinking they were angry but theys happy so you never know what their emotions are really do you”* – pt. 303, training (see section 8.4.7.10.3 for further discussion of this point regarding safety).

*“I thought it was very helpful innit like, its you don’t, it’s not like you’re noticing, it’s hard to explain like, you do notice them but you don’t, if you know what I mean? Like, it does help you like”*. pt. 306, training.

Second, more frequently, comments were made relating to increased self-awareness, self-reflection and monitoring of behaviours, which may in turn lead to increased self-control. References to this were made by three participants (two in training and one in the control condition) and one member of staff.

*“It just, like when you fill it in, like the form thing, and the next day you can see whether or not what you did do and what you didn’t like. Say if I got angry right now and I wrote it on the thing, then tomorrow I can find out innit, but yeah I’ll say yeah kind of, cause I’m looking at what I’m doing wrong and that”* pt. 309, control.

*“I think it made some of the young people um focus on um, on whether they were actually doing any of the, exhibiting any behaviours that were asked in the questions, where the others [referring to the young people who did not appear to be affected by the intervention] could be quite dismissive and um maybe lacking the awareness of having any of those things, any of those behaviours”* staff, RG.

Some participants also made comments questioning whether these mechanisms may be more effective with some recipients than others. For example:

*“if I get angry I just don’t listen to people regardless of what I’ve done. If I’ve done the best work right now and I’ve done the best interventions that you could ever have if I touch that place and I get angry just, give me everything I go I learnt just go through the window”*, pt. 307, training.

This may suggest that those who display more reactive aggression are less receptive to the training effects.

#### *7.4.7.10 Factors affecting management and integration*

This code referred to management of the study and integration of the intervention within the prison setting. There were several recurrent themes regarding management mentioned by both members of staff. This included:

staff resources and burden; training; size and format of the study; study environment and for one member of staff, eligibility criteria.

#### *7.4.7.10.1 Staff resources and burden*

As previously mentioned, (see 'data validity concerns') there were difficulties finding members of staff with consistent contact with the participants who could complete the weekly behaviour diaries. This combined with managing the associated paperwork for each individual increased staff burden.

*“Unfortunately, it was the, it was sort of the wrong time, we didn't have enough staff um and it was trying to sort of get members of staff to sort of buy into what you're doing and sort of, try to um work with the young people. Unfortunately, it clashed with things like um, time off so there was lack in consistency. It also clashed with their holidays as well so we assigned one or two people and they were on holiday for three weeks so, or two weeks so it wasn't the er, you know, it didn't get the best of what it should have – it wasn't as good as it should have been, so to speak. But I think, if we um dedicate staff to it, it would be more coherent and it would actually be a lot better I think. Staff, RG.*

As the need for multiple members of staff was not anticipated in advance of data collection there was no central system within which to co-ordinate this information, an issue mentioned by both staff members. Also, as these staff members spanned different teams within the organisation this made it more difficult to co-ordinate. One staff member commented that having two intervention staff dedicated to the management of the study would make communication and management easier.

#### *7.4.7.10.2 Size and study format*

Staff remarked that it would be difficult to manage the study on a larger scale without dedicated staff to do so. In addition to this, the rigidity of the

procedure (administering the training four times within a short time frame and with the requisition of four weeks of behaviour diaries) added to management difficulty and staff burden.

*“I think really it was just my workload as it was interfering and sort of, sort of not sometimes fully committed to doing it, part of your mind is always in the other work have I gotta do this or have I gotta do that so um, sometimes that would cause a problem. If I were actually delivering this intervention full stop then it wouldn't be the ah, there wouldn't be the issues” - staff, RG*

*(Did you feel as if you had adequate time to perform the tasks you were committed to doing?) (MC)*

*“Retrospectively yes, at the time, no (laughs) no, but like I said that was informed by my anxiety levels so trying to make sure that everything was done and worrying a bit too much about the cut off dates picking them up and then sort of giving them new diaries, etc. ...the diaries, picking them up and you know it could take a large chunk out of your day um so to try and find people and to make sure that they have to get them that day, or at the very least the day after it was, you know, because if your, if it extends any further then there's going to be some inaccuracies in what you're doing so it's trying to sort of make sure they got them that day” Staff, RG.*

#### *7.4.7.10.3 Staff training, safety and eligibility*

Both staff members reported feeling suitably trained to manage and deliver the study and that they understood the rationale of the study and the procedure. The member of staff involved in eligibility assessment (RG) reported that the criteria were clear and straightforward and there was an absence of danger or safety issues in delivering the intervention.

One safety consideration, relating to the comment made by participant 303 in section 7.4.7.9, is whether there are adverse consequences affiliated with the self-perception of their previous FAR as 'wrong' or 'incorrect' as a result of the intervention feedback. This could give the participant the impression that they have poor FAR ability, whereas in reality, their capacity for FAR is in the normal range but the intervention is focused on shifting their bias. This in turn might be unsettling for the participant. There was no indication in this case that this led to increased anxiety or feelings of inferiority in the participant, but this could be a possible adverse effect which should be explored further in future.

#### *7.4.7.10.4 Study environment*

Another important factor mentioned by staff was the current context and environment within the prison. For example, in this particular setting the study was easier to manage at the present time due to having a smaller number of service users in the unit than was usual (approximately at half capacity), and those within the unit were reported to be less reactive than was usual, resulting in fewer infractions and disruptions in the prison schedule.

*"It all depends as well though what kind of mix of boys you have on the unit and things like that. At the moment we're quite lucky, we've got quite a good mix, if you'd have come six months ago it was alarms after alarms after alarms"* Staff, NC.

Questions relating to how the intervention fit within the current organisation and prison schedules were asked within the staff interviews only. Discussion arose around the themes of integration with education and schedule, current aggression interventions and resource issues (including staff, physical space and access to technology). As mentioned previously (see 'factors affecting adherence and engagement'), integrating the training component of the intervention with the educational schedule had varying

degrees of success depending on the timing and the programme. This was mentioned by both members of staff.

*“The only other challenges was clashing with their educational needs, and not all educational needs are equal, if it was the gym if it was, certain areas like um, one was having his portrait drawn yesterday so he didn’t want to and he was partway through so you can understand that, when they’re in the gym, that’s going to be an issue because they don’t want to come out of the gym um or certain aspects because (unclear) ...they play football. If they dislike the other then the availability, one or the other you can pull them from either one”* Staff, RG

However, reference was also made to the advantageous nature of the tablets portability, and the short duration of the training sessions, which made these challenges easier to address.

*“When we have cooking online if we were to implement this then that would be an issue as well um, so there are some clashes, the hub for instance, carpentry um that was an issue, but I was able to take the tablet down there and do it [deliver the intervention] in the office and it was over within 10 minutes or more”* Staff, RG

Another issue was that when the intervention session had to be rescheduled, due to a schedule clash or a request by the participant, this could mean the intervention delivery was handed over to a different member of staff – which increased the complexity of management. In terms of delivering the intervention and integrating it with the schedule, this seemed to be on an opportunistic basis, and may be improved in future by allocating specific intervention time in which to deliver it.

*"It was literally sort of just going up to education, 'you happy enough to come and do this for us quickly?' so we'd just take them off the wing or the education block and take them to a quiet room or whatever or sometimes even they're just in their cell if they're back from gym so then they're in their cell can just crack on just obviously stand to the side and just observing them, watching them do it - ... So, that was the, that was the difficult part there's obviously times outside of their lesson or whatever or in a specifics sort of interventions lesson when you could do this, then that would probably be a lot easier". Staff, NC.*

In terms of fit with the current interventions, it was reported that aggressive behaviour interventions currently in place within that unit are opportunistic depending on what is available in the prison at the time and that this intervention could be readily integrated into what is currently available. One of the members of staff (intervention staff) commented further on this, suggesting that something similar to the FAR training may be beneficial due to its interactive element:

*"Yes, I think um the interventions that we currently have are the only ones that we could appropriate um, the um you know we actually, I sort of borrowed, I asked YOS they brought one in they were talking about one and that was the current anger management model that we use. It is a little perhaps too complex for them, and so, you know sometimes you have to explain it and it's not so very interactive, so I think that we could probably, that we could do with sort of having something more engaging and interactive. But, on a similar level to what we have... ...I'm sure that we could assimilate it in what we do, in what we actually do so, and that might actually break up some certain aspects of the repetition as well, sort of by changing from one thing to another". - Staff, RG.*

Another consideration in relation to study environment is that the use of technology within this unit, and the prison system more widely, is very low. This could affect the ability to integrate an intervention such as this due to the need to purchase equipment and accompanying security checks, however It could

also make the intervention easier to assimilate in some ways, in that the technology aspect may elicit more engagement from the service users due to its novelty.

*“They have access to computers and things but normally that’s just like to listen to music or that’s about it, they used to watch videos on it but they’ve all been taken off now so they have very little access to technology*

*(so there’s nothing on them at all?) (MC)*

*Not much on the computers now at all”. Staff, NC.*

In terms of physical space in which to deliver the intervention, comments indicated that whilst there are restrictions within the unit in terms of available rooms, this was alleviated by the portable nature of the training equipment.

*“I don’t think there were that many problems with it and we do have spacing issues, but um, at the time I don’t recall having too many problems, we’re looking at 20 minutes here that I could fit, you know doing that. The carpentry was good because they’ve got an office down there I could take them out of carpentry 20 minutes and then they’re back doing their carpentry and I’m gone. Um, upstairs if they’re on the unit I could possibly do it in their cell if they’re supposed to be behind their door and just advise the staff not to let anyone on, or I could do it in the um, gold room ensuring that door was locked, so doing it one to one for twenty minutes gives us um a bit of space and it is quite reasonable I would say” Staff, RG*

#### *7.4.7.11 Factors affecting intervention delivery*

Comments relating to intervention delivery included the use of equipment, the aforementioned issues with education integration, negative

effects of repetition and specific considerations in terms of administration and supervision.

Staff commented on decreased motivation observed during later FAR training sessions (see 'factors affecting adherence and engagement') and how this could impact delivery. One staff member referred to the 'forthcoming' nature of the participants in relation to providing behaviour diaries, but also commented on the characteristics of this particular age group, as being reactive and 'hot headed', which could reduce the effectiveness of these interventions. Both staff members agreed that capacity was not an obstacle in delivering interventions.

Staff reported that the equipment was easy to use with a straightforward format, despite one of the tablets having technical issues and not being employed as a consequence. Battery life was reported to be good, if charged each morning before administering training. One member of staff, who had greater involvement in intervention delivery within the prison stressed the importance of delivering interventions individually, rather than in a group setting, and in supervising participants as they complete the training – both for interventions in general and this training programme in particular.

## **7.5 Discussion**

This feasibility study and pilot trial has informed us that the intervention was well accepted, both by participants and staff and that FAR interventions are appropriate for violent young offenders within prison settings, providing a clear answer for research question six (see section 1.8.1). Furthermore, the procedural plan for the intervention implementation was manageable and feasible within a prison setting, as indicated by high adherence and completion rates. However, a key pre-specified success criterion was not met, which hinders the progression of this study to a full-scale definitive trial. We were unable to recruit the forty participants originally specified in the study protocol. As the definitive RCT requires a much larger sample size of four hundred participants, this is an important factor to consider.

These results suggest that there is a need for more novel aggression reduction interventions and that this intervention could be integrated amongst

those currently in use within this prison unit. The procedure outlined in this Chapter was successfully adapted from that used in Penton-Voak et al. (2013) and there is potential for expansion of the current procedure for delivery on a larger scale, given that some of the considerations raised in this study are addressed. In terms of effect estimates, I did observe increased identification of happy facial expressions in the training group compared to those in the control condition, however I did not observe any trends for behavioural changes as indicated by the aggression diaries, which corresponds with the findings for CBM described in Chapter six.

In regards to pilot trial criteria, questions relating to the process of the study indicated that eligibility criteria were easy to understand and not overly restrictive, the measures and data collection tools used were appropriate - with perhaps the exception of the staff behaviour diary, adherence rates were very good, and whilst refusal rates accounted for more than a third of the eligible sample, this was not unexpected given the population of interest. This study has provided more precise estimations for required resources for a definitive trial and has informed us of the usability of equipment and unforeseen challenges in study management. Finally, it has confirmed that the intervention is generally thought to be safe to use and of benefit to the user. Some feedback suggesting frustration due to repetitive administration and the possibility of introducing self-doubt in FAR ability should be explored further in case these constitute adverse intervention outcomes. However, the majority consensus stated they would continue to use the intervention, or components of the training if given the option to do so. Furthermore, the self-perceived reduction in aggression or increased awareness reported by some of the participants following training suggests that this is a promising avenue which warrants further investigation.

### *7.5.1 Implications and recommendations*

Whilst pre-specified success criteria are encouraged in feasibility studies and pilot trials, the CONSORT guidelines advise caution in setting definitive threshold that could be missed due to chance variation (Eldridge et al., 2016). It is worth considering the findings of this study in respect to the specific context in which it was conducted. The inability to recruit forty participants may reflect

difficulty in access within the prison at this particular time, or lower numbers in the YOI unit. The findings reported here reflect the activities of only one feasibility study and pilot trial with limited generalisability. The YOI is a contained unit within the prison, with separate buildings, cell blocks and allocated staff - including intervention staff. In having separate resources to the wider prison, this enabled the navigation of this study on a small and contained scale. This was not achievable in the adult unit and may not apply to other YOI units or secure estates across the UK. These results indicate the need to investigate feasibility on a case-by-case basis. However, if provisions are made, there is no reason why some of these obstacles detailed here cannot be overcome and addressed for a definitive RCT. Suggested amendments are proposed in the following section. This study can be used as a template for future studies within settings and with populations of this nature.

Secondary objectives included collecting baseline characteristics, including health measures and neuropsychological assessment of participants to provide a detailed profile of this population. This was successful, with the exception of the early trauma measure. I advocate repeating the process of baseline profiling for future studies as these populations are complex and there are a multitude of factors which may affect intervention effectiveness. However, it's advisable that provisions are made to either signpost the participant for further support if health related needs are identified or ensuring that there is necessary rapport and follow-up if sensitive topics are included. With regard to individual differences in this sample, some comments were made within the interviews that suggest the intervention may be less effective in those with higher rates of reactive aggression. This is interesting, as it could be argued that those with higher reactive aggression would be more appropriate for an intervention of this nature. However, it was suggested that if an individual is *very* reactive, they are likely to aggress or act regardless of the interventions they have engaged with. Conversely, the intervention may help reduce the likelihood or frequency of reaching that reactive state to begin with (even if ineffective when the individual reaches an elevated state of arousal). This highlights the importance of measuring relevant behavioural and personality attributes and adjusting for these in future analyses.

An interesting outcome of the qualitative analysis was regarding the comments made by both members of the training and control groups regarding the positive effects of the intervention. This may be indicative of a placebo effect or a respondent bias. However, it may also suggest that multiple aspects of the intervention can yield positive results, whether through passive exposure and identification of facial expressions (without the manipulation component), or through the introspective monitoring of behaviours using the self-report behavioural diaries. Recording and monitoring of behaviours has been effective in reducing aggressive and disruptive behaviour in a classroom setting (Zlomke & Zlomke, 2003), however this was delivered in combination with point reward incentives. Monitoring of behaviours did not appear to translate to behavioural outcomes in this sample, but this may have been due to lack of power to detect effects, or insensitivity in the outcome measures, e.g. due to subjective or inconsistent reporting.

A key consideration when deciding whether to progress to a definitive trial is the impact this will have on the organisation, affiliated staff and participants. The responses and engagement we received from the participants was good, with the exception of the training being overly repetitive and, in some cases, frustrating. An important concern is the potential burden that a trial such as this could impose upon affiliated staff. Resources in these settings are very limited and already strained. Whilst feedback received from staff was generally positive, there are concerns that replication of this study on a larger scale would have detrimental effects on the individuals and the organisation.

The most time-consuming aspect of the trial was reported to be the delivery and collection of aggression behaviour diaries and the management of associated paperwork. It would be interesting in future to change the format of these and digitalise the measures, so that they are contained within the same tablet platform as the intervention. This would help to reduce time spent compiling diaries, data loss and printing costs. It might also be beneficial in synthesising staff-rated aggression across multiple members of staff in the event of absences or inconsistency. Alternatively, if prison systems allowed, the use of ecological momentary assessment for daily diary reminders would be a more efficient means of collecting accurate data, with reduced management demands. There were also issues reported with scheduling. I suggest in future

having scheduled time to devote to intervention completion, rather than having the intervention compete with education and being administered opportunistically.

Currently there is very low use of technology and equipment within prison settings, which may make it harder to integrate interventions of this nature as there are not the resources to support it. However, if these low-cost resources could be made available in prison settings, with appropriate security adjustments, it seems a preferred and valuable platform to deliver interactive interventions. The participants enjoyed the novelty of the interventions and the ease of use, and staff commented on the portability of the intervention as beneficial to intervention delivery.

#### *7.5.2 Feasibility and pilot trial limitations*

There are study limitations which should be acknowledged. It is possible that there was a selection bias in those recruited. There was a refusal rate of 37% and it may be that those who declined participation comprised those for whom the intervention would be most appropriate (for example, more aggressive or volatile individuals, or those with poorer social functioning). Our blinding procedures did not appear to be effective for the members of staff involved with the study, who re-labelled the intervention tablets, correctly identifying them as control and training to aid ease of intervention delivery. This did not seem to be communicated to the participants who reported no awareness of study condition. More stringent blinding procedures should be employed in future as this could have introduced bias and the importance of blinding should be conveyed to prison before allocation. Alternatively, it may be that the blinding strategy was appropriate, but the training task is more easily recognised than the control, in which case we should consider creating a subtler manipulation or more tightly matched control.

There were certain data validity concerns as suggested by the qualitative analysis. There may be a lack of engagement with increased repetitions of the intervention, with inaccurate responding as a result. I suggest setting pre-determined criteria to check for reduced engagement, such as a reduction in

accuracy over training sessions, reduced variability (suggestive of selecting the same emotion consistently regardless of stimuli) or too much variability (suggestive of random responding). Some participants suggested there may have been an error in the task, or problems with the randomisation of the stimuli. I could not find any evidence of malfunction within the EPrime commands to support this, but it may be that the participant who suspected malfunction was detecting the task manipulation, which argues again for adaption of the task to increase subtlety. Alternatively, introduction of a distractor emotion could be beneficial in reducing the transparency of the manipulation if this is a problem.

As mentioned, estimates of treatment effects were given here, with comparisons made against previous samples. These tests were underpowered to detect effects and are reported here in line with our pre-specified pilot trial criteria. The samples are very small and there is a considerable amount of variability, especially in relation to the behaviour diaries – I stress that these are not definitive and would not advocate using these to inform future sample size calculations. In addition, the qualitative interviews for the participants were short, which reflects difficulty engaging these individuals and the closed nature of some of the questionnaire items which may have limited the information gathered. A more narrative approach in future may be beneficial in encouraging elaboration from the service users.

### *7.5.3 Progression to definitive trial*

Based on the evidence reviewed here, the following suggestions are made for progression to a full-scale definitive trial.

First, it would be advantageous to better determine the intervention effectiveness generally prior to continuation of this research within a prison setting. The findings of Penton-Voak et al. (2013) were encouraging, but as highlighted in the systematic review described in Chapter six, the translation of FAR training to behavioural outcomes is inconsistent. Replication of the previous findings in a sample of non-incarcerated people with aggressive or violent tendencies would help justify that the effect observed previously is

robust and that the intervention is effective. Due to resource constraints and restrictions within prison environments I advocate investigation in non-prison settings initially. This could include community-based offenders in YOT or probationary services, or young offenders in secure units, outside of prison environments. Additional feasibility studies and pilot trials should be conducted to assess the needs of these settings (this study can be used as a template). Progression to a larger trial within a prison setting or incorporation of the intervention into prison treatment options could be instigated following replication of these effects, better justifying the associated costs.

If it were decided to progress to a definitive trial within a prison setting, I suggest this is conducted across multiple sites in the UK, or internationally to assist with recruitment of a large sample size. I advise appointing a researcher or research assistant to assist with data collection, preferably someone local to the prisons to reduce travel and accommodation costs, who could assist with the diary issuing and collection to help ease staff burden. The restrictions of the intervention procedure could be relaxed to allow more flexibility and convenience in the programme and I would advocate building the intervention delivery into the prison schedule so that it doesn't interfere with educational sessions. Having multiple sites involved, researchers distributed across these sites, and an extended time period in which to conduct this research would increase the likelihood of study success and improve quality of data collected, whilst also reducing staff burden.

I suggest designing and executing lab-based studies prior to this, to investigate the efficacy of the intervention when certain parameters are manipulated. There was consistent feedback from the staff and participants that the FAR training component was repetitive and onerous, and that four intervention sessions within the space of ten days was excessive. This may have caused disengagement and made the intervention less effective. Indeed, I did observe greater response variation in the final session compared with the first, however it remains to be seen whether this was a consequence of reduced engagement. It is worth researching whether similar effects are observed in shorter versions of the task, more varied stimuli presentation, incentives such as pointification of the tasks, a wider interval between administrations (e.g. once per week for a period of one month), or with less intervention sessions in total

(e.g. twice or three times). It may be beneficial to co-design future iterations of the intervention with members of prison staff or participants included within this study. This would help identify which adaptations would promote engagement, prior to trialling effectiveness in a laboratory setting and comparing against the original version. These suggested adaptations are summarised in **Table 7.4**.

I also suggest piloting different, more objective ways of measuring aggressive behaviour outcomes. There were difficulties in this study in terms of subjectivity for responses within the staff-rated behavioural assessments and in terms of consistency with allocated prison staff. Comments were also made regarding the interpretation of behaviours as 'aggressive' or simply 'cheeky' and characteristic of the population. It may be worth trying to incorporate a more effective means of measuring aggression and linking any displays or aggressive events with the prison record system to ensure more systematic reporting of these. The self-report aggression measure seemed well suited and well-received by the participants, although some staff members suggested that behaviours may not be well-recognised or dismissed by certain individuals. However, I recommend these be retained for future use, with a few small adaptations to the instructions and scoring sheet and explanations given prior to their administration to help aid recognition and reflection.

In addition, I suggest inclusion of a screen for current aggressive behaviour in the eligibility assessment. We included those who held convictions for a violent crime, or who had records of aggressive or violent behaviour whilst being incarcerated. However, I had comments from some of the participants suggesting the intervention not being relevant as they were not currently exhibiting any aggressive behaviour. Holding a conviction for a violent crime does not necessarily mean high levels of aggression in everyday life. Criminal behaviour is often a result of a specific contextual or personal situation, commonly under the influence of drugs or alcohol, or with an intentional goal in mind (e.g. theft). In addition, those we deemed ineligible as they held convictions for non-violent crimes may have difficulties with anger and aggression. In future, it may be worth screening all service users for current anger management issues and aggressive behaviour.

I also advocate the collection of criminal histories and gaining permissions for access should be re-visited as profiling and subgroup analysis based on type and severity of crime would be of interest in a larger sample. In addition, if this was conducted on a larger scale, it would be interesting to link the study with prison records to derive an estimate of future reoffending rates, similar to the outcome measures included in Hubble et al. (2015).

#### 7.5.4 Summary

In summary, this study suggested that this intervention and trial protocol were appropriate for use within a prison setting, with young people convicted of violent crimes. Progression to a definitive trial may be impeded by difficulty accessing these populations and recruiting a large enough sample size to provide statistical power, however this may be overcome with testing across sites and with provision of additional resources. Future research should consider revising aspects of the intervention to make it less repetitive and to promote engagement, incorporating more objective staff-rated aggression measures in a central system. The use of interactive digital interventions administered in a portable platform was well received by participants and staff and should be explored further for other forms of rehabilitation and behavioural intervention in these settings. A summary table of key recommendations and limitations detailed in this chapter can be found in **Table 7.3**.

**Table 7.3** Summary table of study limitations and future recommendations

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**Study limitations & proposed solutions**

Possible recruitment or selection bias

Staff behaviour diaries too subjective and difficult to co-ordinate across multiple staff members. *Try and make these more objective (removal of percentage rating system) and incorporate central storage or communication system*

Blinding procedures ineffective. *Explain necessity of these beforehand and introduce more stringent blinding procedures.*

Not large enough sample to derive informative effect size estimates. *Conduct over an extended time period or over multiple sites to increase sample size.*

Short qualitative interview length with participants. *Incorporate more open narrative questions*

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### **Recommendations for FAR training adaptations**

Reduction in number of training sessions overall

Less trials within each session (shortening of task)

Greater time duration between training administrations

More variation in stimuli (use of different actors, facial expressions, distractor stimuli)

Point incentives to promote task engagement (or tracking progress over time)

Greater subtlety on manipulation feedback

Dates on behaviour diaries

Screen for current aggression or anger management difficulties

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### **Recommendations for future research**

Conduct feasibility assessments for this study protocol on a case by case basis in different institutional settings

Include baseline profiling when recruiting these populations, but establish pathways for additional support if health related or emotional needs are identified

Try to utilise a more efficient means of issuing and collecting behaviour diaries (e.g. using a central system or incorporating with intervention programme).

Schedule time to deliver intervention to minimise disruption with education programmes

Conduct engagement checks within study sessions

Incorporate greater flexibility in intervention schedule

Test modifications to intervention parameters on attribution bias shift in laboratory settings prior to piloting in prison settings. Including: number of sessions needed; greater subtlety in training manipulation or incorporation of distractor stimuli; variability in stimulus set

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## 8 General discussion

The main aims of this thesis were to investigate capacity for socioemotional processing in individuals with self-reported TBI and offending behaviour, and to assess avenues for intervention. These aims emerged from the hypothesis that deficits in socioemotional processing may partially mediate effects of TBI on aggressive behaviour. Addressing these aims, I sought to answer six key questions. First, I will summarise and integrate the findings of the research presented within this thesis, in response to these questions. Following this, limitations of the present thesis will be discussed, followed by future directions for subsequent research and policy recommendations. For a more detailed discussion of specific findings and their implications, please refer to the interim discussion sections in the corresponding chapters.

### 8.1 Summary and interpretation of findings

*Is there evidence for a deficit in FAR in those with self-reported TBI, compared to those with mild or no injury, in populations of people with offending behaviour?*

Drawing from the findings described in Study 1 (adolescent offenders) & 2 (young adult offenders) there is no clear evidence for impairment in this domain. This is for young people with offending behaviour who have experienced a substantial dosage of TBI (defined as an injury involving a LoC for 30 minutes or more or experiencing an injury with LoC on three or more separate occasions) in comparison with those with mild or no injury. I initially observed evidence of a large effect in Study 1, where those with substantial TBI demonstrated poorer performance on a measure of FAR compared to those with no or mild injury history. However, this effect was observed in a small sample within a preliminary study and it failed to replicate in a larger sample of young adult males with offending behaviour (Study 2). Furthermore, the observed effect did not replicate in a sample of aged matched, non-offending controls from the general population, with comparable TBI severities. Meta-analysis of these effect sizes across Study 1 and 2 gave no overall evidence of deficit in those with substantial TBI, compared to those without (see Chapter

five, section 5.2.4.2). This may suggest that the effects observed in Study 1 were overexaggerated, or spurious. Conversely, there may have been deficit in the Study 1 sample, attributable to a difference in age at testing, age at injury, injury severity or another unforeseen confounding factor, such as geographical location. Additional analyses of age-related injury parameters did not indicate an association with FAR ability, however this lack of evidence may be attributable to insensitive methods or insufficient power to detect effects and as such are inconclusive. Relating this back to the schematic depicted in **Figure 1.3** in Chapter one, this suggests there is no clear and consistent evidence for deficit in socioemotional processing, in the domain of FAR, in those who have experienced substantial TBI within the CJS. These offending individuals are impaired in this domain, in relation to non-offending aged-matched controls, but there is no clear evidence for an exaggerated deficit in comparison to non-injured offenders as a consequence of injury, as initially hypothesised.

*8.1.1 If there is evidence for deficit in this domain, does this relate to different criminogenic profiles or increased risk of future delinquency?*

As stated above, a convincing deficit in FAR as a function of TBI status was not identified. I did observe weak evidence for an association between overall FAR accuracy and risk of reoffending within the Study 1 sample, with increased risk of reoffending corresponding with poorer FAR, across the whole sample. However, there was no additional evidence for an association between FAR with any other criminogenic factor (such as age of first conviction, number of convictions) in this sample. This observed association between FAR and reoffending risk did not replicate in the Study 2 sample. There was no evidence for an association between FAR accuracy and risk of recidivism, age of first police contact or total number of convictions (see correlational matrices in the appendices for additional details of these associations). In the general population sample in Study 3, there was no evidence for an association between aggression or delinquency and overall FAR, as indicated by their predictive value in the linear regression models detailed in **Table 4.4**. I did observe an association between TBI history and higher risk of violent recidivism

in Study 2 and TBI with increased self-reported aggression and delinquency in Study 3, but these did not appear to be mediated by FAR accuracy.

This is interesting, as based on the theoretical models of social function outlined in Chapter one, we might expect deficit in FAR, a form of social information processing, to translate to more aggressive or antagonistic interactions and poorer social adjustment as a consequence. This in turn may increase the risk of antisocial behaviour or future delinquency, as impaired social function can lead to prioritisation of instrumental over prosocial goals (Yeates et al., 2007). However, no evidence of a relationship between FAR and risk of reoffending or criminal profiles was observed here. It may be that measures of criminal behaviour and recidivism risk are too abstract and too removed from social information processing to observe subtle effects in these samples. These portray serious, infrequent behaviours, and composites of risk are compiled from a range of criminogenic factors such as poverty, SES and educational achievement, for which factors such as FAR may have no relation or bearing.

It is also interesting that an association between FAR and measures of self-reported aggression was not observed in Study 2 or 3. The items within the aggression measure (RPQ) are more proximal and relevant to aspects of social information processing, however no evidence for an association was present. It may be that the influential factor here is the particular way in which emotive expressions are interpreted and responded to, rather than overall FAR accuracy. Perhaps, inability to effectively recognise emotive expressions leads to an alternative interaction strategy, as detailed in the heuristic by Yeates et al. (2012), with greater social withdrawal rather than antagonism or aggression. Conversely, when considering the association between emotion recognition and aggressive or antisocial behaviour, we may need to pay closer attention to the decision-making process that generates that act. The 'Social Information Processing-Moral Decision-Making Framework' (SIP-MDM), proposed by Garrigan, Adlam, and Langdon (2018) explores the relationship between social information processing and subsequent moral decision making, synthesising developmental psychology and neuroscience perspectives. This model suggests that the earlier encoding and interpretation of emotive cues is likely informed by moral judgements and evaluations. This in turn affects the

subsequent stages in information development and informs whether to act in a moral or immoral way. This model illustrates the complexity of factors guiding our moral decision-making processes and emphasises that the process is not linear and can be heavily influenced by prior experience and the development of moral schemas. It may be that the hypothesised relationship between impaired FAR and increased delinquency is overly simplistic given the complexity of factors that lead people to engage in criminal or violent acts and we should invest future research into the decision-making processes that guide these acts. In addition, biased recognition of emotions (hostile biases in particular) may be more influential in exacerbating aggressive or antagonistic responding styles than overall FAR. I did not observe evidence for hostile attribution biases in our Study 1 and 2 offending samples, which may be why we did not observe a relationship between FAR and measures of criminality, aggression or delinquency.

*8.1.2 Is there evidence for different neurocognitive profiles (as indicated by poorer performance on neuropsychological assessments) for members of offending populations with history of TBI, compared to those without injury? If so, does this impact on their capacity for FAR?*

As discussed in Chapter three (section 3.6.1) there was no clear evidence for impaired or differential neuropsychological processing in those with substantial TBI in comparison with those with mild or no injury. The only exception to this was weak evidence for greater susceptibility to interfering material in those with substantial injury. This included greater interference effects in the Stroop task in Study 1 which was replicated in the congruency score for the attention-switching task (AST) in Study 2. This suggests that those with substantial injury struggled with increased attentional demands in the presence of incongruent or interfering material. This is of interest in relation to antisocial or aggressive behaviour as these abilities have been found to correlate with feelings of anger and hostility in an offending sample previously (Seruca & Silva, 2016). This led the authors to conclude that impairments in impulse inhibition and prepotent responses may limit cognitive strategies to control angry feelings and hostile thoughts, eliciting impulsive aggressive

behaviour. Poor 'behavioural inhibition', which has theoretical overlap with impulse inhibition, has also been found to predict poor engagement and treatment outcomes in offending populations (Fishbein, Dariotis, Ferguson, & Pickelsimer, 2016; Fishbein et al., 2009).

These outcome measures did not correlate with overall FAR performance in Study 1 or 2 (see correlational matrices in Appendix A3), however the outcomes for the AST congruency measure in Study 2 did correlate with aggression. These effects should be explored further in future research to investigate whether they effects are robust and to explore whether they mediate the association between TBI and antisocial or criminal behaviour.

### *8.1.3 Are similar associations between TBI, FAR and antisocial behaviour observed in members of the general, non-offending population?*

The effects observed in Study 3's general population sample, suggested that with increased TBI severity there were higher levels of self-reported delinquency and aggression, as well as higher proportions of heavy drug and alcohol use Findings also suggested that increased aggression in those with TBI may be mediated by higher levels of alcohol use. Increased aggression and delinquency as a function of injury corroborated the findings presented in Study 2, where those with substantial TBI were higher risk for violent recidivism compared to those with mild or no injury. The general population sample also replicated findings of the young adult offenders (Study 2), in that no difference in FAR ability was observed as a function of injury status. The weak evidence for poorer describing of emotions in those with TBI, as indicated by the alexithymia measure in Study 2, was not replicated in the general population sample in Study 3.

These findings highlight the predictive value of TBI in aggression and delinquent behaviour in a sample recruited from the general population, in addition to similar associations observed in those recruited from offending populations. Investigating associations within offending organisations reduces sensitivity for these effects as both those with and without TBI history will have

elevated levels of antisocial behaviour, in relation to non-offending controls. Observing these associations of TBI with antisocial behaviour in the general, 'non-offending' population further implicates history of TBI in increased risk for antisocial behaviour. This is informative as it can be used to promote preventative strategies. Preventative strategies might include introducing support systems to assist those who have experienced TBI within the general population to help prevent initial delinquency or contact with the CJS. This is in line with research suggesting early prevention as a much more effective strategy with economic benefits, compared to incarceration (Welsh & Farrington, 2011). As suggested by the meta-analyses described in Chapter five, screening of PCS in addition to TBI history seems to be of particular importance in identifying ongoing difficulties and increased risk of antisocial behaviour.

It is important to conduct studies both with members of the general population, to identify risk factors prior to conviction and inform preventative strategies and for with those already within the justice system, to better understand factors influencing recidivism risk. These efforts will help identify those who are more likely to become persistent, life-long offenders and direct support accordingly.

I will now move away from TBI effects on FAR to consider the role of FAR in antisocial behaviour more generally.

#### *8.1.4 Would interventions targeting the capacity for FAR be effective in reducing antisocial or criminal behaviour?*

Evidence supporting the capacity of FAR intervention in reducing antisocial or criminal behaviour is inconclusive. Extensive research studies have observed poor FAR in antisocial populations and there are well-defined theoretical models suggesting that improvements in FAR, would likely translate to improved social functioning, improved well-being and reductions in antisocial behaviour. However, the application of this knowledge is in its infancy and the research in this area is preliminary. The systematic review described in Chapter six synthesised findings from ten studies in the area, of which four described transfer to improved behavioural outcomes (including reduced aggression and

displaced retaliation, reduced conduct disorder symptomology and reduced severity in future offending). However, translation to behavioural outcomes of reduced aggression and hostility in the other included studies was not observed. The interventions generally seemed effective in manipulating perception of facial expressions, either improving recognition or modifying perceptual biases, however the effectiveness of this in modifying behaviour should be explored further. This draws parallels with the wider cognitive training literature, which often finds near-transfer effects to changes in similar tasks, however the transfer to everyday functioning is less consistent (Jaeggi, Buschkuhl, Shah, & Jonides, 2014). The influence of FAR on antisocial behaviour appears complex, and design and implementation of interventions in this area should be carefully tailored to individuals with evidence of both FAR deficit and current aggression regulation problems. In addition, outcome measurements should be repeated at later time-points (e.g. six months) following the intervention. This could help establish whether changes in perception subtly affect interpersonal behaviours through positive reinforcement and gradual decreases in antisocial behaviour over time (see Chapter six for further discussion).

*8.1.5 Would interventions targeting the capacity for FAR be appropriate for use with members of these populations and within incarcerated settings?*

Based on the evidence presented, I argue here that FAR interventions would be appropriate for individuals with antisocial tendencies, and within incarcerated settings. As outlined above, the effectiveness of these interventions in reducing aggressive or antisocial behaviour is yet to be determined. However, given the consistent finding that those with antisocial or criminal behaviour are impaired in FAR in relation to non-antisocial individuals, and evidence which suggests the relation of FAR to better social adjustment and mental health (Izard et al., 2001), it seems reasonable to explore this avenue further. It is possible that benefits of FAR training do not derive from direct effects (in shifting biases for example) but through increasing self-awareness of emotions and their role in interpersonal interactions. Future research in this area should seek to determine whether any improvements in

distal behaviour (for example, aggression) are mediated by changes in perceptual bias, to address issue of direct versus general mechanism effects. It may be true that better FAR does not translate to reductions in antisocial behaviour, or indeed increased prosocial behaviour (as suggested by Kaltwasser, Hildebrandt, Wilhelm, and Sommer (2017)). However, if FAR training can give rise to even modest improvements in some aspects of social information processing, or social interaction, then this may be of benefit to the welfare and wellbeing of the individual, the value of which should not be disparaged.

The FAR training intervention detailed in the feasibility study and pilot trial described in Chapter seven was low-cost, easy to administer, interactive and well received by participants and staff. Some adaptations to the current format are advised to help with issues of repetition and associated boredom, such as greater stimuli variation, incentivising correct responses using points or progress trackers and reduced number of sessions. An intervention such as this could be easily incorporated into the current intervention tools and could be used accordingly without additional or maintenance costs. The flexibility and novelty of the digital intervention platform received positive evaluations, both for enabling intervention delivery and promoting engagement. Given the potential benefit of these interventions, with the low resource cost associated with their administration, investigation of this application and its efficacy should be investigated further, following the recommendations outlined in Chapter seven.

## **8.2 Limitations**

There are key limitations with the research methods employed here which should be acknowledged when drawing conclusions from these findings. First, within the empirical studies described in chapters two, three and four there is a reliance on self-report data. This makes it difficult to qualify the reliability of this data, especially without available means to compare the data with medical reports or more objective measures. With regards to TBI history, there is suggestion that recall of early injuries (occurring before the age of 9 years) is poor in adults (McKinlay & Horwood, 2017), which may affect the accuracy of participant recall. However, a study conducted by Schofield, Butler, Hollis, and

D'Este (2011) compared prisoner reports of TBI against the 'gold standard' of hospital medical record. They found prisoner reports to be generally honest and accurate, reflecting the information within their medical records with 70% accuracy. There is difficulty corroborating self-report with medical records in studies such as these as medical records can be difficult to access, and in doing so adds complexity to study procedure and associated ethical considerations. Furthermore, there is acknowledgement within the field that prisoner medical records are often missing or incomplete, hindering the ability to draw comparisons (O'Rourke, Templeton, Cohen, & Linden, 2018). Nevertheless, there is a risk acknowledged here that the use of self-report can introduce inaccuracies within the data, introducing noise into the TBI classification systems used.

The reliance on self-report measures also extends to health-related items, which may have introduced inaccuracy due to reluctance to disclose personal or sensitive information (for example, regarding mental health issues, substance use or early trauma). In addition, self-report measures used to measure aggression, delinquency, alexithymia, psychopathic traits and post-concussion symptoms may have been affected by self-serving biases, tendencies to exaggerate or downplay behaviours or symptoms, or having poor insight or introspection into personality traits and behaviours. This was addressed in the pilot trial detailed in Chapter seven, using both self- and staff-reported aggression measures to better validate these outcome measures, however these were still reported (in the case of the staff questionnaire) to be overly subjective. Due to the format of these studies (single testing sessions with the young offenders in Studies 1 & 2, and remote participation with the general population, Study 3), these self-report methods were chosen as the most feasible and appropriate options. However, in future it would be beneficial to consolidate and strengthen these findings with more objective methods, such as neuroimaging methods.

The samples included within Studies 1 and 2 were small and unbalanced between those with history of TBI and those without. This compromised statistical power and hindered the ability to run sub-group analyses on different types of criminal behaviour and different mechanisms of injury. The obtained sample sizes reflects the limited resources available and the difficulty accessing

and recruiting members of these populations (see O'Rourke et al. (2018) for a review of the complexities of recruiting these populations). In Study 2 we managed to recruit 77% of our pre-specified sample size, which was beneficial in providing insight to our main research questions. However, given the number of additional confounds and factors to adjust for within the statistical analyses, larger sample sizes would give increased power to run exploratory analyses with greater confidence in the findings. In addition, the non-offending control groups used in this study were primarily for comparative purposes on the BERT and were not well matched for SES and IQ.

Another important consideration is that FAR is only one component of socioemotional processing, and here we relied predominately on one measure of FAR (the BERT). This enabled consistency across studies and allowed drawing of comparisons. However, we used static facial stimuli, from the Caucasian male adult stimulus set only. This limits our ability to draw conclusions regarding generalisation of FAR in female faces, different ethnicities, and across different ages. In addition, whilst different intensity morphs were presented, the stimuli presentation format was static. Whilst previous research has used static stimuli presentation and found TBI related impairments, this may be more apparent in those with more acute or severe injuries than was present in those sampled in these studies. Knox and Douglas (2009) conversely found evidence that their patients with TBI were impaired in the recognition of dynamic facial expressions, but not static displays. Part of the assumption of using static facial expressions in the studies detailed here, was that if impairment was observed, this would translate to impairment in more complex forms of social cognition. This builds on the assumption that FAR is one of the most fundamental aspects of social information processing and guides subsequent socioemotional processing. However, it may be that dynamic or more complex social displays are more ecologically valid and more sensitive to TBI induced processing differences, than static stimuli used here.

Another issue to acknowledge, is the lack of clarification between different types of offender, or types of antisocial behaviour in Study 1 & 2. Aggression and violence will have different aetiologies from non-violent or sexual offending, and within the violent crime bracket, there is an important distinction to be made between those who exhibit reactive aggression in

response to a situation, and those who engage in instrumental, proactive aggression to achieve their goals. Efforts were made in the pilot trial described in Chapter seven to recruit only those convicted of violent crime, or with history of aggressive behaviour, however the recruitment for the earlier studies was opportunistic and not confined by offending type. Arguments have been made within this thesis that deficits in FAR have more relevance to aggression and violent behaviour, with this as the primary focus of interest. However, it has also been argued that FAR impairment has relevance for antisocial behaviour more generally – through inability to recognise emotions such as disgust and anger that might inhibit antisocial behaviour, rather than the typical fear and sadness recognition deficit associated with aggression or violence (Chapman, Gillespie, & Mitchell, 2018). Ideally, we would aim to recruit a more homogeneous sample of offenders or make clearer distinctions between sub-groups, but this was dictated by the availability of the population and the feasibility of recruitment in the current studies.

Lastly, as described in Chapter one, the mechanisms governing the association between TBI and criminal behaviour are complex, and likely influenced by pre-morbid factors such as early life experience, personality traits such as sensation seeking and impulsivity, and SES or poverty. Conducting cross-sectional research studies, such as those described within this thesis, hinders the ability to infer causation regarding direction of effects. In essence, it is difficult to determine whether certain personality traits or behaviours preceded, or even encouraged, the event of a TBI, or developed as a consequence of the injury. Triangulation of these methods with longitudinal research design would be informative in clarifying causation and strengthening confidence in these findings.

### **8.3 Future directions**

Based on the limitations and considerations mentioned above, here I propose suggestions for future research projects. First, it would be beneficial to continue the study of neuropsychological profiles in individuals with and without history of TBI, within the CJS. Expanding this study across multiple sites in the UK or internationally, and over an extended time period, would be beneficial.

This would allow greater division and comparison based on offence type, participant age, area of residence with more powerful comparisons between severities and types of injuries sustained. The CHAT, from which our measure of TBI and PCS derives, is now employed as a standardised assessment for all young people in the Youth Justice System within the UK and similar efforts are being made for use within the adult services. This data could be used in future to identify those who have experienced moderate to severe TBI and could inform recruitment strategies to derive larger, more balanced groups based on injury severity (such as those detailed in Chapter four). In addition, if these assessments are combined with official reoffending statistics, this could be used to help identify those with the highest levels of need and at greatest risk of reoffending, identifying common patterns of deficit or symptomology within these individuals. If conducting a future study of this nature, I would advocate the inclusion of detailed neuropsychology and health assessment, with additional measures for inhibitory and impulse control, risk-taking behaviour and a more comprehensive battery of social cognition measures (including moral decision-making). Collaboration with other research institutions would be advantageous in enabling this, for example with the University of Cape Town, who are currently conducting similar research projects to those described in Study 1 & 2 here (under the principal investigator, Dr Leigh Schrieff-Elson).

This information can also be used to identify those within the CJS who may have ongoing TBI-related need and direct services accordingly. A preliminary trial of a specialist 'Linkworker' service is detailed in Chitsabesan, Lennox, Williams, Tariq, and Shaw (2015). Their strategy for support included identification of those with TBI history, conducting neuropsychological assessment, and providing guided support in the form of psychoeducation, implementation of behavioural strategies, liaison with other support services and careful discharge planning. Outcomes of this study are published in the Disabilities Trust 2016 report, with positive feedback from service users and recommendations of future TBI awareness training for prison staff. This should be further developed in future, synthesising efforts into current justice services, with continued follow-up following release from custodial organisations.

As previously mentioned, triangulation with other research study designs would be informative in better understanding these associations. Longitudinal

cohort studies are becoming a popular and powerful method for identifying common trends and making causative inferences. The temporal relationship between exposure and outcome allows for more confidence in these causal inferences and in addition access to different longitudinal population cohorts is becoming more available, which enables comparisons of effects across different populations. The 'Avon Longitudinal Cohort Study of Parents and Children', was used by Kennedy, Heron, and Munafo (2017) to identify those with injury and later risk-taking behaviours and criminality. As mentioned previously, this study was strengthened by the inclusion of negative orthopaedic controls, which I would advocate for future research endeavours as it helps separate general injury related factors from TBI-specific factors. This cohort study, and others, are introducing more comprehensive neuropsychological assessments at more frequent time-points, including measures of FAR and social cognition. This approach provides an avenue to assess pre-morbid behaviour and abilities, neuropsychological changes following experience of TBI, and official records of antisocial behaviour, including criminal convictions, following injury. The limitation of this method is bias arising due to study attrition (i.e. those who become involved with the CJS may be more easily lost to follow-up), and constraints made by the availability of included data (i.e. not being able to make accurate severity assessments due to limited information regarding injury), but nevertheless should be considered for future studies in this area.

If replicating or expanding Study 2, I would also suggest supplementing the TBI assessments with medical records (if possible – see discussion above), including measures of post-traumatic amnesia duration (including score on the GCS), and using radiological data to assess for structural or functional impairment to corroborate self-report data. Based on the findings of Chapter five's meta-analysis, I would also highly recommend measuring post-concussion symptomology and using this in combination with LoC duration to create a composite measure of TBI severity and ongoing symptomology. There is wide variation in recovery following TBI, with some experiencing chronic symptoms from 'mild' injuries, and others making speedy recoveries from what would be classified as 'moderate to severe' injuries (McAllister, 2011). Measures of current, ongoing symptoms may be more informative than more general injury severity categorisations.

The studies synthesised in the literature review described in Chapter six were judged to be of high risk of bias, or unclear quality. There is a stark discrepancy between the number of observational studies investigating FAR in antisocial populations, and the number of studies applying this knowledge and theory to inform interventions to bring about positive change. More research is needed in this area to better assess the utility of FAR training interventions for use with antisocial or aggressive populations. Despite the observed inconsistencies in behavioural outcomes across studies, I still believe this is an interesting avenue for intervention and should be explored further. There is a need generally for more aggression reduction interventions for use within the CJS. Interventions in a similar format to that described in Chapter seven would be appropriate and accessible for members of these populations. When considering future intervention development and trialling the implementation of these, I advocate conducting feasibility assessments on a case-by-case basis, for separate organisations or units, or co-creating interventions with members of these organisations to make them more appropriate and acceptable. In addition, neurodisability considerations should be incorporated to ensure interventions are suitable for a range of different abilities and needs, including attention, insight and language.

Furthermore, based on the findings of Chapter four, the association with increased drug and alcohol use, as well as aggression and delinquent behaviour in those with history of TBI, points to earlier screening and intervention as a preventative measure for criminal behaviour. If these associations are prominent within general population, non-offending samples, strategies should be employed that identify survivors of TBI in the community and provide ongoing support and follow-up to assess wellbeing outcomes in later life. This might include educational attainment, symptom management, employability, peer interaction, and substance use. As mentioned previously, early intervention at this stage could alter life-trajectories and reduce the chances of initial involvement with the criminal justice system (Williams et al., 2018). In addition, preventative strategies within wider society to reduce the prevalence of TBI's and inform better identification and management of these injuries would be beneficial, as currently awareness remains low (Williams, McAuliffe, Cohen, Parsonage, & Ramsbotham, 2015).

## 8.4 Concluding remarks

This thesis has advanced our understanding of the association between TBI and criminal behaviour, by investigating whether there is evidence for differential neuropsychological profiles in those with injury compared to those without, in young people with offending behaviour. The lack of consistent evidence for impairment in FAR in those with history of TBI suggests that other mechanisms may be more influential in driving this association, and future studies should investigate alternate neuropsychological domains and pre-morbid risk factors. The observed relationships between TBI, substance use and aggressive or delinquent behaviour in a general population sample highlights the importance of better understanding these mechanisms and employing targeted prevention strategies to deter initial contact with the CJS. In particular, the high prevalence of substance and alcohol use should be investigated as a possible mediator in the risk of future criminal behaviour.

Despite the lack of consistent evidence implicating socioemotional processing as a mediator in the association between TBI and crime, there is still a wealth of evidence suggesting this ability is impaired or biased in individuals with antisocial tendencies, regardless of TBI history. Future research should build upon this knowledge, by further investigating the utility of FAR modification interventions in reducing antisocial behaviour and promoting adaptive social function. This thesis adds to this discussion by reviewing the current evidence for this application. At present this evidence is limited. However, there is encouraging, albeit inconsistent, evidence for positive change. The findings of this thesis also stress the need for development of novel intervention strategies to support vulnerable individuals within the CJS, and to aid this, provide a detailed account of a possible application and intervention platform. Furthermore, these findings highlight the importance of assessing and identifying individuals with neurodisability within the CJS, or those at risk of involvement with the CJS. Presence of neurodisability should be reviewed and attention should be paid to the exaggerated adverse impact this can have on the ability to adhere to the conditions of a judicial sentence and the ability to engage effectively with rehabilitative services. Doing so may have substantial benefits for the welfare of the individual and reduce associated societal and economic costs of offending behaviour in young people and young adults.



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## Appendices

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## **A1 Reflective summary of PhD research journey**

This PhD research was conducted building on the original findings of the preliminary study described in Chapter two. The findings of this study indicated a high proportion of lifetime TBI in an adolescent population, with a disproportionate amount of severe injury. Furthermore, there was evidence for a substantial impairment in overall FAR in those with a higher dosage of TBI, compared to those with mild or no previous history of injury. The prevalence of injury, and the magnitude of the observed deficit was both surprising and of significant concern given the size of the sample and the age of the participants. This led to the assertion that further research in the area was needed, to facilitate a better understanding of the mechanisms governing this observed effect. Originally, this thesis planned to investigate these socioemotional processing deficits in greater detail, investigating biases in emotion processing, neurophysiological responses and the relation to structural damage using neuroimaging techniques in those with injury. However, deriving from the findings of a preliminary study the first aim prior to this was to investigate whether these findings were robust and replicable.

Based on this, a comprehensive replication study was planned and conducted. This utilised the same measure for self-reported injury and an analogous measure of FAR, aiming to recruit a larger sample size with more extensive measures of substance use, personality factors, neuropsychology and criminal histories (see Chapter three). I observed a lower prevalence of substantial injury in this young adult sample and the socioemotional deficit observed previously failed to replicate in those with substantial TBI compared to those with mild or no injury. There are a number of explanations for this deviation between findings and these are discussed in detail in the corresponding chapters (see Chapter three and Chapter eight). However, in light of these new findings the focus of the proposed thesis was adapted. An additional study was conducted, devoted to investigating the differences between those with and without lifetime TBI in relation to socioemotional processing, aggression and delinquency, and to inform the discrepant findings of the first two studies (see Chapter four).

During the time this third study was being planned and conducted the systematic review (Chapter six) and the feasibility study & pilot trial (Chapter seven) were also conducted in parallel. This decision to focus on the applicability of FAR training was made on the rationale that this research project originally aimed to assess potential avenues for intervention, to better support those within the criminal justice system, especially those with neurodisability. Whilst the evidence for the association between TBI and FAR in these populations was inconsistent, FAR was still observed to be impaired in members of these populations. It seemed logical to reason that greater understanding of the application of FAR interventions with these populations and in these settings could be of greater utility and benefit for these individuals. As a consequence of this, the findings of the studies described within this thesis in Chapters four to seven do not inform the study rationale for the subsequent empirical chapter chronologically. However, these studies are clearly related and do inform one another in relation to the wider thesis topic and overarching research questions.

The thesis author coordinated all aspects of the research process. This included conceiving of the ideas for the individual studies, planning the studies and developing study protocols, executing the studies (including data collection and study management where multiple individuals were involved in administering measures), conducting the statistical analyses on the study findings, interpreting the results, and preparing and writing the reports detailed within the thesis chapters.

## A2 Linear Regression Models

**Table A1.** Associations between traumatic brain injury and facial affect recognition overall percentage accuracy, three group analyses (sample split into no injury, mild injury, substantial injury).

	Unadjusted		Sociodemographic adjusted		Health adjusted		Neuropsychology adjusted		Personality questionnaire adjusted	
<b>Study 1</b>										
<i>n</i>	34		34		18		25			
	<i>No vs Mild</i>	<i>No vs Sub</i>	<i>No vs Mild</i>	<i>No vs Sub</i>	<i>No vs Mild</i>	<i>No vs Sub</i>	<i>No vs Mild</i>	<i>No vs Sub</i>		
Unstandardised Coefficient	5.92	-8.83	6.62	-9.0	2.76	-11.69	-.79	-12.90		
95% confidence interval	-0.90 to 12.74	-16.06 to -1.59	-0.31 to 13.57	-16.39 to -1.62	-6.19 to 11.63	-22.11 to -1.27	-10.95 to 9.37	-21.81 to -3.99		
<i>p</i> -value	0.09	0.02	0.06	0.02	0.51	0.03	0.87	0.01		
<i>R</i> <sup>2</sup> ( <i>model p</i> -value)	0.34 (0.002)		0.44 (0.00)		0.44 (0.09)		0.43 (0.08)			
<b>Study 2</b>										
<i>n</i>	58		49		58		50		57	
	<i>No vs Mild</i>	<i>No vs Sub</i>	<i>No vs Mild</i>	<i>No vs Sub</i>	<i>No vs Mild</i>	<i>No vs Sub</i>	<i>No vs Mild</i>	<i>No vs Sub</i>	<i>No vs Mild</i>	<i>No vs Sub</i>
Unstandardised Coefficient	-0.30	-0.39	0.43	-0.06	0.04	-0.31	1.12	-1.84	-0.18	-0.54
95% confidence interval	-3.59 to 2.99	-4.39 to 3.61	-3.10 to 3.95	-4.41 to 4.30	-3.70 to 3.78	-4.90 to 4.28	-2.20 to 4.45	-6.07 to 2.39	-3.85 to 3.50	-4.95 to 3.88
<i>p</i> -value	0.85	0.85	0.81	0.98	0.98	0.89	0.50	0.39	0.92	0.81
<i>R</i> <sup>2</sup> ( <i>model p</i> -value)	0.00 (0.98)		0.21 (0.18)		0.04 (0.94)		0.42 (0.02)		0.02 (0.95)	

The results from unadjusted and adjusted linear regression models are given. Unadjusted gives the associations with TBI status only. In Study 1 'Sociodemographic adjustment' includes adjustment for age, gender and verbal IQ (WASI Vocabulary). 'Health adjustment' includes frequent drug use and post-concussion symptomology. 'Neuropsychology adjustment' includes output from the Stroop test (time and interference score), the Trail Making Task (interference) and performance IQ (WASI Block Design). In Study 2 'Sociodemographic adjustment' includes adjustment for age, verbal IQ (SCOLP), deprivation percentage ranking and age at which the participant left school. 'Health adjustment' includes post-concussion symptomology, frequent drug use, frequent alcohol use, mental health issues, neurodevelopmental diagnosis and experience of early trauma. 'Neuropsychology adjustment' includes output from the Cantab Research Suite (MOT, RTI, SWM & AST). 'Personality questionnaire adjustment' includes the TAS, PTI, and RPQ.

### A3 Correlational matrices

**Figure A1.** Correlational matrices for background variables measured in Study 1. Pearson's  $r$  given with  $p$ -value in parenthesis.

	BERT Overall Accuracy	Postconcussion symptoms	Age	WASI Vocabulary	WASI Block Design	Stroop Interference	Trails A time	Trails Interference	Age first conviction	Number of previous convictions	Risk of reoffending
BERT Overall Accuracy		-.49 (.01)	-.20 (.24)	.28 (.11)	.24 (.17)	-.08 (.70)	.03 (.87)	.20 (.35)	.17 (.54)	-.09 (.73)	-.37 (< .10)
Postconcussion symptoms	-.49 (.01)		.27 (.19)	-.27 (.19)	-.08 (.69)	-.14 (.53)	.10 (.63)	.00 (<1.0)	.59 (.03)	-.32 (.21)	.24 (.33)
Age	-.20 (.24)	.27 (.19)		-.30 (.08)	-.35 (.04)	-.02 (.93)	-.01 (.97)	-.22 (.32)	.09 (.75)	.61 (.01)	.02 (.92)
WASI Vocabulary	.28 (.11)	-.27 (.19)	-.30 (.08)		.58 (< .001)	.25 (.22)	-.16 (.42)	.22 (.32)	.30 (.28)	-.19 (.45)	-0.27 (.24)
WASI Block Design	.24 (.17)	-.08 (.69)	-.35 (.04)	.58 (< .001)		.03 (.90)	-.46 (.02)	-.09 (.67)	-.21 (.45)	-.14 (.57)	.01 (.96)
Stroop Interference	-.08 (.70)	-.14 (.53)	-.02 (.93)	.25 (.22)	.03 (.90)		.09 (.65)	.19 (.39)	-.14 (.63)	.21 (.41)	-.20 (.41)
Trails A time	.03 (.87)	.10 (.63)	-.01 (.97)	-.16 (.42)	-.46 (.02)	.09 (.65)		.19 (.38)	.36 (.18)	-.14 (.56)	.05 (.83)
Trails Interference	.20 (.35)	.00 (<1.0)	-.22 (.32)	.22 (.32)	-.09 (.67)	.19 (.39)	.19 (.38)		.26 (.38)	.16 (.55)	-.12 (.65)
Age first conviction	.17 (.54)	.59 (.03)	.09 (.75)	.30 (.28)	-.21 (.45)	-.14 (.63)	.36 (.18)	.26 (.38)		-.40 (.14)	.26 (.35)
Number of previous convictions	-.09 (.73)	-.32 (.21)	.61 (.01)	-.19 (.45)	-.14 (.57)	.21 (.41)	-.14 (.56)	.16 (.55)	-.40 (.14)		-.01 (.96)
Risk of reoffending	-.37 (< .10)	.24 (.33)	.02 (.92)	-0.27 (.24)	.01 (.96)	-.20 (.41)	.05 (.83)	-.12 (.65)	.26 (.35)	-.01 (.96)	

Evidence Qualifiers	
P < .001	Strong evidence
P = .001 < .01	Evidence
P = .01 < .10	Weak evidence
P = .10 < 1.00	No clear evidence

**Figure A2.** Correlational matrices for background variables measured in Study 2. Pearson's *r* given with *p*-value in parenthesis

	BERT Overall Accuracy	Posttraumatic stress symptoms	Alexithymia	Psychopathic traits	Aggression	Mental health screen	Early Trauma	Verbal comprehension	Speed of comprehension	Age	Age which left school	Deprivation % ranking	Simple Reaction Time	Choice Reaction Time	Working memory errors	Attention congruency cost	Attention switch cost	1 year general reconviction risk	1 year violence reconviction risk	Total convictions	Age of first police contact
BERT Overall Accuracy		-.04 (.38)	-.03 (.41)	.05 (.36)	-.08 (.28)	-.06 (.33)	-.15 (.16)	.35 (.01)	.10 (.25)	.11 (.40)	-.08 (.54)	.13 (.32)	.13 (.35)	.01 (.95)	-.25 (.06)	.12 (.38)	.12 (.40)	-.07 (.89)	-.10 (.81)	.08 (.84)	-.05 (.74)
Posttraumatic stress symptoms	-.04 (.38)		.42 (<.001)	.35 (.00)	.41 (.001)	.35 (.007)	.07 (.32)	-.02 (.44)	.04 (.40)	-.08 (.57)	.01 (.94)	-.03 (.82)	.04 (.79)	.03 (.80)	.17 (.20)	.34 (.01)	-.01 (.95)	.05 (.78)	.22 (.24)	-.02 (.91)	.22 (.19)
Alexithymia	-.03 (.41)	.42 (<.001)		.57 (<.001)	.62 (<.001)	.17 (.18)	.24 (.049)	-.21 (.08)	-.03 (.42)	-.01 (.96)	-.30 (.03)	.06 (.84)	.05 (.74)	-.05 (.73)	.20 (.13)	.20 (.15)	.21 (.13)	-.11 (.55)	.13 (.48)	-.01 (.94)	.22 (.18)
Psychopathic traits	.05 (.36)	.35 (.00)	.57 (<.001)		.63 (<.001)	.14 (.17)	.20 (.08)	.23 (.05)	.18 (.11)	-.01 (.96)	-.05 (.70)	-.05 (.89)	-.04 (.78)	-.11 (.43)	.14 (.30)	.19 (.16)	.28 (.04)	-.09 (.63)	.24 (.20)	-.18 (.32)	.27 (<.10)
Aggression	-.08 (.28)	.41 (.001)	.62 (<.001)	.63 (<.001)		.33 (.009)	.49 (<.001)	.01 (.46)	.13 (.18)	-.12 (.11)	-.17 (.21)	.10 (.44)	-.12 (.38)	-.15 (.28)	.28 (.04)	.23 (.09)	.19 (.17)	.09 (.80)	.41 (.02)	-.05 (.78)	.12 (.47)
Mental health screen	-.06 (.33)	.35 (.007)	.17 (.18)	.14 (.17)	.33 (.009)		.12 (.20)	.22 (.06)	.29 (.02)	-.11 (.39)	-.05 (.72)	.01 (.94)	-.04 (.75)	-.13 (.38)	.23 (.09)	.23 (.09)	.05 (.72)	.05 (.80)	.36 (.05)	-.11 (.50)	.21 (.20)
Early Trauma	-.15 (.16)	.07 (.32)	.24 (.049)	.20 (.08)	.49 (<.001)	.12 (.20)		-.06 (.35)	.13 (.19)	.13 (.34)	-.02 (.88)	.28 (.04)	-.18 (.18)	-.28 (.04)	-.07 (.82)	.11 (.44)	-.19 (.18)	.35 (.04)	.57 (.001)	.19 (.23)	-.23 (.17)
Verbal comprehension	.35 (.01)	-.02 (.44)	-.21 (.08)	.23 (.05)	.01 (.46)	.22 (.06)	-.06 (.35)		.43 (.001)	.19 (.20)	.32 (.02)	.01 (.95)	-.10 (.51)	.00 (<.10)	-.27 (.06)	.06 (.88)	.18 (.24)	-.18 (.35)	-.12 (.55)	-.31 (.08)	.27 (.15)
Speed of comprehension	.10 (.25)	.04 (.40)	-.03 (.42)	.18 (.11)	.13 (.18)	.29 (.02)	.13 (.19)	.43 (.001)		.05 (.73)	.17 (.25)	.19 (.18)	-.31 (.03)	-.37 (<.01)	-.19 (.18)	.01 (.97)	.06 (.87)	.01 (.98)	.23 (.23)	-.18 (.35)	-.03 (.88)
Age	.11 (.40)	-.08 (.57)	-.01 (.96)	-.01 (.96)	-.12 (.11)	-.11 (.39)	.13 (.34)	.19 (.20)	.05 (.73)		.19 (.15)	.02 (.91)	-.09 (.52)	.02 (.88)	-.21 (.12)	.09 (.54)	-.01 (.95)	-.08 (.72)	-.15 (.42)	.11 (.50)	-.03 (.87)
Age which left school	-.08 (.54)	.01 (.94)	-.30 (.03)	-.05 (.70)	-.17 (.21)	-.05 (.72)	-.02 (.88)	.32 (.02)	.17 (.25)	.19 (.15)		-.00 (.99)	.01 (.94)	.02 (.88)	-.08 (.55)	-.11 (.45)	-.12 (.40)	-.22 (.21)	-.24 (.20)	-.30 (.08)	.18 (.28)
Deprivation % Ranking	.13 (.32)	-.03 (.82)	.06 (.84)	-.05 (.89)	.10 (.44)	.01 (.94)	.28 (.04)	.01 (.95)	.19 (.18)	.02 (.91)	-.00 (.99)		-.14 (.31)	-.23 (.08)	-.22 (<.10)	-.19 (.17)	-.28 (.04)	-.13 (.46)	.23 (.21)	-.08 (.81)	-.05 (.78)
Simple Reaction Time	.13 (.35)	.04 (.79)	.05 (.74)	-.04 (.78)	-.12 (.38)	-.04 (.75)	-.18 (.18)	-.10 (.51)	-.31 (.03)	-.09 (.52)	.01 (.94)	-.14 (.31)		.80 (<.001)	.15 (.26)	-.10 (.50)	.10 (.47)	.01 (.98)	-.21 (.28)	.20 (.23)	.09 (.80)
Choice Reaction Time	.01 (.95)	.03 (.80)	-.05 (.73)	-.11 (.43)	-.15 (.28)	-.13 (.38)	-.28 (.04)	.00 (<.10)	-.37 (<.01)	.02 (.88)	.02 (.88)	-.23 (.08)	.80 (<.001)		.05 (.74)	-.09 (.52)	.05 (.71)	-.14 (.43)	-.34 (.04)	.00 (.99)	.16 (.34)
Working memory errors	-.25 (.06)	.17 (.20)	.20 (.13)	.14 (.30)	.28 (.04)	.23 (.09)	-.07 (.82)	-.27 (.06)	-.19 (.18)	-.21 (.12)	-.08 (.55)	-.22 (<.10)	.15 (.26)	.05 (.74)		.19 (.17)	.17 (.23)	.01 (.95)	-.02 (.91)	-.02 (.92)	.01 (.92)
Attention congruency cost	.12 (.38)	.34 (.01)	.20 (.15)	.19 (.16)	.23 (.09)	.23 (.09)	.11 (.44)	.06 (.88)	.01 (.97)	.09 (.54)	-.11 (.45)	-.19 (.17)	-.10 (.50)	-.09 (.52)	.19 (.17)		.21 (.14)	.07 (.72)	.17 (.38)	-.06 (.72)	.28 (<.10)
Attention switch cost	.12 (.40)	-.01 (.95)	.21 (.13)	.28 (.04)	.19 (.17)	.05 (.72)	-.19 (.18)	.18 (.24)	.06 (.87)	-.01 (.95)	-.12 (.40)	-.28 (.04)	.10 (.47)	.05 (.71)	.17 (.23)	.21 (.14)		-.12 (.51)	-.00 (.98)	.04 (.80)	.14 (.41)
1 year general reconviction risk	-.07 (.89)	.05 (.78)	-.11 (.55)	-.09 (.63)	.09 (.80)	.05 (.80)	.35 (.04)	-.18 (.35)	.01 (.96)	-.08 (.72)	-.22 (.21)	-.13 (.46)	.01 (.98)	-.14 (.43)	.01 (.95)	.07 (.72)	-.12 (.51)		.68 (<.001)	.78 (<.001)	-.44 (.01)
1 year violence reconviction risk	-.10 (.81)	.22 (.24)	.13 (.48)	.24 (.20)	.41 (.02)	.36 (.05)	.57 (.001)	-.12 (.55)	.23 (.23)	-.15 (.42)	-.24 (.20)	.23 (.21)	-.21 (.28)	-.34 (.04)	-.02 (.91)	.17 (.38)	-.00 (.98)	.68 (<.001)		.46 (.01)	-.44 (.01)
Total convictions	.08 (.84)	-.02 (.91)	-.01 (.94)	-.16 (.32)	-.05 (.78)	-.11 (.50)	.19 (.23)	-.31 (.08)	-.16 (.35)	.11 (.50)	-.30 (.06)	-.08 (.81)	.20 (.23)	.00 (.99)	-.02 (.92)	-.06 (.72)	.04 (.80)	.76 (<.001)	.46 (.01)		-.65 (<.001)
Age of first police contact	-.05 (.74)	.22 (.19)	.22 (.18)	.27 (<.10)	.12 (.47)	.21 (.20)	-.23 (.17)	.27 (.15)	-.03 (.88)	-.03 (.87)	.18 (.28)	-.05 (.78)	.09 (.80)	.16 (.34)	.01 (.92)	.28 (<.10)	.14 (.41)	-.44 (.01)	-.44 (.01)	-.65 (<.001)	

Evidence Qualifiers	
P < .001	Strong evidence
P = .001 < .01	Evidence
P = .01 < .10	Weak evidence
P = .10 < 1.00	No clear evidence

## A4 Feasibility Assessment, Study 2

$n = 921$  service users (SU's) were identified as eligible, of these we managed to recruit 89 (9%) into the study. This was 77% of the total sample size we were aiming for based on our power calculation ( $n = 116$ ). This study was conducted over a total of 7 months (January 2016 to July 2016).

Of 89 recruited into the study, 71 (80%) completed both testing sessions. Eighteen participants were lost between stage 1 and 2 because they failed to attend the second session. Of those (71) who completed session 2 (neuropsychology), 65 (92%) completed all core tests. For those who did not ( $n = 6$ ), the main reason was due to lack of time, followed by participant declines and lack of comprehension or motor skills for some of the faster measures ( $n = 1$ , attention switching task).

Of the 71 who completed session, 58 (82%) were included in the full analysis. Reasons for exclusion are detailed in the consort diagram (**Figure 3.2**) and included intoxication during or within 12 hours of testing, medication for mental health disorders and poor task comprehension. No participants purposefully withdrew from the study during or following data collection and those who took part provided positive informal feedback on their experience of study participation.

Reflecting on this, the main difficulties encountered lay in recruiting the participants into the study in the first instance and ensuring they attended the second session. This was often due to difficulty in recruiting and engaging members of this population, as many were simply unwilling to participate in the research study. We had to exclude a substantial proportion from the main analysis, due to reasons that are not uncommon within this population (substance use, comprehension difficulties) and these considerations should be incorporated into future study plans. Of those who did attend stage 2, the majority completed the entire core battery and engaged well with the tasks.

There is a large discrepancy between the number of SUs identified as eligible and the number recruited into the study during the data recruitment timeframe. It may be that we needed more stringent exclusion criteria as staff reported that their eligible caseloads included those on work placements, those who did not report to the probation office for meetings and those who could not attend the offices due to gang-related threat.

### A5 Adjusted analyses, Study 3.

**Table A2.** Linear regression models of TBI group on overall FAR performance, excluding neurodevelopmental

	No injury versus mild injury	No injury versus complicated mild injury	No injury versus substantial injury
<b>Unadjusted</b>			
<i>n</i>	206		
Constant (SE)	30.52 (0.77)		
Unstandardised Coefficient	-0.96	-0.32	0.07
95% Confidence interval	-3.25 to 1.33	-2.86 to 2.21	-2.23 to 2.37
p-value	0.41	.80	.95
R <sup>2</sup> (model p-value)	0.00 (0.82)		
<b>Adjusted</b>			
<i>n</i>	206		
Constant (SE)	33.55 (3.94)		
Unstandardised Coefficient	-1.23	-0.54	-0.18
95% Confidence interval	-3.56 to 1.11	-3.09 to 2.00	-2.64 to 2.29
p-value	0.30	0.68	0.89
R <sup>2</sup> (model p-value)	0.03 (0.59)		

Linear regression model without those with co-morbid neurodevelopmental diagnoses ( $n = 21$ ), unadjusted and adjusted for demographic and health variables.

**Table A3.** Linear regression models of TBI group on overall FAR performance, excluding outliers

	No injury versus mild injury	No injury versus complicated mild injury	No injury versus substantial injury
<b>Unadjusted</b>			
<i>n</i>	224		
Constant (SE)	30.72 (0.72)		
Unstandardised Coefficient	-1.54	-0.72	-0.10
95% Confidence interval	-3.65 to 0.57	-3.05 to 1.61	-2.23 to 2.03
p-value	0.15	0.54	0.93
R <sup>2</sup> (model p-value)	0.01 (0.48)		
<b>Adjusted</b>			
<i>n</i>	224		
Constant (SE)	32.08 (3.72)		
Unstandardised Coefficient	-1.82	-0.95	-0.43
95% Confidence interval	-3.95 to 0.32	-3.27 to 1.37	-2.71 to 1.84
p-value	0.10	0.42	0.71
R <sup>2</sup> (model p-value)	0.05 (0.19)		

Linear regression model with probable outliers ( $Z$  values above 2.58) excluded ( $n = 3$ ) unadjusted and adjusted for demographic and health variables.

**Table A4.** Substantial injury group, sub-group analyses

Measure	Repetitive Mild ( <i>n</i> = 22)	Moderate ( <i>n</i> = 13)	Severe ( <i>n</i> = 13)	Very severe ( <i>n</i> = 7)	Evidence for group main effect
Age at testing (yrs)	28.04 (4.07)	28.46 (5.59)	26.31 (5.69)	26.57 (5.35)	$F_{(3,52)} = 0.58$ $p = 0.63$
Years in education	15.17 (1.78)	15.46 (1.90)	14.54 (1.76)	15.43 (1.72)	$F_{(3,52)} = 0.69$ , $p = 0.56$
Neurodevelopmental (Y:N)	2:21	1:12	1:12	1:6	FE = 0.92, $p = 1.0$
Heavy drinking (Y:N)	13:10	7:6	3:10	3:4	FE = 4.12, $p = 0.26$
Drug use (Y:N)	6:17	3:10	3:10	0:7	FE = 2.07, $p = 0.65$
RPQ Total (/46)	12.09 (6.38)	14.38 (7.52)	8.31 (4.27)	11.14 (4.63)	$F_{(3,52)} = 2.24$ , $p = 0.09$
RPQ Proactive (/24)	3.35 (3.34)	4.46 (4.18)	1.31 (1.25)	1.86 (1.68)	$F_{(3,52)} = 2.72$ , $p = 0.05$
RPQ Reactive (/22)	8.74 (4.55)	9.92 (4.63)	7.0 (3.29)	9.29 (3.40)	$F_{(3,52)} = 1.13$ , $p = 0.35$
SR-ABM (/28)	8.87 (6.02)	10.2 (6.69)	5.38 (4.33)	6.14 (4.45)	$F_{(3,52)} = 2.02$ , $p = 0.12$
SR-ABM Serious (/13)	2.48 (2.98)	3.38 (3.07)	1.15 (1.14)	1.29 (1.80)	$F_{(3,52)} = 2.02$ , $p = 0.12$
SR-ABM Rule breaking (/15)	6.39 (3.46)	6.85 (4.30)	4.23 (3.49)	4.86 (3.02)	$F_{(3,52)} = 1.53$ , $p = 0.22$
TAS Total (/100)	51.09 (10.81)	57.15 (13.68)	49.92 (14.26)	49.71 (15.66)	$F_{(3,52)} = 0.91$ , $p = 0.44$
TAS Identify (/35)	17.83 (6.04)	19.69 (7.84)	16.15 (7.37)	16.0 (6.53)	$F_{(3,52)} = 0.73$ , $p = 0.54$
TAS Describe (/25)	14.13 (3.98)	15.85 (3.85)	13.62 (5.33)	14.57 (6.08)	$F_{(3,52)} = 0.59$ , $p = 0.63$
TAS External (/40)	19.13 (4.24)	21.62 (4.75)	20.15 (6.14)	19.14 (4.26)	$F_{(3,52)} = 0.80$ , $p = 0.50$
RPCQ Total (/32)	10.13 (5.55)	12.23 (6.82)	7.08 (5.28)	12.14 (7.56)	$F_{(3,52)} = 1.88$ , $p = 0.15$
RPCQ Somatic (/16)	3.39 (2.15)	4.0 (2.65)	3.31 (1.75)	3.43 (3.05)	$F_{(3,52)} = 0.25$ , $p = 0.86$
RPCQ Cognitive (/12)	5.65 (3.58)	6.62 (4.07)	3.31 (3.75)	7.29 (4.31)	$F_{(3,52)} = 2.31$ , $p = 0.09$
BERT overall accuracy (/48)	30.09 (6.65)	29.46 (4.26)	31.23 (5.07)	31.14 (3.98)	$F_{(3,52)} = 0.29$ , $p = 0.84$

Injury group means are given with standard deviations in parenthesis. FE = Fisher's exact

## A6 Additional details of mini-meta analyses, Chapter 5

**Table A5** Results of mini-meta analysis for individual emotion hit rates and TBI status

	<i>N</i>	<i>t</i>	<i>df</i>	<i>p</i>	<i>Cohen's d</i>	<i>r</i>
<b>Anger</b>						
Study 1	23	0.83	21	0.42	0.36	0.17
Study 2	34	0.04	32	0.97	0.01	0.01
Study 3	128	-0.19	126	0.85	-0.03	-0.02
Mean <i>r</i> (95% CI)	0.01 (-0.14 to 0.15)					
Combined <i>Z</i> (p-value)	0.09 (0.93)					
<b>Disgust</b>						
Study 1	23	1.79	21	0.09	0.76	0.35
Study 2	34	1.06	32	0.30	0.38	0.18
Study 3	128	1.18	126	0.24	0.21	0.11
Mean <i>r</i> (95% CI)	0.15 (0.00 to 0.29)					
Combined <i>Z</i> (p-value)	2.02 (0.04)					
<b>Fear</b>						
Study 1	23	1.93	21	0.07	0.83	0.38
Study 2	34	-2.64	32	0.01	-0.95	-0.41
Study 3	128	0.71	126	0.48	0.13	0.06
Mean <i>r</i> (95% CI)	0.01 (-0.14 to 0.16)					
Combined <i>Z</i> (p-value)	0.15 (0.88)					
<b>Happy</b>						
Study 1	23	0.78	21	0.45	0.34	0.16
Study 2	34	-0.15	32	0.88	-0.05	-0.02
Study 3	128	-0.28	126	0.78	-0.05	-0.03
Mean <i>r</i> (95% CI)	-0.01 (-0.15 to 0.14)					
Combined <i>Z</i> (p-value)	-0.09 (0.93)					
<b>Sad</b>						
Study 1	23	2.47	21	0.04	1.05	0.46
Study 2	34	3.22	32	0.03	1.16	0.49
Study 3	128	-1.88	126	0.06	-0.34	-0.17
Mean <i>r</i> (95% CI)	0.03 (-0.12 to 0.18)					
Combined <i>Z</i> (p-value)	0.39 (0.70)					
<b>Surprise</b>						
Study 1	23	0.70	21	0.49	0.30	0.15
Study 2	34	0.60	32	0.55	0.21	0.10
Study 3	128	0.24	126	0.81	0.04	0.02
Mean <i>r</i> (95% CI)	0.05 (-0.10 to 0.19)					
Combined <i>Z</i> (p-value)	0.65 (0.52)					

2-tailed significance calculated for combined *Z*,  $r_z$  converted back to *r* to aid interpretation (not Fisher *Z* transformed). Negative values for *t*, *d* and *r* denote better performance for those with TBI compared to non-injured controls.

**Table A6** Results of mini-meta analysis for individual emotion false alarm rates and TBI status

	<i>N</i>	<i>t</i>	<i>df</i>	<i>p</i>	<i>Cohen's d</i>	<i>r</i>
<b>Anger</b>						
Study 1	23	0.18	21	0.86	0.08	0.04
Study 2	34	-1.90	32	0.07	-0.70	-0.32
Study 3	128	0.55	126	0.58	0.10	0.05
Mean <i>r</i> (95% CI)	-0.02 (-0.17 to 0.13)					
Combined <i>Z</i> (p-value)	-0.24 (0.81)					
<b>Disgust</b>						
Study 1	23	-0.41	21	0.68	-0.18	-0.09
Study 2	34	-1.26	32	0.22	-0.47	-0.22
Study 3	128	-1.29	126	0.22	-0.23	-0.11
Mean <i>r</i> (95% CI)	-0.13 (-0.27 to 0.02)					
Combined <i>Z</i> (p-value)	-1.70 (0.09)					
<b>Fear</b>						
Study 1	23	-0.87	21	0.39	-0.39	-0.19
Study 2	34	0.69	32	0.49	0.26	0.12
Study 3	128	0.48	126	0.63	0.09	0.04
Mean <i>r</i> (95% CI)	0.03 (-0.12 to 0.17)					
Combined <i>Z</i> (p-value)	0.37 (0.71)					
<b>Happy</b>						
Study 1	23	-0.59	21	0.56	-0.26	-0.13
Study 2	34	-1.74	32	0.09	-0.64	-0.29
Study 3	128	0.36	126	0.72	0.07	0.03
Mean <i>r</i> (95% CI)	-0.05 (-0.19 to 0.10)					
Combined <i>Z</i> (p-value)	-0.61 (0.54)					
<b>Sad</b>						
Study 1	23	-1.73	21	0.10	-0.77	-0.35
Study 2	34	-0.06	32	0.95	-0.02	-0.01
Study 3	128	0.20	126	0.84	0.04	0.02
Mean <i>r</i> (95% CI)	-0.03 (-0.18 to 0.12)					
Combined <i>Z</i> (p-value)	-0.39 (0.70)					
<b>Surprise</b>						
Study 1	23	-0.74	21	0.47	-0.33	-0.16
Study 2	34	2.89	32	0.01	1.07	0.46
Study 3	128	-0.18	126	0.86	-0.03	-0.02
Mean <i>r</i> (95% CI)	0.06 (-0.09 to 0.20)					
Combined <i>Z</i> (p-value)	0.73 (0.47)					

2-tailed significance calculated for combined *Z*, *r<sub>z</sub>* converted back to *r* to aid interpretation (not Fisher *Z* transformed). Negative values for *t*, *d* & *r* indicate those with TBI have scored higher (making more false alarms, corresponding with greater inaccuracy), than non-injured controls.

**Table A7** Results of mini-meta analysis for individual emotion unbiased hit rates and TBI status

	<i>N</i>	<i>t</i>	<i>df</i>	<i>p</i>	<i>Cohen's d</i>	<i>r</i>
<b>Anger</b>						
Study 1	23	0.76	21	0.45	0.35	0.17
Study 2	34	0.92	32	0.37	0.34	0.16
Study 3	128	-0.54	126	0.59	-0.10	-0.05
Mean <i>r</i> (95% CI)	0.01 (-0.14 to 0.16)					
Combined <i>Z</i> (p-value)	0.16 (0.87)					
<b>Disgust</b>						
Study 1	23	1.61	21	0.12	0.72	0.33
Study 2	34	1.23	32	0.23	0.46	0.21
Study 3	128	1.64	126	0.10	0.30	0.15
Mean <i>r</i> (95% CI)	0.18 (0.04 to 0.32)					
Combined <i>Z</i> (p-value)	2.44 (0.01)					
<b>Fear</b>						
Study 1	23	2.18	21	0.04	0.98	0.43
Study 2	34	-1.98	32	0.06	-0.73	-0.33
Study 3	128	0.92	124	0.36	0.14	0.08
Mean <i>r</i> (95% CI)	0.05 (-0.10 to 0.19)					
Combined <i>Z</i>	0.65 (0.52)					
<b>Happy</b>						
Study 1	23	2.10	21	0.05	0.94	0.24
Study 2	34	0.62	32	0.54	0.23	0.11
Study 3	128	-0.08	126	0.94	-0.01	-0.01
Mean <i>r</i> (95% CI)	0.04 (-0.11 to 0.19)					
Combined <i>Z</i>	0.53 (0.60)					
<b>Sad</b>						
Study 1	23	3.38	21	0.003	1.51	0.59
Study 2	34	2.95	32	0.01	1.09	0.46
Study 3	128	-1.40	126	0.16	-0.25	-0.12
Mean <i>r</i> (95% CI)	0.08 (-0.07 to 0.22)					
Combined <i>Z</i>	1.05 (0.29)					
<b>Surprise</b>						
Study 1	23	1.44	21	0.11	0.64	0.30
Study 2	34	-1.30	32	0.20	-0.48	-0.22
Study 3	128	0.64	126	0.53	0.12	0.06
Mean <i>r</i> (95% CI)	0.04 (-0.11 to 0.18)					
Combined <i>Z</i>	0.51 (0.61)					

2-tailed significance calculated for combined *Z*, *r<sub>z</sub>* converted back to *r* to aid interpretation (not Fisher *Z* transformed). Negative values for *t*, *d* and *r* denote better performance for those with TBI compared to non-injured controls.

**Table A8.** Mini meta-analysis for post-concussion symptoms and overall FAR, participants with history of TBI

<b>Study sample characteristics</b>			
	<i>N</i>	Offending status	
Study 1	16	Youth offender	
Study 2	36	Adult offender & control	
Study 3	149	Non-offending adults	
<b>Results of mini-meta analysis</b>			
	<i>PCS total</i>	<i>PCS somatic</i>	<i>PCS cognitive</i>
Study 1	-0.44	-0.11	-0.47
Study 2	-0.03	0.11	-0.11
Study 3	-0.12	-0.05	-0.16
Mean <i>r</i> (95% CI)	-0.13 (-0.26 to 0.01)	-0.03 (-0.17 to 0.11)	-0.17 (-0.31 to -0.04)
Combined <i>z</i> (p-value)	-1.79 (0.07)	-0.37 (0.71)	-2.44 (0.01)

Correlations between age at injuries/time since injury and overall FAR combined, with  $r_z$  converted back to  $r$  to aid interpretation (not Fisher Z transformed). 2-tailed significance calculated for combined Z.

**Table A9.** Mini meta-analysis for post-concussion symptoms and overall FAR, non-injured controls

<b>Study sample characteristics</b>			
	<i>N</i>	Offending status	
Study 1	9	Youth offender	
Study 2	22	Adult offender & control	
Study 3	72	Non-offending adults	
<b>Results of mini-meta analysis</b>			
	<i>PCS total</i>	<i>PCS somatic</i>	<i>PCS cognitive</i>
Study 1	-0.54	-0.07	-0.62
Study 2	0.02	0.05	0.15
Study 3	0.009	-0.10	-0.007
Mean <i>r</i> (95% CI)	-0.03 (-0.23 to 0.17)	-0.07 (-0.26 to 0.13)	0.02 (-0.22 to 0.18)
Combined <i>z</i> (p-value)	-0.27 (0.78)	-0.66 (0.51)	-0.20 (0.84)

Correlations between age at injuries/time since injury and overall FAR combined, with  $r_z$  converted back to  $r$  to aid interpretation (not Fisher Z transformed). 2-tailed significance calculated for combined Z.

**Table A10.** Mini meta-analysis for post-concussion symptoms and additional measures, participants without history of TBI

<b>Study sample characteristics</b>			
	<i>N</i>	Offending status	
Study 1	11	Young offenders	
Study 2 (OGRS)	27	Young adult offenders	
Study 2 (RPQ & TAS)	36	Young adult offenders and controls	
Study 3	157	Non-offending adults	
<b>Results of mini-meta analysis</b>			
	Re-offending risk	Aggression (RPQ)	Alexithymia (TAS)
Study 1	0.27		
Study 2	0.09	0.32	0.38
Study 3		0.42	0.41
Mean <i>r</i> (95% CI)	0.14 (-0.21 to 0.45)	0.40 (0.28 to 0.52)	0.41 (0.28 to 0.52)
Combined <i>z</i> (p-value)	0.77 (0.44)	5.84 (< 0.001)	5.81 (< 0.001)

Correlations between age at injuries/time since injury and overall FAR combined, with  $r_z$  converted back to  $r$  to aid interpretation (not Fisher Z transformed). 2-tailed significance calculated for combined Z. Reoffending risk data not available for whole sample in Study 1 or 2, due to missing data in justice records. OGRS at 1 year used for reoffending risk in Study 2. PCS not collected for non-offending controls in Study 1.

**Table A11.** Mini meta-analysis for post-concussion symptoms and additional measures, participants without history of TBI

<b>Study sample characteristics</b>			
	<i>N</i>	Offending status	
Study 1	9	Young offenders	
Study 2 (OGRS)	14	Young adult offenders	
Study 2 (RPQ & TAS)	22	Young adult offenders and controls	
Study 3	72	Non-offending adults	
<b>Results of mini-meta analysis</b>			
	Re-offending risk	Aggression (RPQ)	Alexithymia (TAS)
Study 1	0.30		
Study 2	-0.27	0.21	0.30
Study 3		0.47	0.18
Mean <i>r</i> (95% CI)	-0.07 (-0.50 to 0.39)	0.42 (0.23 to 0.56)	0.21 (0.001 to 0.40)
Combined <i>z</i> (p-value)	-0.29 (0.77)	4.18 (< .001)	1.97 (0.04)

Correlations between age at injuries/time since injury and overall FAR combined, with  $r_z$  converted back to  $r$  to aid interpretation (not Fisher Z transformed). 2-tailed significance calculated for combined Z. Reoffending risk data not available for whole sample in Study 1 or 2, due to missing data in justice records. OGRS at 1 year used for reoffending risk in Study 2. PCS not collected for non-offending controls in Study 1.

No correlation observed between PCS and self-reported delinquency (SR-ABM) for those without injury ( $r = 0.12$ ,  $p = 0.34$ ).

**Table A12** Results of mini-meta analysis for individual emotion hit rates and offending status

	<i>N</i>	<i>t</i>	<i>df</i>	<i>p</i>	<i>Cohen's d</i>	<i>r</i>
<b>Anger</b>						
Study 1	75	6.29	73	< 0.001	1.48	0.59
Study 2	70	3.44	68	0.001	1.46	0.48
Mean <i>r</i> (95% CI)	0.54 (0.41 to 0.65)					
Combined <i>Z</i> (p-value)	7.11 (< 0.001)					
<b>Disgust</b>						
Study 1	75	8.74	73	< 0.001	2.05	0.72
Study 2	70	3.43	68	0.02	1.10	0.38
Mean <i>r</i> (95% CI)	0.58 (0.46 to 0.68)					
Combined <i>Z</i> (p-value)	7.82 (< 0.001)					
<b>Fear</b>						
Study 1	75	1.62	73	0.11	0.38	0.19
Study 2	70	1.41	68	0.16	0.45	0.17
Mean <i>r</i> (95% CI)	0.18 (0.02 to 0.34)					
Combined <i>Z</i> (p-value)	2.15 (0.03)					
<b>Happy</b>						
Study 1	75	-1.34	73	0.19	-0.31	-0.16
Study 2	70	1.66	68	0.10	0.53	0.20
Mean <i>r</i> (95% CI)	0.01 (-0.15 to 0.18)					
Combined <i>Z</i> (p-value)	0.17 (0.87)					
<b>Sad</b>						
Study 1	75	4.87	73	< 0.001	1.14	0.50
Study 2	70	4.11	68	< 0.001	1.32	0.45
Mean <i>r</i> (95% CI)	0.48 (0.34 to 0.59)					
Combined <i>Z</i> (p-value)	6.11 (< 0.001)					
<b>Surprise</b>						
Study 1	75	4.53	73	< 0.001	1.06	0.47
Study 2	70	1.88	68	0.06	0.61	0.22
Mean <i>r</i> (95% CI)	0.36 (0.20 to 0.49)					
Combined <i>Z</i> (p-value)	4.39 (< 0.001)					

2-tailed significance calculated for combined *Z*,  $r_z$  converted back to *r* to aid interpretation (not Fisher *Z* transformed). Negative values for *t*, *d* and *r* denote better performance for those with offending behaviour compared to non-offending controls.

**Table A13** Results of mini-meta analysis for individual emotion false alarm rates and offending status

	<i>N</i>	<i>t</i>	<i>df</i>	<i>p</i>	<i>Cohen's d</i>	<i>r</i>
<b>Anger</b>						
Study 1	75	-0.99	73	0.33	-0.23	-0.12
Study 2	70	-1.12	68	0.27	-0.36	-0.14
Mean <i>r</i> (95% CI)	-0.13 (-0.29 to 0.04)					
Combined <i>Z</i> (p-value)	-1.54 (0.12)					
<b>Disgust</b>						
Study 1	75	-2.71	73	0.01	-0.64	-0.30
Study 2	70	-2.93	68	0.005	-0.94	-0.34
Mean <i>r</i> (95% CI)	-0.32 (-0.46 to -0.16)					
Combined <i>Z</i> (p-value)	-3.90 (< 0.001)					
<b>Fear</b>						
Study 1	75	-3.42	73	0.001	-0.80	-0.37
Study 2	70	-3.44	68	0.001	-1.11	-0.39
Mean <i>r</i> (95% CI)	-0.38 (-0.51 to -0.23)					
Combined <i>Z</i> (p-value)	-4.71 (< 0.001)					
<b>Happy</b>						
Study 1	75	-4.21	73	< 0.001	-0.99	-0.44
Study 2	70	-0.39	68	0.70	-0.13	-0.05
Mean <i>r</i> (95% CI)	-0.26 (-0.41 to -0.10)					
Combined <i>Z</i> (p-value)	-3.17 (0.001)					
<b>Sad</b>						
Study 1	75	-1.01	73	0.31	-0.24	-0.12
Study 2	70	0.96	68	0.34	0.31	0.12
Mean <i>r</i> (95% CI)	-0.00 (-0.17 to 0.16)					
Combined <i>Z</i> (p-value)	-0.05 (0.96)					
<b>Surprise</b>						
Study 1	75	0.23	73	0.82	0.05	0.03
Study 2	70	-1.44	68	0.16	-0.46	-0.17
Mean <i>r</i> (95% CI)	-0.07 (-0.23 to 0.10)					
Combined <i>Z</i> (p-value)	-0.79 (0.43)					

2-tailed significance calculated for combined *Z*, *r<sub>Z</sub>* converted back to *r* to aid interpretation (not Fisher *Z* transformed). Negative values for *t*, *d* & *r* indicate those with offending behaviour have scored higher (making more false alarms, corresponding with greater inaccuracy), than non-offending controls.

**Table A14** Results of mini-meta analysis for individual emotion unbiased hit rates and offending status

	<i>N</i>	<i>t</i>	<i>df</i>	<i>p</i>	<i>Cohen's d</i>	<i>r</i>
<b>Anger</b>						
Study 1	75	5.77	73	< 0.001	1.35	0.56
Study 2	70	5.37	68	< 0.001	1.73	0.55
Mean <i>r</i> (95% CI)	0.56 (0.43 to 0.66)					
Combined <i>Z</i> (p-value)	7.38 (< 0.001)					
<b>Disgust</b>						
Study 1	75	9.55	73	< 0.001	2.24	0.75
Study 2	70	4.69	68	< 0.001	1.51	0.49
Mean <i>r</i> (95% CI)	0.64 (< 0.001)					
Combined <i>Z</i> (p-value)	8.99 (< 0.001)					
<b>Fear</b>						
Study 1	75	2.90	73	0.006	0.68	0.32
Study 2	70	3.02	68	0.004	0.97	0.34
Mean <i>r</i> (95% CI)	0.33 (0.17 to 0.47)					
Combined <i>Z</i> (p-value)	4.04 (< 0.001)					
<b>Happy</b>						
Study 1	75	0.71	73	0.06	0.17	0.08
Study 2	70	2.62	68	0.01	0.84	0.30
Mean <i>r</i> (95% CI)	0.19 (0.02 to 0.34)					
Combined <i>Z</i> (p-value)	2.25 (0.02)					
<b>Sad</b>						
Study 1	75	4.29	73	< 0.001	1.01	0.45
Study 2	70	2.52	68	0.01	0.81	0.29
Mean <i>r</i> (95% CI)	0.38 (0.23 to 0.51)					
Combined <i>Z</i> (p-value)	4.66 (< 0.001)					
<b>Surprise</b>						
Study 1	75	3.94	73	< 0.001	0.92	0.42
Study 2	70	2.90	68	0.005	0.93	0.33
Mean <i>r</i> (95% CI)	0.38 (0.23 to 0.51)					
Combined <i>Z</i> (p-value)	4.68 (< 0.001)					

2-tailed significance calculated for combined *Z*, *r<sub>z</sub>* converted back to *r* to aid interpretation (not Fisher *Z* transformed). Negative values for *t*, *d*, & *r* denote better performance for those with offending behaviour compared to non-offending controls.

## A7 Example search strategy, Chapter six.

MEDLINE (PubMed)

Search conducted 27/02/2018, 13:45

<b>Criteria</b>	<b>Search Term</b>	<b>Records retrieved</b>
<b>Population</b>	1 crime[MeSH Major Topic]	92284
	2 antisocial personality disorder[MeSH Major Topic]	5772
	3 conduct disorder[MeSH Major Topic]	2088
	4 aggress*[Title/Abstract]	178376
	5 antisocial[Title/Abstract]	7874
	6 1 or 2 or 3 or 4 or 5	275846
<b>Intervention</b>	7 emotion recognition training[Title/Abstract]	15
	8 facial affect recognition[Title/Abstract]	236
	9 facial emotion recognition[Title/Abstract]	572
	10 emotion recognition[Title/Abstract]	2187
	11 behaviour modification[Title/Abstract]	535
	12 cognitive bias modification[Title/Abstract]	231
	13 social perception[MeSH Major topic]	11801
	14 7 or 8 or 9 or 10 or 11 or 12 or 13	14666
<b>Combined</b>	16 6 and 14	<b>930</b>

## A8 Chapter seven, Study 4.

### *Semi-structured interview, participant version*

1. Overall, would you say you were satisfied with the intervention? (Y/N). Can you rate your satisfaction with the intervention on a scale from 0 (completely dissatisfied) to 100 (complete satisfaction) (score:\_\_\_)
2. If you had the option of continuing to use this intervention, would you do so? (Y/N). Please explain why.
3. Do you think this intervention was appropriate for use within a prison setting? (Y/N). Please explain why.
4. Do you think this intervention had any positive or negative effects on you as a participant (Y/N). If yes, please provide details of these positive or negative effects.
5. Did you know which group (i.e. experimental or control) you had been allocated to? (Y/N). If yes, could you explain how?
6. How difficult did you find the training programme (on a scale of 1 to 10, 1 being very easy and 10 being very difficult). Can you explain why you chose this number?
  
7. Qualitative analysis: Participant experience of measures

Now we want to ask you a bit more about your experience of using the measures in the study (the questionnaires, the tablet, the intervention, etc.)

#### Prompts:

- *Did you find the equipment/behaviour diaries/questionnaires easy to use?*
  - *Did you find the instructions easy to understand? (diary/training)*
  - *How did you find using the behavioural diary? (Was it easy, difficult – would you have preferred a different way of recording the data, if so – what? Did you find it difficult to remember to complete it?)*
  - *Did you have adequate time to complete each part?*
  - *Was there any part of the study you found confusing, or difficult to understand?*
  - *How did you find the intervention (+/-)? Were four sessions enough/too little/too much?*
  - *Is there anything we could have done to make the training programme better?*
8. Before the retraining programme, how did you get on with your peers?*(Prompt – Are you friendly with other young people/people in the prison? Has this changed since completing the retraining programme? If so, how?)*
  9. Do you get angry with other young people/people on the unit? *(Prompt - Has this changed since completing the training programme? If so, how?)*
  10. Do you feel different now compared to how you felt before you completed the training? If so, how?
  11. Is there anything else you would like to discuss that we haven't already covered?

### *Semi-structured interview, staff version*

1. Overall, would you say you were satisfied with the intervention? (Y/N). Can you rate your satisfaction with the intervention on a scale from 0 (completely dissatisfied) to 100 (complete satisfaction) (score:\_\_\_)
2. If you had the option of continuing to use this intervention in your unit, would you do so? (Y/N). Please explain why.
3. Qualitative: Acceptability and demand

We want to learn a bit more about your views on how this intervention would fit within Parc and prisons in a broader sense, so these next few questions will be more 'open'.

- *Do you think this intervention was appropriate for use within a prison setting?*
  - *Do you think this intervention could be easily integrated into the current intervention programmes used at HMP Parc?*
  - *Do you think this intervention had any positive or negative effects on the unit?*
  - *Do you think there's a need for more aggressive behaviour interventions for use within this prison, or prisons generally?*
  - *Do you think there's a need for more digital behavioural interventions, similar to the one used in this study (emotion recognition training)?*
  - *Based on your experience of the feasibility study, do you think replication on a larger scale within HMP Parc would cause disruption to the current programmes or routine within the prison?*
4. What do you think helped us implement the intervention? Did anything make it easier/harder to do this? (e.g. efficiency of the tablets, training of staff).
  5. How did you find using the behaviour diary? (*Prompt: Was it easy, difficult – would you have preferred a different way of recording the data, if so – what? Did you find it difficult to remember to complete it? Did the response forms have adequate space for responses?*)
  6. Did you find the equipment easy to use? (Y/N)
  7. Was the equipment available when you needed it? (Y/N)
  8. Did you encounter any difficulties using the equipment? (*e.g. technical issues with loading the task or saving the data*). If yes, please provide details
  9. Did you find it easy to recruit using the pre-determined eligibility criteria, or were they too restrictive? Was it obvious who met this criteria?
  10. Did you encounter any other challenges with managing this study?
  11. Did you feel suitably prepared and trained to manage this study? If not, can you tell us why this is?
  12. Do you think this intervention had any positive or negative effects on the participants that we should know about? If yes, please provide details of these positive or negative effects
  13. Do you consider this intervention safe to use? If no, please provide details
  14. Did you know which group (i.e. experimental or control) the young person had been allocated to? If yes, please indicate how

15. How difficult do you think the participants found the training programme (on a scale of 1 – 10, 1 being very easy and 10 being the most difficult). Why this number?
16. What did you think of the training programme instructions? (*Were they well/poorly explained?*)
17. How could we make the training programme better?
18. Do you think that there was an appropriate number of staff members helping to coordinate this study? (Yes, no – too few, no – too many). Do you think having more/less would have made the study easier to manage and more efficient?
19. Did you feel as if you had adequate time to perform the tasks you had committed to doing (recruitment, administering the intervention, behaviour diary reminders).
20. Are there any capacity issues in your unit? E.g. was it difficult to find space to run the intervention, or to run the intervention on multiple people at once? If yes, please explain
21. Is there anything else you would like to discuss that we haven't already covered?