Does mental toughness moderate the relationship between pain intensity and working memory?

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I certify that all material in this dissertation which is not my own work has been identified and that no material has previously been submitted and approved for the award of a degree by this or any other University.

Signature:………………………………………………..

Table of Contents

Table of Contents ... **2**

Table of Tables ... **4**

Abstract ... **5**

Introduction ... **6**

Pain ... 6

Working Memory ... 8

Mental Toughness ... 11

Mental Toughness, Working Memory and Pain ... 12

Study 1: Method ... **16**

Participants ... 16

Task ... 16

Conditions ... 18

Measures ... 19

Procedure ... 22

Data Analysis ... 22

Study 1: Results ... **23**

Study 1: Discussion ... **29**

Study 2: Introduction ... **31**

Study 2: Method ... **34**

Trial 2-Back Task ... 34

Participants ... 34

Measures ... 35

Data Analysis ... 35

Study 2: Results ... **36**

Study 2: Discussion 46

General Discussion 48

Pain Intensity 48

Measurement of Mental Toughness 49

Mental Toughness and Pain Intensity vs. Pain Tolerance 50

The Nature of Pain Measured 51

Confounding Variables 53

Methodological Issues 55

Implications 56

Conclusion 58

References 59

Appendices 77

Table of Tables

Table 1: Descriptive statistics for the MTI, pain intensity VAS and 2-back test results (study 1). 24

Table 2: Zero-order Pearson's correlations between MTI, VAS and CPS in 'Pain' condition 27

Table 3: Independent samples t-test (study 1) 28

Table 4: Descriptive statistics for the mental toughness components, composite performance scores and pain intensity 37

Table 5: Zero-order Pearson's correlations between the mental toughness, pain intensity and composite performance scores in the 'Pain' condition..... 41

Table 6: Results of Welch's *t*-test on order of test completion (study 2)....... 45

Abstract

The purpose of this study was to investigate whether mental toughness can moderate the relationship between pain and attention. Two studies were conducted with the second addressing methodological issues encountered in the first. The studies consisted of a within-subjects design and involved the completion of a 2-back task in a 'Pain' condition and a 'No Pain' condition. The pain manipulation was a cold pressor machine circulating water at 12^{o}C ± 1^{o}C, which participants held their hand in for 2 minutes whilst completing the 2-back task in the 'Pain' condition. Independent variables were mental toughness and pain intensity ratings, and the dependent variable were 2-back performance scores in each condition. Results did not support the hypotheses: performance on the 2-back task was not worse in the 'Pain' condition compared with the 'No Pain' condition; performance on the 2-back task did not decline as pain increased and mental toughness did not moderate the relationship between pain and attention (performance on the 2-back task). Potential reasons for the lack of supportive findings are discussed.

Does mental toughness moderate the relationship between pain intensity and working memory?

Introduction

Everyone has experienced pain during their lifetime and for some pain is a quotidian experience. Maintaining attention on tasks while experiencing pain can be difficult and, if not done successfully, can lead to task failure. Some individuals are better able at maintaining their attention when met with the adverse condition of pain than others (Engle, Kane & Tuholski, 1999). This study set out to investigate the relationship between pain and attention, by assessing participants' working memory performance while they were subjected to acute experimentally-induced pain. It also investigated whether the psychological construct of mental toughness can enhance an individual's ability to overcome the adversities of pain and allow them to maintain their attention on the task.

Pain

Pain is 'an unpleasant sensory and emotional experience associated with actual or potential tissue damage' (Merskey & Bogduk, 1994, p210). It is a subjective psychological state, with varying appraisals based on individual differences (Main & Watson, 1999). Pain can be measured in a number of different ways. For example, the McGill Pain Questionnaire (MPQ; Melzack & Torgerson, 1971) is a self-report questionnaire consisting of a list of words that participants have to choose to represent the pain they are experiencing. The Wong-Baker FACES Pain Rating Scale (Wong & Baker, 1988) consists of a series of faces expressing different levels of pain that participants have to choose from to appropriately describe their pain.

However, the most commonly used measure is the visual analogue scale (VAS; Woodforde & Merskey, 1972), a psychometric response scale used to assess subjective attitudes that cannot otherwise be directly measured, which is considered one of the best measures for intensity of pain (Scott & Huskisson, 1976).

Pain interrupts and demands attention (Eccleston & Crombez, 1999); however, the interpretive function of pain depends on a range of variables that vary across people (Galer, Gianas & Jensen, 2000; Main & Watson, 1999). For example, individuals with a greater propensity for emotional regulation, who perceive the threat, level of pain to be relatively low, will likely have a less disruptive effect of pain than their more neurotic, and threat focused counterparts (Wiech, Ploner & Tracey, 2008). Moreover, the perception of pain depends on the attention that is allocated to a nociceptive stimulus. Directing attention away from a nociceptive stimulus can reduce perceived pain, and therefore the ability to regulate attention will likely moderate the interruptive function of pain (Van Damme, Crombez & Eccleston, 2004).

Researchers have consistently shown that people in pain report impaired cognitive function. For example, Berryman, Stanton, Bowering, Tabor, McFarlane, and Moseley (2013) conducted a meta-analysis on the evidence for working memory deficits in pain, which included 24 observational studies that evaluated physiological and/or behavioural outcomes in pain conditions and control conditions. They found small to moderate impairments in response inhibition, set shifting and complex executive function in participants with chronic pain compared with healthy controls. This may suggest that pain was pre-empting working memory resources via attention disruption.

Focusing on pain can have a detrimental effect on working memory task performance, highlighting the value of being able to direct attention away from pain (Eccleston, 1995). This research was conducted with chronic pain patients, suffering from high-intensity pain, who demonstrated a significant impairment on an attentionally demanding task compared with low pain patients and controls. More contemporary research would suggest that this effect is also present in naturally-occurring acute pain, such as menstrual pain, which can also lead to performance deficits on cognitive tasks (Keogh, Cavill, Moore & Eccleston, 2014).

Working Memory

Working memory is a limited-capacity cognitive system responsible for holding information available for processing (Miyake & Shah, 1999) and is important for guidance and decision making (Malenka, Nestler & Hyman, 2009). The concept of working memory is different to short-term memory due to the latter only referring to the storage of information and not the manipulation of that stored information, which the former accounts for (Cowan, 2008). As a term of description, 'working memory' was first coined by Pribram, Miller & Galanter in 1960, and the first model was developed by Atkinson and Shiffrin in 1968, later further developed by Baddeley and Hitch in 1974. This model of working memory describes a multi-component system, consisting of the phonological loop, visuospatial sketchpad, the episodic buffer (added by Baddeley in 2000) and the central executive. More recently, and perhaps of more relevance to the present study, is the emergence of a different conceptualisation of working memory; one which "represents a domain-free limitation in ability to control attention" (Engle, 2002, p.1).

Engle (2002) developed the executive attention theory of working memory capacity that posits that working memory capacity is "the ability to maintain stimulus and response elements in active memory, particularly in the presence of events that would capture attention away from that enterprise" (p. 192-193). Furthermore, Engle highlighted the importance of working memory capacity in conflict resolution between choosing task-appropriate and inappropriate responses. The tenets of this theory would suggest that greater working memory capacity would lead to more items maintained as active (because of the increased ability to control attention) and therefore a greater ability to use attention to avoid distraction. Furthermore, Engle suggested that working memory capacity is particularly important under conditions in which interferences lead to conflicts in retrieval and focus on concurrent tasks. This is particularly pertinent to the current study as it could help to explain the effect of pain on working memory, a key aim in this study.

Working memory capacity can be measured using cognitive tests, a typical example being the n-back task (Jarrold & Towse, 2006), which comprises a series of stimuli to which participants report the stimulus that was presented "n" stimuli ago. For example, in a 2-back task, participants are asked to indicate whether the current stimulus was the same as that presented two items ago. Therefore, in the sequence A–A–C–D–C, a "yes" answer would only be given to the final stimulus, as the letter C was presented two stimuli previously. Importantly, N-back task performance is impaired in conditions designed to induce acute pain (Attridge, Noonan, Eccleston & Keough, 2015; Buhle & Wager, 2010; Moore, Keough & Eccleston, 2012).

According to Engle's 2002 executive attention model of working memory capacity, n-back tasks require a substantial amount of attention control in order to maintain the task goal (correctly identifying whether a letter is the same as 'n' letters ago) in the presence of a distracting stimuli (e.g., pain) that could potentially capture attention. In this situation, any lapse in attention directed towards the goal will, likely, lead that attention to be captured by the distracting stimuli and therefore result in errors on the task (Unsworth, Redick, Spillers & Brewer, 2012), as demonstrated by research cited previously (Attridge, Noonan, Eccleston & Keough, 2015; Buhle & Wager, 2010; Moore, Keough & Eccleston, 2012).

Working memory capacity often correlates positively with a number of other factors, including meditation (Tang et al, 2007), playing video games (Boot, Kramer, Simons, Fabiani & Gratton, 2008), fluid intelligence (Jaeggi, Studer-Luethi, Buschkuehl, Jonides & Perrrig, 2010), yoga and aerobic fitness (Diamond & Lee, 2011) and mindfulness (Tang, Yang, Leve & Harrold, 2012). It also correlates negatively with pain intensity, with studies suggesting that as pain increases, working memory capacity function decreases (Attridge, Noonan, Eccleston & Keough, 2015). This relationship is of particular interest to this paper, as well as the relationship between working memory capacity and mental toughness, and its attention regulation properties (Clough, Earle & Sewell, 2002; Gucciardi, Hanton, Gordon, Mallett & Temby, 2015; Gucciardi, 2017; Loehr, 1982).

Mental Toughness

Mental toughness is defined as “a state-like psychological resource that is purposeful, flexible, and efficient in nature for the enactment and maintenance of goal-directed pursuits” (Gucciardi, 2017, p5). Gucciardi (2017) asserted that mental toughness represents a unidimensional concept consisting of a collection of attributes acquired and integrated over time (Hobfoll, 2002; Gucciardi, Hanton, Gordon, Mallett & Temby, 2015; Madrigal, Hamill & Gill, 2013). Attributes include, generalized self-efficacy (Litt, 1988; Nicholas, 2007; Hoffman & Schraw, 2009), optimism (Levens & Gotlib, 2012; Peters & Vancleef, 2008; Pulvers & Hood, 2013), emotional regulation (Berna, Leknes, Holmes, Edwards, Goodwin & Tracey, 2010; Schmeichel & Demaree, 2010; Schmeichel, Volokhov & Demaree, 2008; Wiech, Ploner & Tracey, 2008) and attention regulation (Kane, Bleckley, Conway & Engle, 2001; Kane & Engle, 2003; Schmeichel, 2007; Villemure, Slotnick & Bushnell, 2003;).

The measurement of mental toughness has been subject to a substantial amount of investigation (and debate) over the years. An early measurement tool was the Performance Profile Inventory (Loehr, 1982), however questions regarding the reliability and validity of this measure were raised leading to the development of the Mental Toughness Inventory (MTI; Middleton, Marsh, Martin, Richards & Perry, 2004), based on a multi-dimensional approach of mental toughness. However, Gucciardi, Hanton, Gordon, Mallett and Temby (2015) later questioned the validity of the MTI and the dimensionality of mental toughness. They posited that mental toughness is better described as a unidimensional construct and adapted the MTI accordingly. The new 8-item measure produced internally reliable scores and displayed strong factor analysis, as well as having greater generalisability and taking less time to complete.

Mental Toughness, Working Memory and Pain

Several researchers have implicated mental toughness in the pain process. For example, Jones, Hanton, and Connaughton (2002) defined mental toughness in terms of the ability to push through pain barriers while maintaining effort and technique. Similarly, Levy, Polman, Clough, Marchant, and Earle (2006) suggested that high mentally tough individuals displayed more positive threat appraisals (of stressors) and were better able to cope with pain (i.e., blocking out pain) than their less mentally tough counterparts.

It is important to note that in many of these studies the researchers did not measure pain directly but rather, inferred pain based on the nature of the tasks tested (e.g., the multi-stage fitness test). For instance, Crust and Clough (2005) revealed a positive relationship between mental toughness and physical endurance during a weight hold task. Bell, Hardy, and Beattie (2013) discovered that a mental toughness intervention group, who were given skills to improve their mental toughness behaviour, improved their multistage fitness test score more so than a control group. Gucciardi, Peeling, Ducker, and Dawson (2016) also used the multi-stage fitness test performance as a measure of behavioural perseverance and included age, height, mass, and playing experience as covariates. Gucciardi et al. showed that mental toughness accounted for an additional 5.4% of the variance in multi-stage fitness test performance beyond age, height, playing experience, body mass. Based on the evidence it would appear that mental toughness influences pain behaviours positively, however it should be noted, again, that these researchers are not measuring pain, as defined earlier in this paper, demonstrating a gap in the extant literature that the present study seeks to fill.

Crust and Clough (2005) attributed the positive relationship between mental toughness and pain tolerance to the ability of mentally tough participants to be able to block out painful stimuli and therefore tolerate pain for longer. Other researchers have also noted blocking out distractions (e.g., pain). For example, Weinberg, Butt, and Culp (2011) interviewed coaches about their views on mental toughness. They identified focus and blocking out distractions as important components of mental toughness; with one coach commenting that “mental toughness is someone who can play the moment and put all other distractions out of their mind, being totally focussed” (p.161). Similarly, Coulter, Mallett, and Gucciardi (2010) discussed how mentally tough Australian soccer players could block out distractions, including pain. Essentially, the ability to regulate attention during pain enables those people with high levels of mental toughness to shift attention from pain to other tasks. Considered in terms of Engle’s (2002) theory, those high in mental toughness may possess greater working memory capacity that would allow them enhanced ability to control attention to avoid distraction. Furthermore, research with athletes found that directing attention away from pain can increase tolerance towards pain leading the researchers to posit that an athletes’ endeavour to maintain a skilled performance results in intense concentration, focussing their attention towards the task (Kanfer & Goldfoot, 1966; Kress & Statler, 2007), both demonstrating mental toughness and providing evidence for the executive attention model.

The abundance of research investigating the relationships between pain and working memory capacity would suggest that greater working memory capacity leads to the enhanced ability to control the direction of attention to certain tasks and avoid distraction caused by pain stimuli. Furthermore, it is implied that the attentional regulation aspects of mental toughness may help to facilitate working memory capacity, as described in the executive attention model, suggesting that there could be a positive correlation between working memory capacity and mental toughness.

Another important area for investigation is how the interaction between mental toughness and pain can affect working memory. Research has shown that an increased perceived threat level of pain is associated with maladaptive coping (Ramirez-Maestre, Esteve & Lopez, 2008; Van Damme, Crombez, van de Wever & Goubert, 2008), such as catastrophic thinking and increased anxiety, which leads to a higher pain intensity score (Arntz & Claasens, 2004). Conversely, as expected, a decreased perceieved threat level leads to lower pain intensity scores (Leeuw, Goosens, Linton, Crombez, Boersma & Vlaeyen, 2007). The degree to which pain is perceieved to be threatening is dependent on the individual’s own beliefs about their abilities to cope with pain (Lazarus & Folkman, 1984; i.e. the confidence aspect of mental toughness). If coping mechanisms are perceived to be sufficient, pain can appear to be somewhat controllable (Wiech, Ploner & Tracey, 2008;

i.e. the control aspect of mental toughness). Individuals who recognise this degree of control work hard to take action and resist succumbing to the pain, whereas individuals with a low degree of control demonstrate more passive responses in the face of stressors such as pain (Skinner, 1996). Perceieved control is thought to trigger reappraisal processes that can change the pain experience, however it is internal, as opposed to external, control over pain that has been shown to reduce pain intensity (Arntz & Schmidt, 1989). This research demonstrates that the interaction between pain and mental toughness is a completely distinct concept from the two in isolation and therefore should be treated as such with regard to measurement.

This study will investigate the relationship between pain and working memory capacity and whether mental toughness can explain changes in working memory performance between pain and no pain conditions. An initial study will focus on a heterogeneous sample of university students from different athletic backgrounds, ranging from sedentary individuals to individuals with national representative honours and will involve the completion of a mental toughness questionnaire followed by a cognitive task, performed once with experimentally-induced pain and once without. The following statements are hypothesised:

H_1: There will be a performance deficit in 2-back performance in the 'Pain' condition compared with the 'No Pain' condition.

H_2: There will be a negative ($r > \sim.10$) correlation between pain intensity and performance on the 2-back task.

H_3: Mental toughness will moderate the relationship between pain intensity and 2-back performance when in pain.

Study 1: Method

Participants

In total, 107 participants took part in this study. All who participated were students and faculty of the University of Exeter or residents of the local area. The sample comprised 63 males (M_{age} = 22.92, *SD* = 4.61, 59%) and 44 females (M_{age} = 22.57, *SD* = 3.19, 41%). A missing values analysis revealed that there were no missing data points. Individuals were ineligible to participate if they reported any of the following health conditions: a history of fainting or seizures, history of cardiovascular disease, neurological conditions (e.g., MS, cerebral palsy), Raynaud's disease, pregnancy, fibromyalgia, chronic pain syndrome, arthritis, or musculoskeletal injury of their non-dominant hand or wrist. Ethical approval was granted by the University of Exeter Sport and Health Sciences ethics committee and participants provided written informed consent prior to taking part. Diligence was taken in adhering to these ethical guidelines and the guidelines set forth by the British Psychological Society for conducting research. Sample size calculations were conducted using G*Power (Faul, Erdfelder, Lang & Buchner, 20009) and showed that to achieve 80% power a total sample size of 98 was required.

Task

A meta-analysis of research utilising N-back tests has shown that it is a reliable test for working memory (Owen, McMillan, Laird & Bullmore, 2005) and that it will consume most of the working memory capacity. A 2-back task was used in this study as it is sensitive to the effects of experimental (Buhle & Wager, 2009; Moore, Keough & Eccleston, 2012) and naturally-occurring

(Keough, Cavill, Moore & Eccleston, 2014; Moore, Keough & Eccleston, 2012) pain. During the 2-back task participants were presented with a string of letters. The aim was to correctly identify whether the letter presented to them was the same as the letter presented two turns ago.

The 2-back test was delivered to participants using PsychoPy, a Python-based programme used to create psychological tests (Pierce, 2007, 2009). The tests were created according to specifications laid out in Attridge, Noonan, Eccleston and Keough's (2015) study investigating the effects of pain on N-back task performance. The letter strings consisted of sixty characters, excluding all vowels and the letter 'y', which were presented one at a time in the centre of the laptop screen. The letters were capitalized and appeared in black Arial font on a white background. The letters were 20% of the screen height, and each letter was presented for 500ms followed by a blank screen for 1500ms. The total time of the 2-back test was two minutes.

Participants were asked to report whether the letter presented to them on the screen matched the letter shown two letters previously. Participants indicated whether the letter was the same as "2-back" by using two separate keyboard keys; the right arrow key for a letter they believed matched the letter two letters back and the left arrow key for any letters they did not think matched. The letter strings for both conditions consisted of 20 target stimuli (letters that matched the letter two letters previously), and 40 non-target stimuli (letters that did not match). The number of correct responses and response reaction times are used to calculate a composite performance score.

Conditions

In the pain condition, participants were asked to remove any jewellery on their non-dominant hand and wrist and submerge their non-dominant hand in a cold pressor machine (Thermo Fisher, USA) circulating water at 12°C ± 1°C for 2 minutes. This temperature was chosen based on theoretical considerations and previous studies on distraction (e.g., Verhoeven, Crombez, Eccleston, Van Ryckeghem, Morley & Van Damme, 2010) that have shown the use of very low temperatures (0-5°C) could lead to high rates of dropout and inhibit the effects of distraction (Eccleston & Crombez, 1999). Moderately cold temperatures (7-10°C) can lead to high levels of pain and mean that participants are unable to tolerate the water for the two minutes (Verhoeven et al., 2010), which was required to complete the 2-back test. Verhoeven and colleagues indicated that 12°C would create a painful stimulus that most people could withstand for two minutes, which also allowed time for the partipants to complete the 2-back task and produce sufficient data to be analysed.

During the two minutes of submersion, the participants completed the computerized 2-back tasks, using their dominant hand to provide answers. On completion of the 2-back task and withdrawal of their hand from the water, participants were asked to rate the intensity of the pain experienced on a visual analogue scale (VAS). In the no pain condition participants were asked to complete another 2-back task test, with different letter strings to reduce learning effects between the conditions, with their non-dominant hand resting to the side of their body. On completion of the tasks, participants were given the opportunity to ask any questions about the study and reminded of contact details they could use should they think of questions at a later date.

Measures

Demographic Questionnaire. Participants completed a demographic questionnaire, providing details including their name, date of birth, gender, ethnicity and details of their dominant hand.

Mental Toughness Inventory. The Mental Toughness Inventory (MTI) was developed in 2015 after Gucciardi, Hanton, Gordon, Mallett and Temby as part of a broad investigation into mental toughness, during which they scrutinised its dimensionality. This research established three key contributions to the research area: (1) the dimensionality of MT as unidimensional, as opposed to multidimensional, (2) individuals with higher levels of MT are less likely to believe that the situational demands at any given moment will exceed their available coping strategies, and (3) MT is conceptualised, more suitably, as state-like, with varying properties across situations and times (Harmison, 2011). Furthermore, the MTI outperformed existing measures, based on a multidimensional approach to MT (Clough et al., 2002), on predictive validity (Gucciardi et al., 2015).

The MTI was used to measure participants' ability to maintain their focus when faced with adversity, in this case, the pain caused by the cold pressor test. The MTI consists of 8 items scored on a 7-point scale (1 = *false 100% of the time* and 7 = *true 100% of the time*), and participants rated the extent to which they agreed with each statement. Total mental toughness score is achieved by adding together the answers to each of the eight statements. High total ratings reflect high levels of mental toughness and low total scores reflect low levels of mental toughness. The MTI demonstrated acceptable internal reliability (α = .78, Cronbach, 1951; λ-2 = .78, Guttman, 1945).

2-back Composite Performance Score. To create the composite 2-back performance score that includes both reaction time and number of correct responses, the mean reaction time was subtracted from two (the maximum possible reaction time in seconds). Numbers closer to zero indicate poorer reaction times. This number was then multiplied by the percentage of correct answers (ranging from 0-100%), giving a score between 0 and 200 (0 reflects the worst performance, and 200 indicates the best performance). For example, if a participant had a rapid mean reaction time of 0.001 seconds and they had an accuracy rating of 90% their score would be 179.91 (i.e., $(2 - 0.001) \times 90$). Similarly, if someone had rapid mean reaction time but got all answers incorrect their composite score would be zero (i.e., $(2 - 0.001) \times 0$).

This measure of 2-back performance is unique to the present study and was developed in order to improve the data analysis process. This measure takes into account the standard measures of 2-back tasks, reaction times and percentage of correct responses, but places greater importance on the percentage of correct responses, which is of more relevance to the present study than reaction time (as we were investigating whether pain led to errors in performance). (Mean reaction time and percentage of current answers data, which were used to calculate composite performance scores, can be found in Appendices 4 and 10).

Pain Intensity Visual Analogue Scale. Visual analogue scales (VAS) provide an easy, convenient and quickly administered measurement option that allows a researcher to efficiently collect participant data (Wewers & Lowe, 1990). Furthermore, based on subject feedback, the VAS is accurate, sensitive and is a good indicator of pain (Joyce, Zutshi, Hrubes & Mason, 1975; Ohnhaus & Adler, 1975). The pain intensity visual analogue scale was used to measure pain intensity, which has been shown to have strong test-retest reliability (Revill, Robinson, Rosen & Hogg, 1976; Henderson, Byrne & Duncan-Jones, 1981).

The VAS consisted of a 10cm horizontal line (Scott & Huskisson, 1976), anchored by two verbal descriptions of each symptom extreme ('no pain at all', 'worst pain ever experienced'). Research has indicated that participants can have difficulty fully understanding the conceptual underpinnings of scales of this nature and therefore not follow instructions carefully (Huskisson, 1983; Kremer, Atkinson & Ignelzi, 1981; Williams et al., 1988, April), however this effect can be avoided with careful instruction (Price et al., 1983). Prior to starting the task in the 'pain' condition, participants were instructed how to indicate their pain on the VAS, by using a mouse to place a line perpendicular to the VAS line, presented on a computer screen, at the point that represented their pain. This was done after the 2-back task had been completed. Pain intensity VAS score was calculated by measuring the distance between 'no pain at all' and the line placed by the participant on the scale, providing a score ranging from 0 to 100. Scores falling between 0mm and 4mm on the line are considered indicative of 'no pain', scores between 5mm and 44mm are considered to indicate 'mild pain', scores between

45mm and 74mm indicate ‘moderate pain’ and scores between 75mm and 100mm indicate ‘severe pain’ (Jensen, Chen & Brugger, 2003).

Procedure

The study had a within-subjects design and consisted of one group of participants and two experimental conditions, counterbalanced to avoid order effects (Shaughnessy & Zechmeister, 1985). The two conditions were counterbalanced based on participant number; odd-numbered participants completed the pain condition first followed by the no pain condition and even numbered participants completed the conditions in the opposite order.

Participants were asked to make a single twenty-minute visit to the lab. On arrival, participants were given a consent form to read through and complete before starting the study. Providing they had given consent to participate, they were asked to complete a battery of questionnaires, supplied to them on a laptop via Google Forms. On completion of the questionnaires, participants were invited to participate in either the pain or no pain condition (depending on their number).

Data Analysis

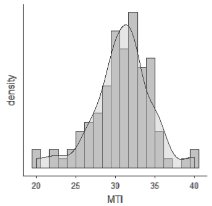
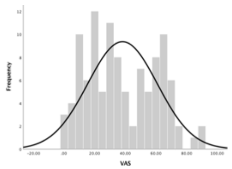
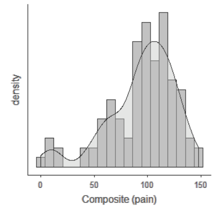
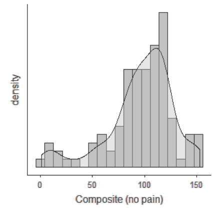
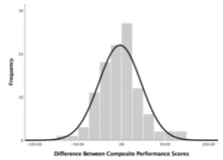
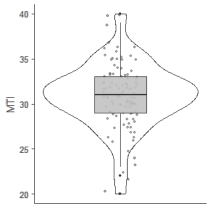
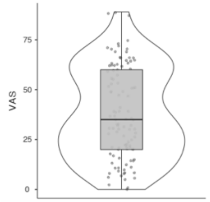
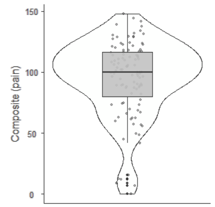
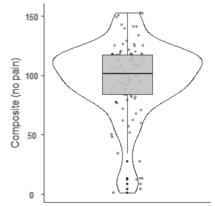
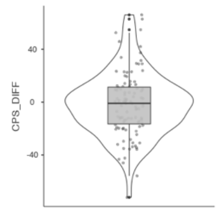
Paired-samples *t*-Tests were conducted to assess whether the pain manipulation affected the performance of the 2-back task. A zero-order Pearson’s correlation, with 5000 bootstrapped resampled confidence intervals, was conducted to assess the relationships between pain intensity, composite performance score in the ‘Pain’ condition and mental toughness. For the moderated regression, pain (pain intensity VAS score) was variable ‘X’, attention (composite performance score) was variable ‘Y’, and mental toughness (MTI score) was ‘M’.

Welch's *t*-tests were conducted to assess whether the order in which participants completed the tasks affected their score. Delacre, Lakens, and Leys (2017, p 92) stated that "Welch's *t*-test provides better control of Type 1 error rates when the assumption of homogeneity of variance is not met, and it loses little robustness compared to Student's t-test when the assumptions are met". Delacre et al. also argued that Welch's t-test should be used as a default strategy (over Student's and Yuen's).

Study 1: Results

Standardised scores for skewness (z_{skew}) and kurtosis (z_{Kurt}) were calculated (Field, 2013). Data were non-normal if z_{skew} or z_{Kurt} exceeded ± 3.29 *z* scores from the mean (Rose, Spinks & Canhoto, 2014). Composite performance scores in the 'Pain' (z_{skew} = 4.444) and 'No Pain' (z_{skew} = 4.637) conditions were skewed however this was not corrected as parametric testing is robust with respect to violations of the assumptions of skewness and kurtosis (Norman, 2010). (See Table 1).

Table 1: Descriptive statistics for the MTI, pain intensity VAS and 2-back test results (study 1).

	MTI	VAS	CPS – Pain	CPS – No Pain	CPS Difference
Mean	30.841	38.146	94.644	96.386	-1.7413
SD	3.663	22.798	31.643	101.460	24.316
Minimum	20	0	0	1.017	-72.080
Maximum	40	89	147.933	152.772	66.020
z_{skew}	-1.816	1.043	-4.444	-4.637	.927
z_{kurt}	2.508	-2.201	2.197	3.006	1.336
Distribution					
Box Plots					

Composite performance scores in the ‘No Pain’ condition were 1.741 increments better than scores in the ‘Pain’ condition (t_{106}= -.741, *p* = .460, [-6.402, 2.919], *d* = .072). These results suggest that the pain manipulation does not affect composite performance scores in a meaningful way.

A zero-order Pearson’s correlation, with 5000 bootstrapped resampled confidence intervals, was conducted to assess the relationships between pain intensity, composite performance score in the ‘Pain’ condition and mental toughness (see Table 4). A Bonferroni adjustment was made to the significance level to reduce the risk of Type 1 errors occurring (*p* = .05/3 = .017; Dunn,1958). The results showed small and non-significant relationships (at the $p < .017$ level) with 95% CIs that crossed zero, which could indicate a potentially meaningless relationship. (See Table 2).

Despite not meeting the assumptions for moderated regression analysis (i.e., non-significant correlations; Judd & Kenny, 2010), we ran this purely for exploratory purposes and to investigate whether the interaction between pain and mental toughness could predict variances in composite performance scores in the ‘Pain’ condition. The interaction between mental toughness and pain intensity predicted 3.8% (r^2 = .038) of the variance in composite performance scores in the ‘Pain’ condition, which was not significant (*p* = .260). (See Appendix 5.)

Results revealed a significant order effect on the difference in composite performance scores between conditions ($t_{102.146}$ = -7.210, $p <$ .001), as well as composite performance scores from the pain condition ($t_{104.484}$ = -2.411, *p* = .018), and composite performance scores from the no pain condition ($t_{103.916}$ = 2.196, *p* = .030). Results revealed that participants performed better on their second task regardless of whether they were completing the pain condition or the no pain condition, providing support for the presence of learning effects (see Table 3). The order in which participants completed the tests (whether participants completed the pain condition first or the no pain condition first, identified by 0 and 1 respectively) was used as the grouping variable and composite performance score, in both the ‘Pain’ and ‘No Pain’ condition, and difference in composite performance scores between the two conditions were the dependent variables.

Table 2: Zero-order Pearson's correlations between MTI, VAS and CPS in 'Pain' condition

		MTI	VAS	'Pain' CPS.
MTI	Pearson's *r*		-.038	-.172
	p (1-tailed)		.348	.038
	95% CI Upper		.025	.161
	95% CI Lower		-.037	-3.132
VAS	Pearson's *r*			-.135
	p (1-tailed)			.082
	95% CI Upper			.078
	95% CI Lower			-.454
'Pain' CPS	Pearson's *r*			
	p (1-tailed)			
	95% CI Upper			
	95% CI Lower			

Table 3: Independent samples t-test (study 1)

						95% Confidence Interval		
	Welch's t	*df*	*p*	Mean difference	*SE* difference	Lower	Upper	Cohen's *d*
CPS Pain	-2.411	104.484	.018	-14.415	5.979	-26.271	-2.558	-0.466
CPS No Pain	2.196	103.916	.030	13.467	6.131	1.308	25.625	0.425
Difference in CPS	-7.210	102.146	<.001	-27.881	3.867	-35.551	-20.211	-1.396

Study 1: Discussion

The purpose of this study was to examine variation in working memory between a no pain and an acutely painful task and to consider whether mental toughness predicted the magnitude of working memory variation. The hypotheses were:

H_1: There will be a performance deficit in 2-back performance in the ‘Pain’ condition compared with the ‘No Pain’ condition.

H_2: There will be a negative (r > ~-.10) correlation between pain intensity and performance on the 2-back task in the 'Pain’ condition.

H_3: Mental toughness will moderate the relationship between pain intensity and composite performance score when in pain.

Divergent to Hypothesis H_1, the paired samples t test results suggested that the pain manipulation did not affect performance on the 2-back task (cf. Attridge, Noonan, Eccleston & Keough, 2015; Berryman, Stanton, Bowering, Tabor, McFarlane & Moseley, 2013; Buhle & Wager, 2010; Moore, Keough & Eccleston, 2012). A reason for this result could be due to the fact that, on average, pain intensity as a result of the cold pressor test was rated as mild on the visual analogue scale (VAS_{mean} = 38.146; Jensen, Chen & Brugger, 1986). It could be that, for most, the cold pressor test did not cause intense enough pain for it to grasp their attention and inhibit their performance on the 2-back test.

Correlation analyses investigating Hypothesis H_2 showed that there was a small negative relationship between pain intensity and composite performance scores in the ‘Pain’ condition however this was not significant after making Bonferroni corrections. Hypothesis 2 was developed based on results found by Attridge, Noonan Eccleston and Keough (2015), who found significant effect sizes (r = -.16, p < .001) and showed that as pain intensity increased, correct answers decreased. This lack of support for the hypothesis could be due to the cold pressor machine not causing intense enough pain.

We were also not able to support Hypothesis H_3, which again was not in-keeping with findings from extant literature, which would suggest positive correlations between mental toughness and pain and between these two variables and composite performance scores (Clough, Earle & Sewell, 2002; Eccleston, 1995; Gucciardi, 2017; Gucciardi, Gordon, Mallett & Temby, 2015; Jones, Hanton & Connaughton, 2002; Levy, Polman, Clough, Marchant & Earle, 2006; Loehr, 1982). This could be due to the measure of mental toughness not being sensitive enough, due to the fact it was developed on the basis of mental toughness being a unidimensional model. Moving forward, consideration should be made regarding the argument that mental toughness is multidimensional and consists of a number of core components that can be measured as a unit or in isolation (Clough, Earle & Sewell, 2002) as this would lead to a more sensitive way of measuring mental toughness. Moreover, critics of Middleton et al's 2004 MTI have questioned the development of this measure suggesting that validation was limited to elite high school athletes with a mean age of 14 years (12-19 years; Golby, Sheard & van Wersch, 2009), suggesting that Gucciardi et al's 2015 updated version (used in this study) could have been developed on weak foundations.

Finally, the independent samples *t*-test results showed that the difference in CPS between conditions was actually more affected by learning effects (an improvement in performance due to repeated attempts on similar tasks; Catron, 1978; Temkin, Heaton, Grant & Dikmen, 1999) than the pain manipulation. There was a significant improvement in composite performance scores on the second attempts, regardless of whether this attempt was completed with the pain manipulation or not. This would suggest that scores reflect the fact that participants have gone from not knowing how to complete the task to learning how it is done as opposed to measuring their cognitive capabilities.

In conclusion, the results failed to support any of the hypotheses, however this could be due to task learning effects overshadowing any other effect that may have been present. Furthermore, issues with the sensitivity of the measure of mental toughness could have affected the results. In the second study, measures should be put in place to reduce the learning effects and increase the sensitivity of the measure of mental toughness.

Study 2: Introduction

Considering results from Study 1, a second study was conducted, making relevant changes to avoid the confounding effects that occurred in the first study. It was decided to introduce a trial run of the 2-back task prior to completion of the experimental conditions which would allow participants to familiarise themselves with the process of completing the task.

Pain intensity VAS scores in Study 1 were rated as ‘mild’ (VAS_{mean} = 38.146; Jensen, Chen & Brugger, 1986), and gender difference in scores were not significant ($t_{(105)}$ = .378, p = .703, [-7.152, 10.574]; cf. Chesterton, Barlas, Foster, Baxter & Wright, 2003; Ellermeier & Westphal, 1995; Orilonise & Olatosi, 2016; Paulson, Minoshima, Morrow & Casey, 1998;

Plesh, Curtis, Hall & Miller, 1998; Wiesenfeld-Hallin, 2005). Despite this we decided to maintain the temperature of the cold pressor machine at 12^{o}C ± 1^{o}C as previous research has shown that with temperatures of < 10^{o}C and an immersion time of 2 minutes, a number of participants would withdraw their hand from the water prior to finishing the 2-minute task (Verhoeven, Crombez, Eccleston, van Ryckeghem, Morley & van Damme, 2010). Also, some participants have reported that at 10^{o}C numbness replaced any pain they were experiencing (Williams & Thorn, 1986). Based on this and considering the nature of the study design being a fixed immersion paradigm, it was felt that the dropout risks associated with lowering the temperature would jeopardise the ability of the study to produce significant findings.

As mentioned previously, a lack of significant findings from Study 1 could have been due to the MTI not being a sufficiently sensitive measure, therefore it was decided to replace it with the MTQ48 (Clough, Earle & Sewell, 2002), which was developed on the basis of mental toughness being a multicomponent model. Clough and colleagues (2002) proposed this multicomponent model of mental toughness, conceptualising it as more akin to a personality trait, and consisting of four components: control, commitment, challenge and confidence. Control is the extent to which a person feels in control of their circumstances and life in general (can be split into two sub-sub-components; life control and emotional control). Commitment is the extent to which a person is able to stick to achieving their goals. Challenge is the extent to which the individual will embrace change, accept risk and push boundaries. Finally, confidence is the interpersonal confidence they possess to influence others and deal with conflict and adversity and the confidence they have in their own abilities (can be split into two sub-sub-components; interpersonal confidence and confidence in own abilities). The MTQ48 is a measurement tool consisting of 48 questions which allows for isolated measurement of the sub-components (and the sub-sub-components) and, as a result, is more sensitive than the MTI. The isolated measurement of specific components allows for the investigation to focus on whether a sub-component of mental toughness could moderate the relationship between pain and attention. It has been shown that correlations between the sub-components in isolation and fatigue and anxiety exist (Clough, Marchant & Earle, 2007) and therefore it could be possible that the subcomponents in isolation also have a relationship with pain and attention.

This study will investigate the same relationships as Study 1, with a more in-depth focus on the sub-components of mental toughness. The first hypothesis will remain the same as the confounding variables implicated in the investigation of this hypothesis will be controlled for. The second hypothesis will reflect the changes in the measurement tool for mental toughness. The following statements are hypothesised:

H_1: There will be a performance deficit in 2-back performance in the 'Pain' condition compared with the 'No Pain' condition.

H_2: There will be a negative (r > ~-.10) correlation between pain intensity and performance on the 2-back task in the 'Pain' condition.

H_3: Mental toughness, or one of its components, will moderate the relationship between pain intensity and composite performance score when in pain.

Study 2: Method

Study 2 followed the same procedure as Study 1 with the addition of a trial run of the 2-back task, prior to completing the experimental conditions, and the MTQ48 replacing the MTI.

Trial 2-Back Task

The ‘trial 2-back’ task adhered to the specifications as the ‘experimental 2-back’ used in Study 1 (see Attridge, Noonan, Eccleston, & Keough, 2015), however it was administered on a loop, allowing participants to complete it as many times as they wanted to ensure they understood the procedure fully. Trial task feedback was verbally provided by the researcher so that participants could learn from their performance on the trial. Once satisfied they knew how to complete the 2-back task, they completed the two experimental conditions.

Participants

Ninety-eight males (M_{age} = 20.13, *SD* = 1.31, 100% of sample) participated in the second study, all of whom were students at the University of Exeter and members of the men’s student rugby union club. This homogeneous sample was chosen, over a heterogenous sample, as in Study 1, due to the occurrence of gender differences in mental toughness, with females scoring significantly lower on the MTI than males ($t_{(105)}$ = 2.728, p = .007, [.518, 3.272]), as expected based on findings in extant literature (Gerber et al., 2012; Nicholls, Polman, Levy & Blackhouse, 2009). Furthermore, the inclusion of a homogenous sample in Study 2 could help to reduce standard deviation in results, which was high in Study 1, possibly as a result of the heterogeneity of the sample. Sample size calculations were conducted using G*Power (Faul, Erdfelder, Lang, & Buchner, 2009) and showed that to achieve 80% power a total sample size of 98 was required.

Measures

Mental Toughness Questionnaire-48. The MTQ48 (Clough, Earle & Sewell, 2002) was developed based on a multicomponent model of mental toughness and has demonstrated a good level of test-retest reliability, internally consistent subscales and validity (Clough, Marchant & Earle, 2007). The questionnaire consists of 48 items scored on a 5-point scale (1 = *disagree* and 5 = *agree*), participants rated the extent to which they agreed or disagreed with each statement. The 48 statements can be separated into 4 sub-components and a further 2 sub-sub-components, control (emotional and life), commitment, challenge, confidence (in abilities and interpersonal). Each component was scored by calculating an average of the response scores given and total mental toughness score was an average of the component scores. Higher MTQ48 scores (e.g., 5) reflected higher levels of mental toughness and vice versa. The MTQ48 and all of the sub-component measures have acceptable levels of internal consistency (Challenge: $\alpha = .71$, Commitment: $\alpha = .80$, Control: $\alpha = .74$, Emotional Control: $\alpha = .70$, Life Control: $\alpha = .72$, Confidence: $\alpha = .81$, Confidence in Abilities: $\alpha = .75$, Interpersonal Confidence: $\alpha = .76$, entire scale: $\alpha = .91$; Cronbach, 1951; λ-2 = .90, Guttman, 1945).

Data Analysis

Paired-samples *t*-Tests, zero-order Pearson's correlations, with 5000 bootstrapped resampled confidence intervals, and moderated regression were conducted in the same capacity as they were for Study 1, however all of the sub-components of mental toughness were included as individual variables. For the moderated regression, pain (pain intensity VAS score) was variable ‘X’, attention (composite performance score) was variable ‘Y’, and mental toughness and its sub-components (MTQ48 scores) were ‘M’. Welch’s *t*-tests were conducted to assess whether the order in which participants completed the tasks affected their score.

Study 2: Results

A missing values analysis showed that 26 out of 1666 (1.561%) data points were missing. No individual variable was missing more than 2% of data points. Little’s Missing Completely at Random (MCAR: Little, 1988) test determined that the data was not missing completely at random (χ^2 = 138.757; *df* = 106; *p* = .018). Based on the magnitude of missing data multiple imputation was used to create values to replace the 26 missing data points.

Standardized scores for skewness (z_{skew}) and kurtosis (z_{Kurt}) were calculated (Field, 2013). Data were nonnormal if z_{skew} or z_{Kurt} exceeded ± 3.29 *z* scores from the mean (Rose, Spinks & Canhoto, 2014). Composite performance score data were non-normal in the ‘Pain’ condition (z_{skew} = -7.377, z_{kurt} = 8.149) and the ‘No Pain’ condition (z_{skew} = -7.016, z_{kurt} = 9.135), as well the ‘difference in composite performance score’ data (z_{kurt} = -4.344), however this was not corrected as parametric testing is robust with respect to violations of the assumptions of skewness and kurtosis (Norman, 2010). (See table 4).

Table 4: Descriptive statistics for the mental toughness components, composite performance scores and pain intensity

	MT	Challenge	Commitment	Emotional Control	Life Control	Total Control
Mean	3.629	3.710	3.692	3.284	3.684	3.484
SD	.357	.468	.475	.477	.420	.363
Minimum	2.75	2.61	2.45	2.14	2.43	2.79
Maximum	4.52	4.78	4.64	4.71	4.57	4.50
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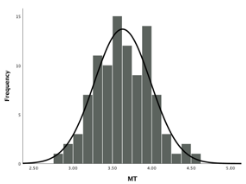
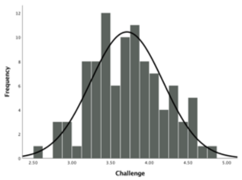
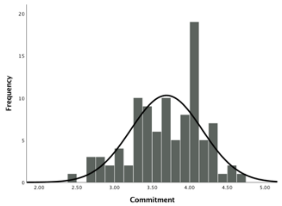
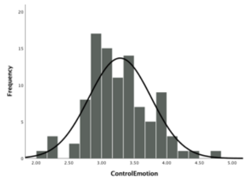
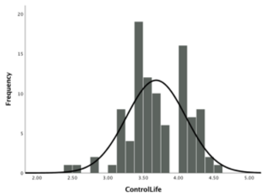
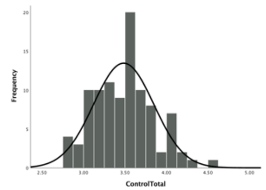
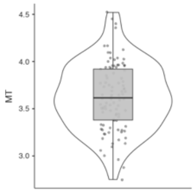
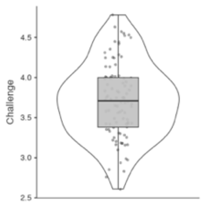
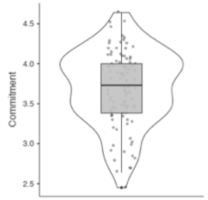
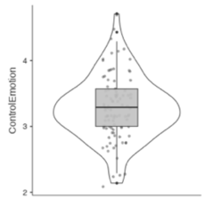
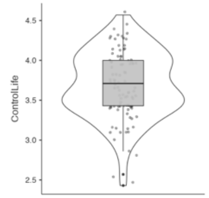
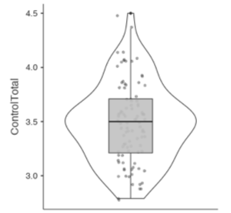
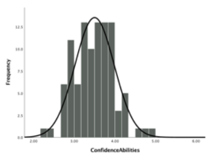
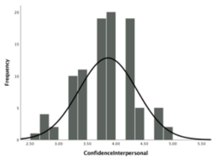
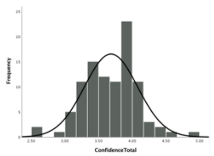
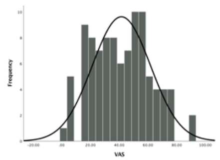
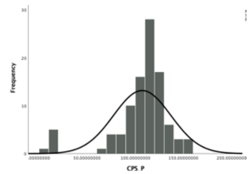
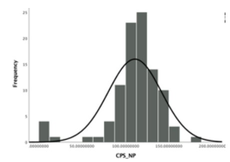
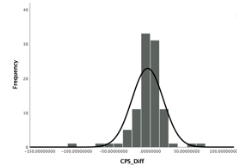
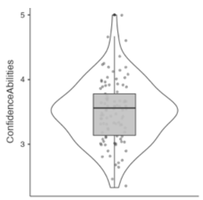
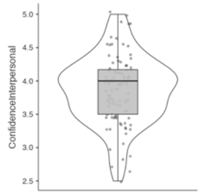
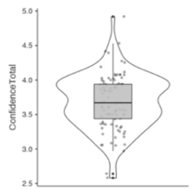
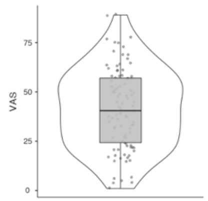
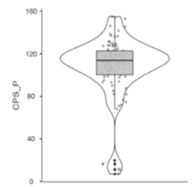
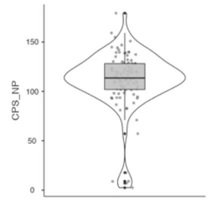
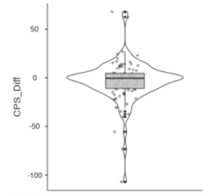
z_{kurt}	-.460	-.959	-.692	.812	.037	-.422
Distribution						
Box Plots						

Table 4 continued.

Descriptive statistics for the mental toughness components, composite performance scores and pain intensity.

	Confidence in Abilities	Interpersonal Confidence	Total Confidence	VAS	CPS - Pain	CPS – No Pain	CPS - Difference
Mean	3.500	3.862	3.684	41.469	107.131	110.764	-3.634
SD	.481	.508	.395	20.323	29.733	30.563	21.364
Minimum	2.33	2.50	2.58	1	6.958	2.48	-107.003
Maximum	5.00	5.00	4.92	89	154.911	179.268	67.815
z_{skew}	.959	-.848	-.320	.422	-7.377	-7.016	-4.344
z_{kurt}	.853	.441	1.234	-1.296	8.149	9.135	-1.296
Distribution							
Box Plots							

Paired-samples *t*-Tests, using composite performance scores as the dependent variables, were conducted to assess whether the pain manipulation affects the performance of the 2-back task in sample from study two. Composite performance scores in the no pain condition were 3.364 increments better than scores in the pain condition (t_{97}= -.1.684, p = .095, [-7.917, 2.919], d = .170). These results suggest that the pain manipulation does not affect composite performance score in a significant way.

A zero-order Pearson's correlation, with 5000 bootstrapped resampled confidence intervals, was conducted to assess the relationships between mental toughness, pain intensity and composite performance score in the 'Pain' condition (see Table 8). A Bonferroni adjustment was made to the significance level to reduce the risk of Type 1 errors occurring (p = .05/19 = .003; Dunn, 1958). The results showed small and non-significant relationships (at the $p < .003$) level with 95% CIs that crossed zero, which could indicate meaningless relationships. (See Table 5.)

Moderated regression revealed that interactions between pain intensity and each component of mental toughness only predicted very small percentages of variation (<5% in every case) in composite performance scores in the 'Pain' condition, of which none were significant (at the $p \leq .05$ level).

Welch's *t*-tests were conducted to assess whether the order in which participants completed the tasks affected their score. The order in which participants completed the tests (whether participants completed the pain condition first or the no pain condition first, identified by 0 and 1 respectively) was used as the grouping variable and composite scores in both conditions and the difference in composite performace scores were the dependent variables. Results revealed small and nonsignificant order effect on any of the dependent variables, which suggests that the trial run addressed the learning effects observed in study one. (See Table 6.).

Table 5: Zero-order Pearson's correlations between the mental toughness, pain intensity and composite performance scores in the 'Pain' condition

		MT	Challenge	Commitment	Emotional Control	Life Control
CPS -Pain	Pearson's *r*	.124	.190	.099	.121	.080
	p (1-tailed)	.113	.030	.165	.118	.216
	95% CI Upper	27.026	24.715	18.861	20.061	20.001
	95% CI Lower	-6.450	-.537	-6.399	-5.011	-8.607

Table 5 continued.

Zero-order Pearson's correlations between the mental toughness, pain intensity and composite performance scores in the ‘Pain’ condition.

		Total Control	Confidence in abilities	Interpersonal confidence	Total Confidence	VAS
CPS – Pain	Pearson’s *r*	.126	.109	.052	.036	-.090
	p (1-tailed)	.108	.143	.304	.361	.188
	95% CI Upper	26.796	19.176	8.766	17.991	.163
	95% CI Lower	-6.142	-5.724	-14.903	-12.523	-.427

Table 5 continued.

Zero-order Pearson's correlations between the mental toughness, pain intensity and composite performance scores in the 'Pain' condition.

		MT	Challenge	Commitment	Emotional Control	Life Control
VAS	Pearson's *r*	-.029	-.035	-.080	-.024	-.116
	p (1-tailed)	.388	.366	.216	.406	.127
	95% CI Upper	9.875	7.270	5.210	7.597	4.105
	95% CI Lower	-13.174	-10.302	-12.087	-9.662	-15.379

Table 5 continued.

Zero-order Pearson's correlations between the mental toughness, pain intensity and composite performance scores in the ‘Pain’ condition.

		Total Control	Confidence in Abilities	Interpersonal Confidence	Total Confidence
VAS	Pearson’s *r*	-.085	.090	.015	.064
	p (1-tailed)	.204	.190	.443	.264
	95% CI Upper	6.565	12.312	8.681	13.734
	95% CI Lower	-16.030	-4.740	-7.518	-7.094

Table 6: Results of Welch's *t*-test on order of test completion (study 2)

						95% Confidence Interval		
	Welch's t	*df*	*p*	Mean difference	*SE* difference	Lower	Upper	Cohen's d
CPS - Pain	.720	92.079	.473	4.314	5.993	-7.588	16.216	.145
CPS – No Pain	-.346	81.815	.730	-2.128	6.146	-14.355	10.100	-.069
CPS – Difference	1.506	94.921	.135	6.441	4.276	-2.048	14.932	.304

Study 2: Discussion

The purpose of this second study, like the first, was to investigate the variation in working memory between a no pain and an acutely painful task, after adapting the methodology from Study 1 to reduce the effects of confounding variables. The second area investigated was whether interactions between any of the individual components of the multi-dimensional mental toughness model (Clough, Earle & Sewell, 2002) and pain could explain variances in working memory performance. The hypotheses were:

H_1: There will be a performance deficit in 2-back performance in the ‘Pain’ condition compared with the ‘No Pain’ condition.

H_2: There will be a negative (r > ~-.10) correlation between pain intensity and performance on the 2-back task in the 'Pain’ condition.

H_3: Mental toughness, or one of its components, will moderate the relationship between pain intensity and composite performance score when in pain.

Despite changes in methodology, results for Study 2 failed to support hypotheses, as was the case in Study 1. However, the independent samples t-tests showed a small but non-significant order effect on performance of the 2-back task between conditions, suggesting the 2-back trial run did address the learning effects seen in Study 1. The homogeneity of the sample did improve standard deviations of responses compared with Study 1.

The MTQ48 was introduced as a more sensitive measure of mental toughness, compared with the MTI, allowing for the isolation of sub-components, however, even with these sub-components isolated, they did not significantly affect performance on the 2-back task. Despite the MTQ48 being considered a robust and more sensitive measure of mental toughness (Clough, Earle & Sewell, 2002; Perry, Clough, Crust, Earle, & Nicholls, 2013), there is scholarly debate regarding its suitability as a measure of mental toughness (see Gucciardi, Hanton & Mallett, 2012, Clough, Earle, Perry & Crust, 2012 and Gucciardi, Hanton & Mallett, 2013). Findings would suggest that there are issues with the conceptualisation that underpins the MTQ48 and the lack of independent scrutiny of the factor structure based on the fact that construct validation has only been performed with a small sample of athletes (Sheard, Golby & Van Wersch, 2009). Horsburg, Schermer, Veselka and Vernon (2009) went on to comment that there is a need for further psychometric testing of the MTQ48. This study did not set out to be a comparative investigation between measures of mental toughness, however if the study were to be replicated in the future, the methodology should follow that of Study 2 with the addition of the MTI alongside the MTQ48.

In conclusion, the introduction of a trial-run of the 2-back task did successfully address the learning effects seen in Study 1, however the results still failed to support the hypotheses. Using a more sensitive measure of mental toughness did not make a difference to the results however, the use of a homogeneous sample did improve the standard deviations of responses.

General Discussion

This study set out to examine the variation in working memory between a no pain and an acutely painful task and to consider whether mental toughness predicted the magnitude of change in working memory between the two conditions. The results from Study 1 were clouded by the influence of confounding variables (factors that have an effect on both the dependent and independent variables, creating a questionable association; Greenland, Robbins & Pearl, 1999), such as learning effects, which were then controlled for in Study 2. Despite this, the results did not meet the expectations of the hypotheses or align with findings from extant literature. This could be due to a number of reasons, all of which will be discussed in this section of the paper.

Pain Intensity

The issue regarding whether the cold pressor test produced sufficient pain was touched on in the discussion of the first study and introduction to Study 2. Although pain intensity pain intensity VAS scores from the first study showed that participants rated pain, on average, as ‘mild’ (VAS_{mean} = 38.146; Jensen, Chen & Brugger, 1986), it was decided to maintain the temperature at 12^{o}C ± 1^{o}C due to issues regarding lower temperatures in previous research (Verhoeven, Crombez, Eccleston, van Ryckeghem, Morley & van Damme, 2010; Williams & Thorn, 1986). Average pain intensity VAS scores increased slightly in Study 2 (VAS_{mean} = 41.469), however they were still ‘mild’ (Jensen, Chen & Brugger, 1986). These results would suggest that the pain manipulation did not produce a sufficient intensity of pain to effect attention on the 2-back task that could explain the lack of support for the hypotheses. Future studies could introduce pilot trials to assess the optimal water temperature for causing sufficient pain, whilst avoiding numbness or withdrawal. This may need to be tailored to each participant in order to ensure that each participant is tested under the same conditions.

Measurement of Mental Toughness

Measurement of mental toughness is notoriously tricky, with ongoing debate in the research community regarding its dimensionality and the psychometric properties of existing measures (Clough, Earle, Perry & Crust, 2012; Coulter, Mallett & Gucciardi, 2010; Crust, 2007; Golby & Sheard, 2004). The two measures used in this study were chosen based on the fact that they are not limited to sports communities and are relevant to the measurement of mental toughness in non-sports people (Clough, Earle & Sewell, 2002; Gucciardi, Hanton, Gordon, Mallett & Temby, 2015; Middleton, Marsh, Richards & Perry, 2004), unlike another validated measure, the Sports Mental Toughness Questionnaire (SMTQ; Sheard, Golby & van Wersch, 2009). Both measures used have had their validity and suitability for measuring mental toughness questioned (Golby, Sheard & van Wersch, 2009; Horsburg, Schermer, Veselka & Vernon, 2009), however, it would have been remiss of this study not to consider both sides of the debate, therefore both a unidimensional and multidimensional measure were used. It is important for these considerations to be made until a widely accepted decision has been made regarding the dimensionality of mental toughness. In future research, consideration could be made to include both measures of mental toughness in the study, allowing for a comparison between the two and giving researcher a start point to address some of the concerns raised here.

Mental Toughness and Pain Intensity vs. Pain Tolerance

Pain intensity is one’s perception of how much pain participants are experiencing, but pain tolerance is the maximum intensity of a pain-producing stimulus that an individual is willing to accept in a given situation (IASP, 2017). Pain tolerance is built up over time, through years of experience and exposure to painful situations and is susceptible to change depending on what is going on in your life at that point. In sport, certain pain is often a source of pride, symbolising that a struggle has been endured and that a significant effort has been made to achieve goals (e.g., delayed onset muscle soreness the day after an intense gym session (Tipirneni, 2018). This is an example of pain being reconceptualised into a positive outcome and is indicative of mental toughness.

There is suggestion, by some researchers, that mental toughness and pain intensity do not share a relationship, rather it is pain tolerance that is related to mental toughness (Jones, 2002). As mentioned in descriptions of mental toughness, it is the ability to persevere through adversity, that constitutes being mentally tough. When describing mental toughness in relation to pain it has been said that “it is a question of pushing yourself… it’s mind over matter, just trying to hold your technique and perform while under distress and go beyond your limits” (Jones, 2002, p212). Based on these definitions and conceptualisations of pain and mental toughness it would seem that mental toughness does not affect an individual’s ability to recognise the intensity of a pain stimulus, but it does provide them with the mental capabilities to overcome this pain and tolerate it for longer.

Given that this study measured pain intensity and not pain tolerance, it could explain why mental toughness had little effect on pain intensity VAS scores. In future, studies investigating the relationship between pain and mental toughness should consider measuring pain tolerance and therefore use a more suitable pain paradigm that requires individuals to rely on their pain tolerance levels.

The Nature of Pain Measured

Mental toughness is a construct that emerged in the context of sport (Jones, Hanton & Connaughton, 2002) and has recently been applied to non-sport situations (Clough & Strycharczyk. 2012; Miller, 2007; Marchant, Polman, Clough, Jackson, Levy & Nicholls, 2009). In relation to pain, mental toughness has primarily been implicated in sport-related pain and coping with physical endurance outcomes in athletes (Bell, Hardy & Beattie, 2013; Coulter, Mallett & Gucciardi, 2010; Crust & Clough, 2005; Gucciardi, Peeling, Ducker & Dawson, 2016; Jones, 2002; Levy, Polman, Clough, Marchant & Earle, 2006; Nicholls, Polman, Levy & Blackhouse, 2009; Thelwell, Weston & Greenlees, 2005). The pain experienced in this study is not sport-related and may therefore not elicit the need for mental toughness in order to endure it.

Extant literature would suggest that when mental toughness is required or utilised during performance, there is a positive outcome to be gained, for example, pushing through ‘the wall’ to finish a marathon. Perhaps it is this additional variable that facilitates mental toughness and unless there is something to be gained from overcoming the pain, mental toughness will not be used. Furthermore, the pain paradigm used in this study is ‘safe’ and participants know that it is temporary and can be stopped at any time. This, combined with the lack of potential positive outcome, could have inhibited participants from fully utilising their mental toughness and may explain why mental toughness did not predict variances in 2-back performance between conditions. Moreover, the type of pain experienced, caused by the cold pressor test, was acute, controlled and temporary, unlike that experienced in real life, which would be unpredictable and varying. Individuals would likely face these different types of pain with different mindsets regarding overcoming the pain, possibly not even trying to overcome the pain from the cold pressor, instead just trying to endure it for the 2 minutes.

Future research investigating how mental toughness affects the relationship between pain and attention may benefit from a more suitable pain paradigm that is more realistic to everyday life. For example, the 2-back task could be completed in a ‘no pain’ condition with an extended arm hold, however a second 2-back task could be completed during a weighted extended arm hold (see Crust & Clough 2005), a more realistic form of pain. This would also improve the ecological validity (the extent to which the measures, materials and settings approximate to the real world; Mitchell & Jolley, 2001) and generalisability of the results (extent to which research findings can be applied to settings outside of the experimental condition; Mitchell & Jolley, 2001).

Confounding Variables

The main confounding variable from Study 1 (learning effects) has already been discussed and was successfully addressed in Study 2 with the introduction of a trial run of the 2-back task prior to completing the experimental conditions. However, there is a strong possibility that the results were affected by other confounding variables that were not controlled but should have been.

One such variable is somatic anxiety, a heightened awareness of physical symptoms associated with anxiety (Gelenberg, 2000), which can cause an individual’s attention to focus on the pain. Studies on the effects of induced anxiety on responses to acute laboratory pain stimuli have shown that anxiety related to pain increases ratings of perceived pain intensity (Al Absi & Rokke, 1991; Cornwall & Donderi, 1988; Weisenberg, Aviram, Wolf & Raphaeli, 1984). Furthermore, pain-related anxiety may influence the emotional response to pain (Cornwall & Donderi, 1988) and therefore may increase the suffering component of the pain experience (Fordyce, 1976). The effects of somatic anxiety could result in some people finding the water more or less painful than it actually is depending on the degree to which they experience somatic anxiety. In the future a questionnaire, such as the Pain Anxiety Symptoms Scale (McCracken, Zayfert & Gross, 1992), could be used to assess participant’s anxiety levels towards pain prior to completing the task, providing more context for the results they produce.

Another interesting variable that could have been measured is pain catastrophising, which is the tendency to exaggerate pain experience (Sullivan, Thorn, Haythornthwaite, Keefe, Martin, Bradley & Lefebvre, 2001) or worry and fear associated with pain, combined with an inability to divert attention away from these thoughts (Spanos, Radtke-Bodorik, Ferguson & Jones, 1979). It may be that in individuals who are somatically focused (an individual's awareness of physical symptoms experienced); it is the degree of catastrophising that governs emotional and physiological arousal which in turn alters pain sensitivity (Main & Watson, 1999). This study would have benefited from a measure of pain catastrophising, such as the Pain Catastrophising Scale (PCS; Sullivan, Bishop & Pivik, 1995), which would highlight the degree to which participants are worrying about the pain as this may indicate the extent to which they are able to focus on the 2-back task.

Another potential confounding variable is acclimation to cold water, which occurs when an individual is over-exposed to cold water or cold temperatures and develops a tolerance towards these conditions and they no longer elicit the same negative effects (Bouton, 2007). Certain individuals may be acclimated more than others depending on factors such as; growing up in a cold country (Mäkinen, 2007; Scholander, Hammel, Hart, LeMessurier & Steen, 1958; Steegmann Jr, 2007), winter sport participation or training and playing in these conditions (e.g., surfers and skiers; Jones, Bailey, Roelands, Buono & Meeusen, 2017; Keatinge & Evans, 1961; Young, 1996). This may result in an untrue average pain rating due to acclimated participants perceiving the water as less cold, and therefore less painful, than it actually was.

In summary, the study lacks internal control and the effect of variables, other than the independent variables (mental toughness and pain), on the dependent variable (2-back performance) has not been minimised (Mitchell & Jolley, 2001).

Methodological Issues

Some methodological issues have already been discussed, such as the learning effects in Study 1, the efficacy of the pain paradigm used throughout, issues with internal control and ecological validity, however, as with many lab-based experiments, others were present. The VAS is an accurate and reliable measure of pain (Ohnhaus & Adler, 1975); however, the timing of its administration is critical and should be done during the pain experience to ensure a true rating of pain intensity (Williams & Thorn, 1986).

The participants in this study completed the pain intensity VAS after completing the 2-back task and were recalling the pain intensity experienced which could have resulted in inaccurate ratings. Furthermore, the pain intensity VAS responses could have been subject to social desirability bias, where participants provide responses that they believe may be viewed favourably by others (Edwards, 1958). Participants may have provided lower pain ratings to appear braver, this could also have affected MTI and MTQ48 responses. Furthermore, there is some suggestion in extant literature that participants struggle to conceive the unit of the line as an accurate representation of their pain (Wewers & Lowe, 1990). This is due to the lack of experiential grounding for the maximal label: “worst pain ever experienced” has no absolute value, compared with “no pain at all”, which could mean it is unmeasurable and any mark placed along the line is dependent upon the experiences of the individual and their unique interpretation of the label. Based on this reasoning it can be argued that the VAS is ipsative (Baron, 1996), meaning it does not allow for between-subject comparison due to the measurement relating to individual experiences and not a commonly shared one (Wewers & Lowe, 1990). Wewers and Lowe (1990) made a recommendation that the VAS should be used in conjunction with other scales when measuring something multidimensional, such as pain intensity, as the unidimensional nature of the VAS causes difficulties in distinguishing what is actually being measured.

Implications

There are many aspects of the present study that can inform future practice and help give a better understanding of the particular areas of focus. For example, researchers undertaking similar studies in future should consider the type of pain being measured. Measuring pain tolerance, as opposed to pain intensity in relation to mental toughness is more appropriate as this falls more in-line with definitions of mental toughness, however if pain intensity is measured, ensuring that sufficient pain is produced is crucial.

When using a cold pressor machine to create pain, there may be specific issues with regards to the temperature chosen. It could be argued that a cold pressor machine set at a low enough temperature would induce sufficient pain, however there are no universal guidelines for what this temperature should be, mainly due to the fact that pain is a subjective experience and effects people in different ways (i.e. someone that is used to living in a cold climate may need a lower temperature than someone who is used to living in a warmer climate in order to induce pain). Furthermore, the pain induced by the cold pressor machine is not something many people have experienced before, therefore it may be an unrealistic stimulus that does not elicit the same response that other sources of ‘known’ pain may do. In order to be less reductionist, and better understand how mental toughness may help athletes deal with difficulties in sport, future research should adopt more ecologically valid manipulations to explore how an individual usually copes with pain. It is therefore necessary to try and match the pain stimulus more carefully to the individual athletic requirements so that the pain is relevant to their past experiences and forces them to utilise their standard coping mechanisms. Alternatives to cold-pressor pain include ischemic pain (blood flow is interrupted with a tourniquet in conjunction with isometric exercises; Sternbach, 1983) and mechanical pressure (either with a dull-edged weight placed on the phalanx, Forigone & Barber, 1971, or with a pressure algometer placed on bony portions of the body, Keele, 1954), both of which have been shown to produce reliable and valid results and are easily applicable (Göbel & Westphal, 1989).

In terms of n-back tasks, the present study has demonstrated the benefits of introducing a trial run prior to completion of experimental conditions as this ensures that results are not subject to learning effects. A consequence of these effects could be results which are not a true reflection of participant performance. In future, research utilising an n-back test should, as standard practice, include a trial-run prior to completion of an experimental condition.

Finally, all research in the area of mental toughness would benefit from the development of a fully validated measure, which is applicable to all population groups. Further research is needed into mental toughness and its measurement in order to better establish what underpins this trait/state. An attempt is a needed to synthesise existing research on the subject and come to a widely accepted conclusion regarding a definition for mental toughness, its dimensionality and also a single measurement tool that can be applied universally. This could be done with meta-analyses of existing research involving definition development and the measurement of mental toughness and the introduction of new research, focusing on comparisons between existing definitions and measures. Once all of this information is brought together and analysed, it may be possible to draw conclusions regarding its definition, dimensionality and measurement that can be applied to a universal population.

Conclusion

In conclusion, this study did not meet the expectations of the hypotheses it set out to test; pain did not affect attention and mental toughness did not predict variances in the relationship between pain and attention, mainly because there was no relationship present. Other reasons for lack of significant findings included methodological issues, such as confounding variables, and design issues, such as measuring pain intensity instead of pain tolerance and the possibility that mental toughness is not present unless there is something to be gained from overcoming adversity. If these relationships were to be investigated in the future, researchers would benefit from measuring pain tolerance, introducing a pain paradigm that is more realistic to everyday pain and reducing the effects of confounding variables.

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Appendices

Appendix 1: Participant information letter (Study 1) 78
Appendix 2: Informed consent form (Study 1) 80
Appendix 3: MTI 81
Appendix 4: Descriptive statistics for mean reaction times and percentages of correct scores used for calculation of composite performance scores (Study 1). 82
Appendix 5: Correlation graphs (Study 1). Relationships between mental toughness, pain and composite performance scores in the 'Pain' condition 83
Appendix 6: Moderated regression analysis (Study 1) 85
Appendix 7: Simple slopes plot (study) 1 86
Appendix 8: Participant information letter (Study 2) 87
Appendix 9: Informed consent form (Study 2) 89
Appendix 10: MTQ48 90
Appendix 11: Descriptive statistics for mean reaction times and percentages of correct scores used for calculation of composite performance scores (Study 2). 93
Appendix 12: Correlation graphs for the relationships between mental toughness components, pain intensity and composite performance scores in the 'Pain' condition 94
Appendix 13: Moderated regression analysis (Study 2). 104
Appendix 14: Simple slopes plots (study 2) 106

Appendix 1: Participant information letter (Study 1)

Participant Information Letter

An investigation into the size of the relationship between mental toughness and attentional interference when in pain.

Thank you for showing an interest in the project. Please read this information sheet carefully before deciding whether to participate. You are free to choose not to participate. If you do wish to take part, you are free to withdraw at any time, and you can request to have your data destroyed by contacting a member of the research team via email.

We are researchers at the University of Exeter. We would like to invite you to take part in a research study. We will only include your data if you give us your permission. **The purpose of this study is to explore the relationship between attention and pain and investigate whether mental toughness can predict variances in this relationship.**

We would like to invite you to a laboratory in the Richards Building on St Luke's Campus to complete two surveys that explore your previous pain experiences and personality. There are no right or wrong answers. Please answer each question honestly. We will then show you the study procedures and ask you to immerse your nondominant hand in cold water for a fixed time. You are free to remove your hand from the water whenever you wish. During submersion you will complete a computer-based task. Following withdrawal of your hand from the cold pressor machine we will ask you to identify how painful the situation was using a visual analogue scale. We estimate that each visit will last approximately 30 minutes.

By participating in this study, you will be providing information that may help us understand how pain effects concentration. The main benefits of the proposed research are educational, and any benefit to you or science will be limited. It is likely that you will experience pain during your cold-water immersion; however, this discomfort usually dissipates within two minutes after you withdraw your hand. There are no further risks associated with this research

We will keep all data private and secret. We will keep data in a locked office and only the research team will have access to your data. We will keep data for five years after the study has finished. After five years, we will destroy the data. Once we have completed the study, we will present the results at conferences and publish in an academic journal. If you would like to receive a copy of the findings, please forward your email address to the research team.

If you would like to participate in this study, please read and sign the informed consent form and complete the attached questionnaires. If you would like to know about the study, or wish to ask questions, please contact me via email (m.i.jones@exeter.ac.uk). You may contact me at any time via email throughout the study if you want to ask questions or withdraw your data.

Many thanks

Martin I. Jones, PhD

Appendix 2: Informed consent form (Study 1)

Informed Consent Form for Participants

		Please initial box
1	I confirm that I have read and understand the information sheet for this study.	
2	I have had the opportunity to consider the information, ask questions and have had these answered satisfactorily.	
3	I understand that my participation is voluntary and that I am free to withdraw at any time, without giving any reason.	
4	I understand that the researcher team can use any information given by me in future reports, articles or presentations.	
5	I understand that my name will not appear in any reports, articles, or presentations.	
6	I will be asked to provide answers to questionnaires and participate in a cold-water immersion task during the course of the study.	
7	I understand and consent to the procedures involved during the cold-water immersion task.	
8	I give consent for the research team to keep my data for future studies.	
9	I agree to take part in the above study.	

Name of participant		Date		Signature	
Name of Researcher	Martin I. Jones	Date		Signature	

Appendix 3: MTI

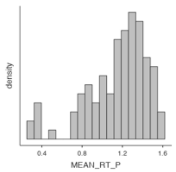
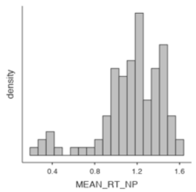
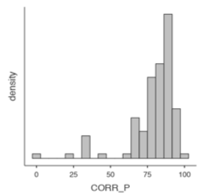
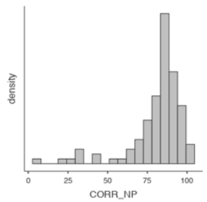
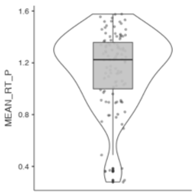
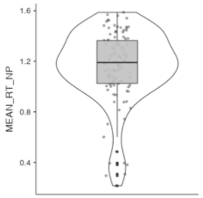
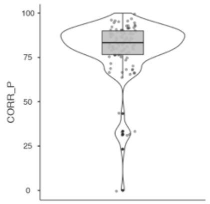
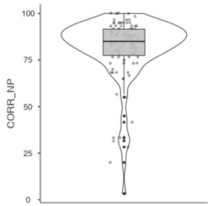
MTI

Using the scale below, please indicate how true each of the following statements is an indication of how you typically think, feel, and behave. *Remember there are no right or wrong answers so be as honest as possible*.

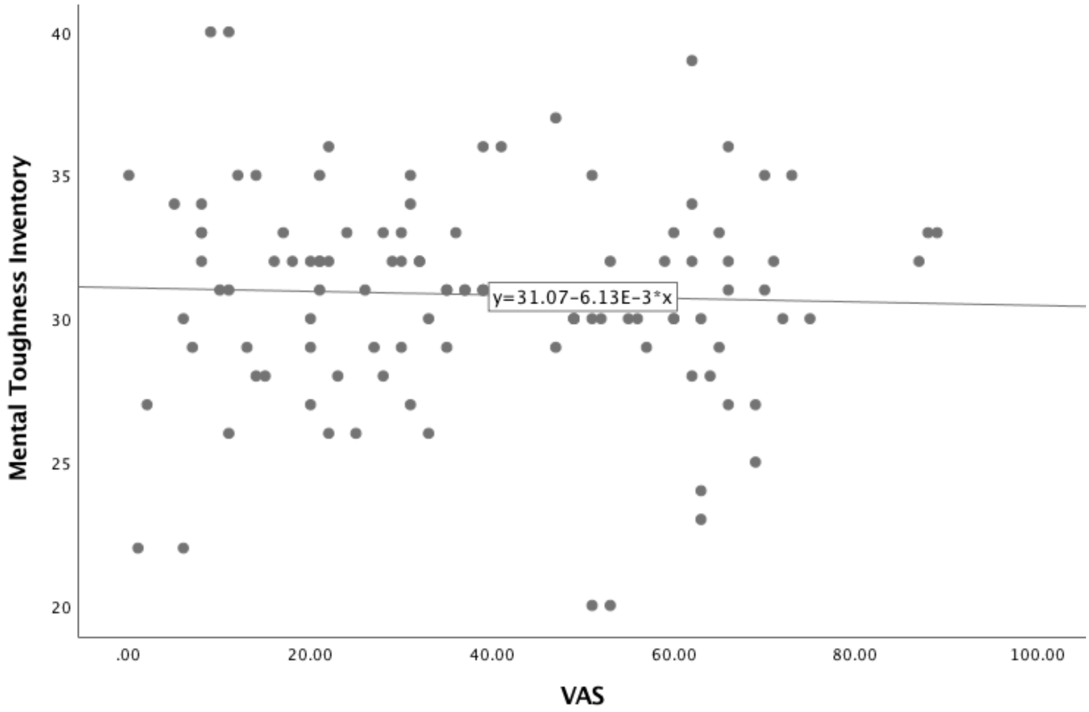
1	2	3	4	5	6	7
False, 100% of the time						True, 100% of the time

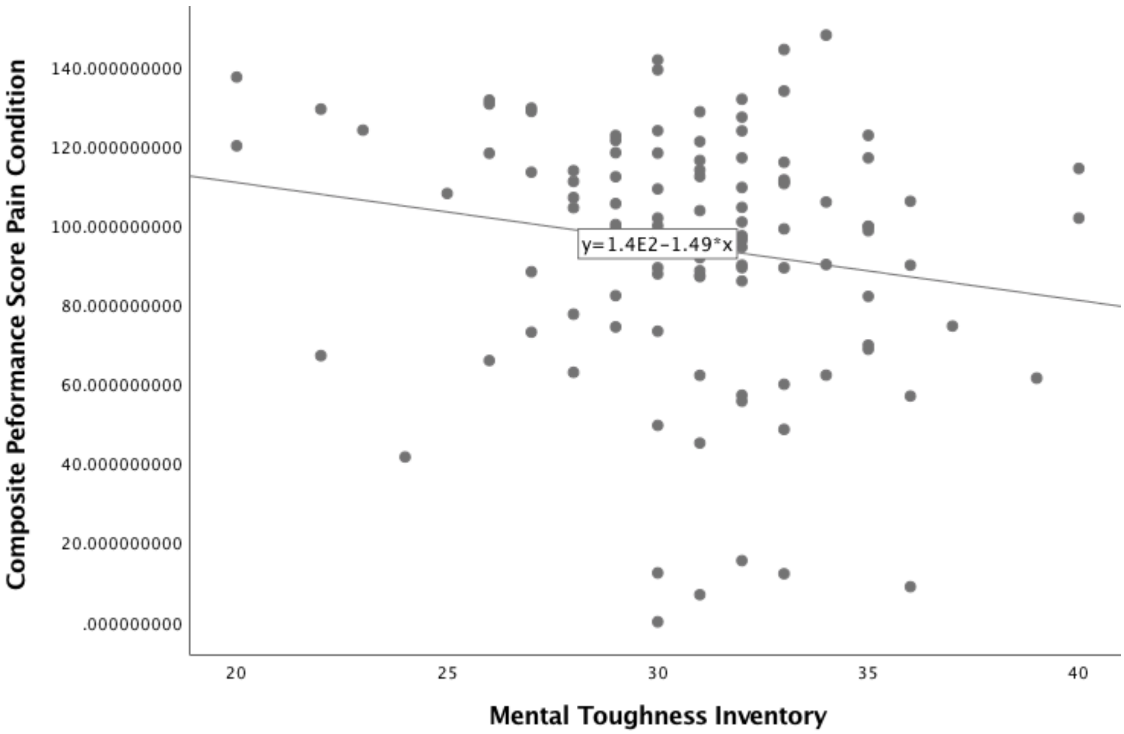
		False, 100% of the time						True, 100% of the time
1	I believe in my ability to achieve my goals	1	2	3	4	5	6	7
2	I can regulate my focus when performing tasks	1	2	3	4	5	6	7
3	I bounce back from adversity	1	2	3	4	5	6	7
4	I strive for continued success	1	2	3	4	5	6	7
5	I can find a positive side in most situations	1	2	3	4	5	6	7
6	I can use my emotions to perform the way I want to	1	2	3	4	5	6	7
7	I maintain high levels of performance when challenged	1	2	3	4	5	6	7
8	I effectively execute my knowledge of what is required to achieve my goals	1	2	3	4	5	6	7

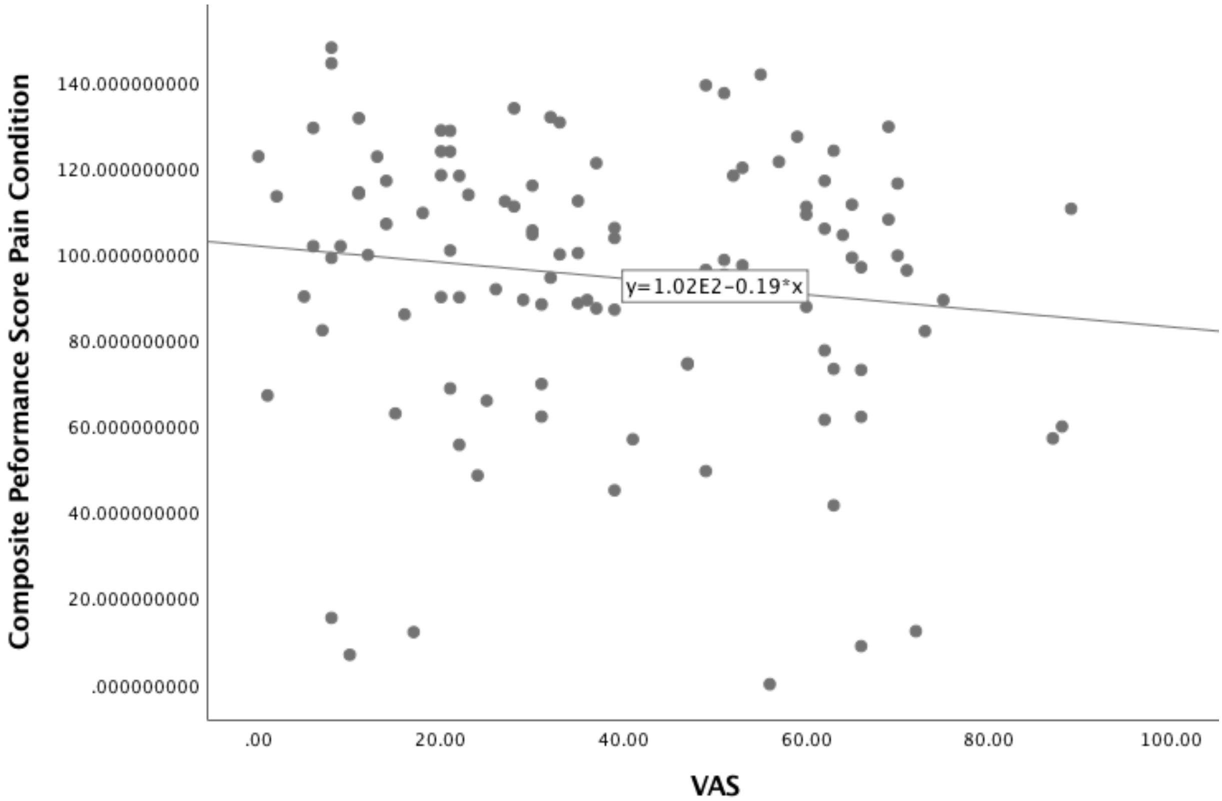
Appendix 4: Descriptive statistics for mean reaction times and percentages of correct scores used for calculation of composite performance scores (Study 1).

	Mean RT 'Pain'	Mean RT 'No Pain'	% correct scores 'Pain'	% correct scores 'No Pain'
Mean	1.150	1.152	79.250	80.673
SD	.300	.295	16.867	17.546
Min	.280	.216	0	3.3
Max	1.576	1.587	100	96.7
z_{skew}	-4.692	-5.184	-10.068	-9.248
z_{kurt}	2.160	3.521	13.778	11.378
Distribution				
Box Plots				

Appendix 5: Correlation graphs (Study 1). Relationships between mental toughness, pain and composite performance scores in the 'Pain' condition



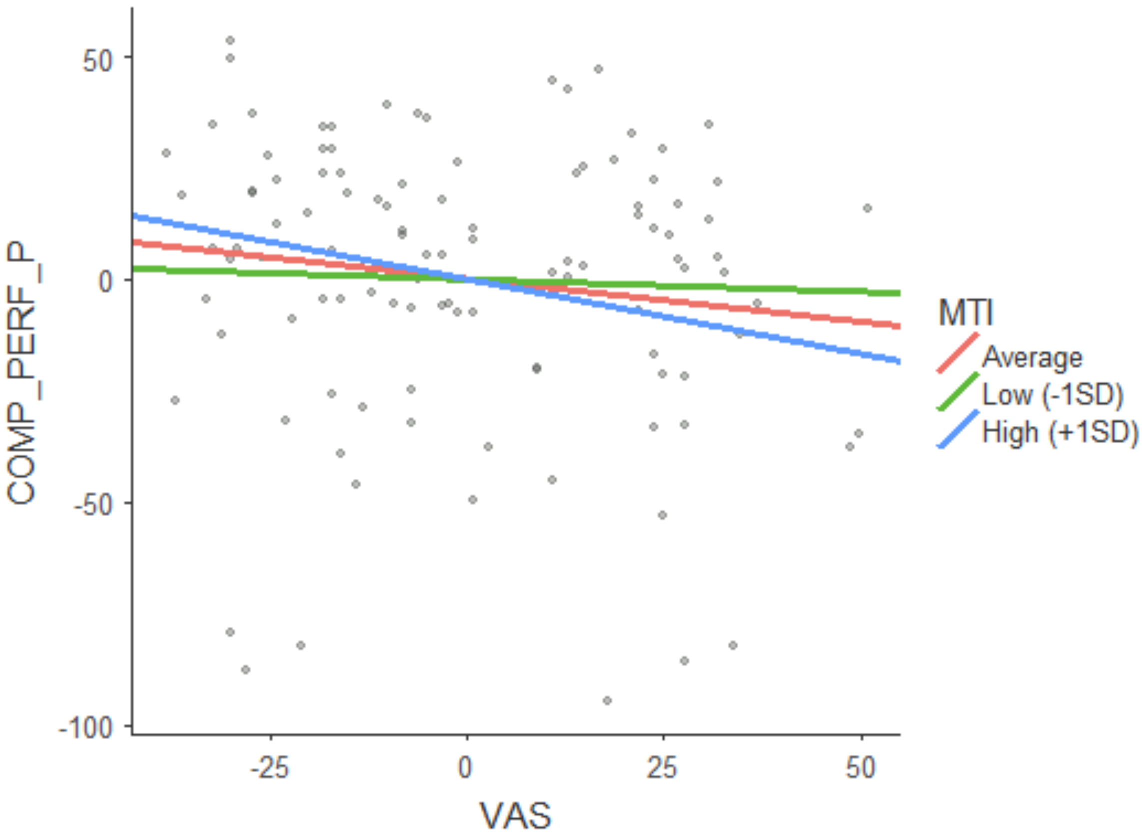



Composite Peformance Score Pain Condition
140.000000000
120.000000000
100.000000000
80.000000000
60.000000000
40.000000000
20.000000000
.000000000
y=1.02E2-0.19*x
.00
20.00
40.00
60.00
80.00
100.00
VAS

Appendix 6: Moderated regression analysis (Study 1)

			95% Confidence Intervals			
	R^2	SE	Lower	Upper	Z	P
VAS	-.093	.130	-.448	.062	-1.48	.139
MTI	-1.621	.809	.809	-.035	-2.00	.045
VAS*MTI	-.038	.034	.034	.028	-1.13	.260

Appendix 7: Simple slopes plot (study) 1



Appendix 8: Participant information letter (Study 2)

Thank you for showing an interest in the project. Please read this information sheet carefully before deciding whether to participate. You are free to choose not to participate. If you do wish to take part, you are free to withdraw at any time, and you can request to have your data destroyed by contacting a member of the research team via email.

We are researchers at the University of Exeter. We would like to invite you to take part in a research study. We will only include your data if you give us your permission. The purpose of this study is to explore the relationship between attention and pain and investigate whether aspects of your personality can predict variances in this relationship.

We would like to invite you for a single 40-minute visit to a laboratory in the Richards Building on St Luke's Campus to complete two surveys that explore your previous pain experiences and personality. There are no right or wrong answers. Please answer each question honestly. We will then show you the study procedures and allow you to have three test runs of a computerised test of working memory. We will then ask you to immerse your nondominant hand in cold water for a fixed time. You are free to remove your hand from the water whenever you wish. During submersion, you will complete the same computer-based task that you experienced previously. Following the withdrawal of your hand from the cold water we will ask you to identify how painful the situation was using a visual analogue scale. We will then ask you to lift a small weight and to hold it for as long as you can.

By participating in this study, you will be providing information that may help us understand how pain influences concentration. The main benefits of the proposed research are educational, and any benefit to you or science will be limited. It is likely that you will experience pain during your cold-water immersion; however, this discomfort usually dissipates within two minutes after you withdraw your hand. There are no further risks associated with this research

We will keep all data private and secret. We will keep data in a locked office, and only the research team will have access to your data. We will keep data for five years after the study has finished. After five years, we will destroy the data. Once we have completed the study, we will present the results at conferences and publish in an academic journal. If you would like to receive a copy of the findings, please forward your email address to the research team.

If you would like to participate in this study, please read and sign the informed consent form and complete the attached questionnaires. If you would like to know about the study or wish to ask questions, please contact me via email (m.i.jones@exeter.ac.uk). You may contact me at any time via email throughout the study if you want to ask questions or withdraw your data. Alternatively, please contact Alex Saunders (aes230@exeter.ac.uk) who will be conducting the research.

Many thanks

Martin I. Jones, PhD

Appendix 9: Informed consent form (Study 2)

Informed Consent Form for Participants

		Please initial box
1	I confirm that I have read and understand the information sheet for this study.	
2	I have had the opportunity to consider the information, ask questions and have had these answered satisfactorily.	
3	I understand that my participation is voluntary and that I am free to withdraw at any time, without giving any reason.	
4	I understand that the researcher team can use any information given by me in future reports, articles or presentations.	
5	I understand that my name will not appear in any reports, articles, or presentations.	
6	I will be asked to provide answers to questionnaires and participate in a cold-water immersion task during the course of the study.	
7	I understand and consent to the procedures involved during the cold-water immersion task.	
8	I give consent for the research team to keep my data for future studies.	
9	I agree to take part in the above study.	

Name of participant		Date		Signature	
Name of Researcher	Martin I. Jones	Date		Signature	

Appendix 10: MTQ48

Please indicate your response to the following items by circling one of the numbers, which have the following meaning;

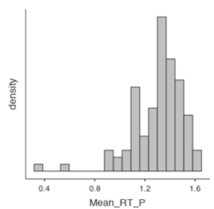
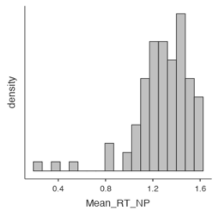
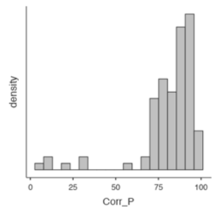
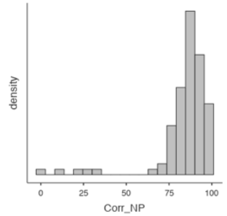
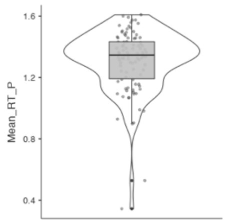
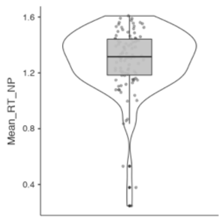
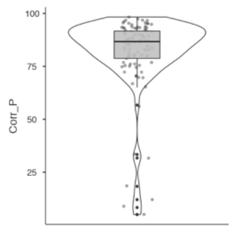
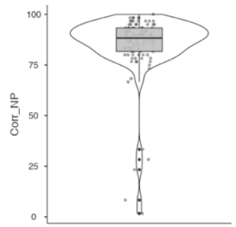
1	2	3	4	5
strongly disagree	disagree	neither agree nor disagree	agree	strongly agree

		strongly disagree				strongly agree
1	I usually find something to motivate me	1	2	3	4	5
2	I generally feel in control	1	2	3	4	5
3	I generally feel that I am a worthwhile person	1	2	3	4	5
4	Challenges usually bring out the best in me	1	2	3	4	5
5	When working with other people I am usually quite influential	1	2	3	4	5
6	Unexpected changes to my schedule generally throw me	1	2	3	4	5
7	I don’t usually give up under pressure	1	2	3	4	5
8	I am generally confident in my own abilities	1	2	3	4	5
9	I usually find myself just going through the motions	1	2	3	4	5
10	At times I expect things to go wrong	1	2	3	4	5
11	I just don’t know where to begin” is a feeling I usually have when presented with several things to do at once	1	2	3	4	5
12	I generally feel that I am in control of what happens in my life	1	2	3	4	5
13	However bad things are, I usually feel they will work out positively in the end	1	2	3	4	5
14	I often wish my life was more predictable	1	2	3	4	5
15	Whenever I try to plan something, unforeseen factors usually seem to wreck it	1	2	3	4	5
16	I generally look on the bright side of life	1	2	3	4	5
17	I usually speak my mind when I have something to say	1	2	3	4	5
18	At times I feel completely useless	1	2	3	4	5
19	I can generally be relied upon to complete the tasks I am given	1	2	3	4	5

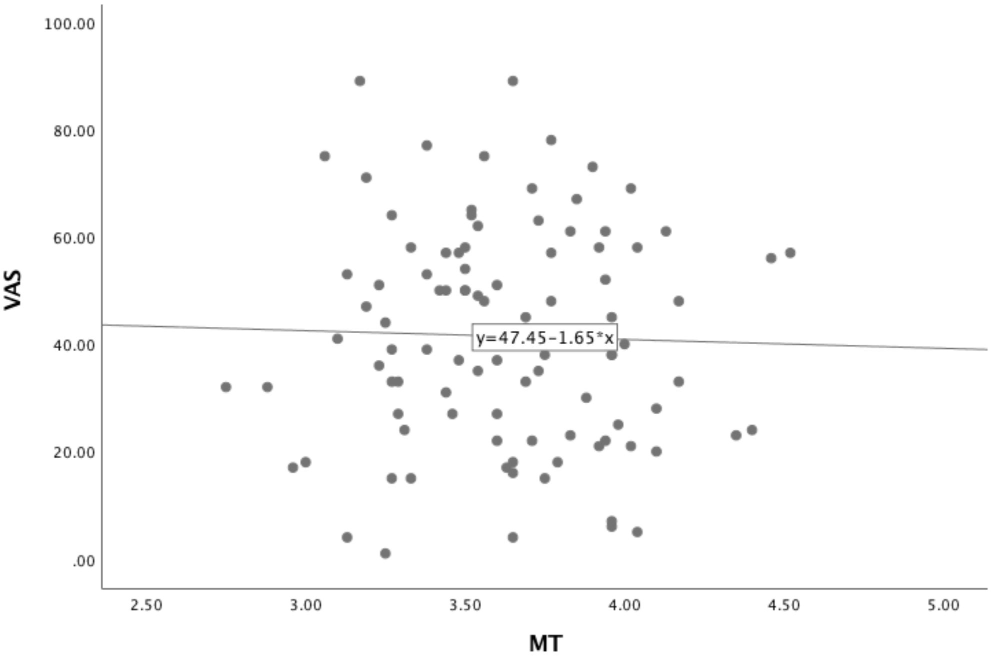
20	I usually take charge of a situation when I feel it is appropriate	1	2	3	4	5
21	I generally find it hard to relax	1	2	3	4	5
22	I am easily distracted from tasks that I am involved with	1	2	3	4	5
23	I generally cope well with any problems that occur	1	2	3	4	5
24	I do not usually criticise myself even when things go wrong	1	2	3	4	5
25	I generally try to give 100%	1	2	3	4	5
26	When I am upset or annoyed I usually let others know	1	2	3	4	5
27	I tend to worry about things well before they actually happen	1	2	3	4	5
28	I often feel intimidated in social gatherings	1	2	3	4	5
29	When faced with difficulties I usually give up	1	2	3	4	5
30	I am generally able to react quickly when something unexpected happens	1	2	3	4	5
31	Even when under considerable pressure I usually remain calm	1	2	3	4	5
32	If something can go wrong, it usually will	1	2	3	4	5
33	Things just usually happen to me	1	2	3	4	5
34	I generally hide my emotion from others	1	2	3	4	5
35	I usually find it difficult to make a mental effort when I am tired	1	2	3	4	5
36	When I make mistakes I usually let it worry me for days after	1	2	3	4	5
37	When I am feeling tired I find it difficult to get going	1	2	3	4	5
38	I am comfortable telling people what to do	1	2	3	4	5
39	I can normally sustain high levels of mental effort for long periods	1	2	3	4	5
40	I usually look forward to changes in my routine	1	2	3	4	5
41	I feel that what I do tends to make no difference	1	2	3	4	5
42	I usually find it hard to summon enthusiasm for the tasks I have to do	1	2	3	4	5
43	If I feel somebody is wrong, I am not afraid to argue with them	1	2	3	4	5
44	I usually enjoy a challenge	1	2	3	4	5
45	I can usually control my nervousness	1	2	3	4	5

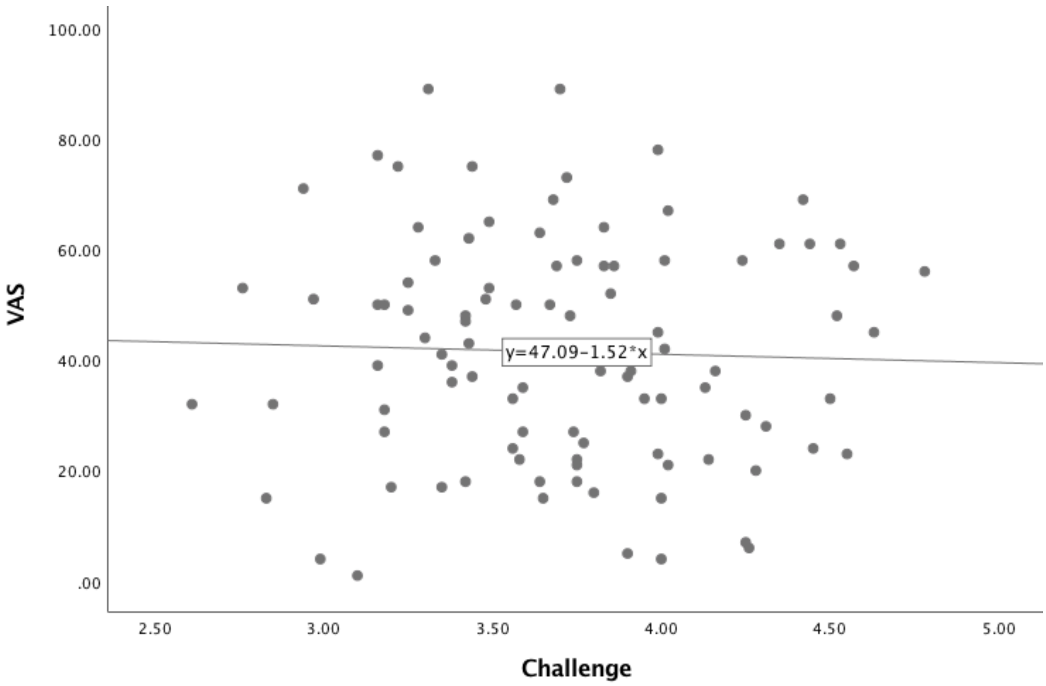
46	In discussions, I tend to back-down even when I feel strongly about something	1	2	3	4	5
47	When I face setbacks I am often unable to persist with my goal	1	2	3	4	5
48	I can usually adapt myself to challenges that come my way	1	2	3	4	5

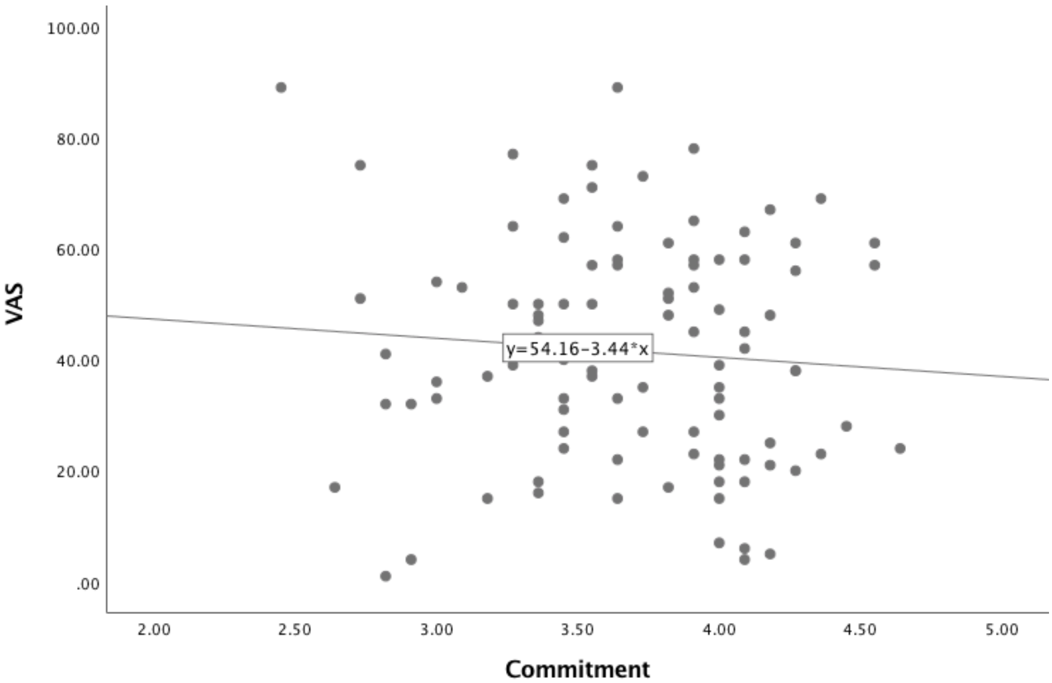
Appendix 11: Descriptive statistics for mean reaction times and percentages of correct scores used for calculation of composite performance scores (Study 2).

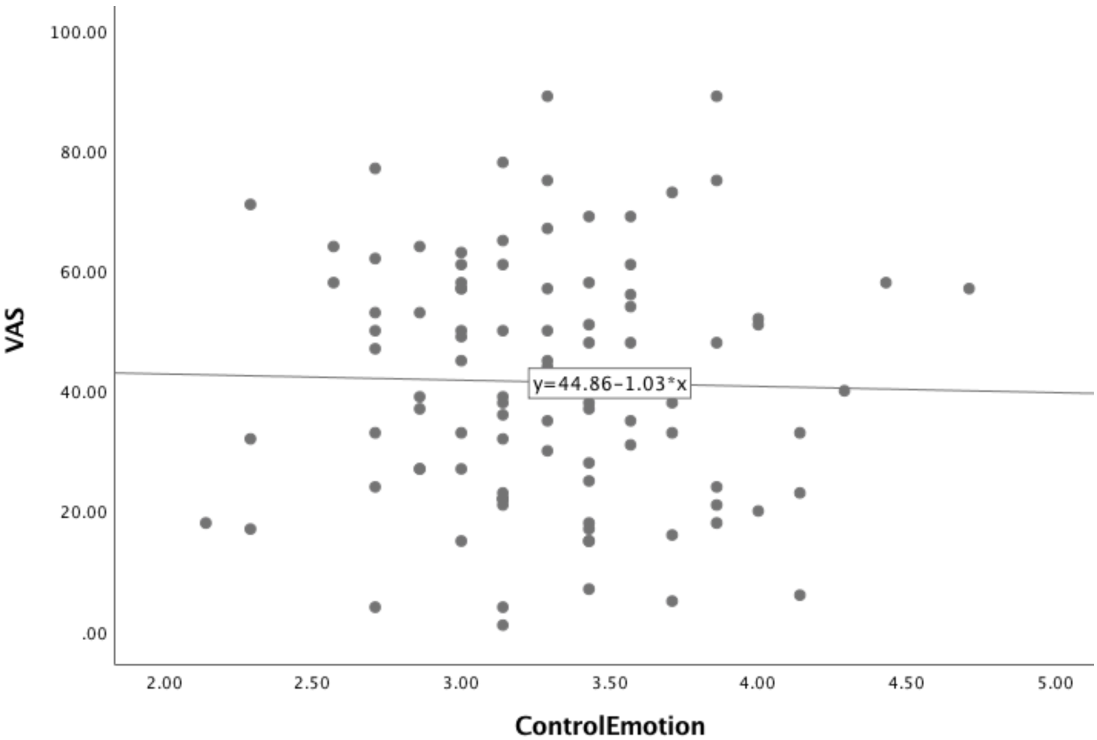
	Mean RT ‘Pain’	Mean RT ‘No Pain’	% correct score ‘Pain’	% correct scores ‘No Pain’
Mean	1.306	1.286	81.280	84.352
SD	.207	.237	18.431	16.988
Min.	.345	.247	5.0	1.7
Max.	1.609	1.609	98.3	100.0
z_{skew}	-7.057	-7.471	-11.045	-13.254
z_{kurt}	10.834	10.965	16.002	28.983
Distribution				
Boxplots				

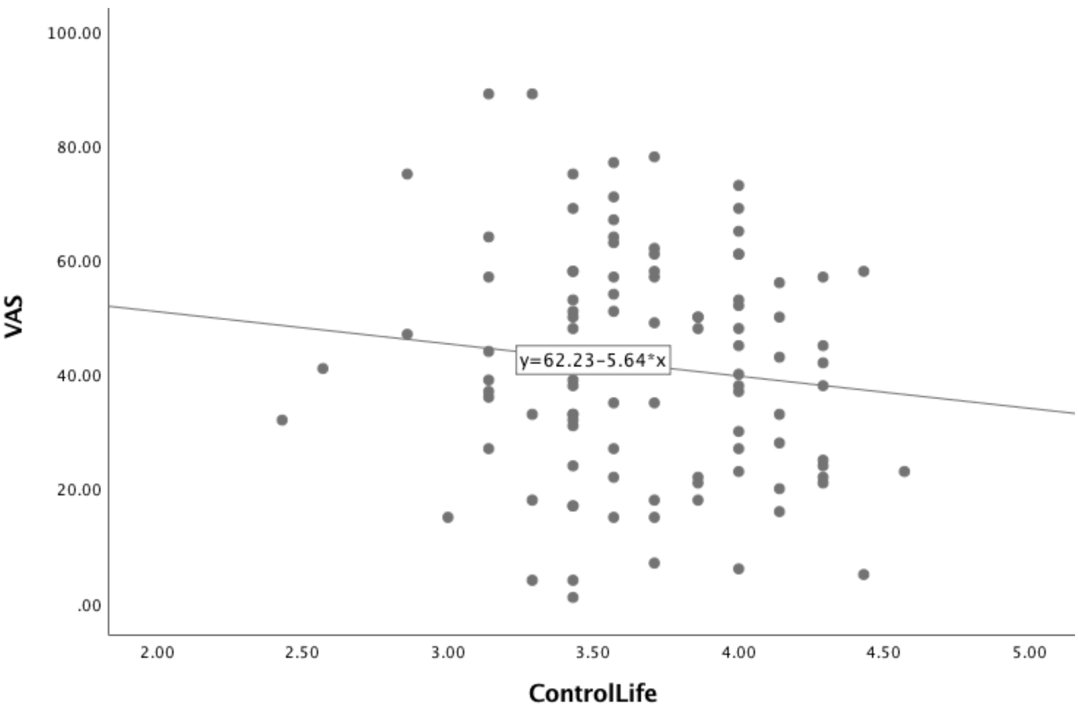
Appendix 12: Correlation graphs for the relationships between mental toughness components, pain intensity and composite performance scores in the 'Pain' condition






VAS
Commitment
y=54.16-3.44*x
100.00
80.00
60.00
40.00
20.00
.00
2.00
2.50
3.00
3.50
4.00
4.50
5.00


VAS
ControlEmotion
y=44.86-1.03*x
100.00
80.00
60.00
40.00
20.00
.00
2.00
2.50
3.00
3.50
4.00
4.50
5.00


100.00
80.00
60.00
40.00
20.00
.00
VAS
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2.00
2.50
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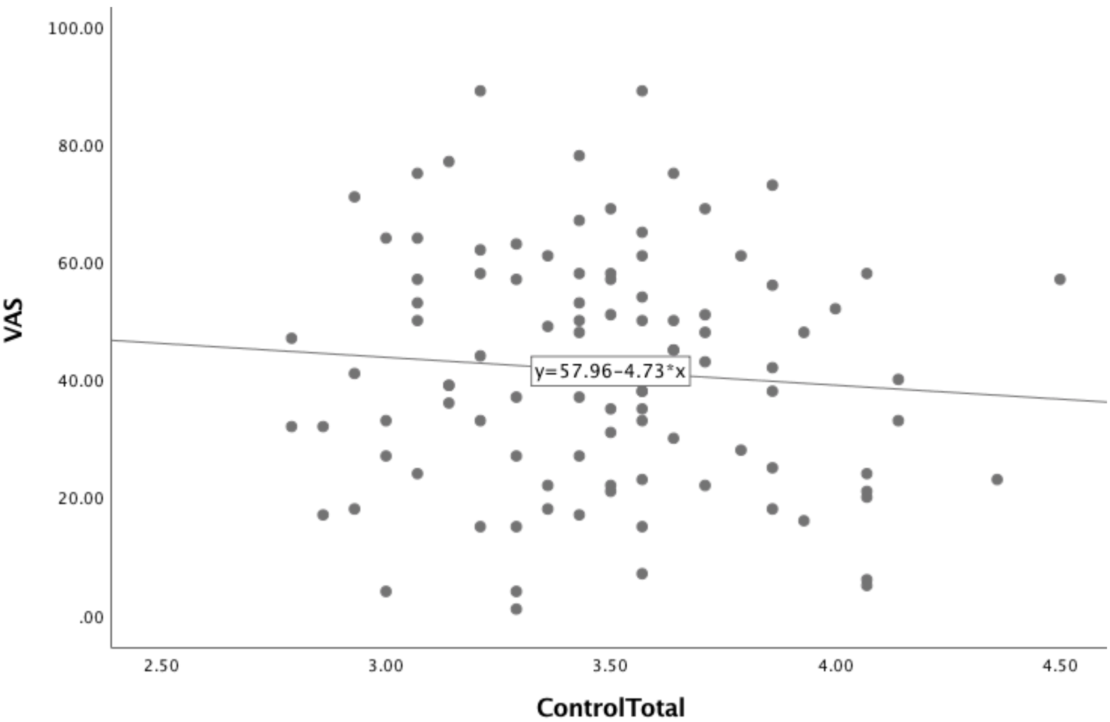
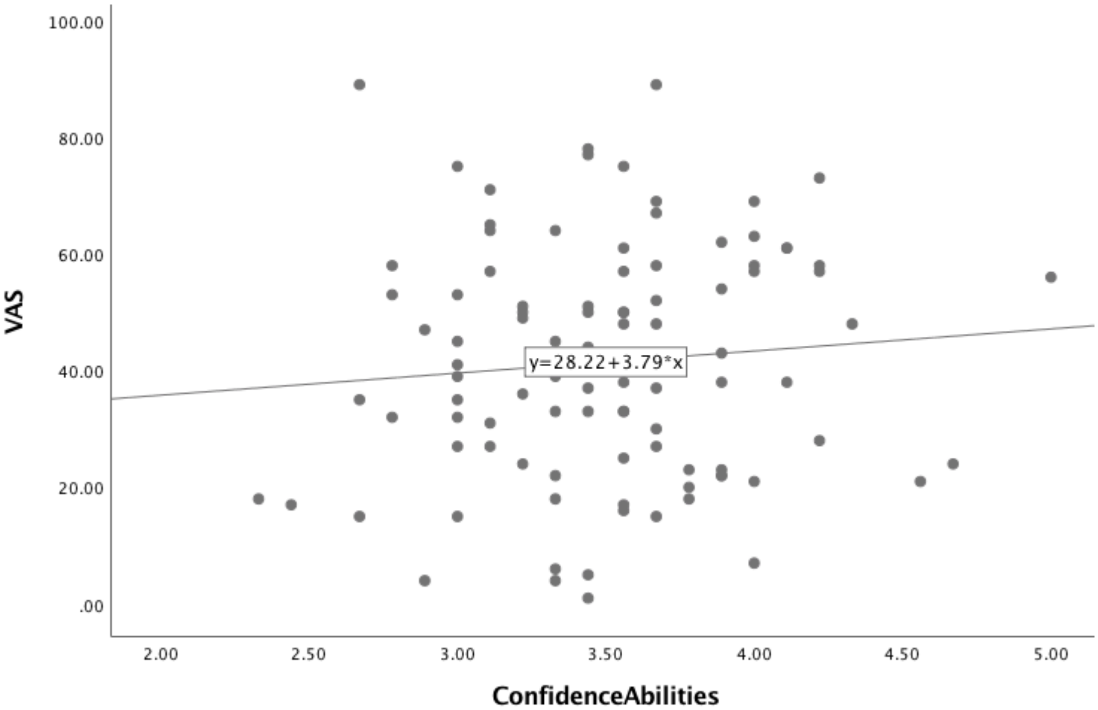
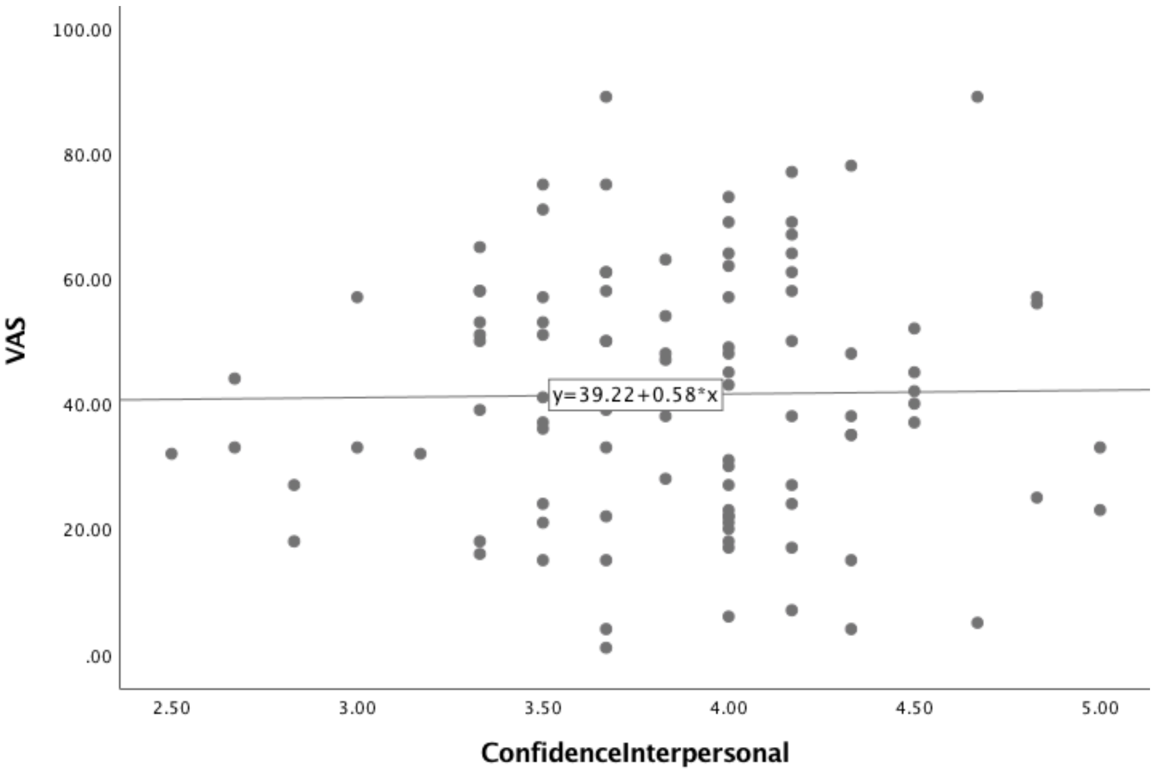
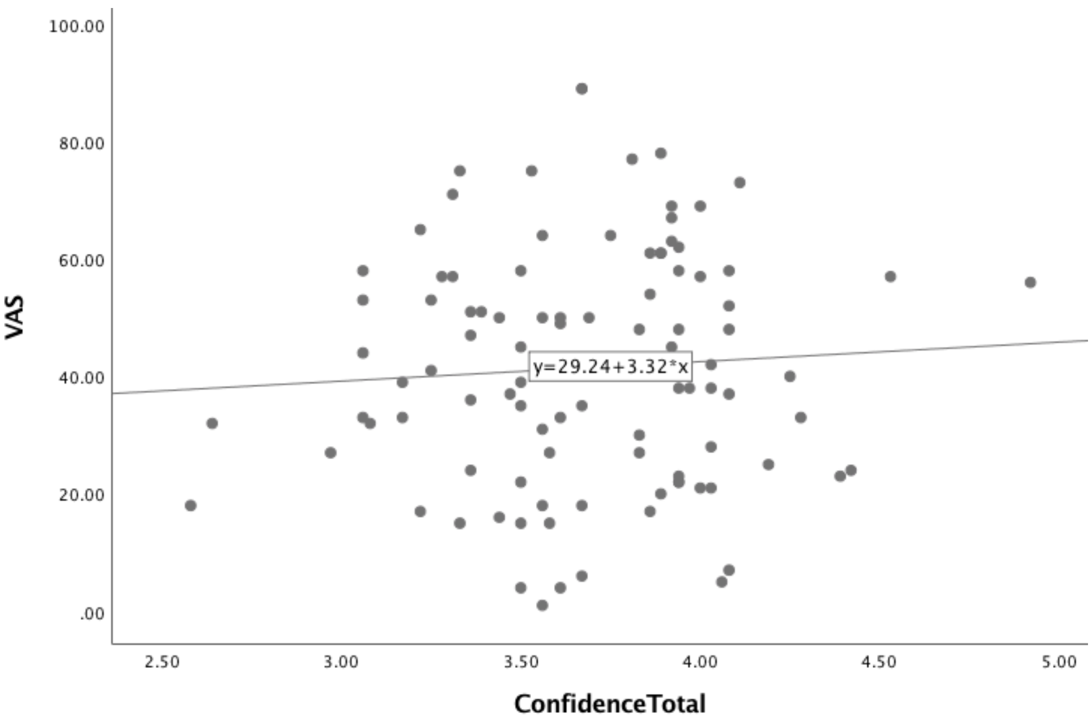
3.50
4.00
4.50
5.00
ControlLife


100.00
80.00
60.00
40.00
20.00
.00
VAS
y=57.96-4.73*x
2.50
3.00
3.50
4.00
4.50
ControlTotal


VAS
100.00
80.00
60.00
40.00
20.00
.00
y=28.22+3.79*x
2.00
2.50
3.00
3.50
4.00
4.50
5.00
ConfidenceAbilities


VAS
100.00
80.00
60.00
40.00
20.00
.00
y=39.22+0.58*x
2.50
3.00
3.50
4.00
4.50
5.00
ConfidenceInterpersonal


100.00
80.00
60.00
40.00
20.00
.00
VAS
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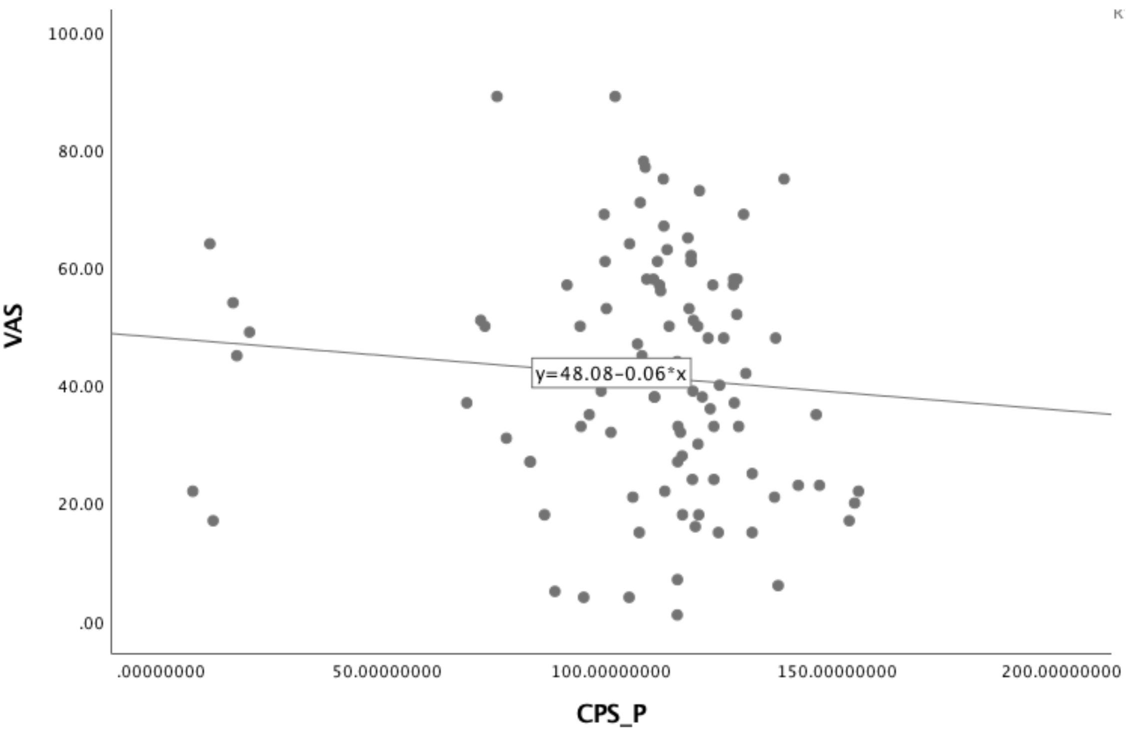
2.50
3.00
3.50
4.00
4.50
5.00
ConfidenceTotal


100.00
80.00
60.00
40.00
20.00
.00
VAS
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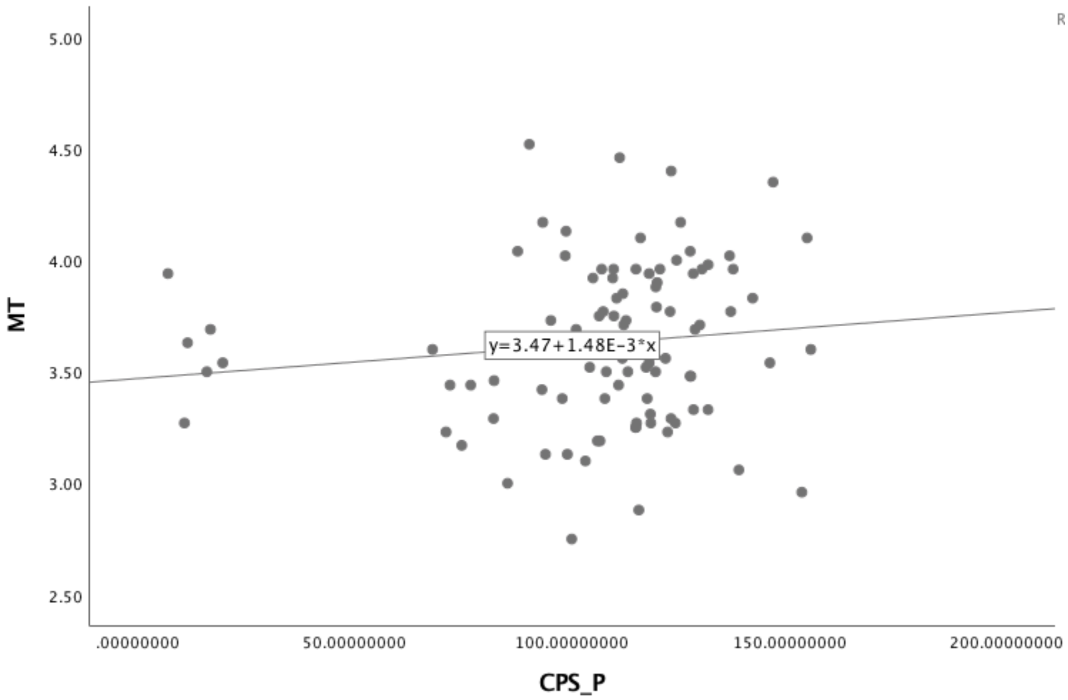
.00000000
50.00000000
100.00000000
150.00000000
200.00000000
CPS_P


MT
CPS_P
y=3.47+1.48E-3*x
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4.50
4.00
3.50
3.00
2.50
.00000000
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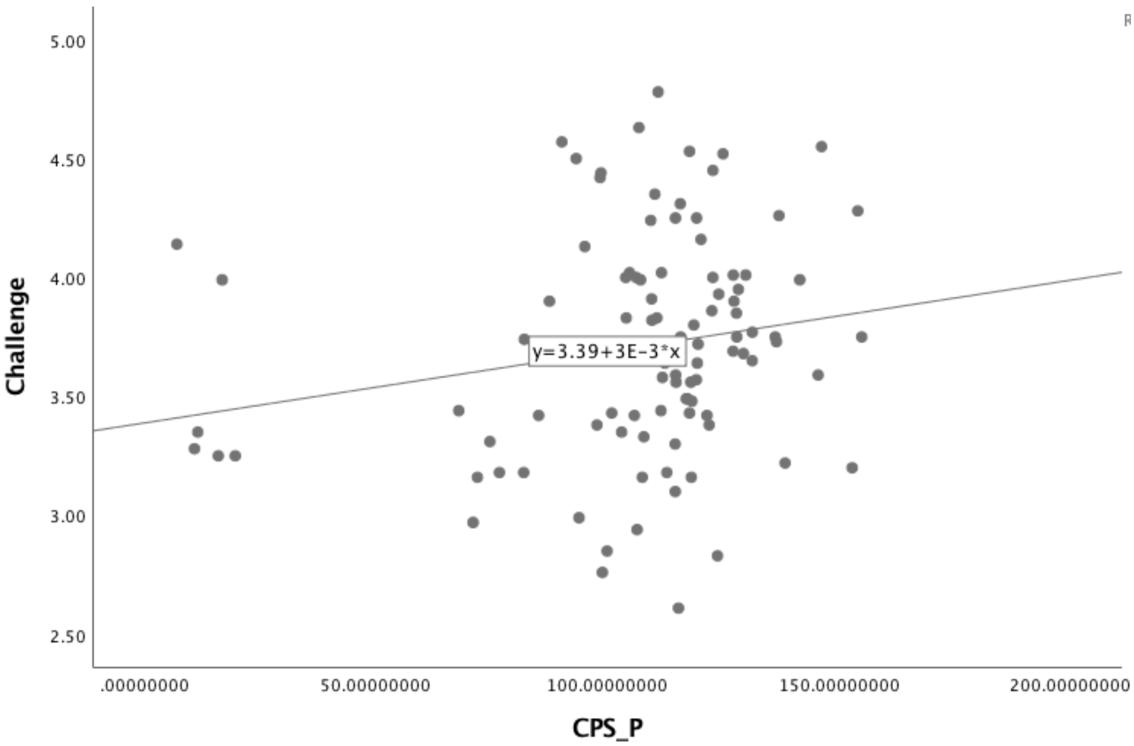
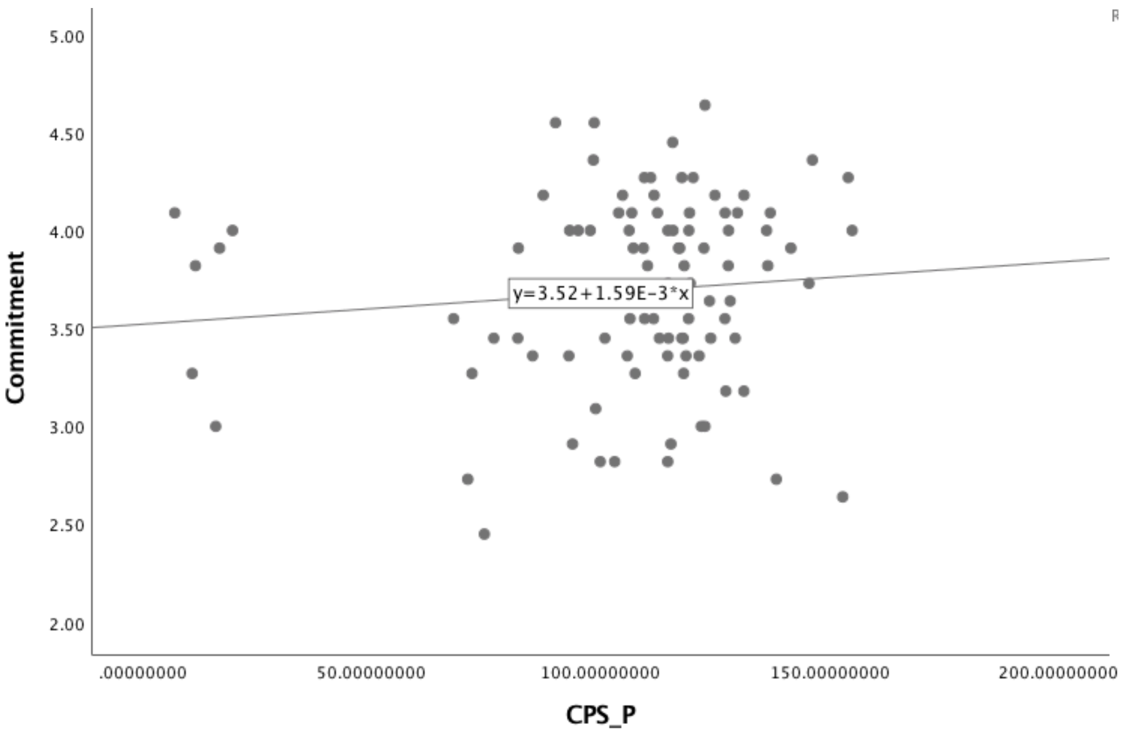
100.00000000
150.00000000
200.00000000


Challenge
CPS_P
y=3.39+3E-3*x
5.00
4.50
4.00
3.50
3.00
2.50
.00000000
50.00000000
100.00000000
150.00000000
200.00000000



5.00
4.50
4.00
3.50
3.00
2.50
2.00
Commitment
y=3.52+1.59E-3*x
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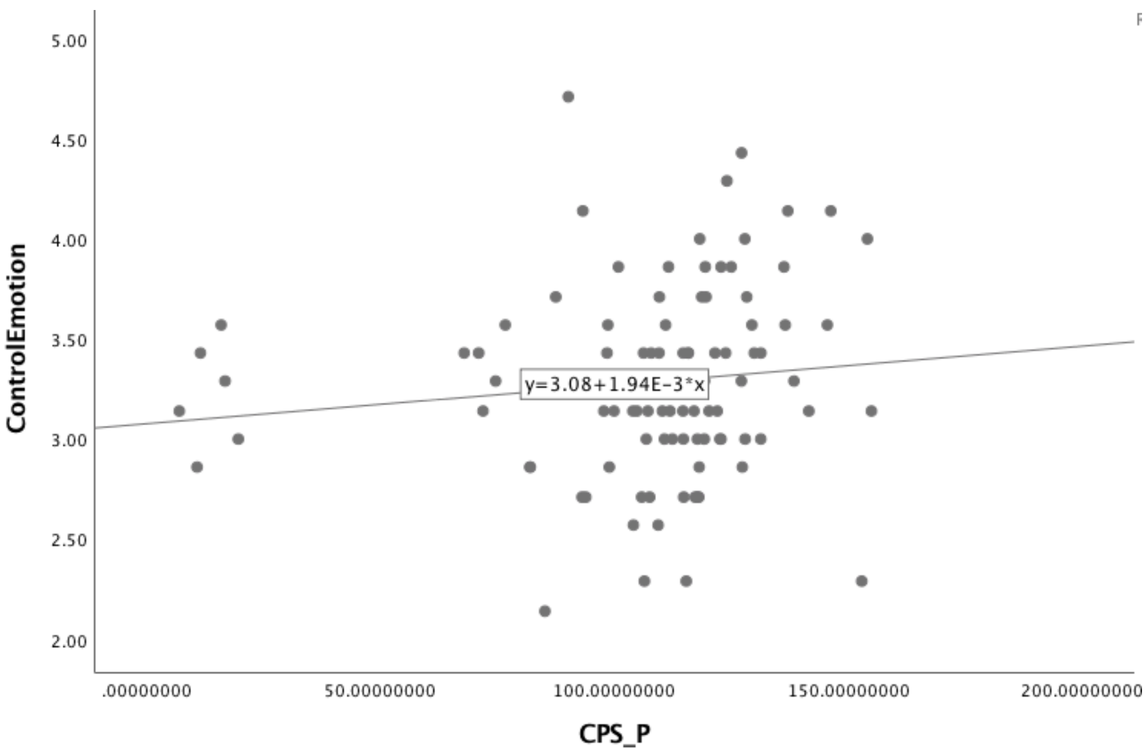
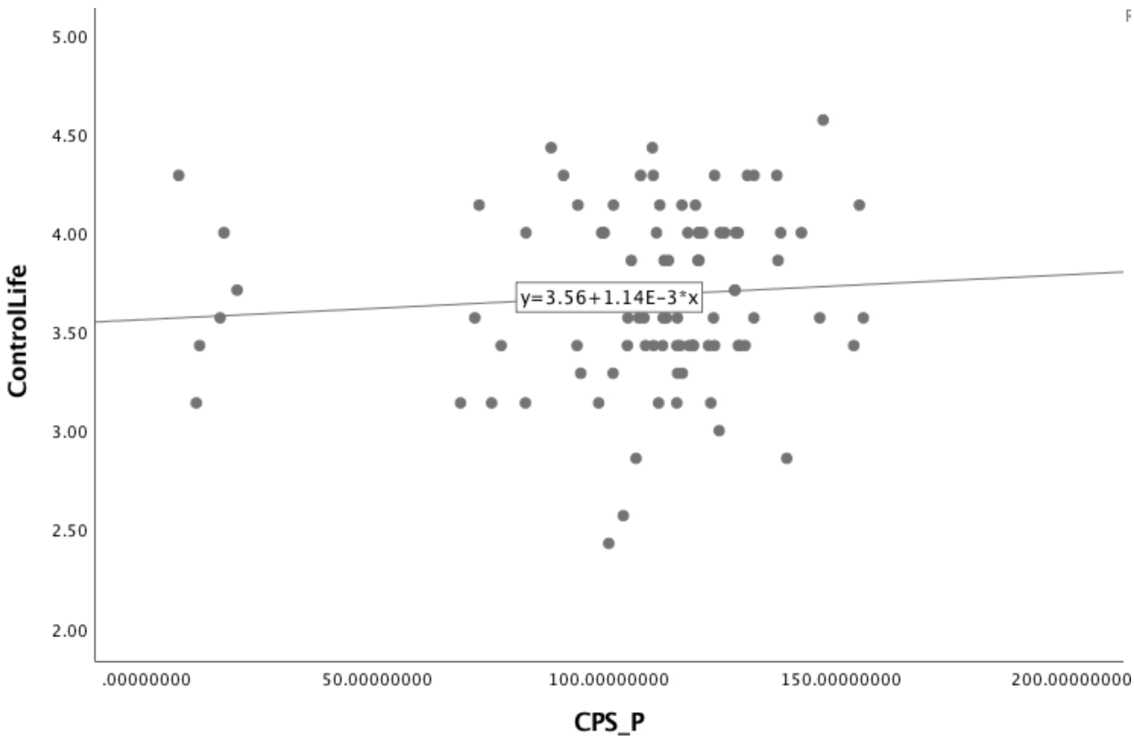
50.00000000
100.00000000
150.00000000
200.00000000
CPS_P



5.00
4.50
4.00
3.50
3.00
2.50
2.00
ControlEmotion
y=3.08+1.94E-3*x
.00000000
50.00000000
100.00000000
150.00000000
200.00000000
CPS_P


5.00
4.50
4.00
3.50
3.00
2.50
2.00
ControlLife
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.00000000
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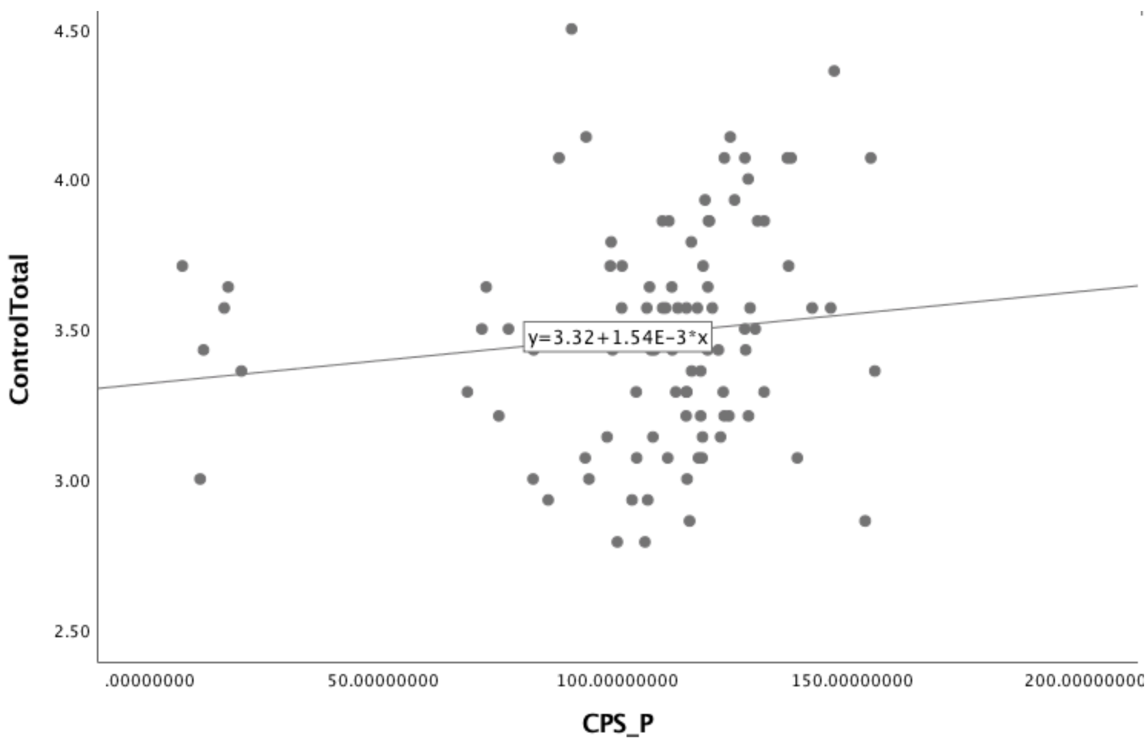
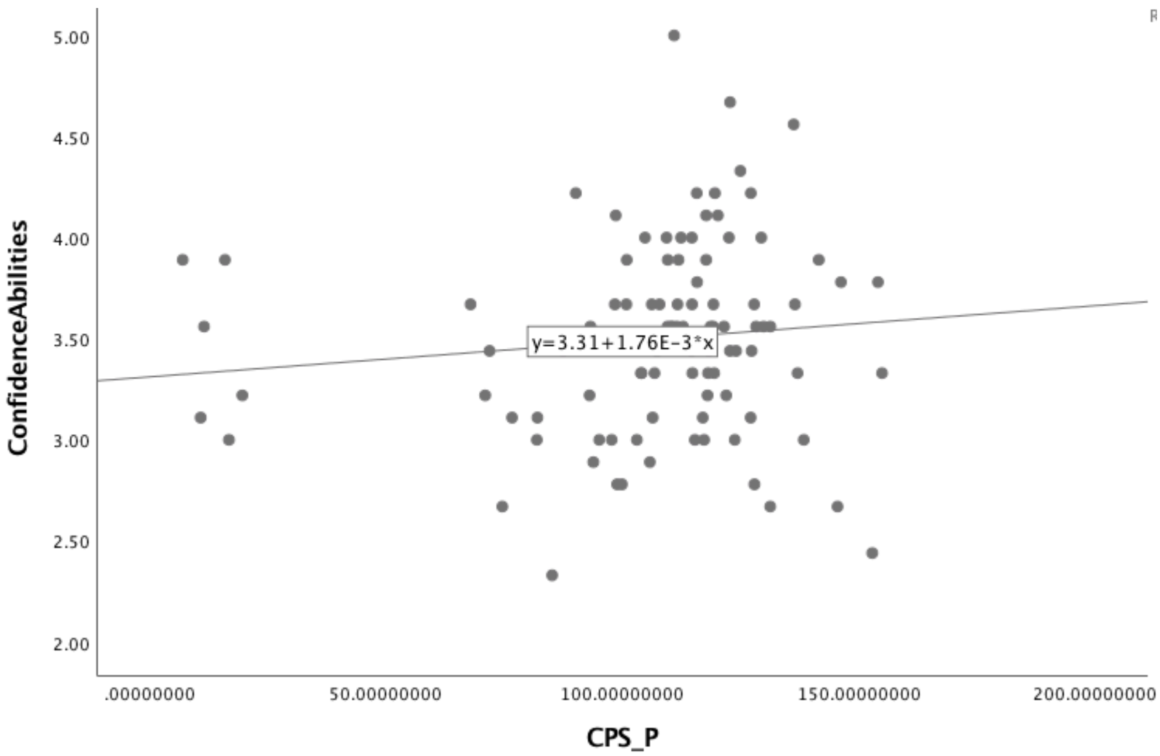
150.00000000
200.00000000
CPS_P


4.50
4.00
3.50
3.00
2.50
ControlTotal
y=3.32+1.54E-3*x
.00000000
50.00000000
100.00000000
150.00000000
CPS_P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4.50
4.00
3.50
3.00
2.50
2.00
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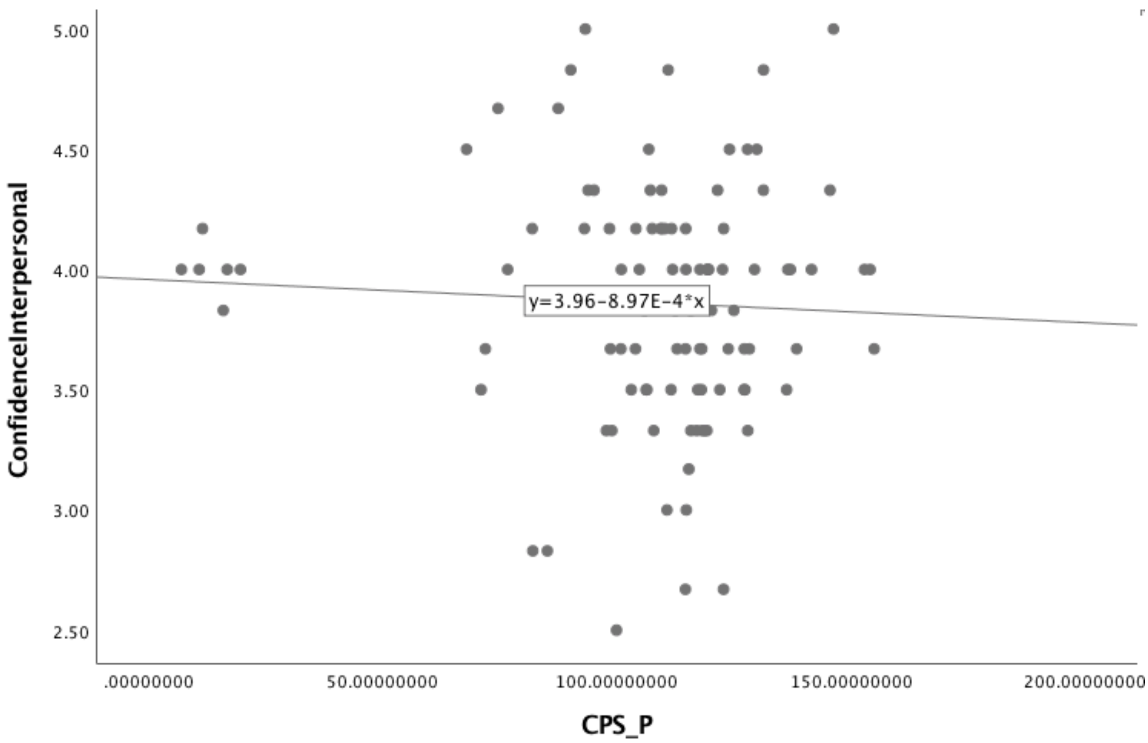
150.00000000
200.00000000
CPS_P


5.00
4.50
4.00
3.50
3.00
2.50
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.00000000
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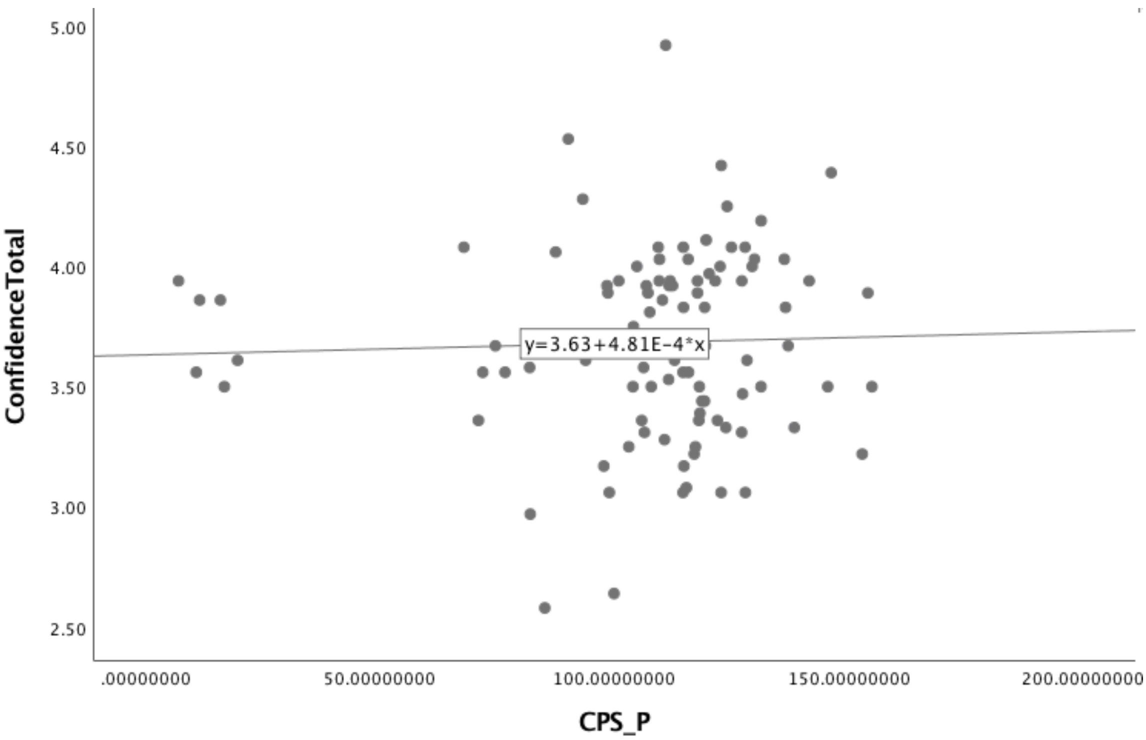
150.00000000
200.00000000
CPS_P


5.00
4.50
4.00
3.50
3.00
2.50
ConfidenceTotal
y=3.63+4.81E-4*x
.00000000
50.00000000
100.00000000
150.00000000
200.00000000
CPS_P

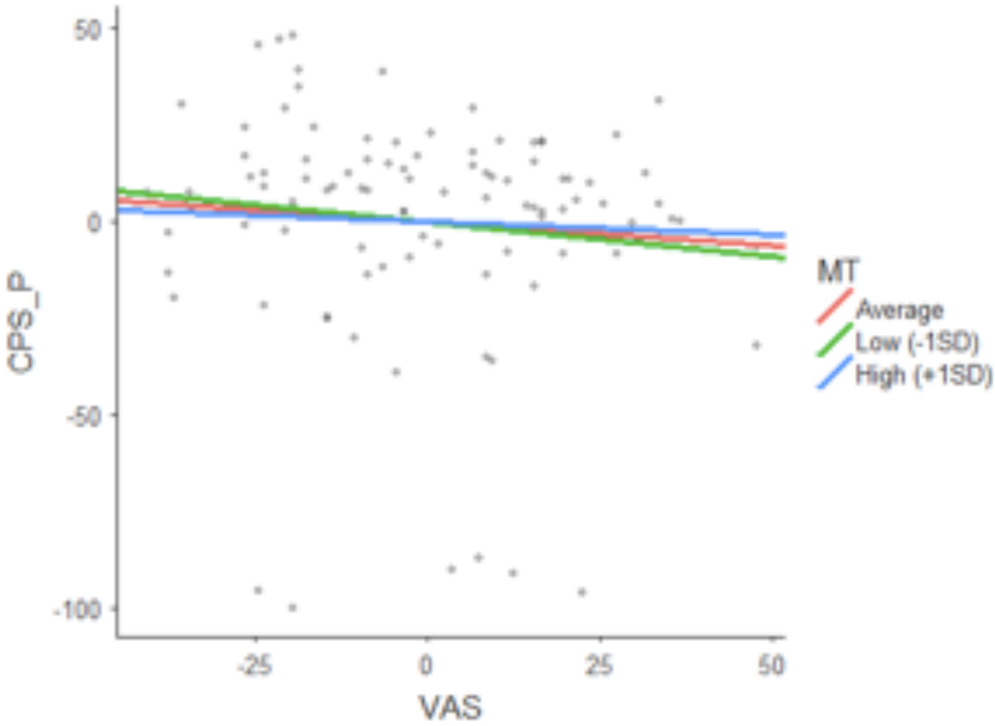
Appendix 13: Moderated regression analysis (Study 2).

			95% Confidence Intervals			
	R^2	*SE*	Lower	Upper	*Z*	*P*
VAS	-.123	.146	-.410	.164	-.838	.402
MT	10.453	8.308	-5.830	26.737	1.258	.208
VAS*MT	.160	.423	-.669	.989	.378	.705
VAS	-.123	.145	-.407	.162	-.845	.398
Challenge	11.903	6.273	-.391	24.198	1.898	.058
VAS*Chall.	-.002	.323	-.634	.630	.007	.994
VAS	-.106	.147	-.395	.182	-.721	.471
Commitment	5.831	6.255	-6.428	18.091	.932	.351
VAS*Comm.	.218	.269	-.309	.746	.813	.417
VAS	-.126	.146	-.412	.161	-.860	.390
Emotion Control	7.407	6.222	-4.787	19.601	1.191	.234
VAS*E_Cont.	-.119	.304	-.716	.478	-.391	.696
VAS	-.121	.148	-.412	.170	-.816	.414

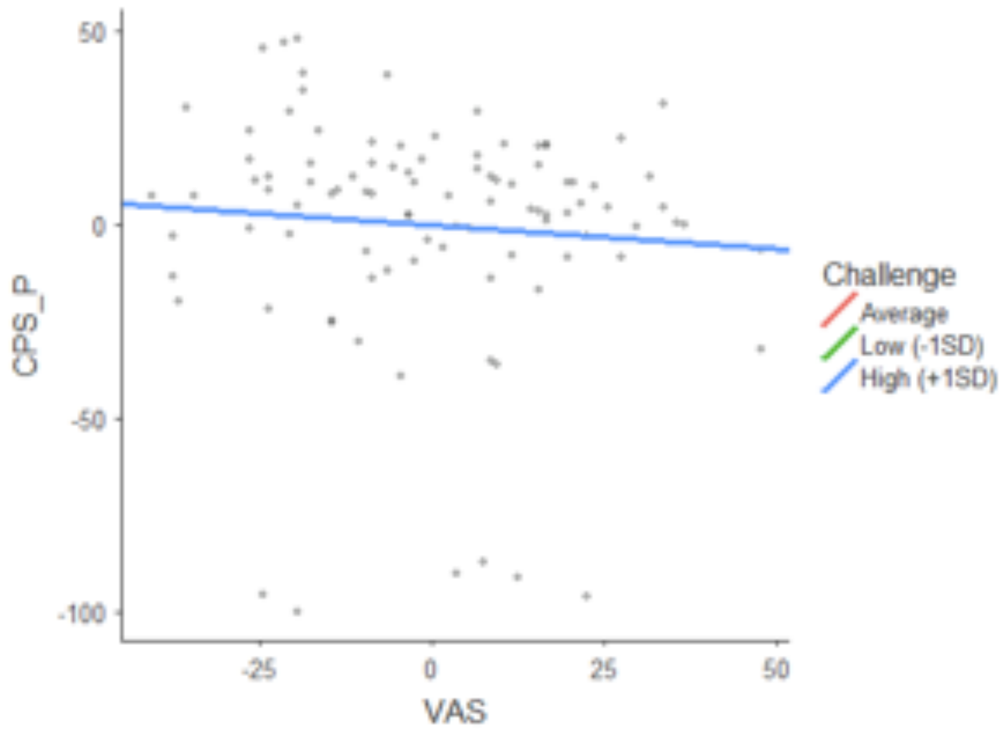
Life Control	4.972	7.108	-8.959	18.904	.700	.484
VAS*L_Cont.	-.018	.382	-.767	.730	-.048	.962
VAS	-.119	.146	-.405	.168	-.811	.417
Total Control	9.556	8.178	-6.472	25.583	1.169	.243
VAS*T_Cont.	-.055	.420	-.818	.767	-.132	.895
VAS	-.137	.146	-.424	.149.	-.939	.348
Confidence in Abilities	7.443	6.155	-4.622	19.507	1.209	.227
VAS*A_Conf.	.247	.304	-.349	.843	.812	.417
VAS	-.112	.149	-.403	.180	-.751	.453
Interpersonal Confidence	-3.695	5.859	-15.179	7.790	-.631	.528
VAS*I_Conf.	-.258	.331	-.906	.391	-.778	.463
VAS	.137	.147	-.425	.152	-.930	.352
Total Confidence	3.289	7.574	-11.556	18.133	.434	.664
VAS*T_Conf.	.058	.452	-.829	.944	.127	.899

Appendix 14: Simple slopes plots (study 2)

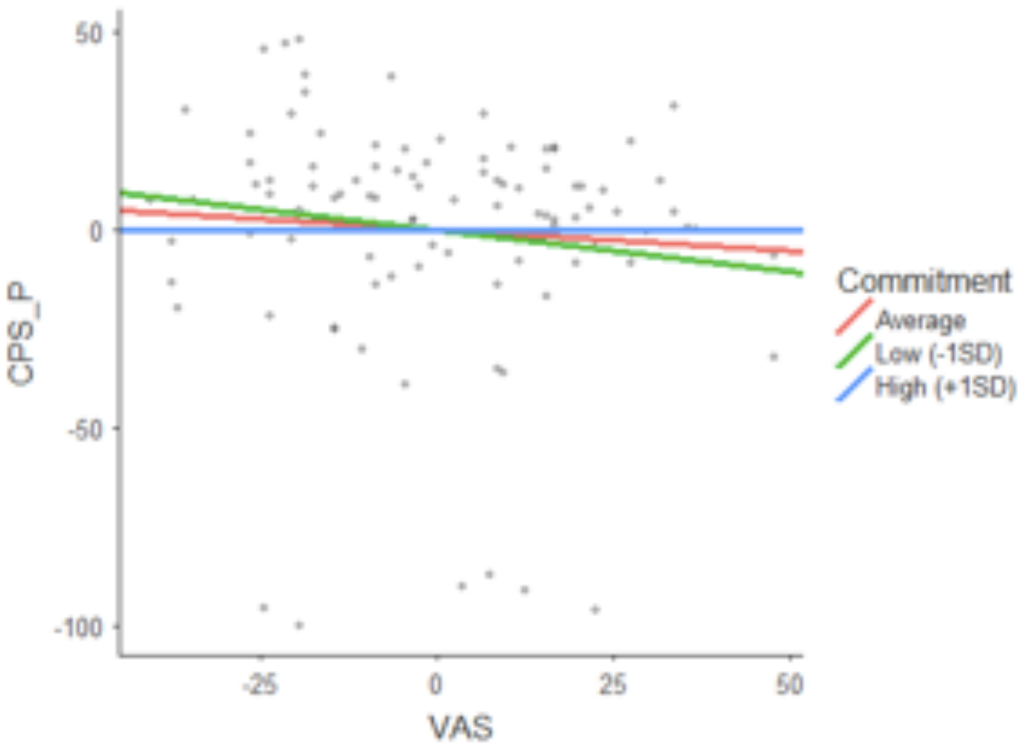
Simple slope 1:



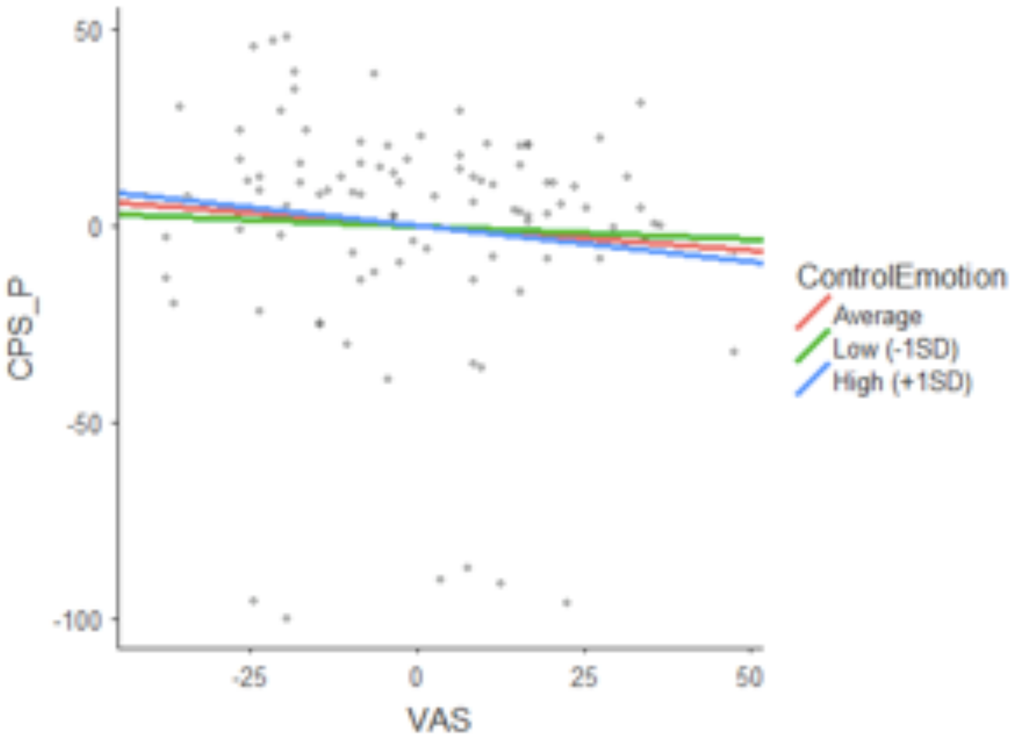
Simple slope 2:



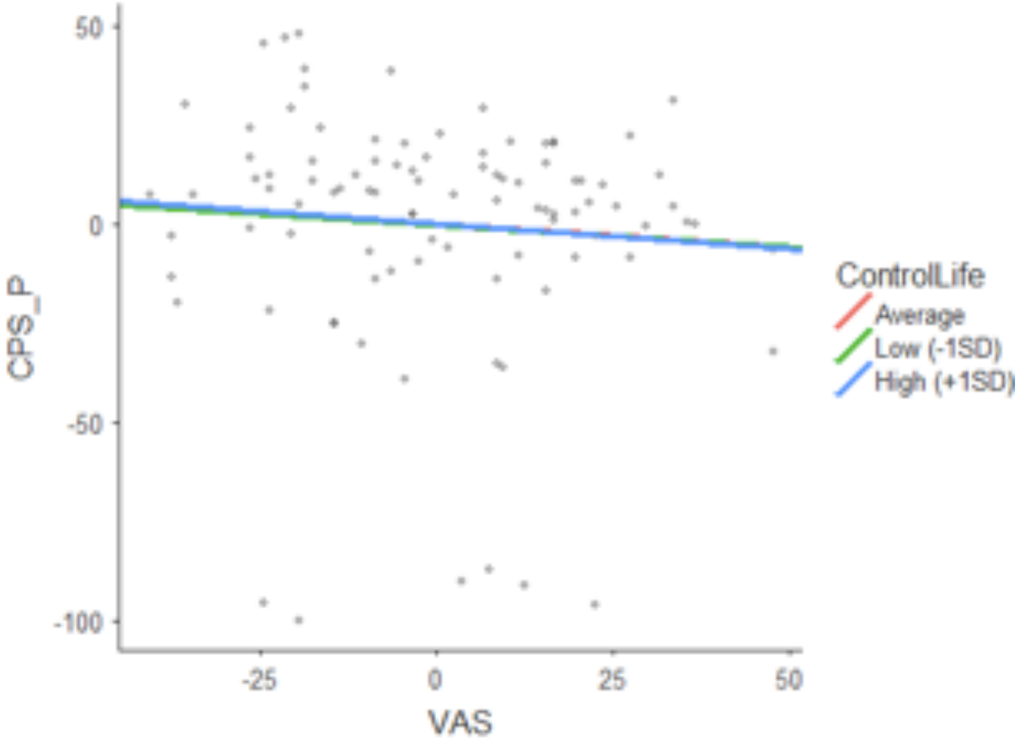
Simple slope 3:



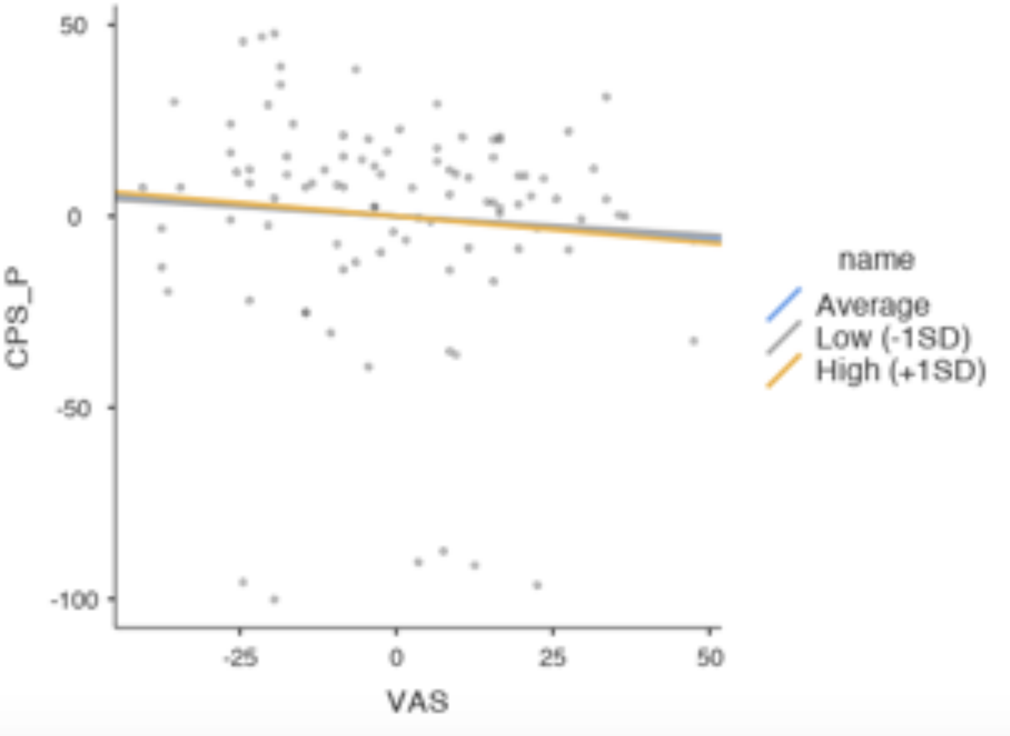
Simple slope 4:



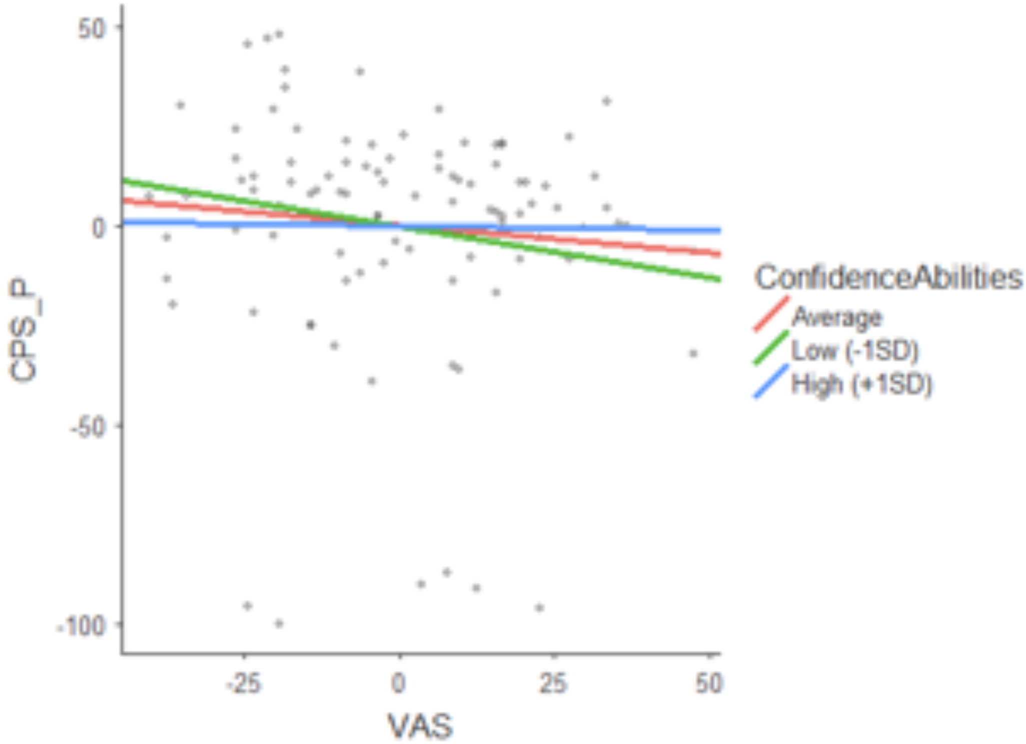
Simple slope 5:



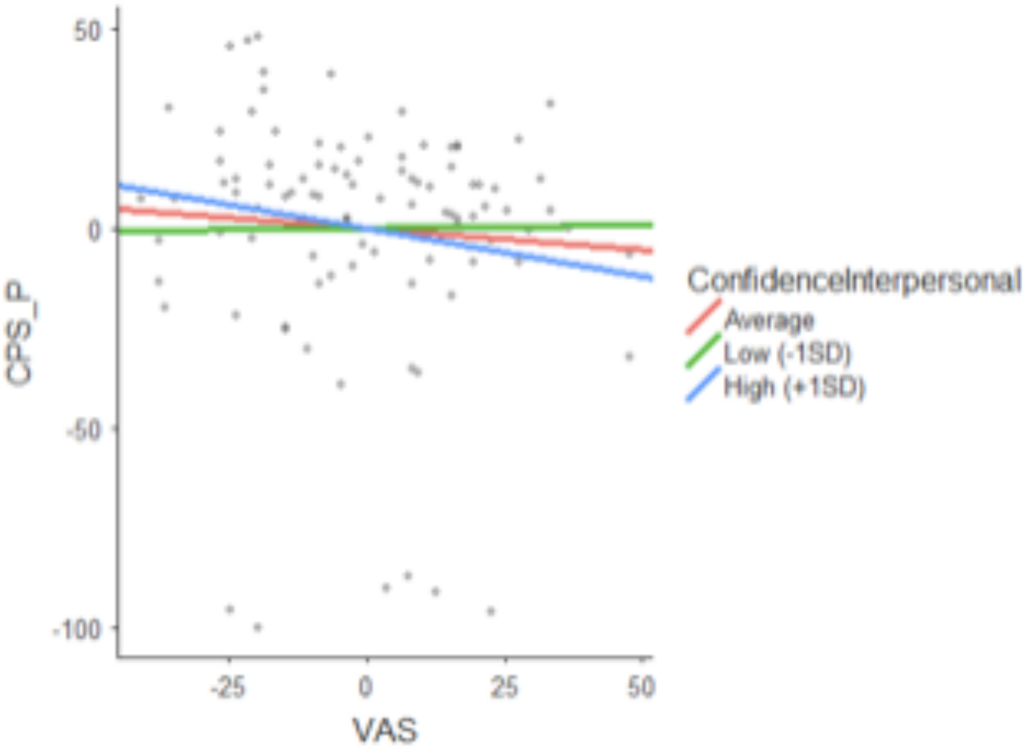
Simple slope 6:



Simple slope 7:



Simple slope 8:



Simple slope 9: