The Relationship between Self and Pain in Healthy Adults: Competition and Individual Differences

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Abstract

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Understanding the mechanisms that underlie psychological pain treatments is vital to improving them. Attention plays a crucial role in the development of chronic pain, and recent research has highlighted the need for better assessments of attentional bias towards pain. Attention is also important for pain treatments that rely on distraction, including novel virtual reality-based interventions. Distraction is hypothesised to reduce perceived pain intensity by diminishing cognitive resources available to process pain. Pain parameters, inter-personal differences and distraction task characteristics impact distraction effectiveness, but the role of motivational distraction components such as reward is little understood. The relationship between pain- and self-schemas has also been proposed as a factor in chronic pain. The schema enmeshment model (Pincus & Morley, 2001) postulates that frequent pain experience causes integration of pain- and self-schema, which maintains chronic pain and leads to detrimental pain outcomes in patients.

This thesis addresses 3 questions in healthy individuals: 1) Can a pain adaptation of the Perceptual Matching Paradigm (PMP; Sui, He & Humphreys, 2012) assess pain-bias, 2) Can self-related task content enhance the effectiveness of distraction from pain, and 3) does self-pain enmeshment reflect non-clinical variations in pain experience, or individual differences in self- or pain-related cognition?

In the PMP Bias task, our healthy sample prioritised pain as expected, but it is doubtful whether pain-processing was successfully elicited and pain-bias demonstrated. The relative effectiveness of neutral and self-related distraction task content and performance-based monetary reward was explored in a between-group cold pressor pain induction study. Basic distraction effects could not be replicated, although a self-related distraction reduced attention to pain more effectively than a neutral task. Finally, we showed that self-pain enmeshment is linked to increases in pain-related disability and locus of control in healthy individuals. Our findings support and add to the enmeshment model, suggesting interpersonal differences and pain disability contribute to schema enmeshment.

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This thesis comprises work conducted by Emilia Boehm for the degree of Doctor of Philosophy from the University of Oxford. Emilia Boehm has conducted all the work presented in this thesis, including the study design, implementation, writing of programming scripts to present experiments and collect and process data, participant recruitment and testing, and data analysis of the studies which form the basis for this thesis. Studies presented in this thesis were performed in Oxford.

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Chapter 1

1

Introduction

1.1. Setting the Stage: The Role of Attention and other Psychological Factors in Pain and Chronic Pain

Pain and pain-related stimuli inherently possess the power to draw our attention (Van Damme, Legrain, Vogt & Crombez, 2005). Pain itself has been described as an attention-demanding modality which, though it can be modulated by attention, in turn modulates our ability to focus and regulate our attention (Villemure & Bushnell, 2001; Moore, Keogh & Eccleston, 2012). Because pain acts as motivation to avoid incurring physical harm, it is vital that attention can easily be captured by pain (Eccleston & Crombez, 1999). As a result, pain can disrupt attentional performance and has been considered unique in its ability to draw attention (Moore, Keogh & Eccleston, 2012).

The relationship between pain and attention has been particularly important in the research of clinical populations experiencing chronic pain. Many studies and cognitive-affective models have proposed a role of abnormal attentional processing of pain (e.g. faster orienting towards, longer dwelling on and slowed disengagement from pain) in the development or maintenance of chronic pain disorders (Peters, Vlaeyen & Van Drunen, 2000; Pincus & Morley, 2001; Eccleston & Crombez, 1999; Rollman & Lautenbacher, 1993; Van Damme, Legrain, Vogt & Crombez, 2005; Van Damme, Crombez & Lorenz, 2007; Crombez,

Eccleston, Van Damme, Vlaeyen & Karoly, 2012; Todd, Sharpe, Johnson, Nicholson Perry, Colagiuri & Dear, 2015). Psychopathology models of emotional disorders such as anxiety and depression have formed the basis for more recently developed models of pain. These models generally attribute a central role to cognitive biases, which are often considered a vulnerability factor instrumental to the development or maintenance of disorders (Mathews & MacLeod, 2005). Pain experience is generally thought to depend only in part on physical parameters of the underlying sensation (Phillips, 1977), with psychological factors contributing significantly to the overall perception of pain. Even early models of pain (Melzack & Dennis, 1978) highlight the contribution of a physiological sensation of nociception (sensory-discriminative dimension) as well as psychological factors (motivational-affective dimension) to the individual's experience of pain.

The phenomenon of chronic pain particularly highlights the importance of non-physiological components in pain experience. Chronic pain is a somatic symptom disorder, in which patients experience prolonged and repeated sensations of pain despite the lack of a medically diagnosable anatomical or neuropsychological origin. Just like acute pain, chronic pain may arise from an initial injury or illness, but in contrast to acute pain, chronic pain persists for a long time – weeks, or even months, beyond the reasonably expected healing time for the given cause. However, chronic pain can also occur without being triggered by any specific event or condition. Given this variability in development, chronic pain is a poorly defined condition. However, one of the most agreed-upon defining characteristics of the disorder are its detrimental cognitive and psychological consequences. Chronic pain is associated with severe psychological distress, job loss, social isolation, depression and anxiety (Katz, Rosenbloom and Fashler, 2015). A considerable percentage of the population are affected by this condition, reports of prevalence rates for adults ranging from 16% to as much as 53% (Latina, Sansoni, D'Angelo, Di Biagio, De Marinis & Tarsitani, 2013). As a result,

chronic pain is considered one of the most costly disorders that exist in modern western society (Sleed, Eccleston, Breecham, Knapp & Jordan, 2005).

The economic detriment of chronic pain has been demonstrated across different nations and populations. In Portugal, chronic pain was estimated to cost €4,611.69 million annually, corresponding to 2.71% of the GDP (Azevedo, Cost-Pereira, Mendonca & Dias, 2016). The cost of chronic pain in adolescents alone was estimated at £3840 million a year in the United Kingdom by a study in 2005 (Sleed, Eccleston, Breecham, Knapp & Jordan, 2005). In Sweden, chronic pain in older adults (aged 65 or older) was estimated to cost €1 billion annually in addition to the costs expected for healthy individuals in this age group (Bernfordt, Gerdle, Rahmqvist, Husberg &Levin, 2015).

Given the severe consequences of chronic pain both in terms of individual suffering and detrimental economic impact, it is vital to understand factors that contribute to the development and maintenance of the disorder, identify individual differences that may predispose individuals to developing the disorder, and investigate mechanisms that may be important in the treatment of chronic pain. The aetiology of chronic pain is still poorly understood, and it is often puzzling to contemplate why some individuals develop chronic pain and others do not despite having suffered physically similar injuries. A better understanding of the factors and mechanisms underlying chronic pain development and maintenance may aid treatments which are at present often challenging (Williams, Eccleston & Morley, 2012; Linton, Flink & Vlaeyen, 2018).

One of the early models put forth to explain the aetiology of chronic pain is the fear-avoidance model (Lethem, Slade, Troup & Bentley, 1983), which focuses in particular on the psychological rather than sensory factors contributing to pain problems. The model distinguishes between two coping strategies which an individual may employ in response to pain, namely confrontation or avoidance. According to the model, avoidance behaviours (i.e.

avoiding activities which may be painful) lead to an exacerbation of fear of pain and a range of detrimental psychological and physical outcomes, while confrontation results in a reduction of pain-related fear. The authors argue that a variety of factors determine which strategy an individual is likely to utilise ('psychosocial context'), including the individual's personality, pain history and life events, pain coping strategies and fear of pain. Avoidance strategies in turn reinforce factors like fear of pain and the individual's pain experience which increase the likelihood of future pain avoidance, resulting in an avoidance spiral.

The fear-avoidance model has since been tested by numerous authors (Leeuw, Goossems, Linton, Crombez, Boersma & Vlaeyen, 2007) and multiple extensions and variations of the model have been proposed (Vlaeyen, Kole-Snijders, Boeren & Van Eek, 1995; Vlaeyen & Linton, 2000; Asmundson, Norton & Vlaeyen, 2004; Vlaeyen & Linton, 2012; Crombez, Eccleston, Van Damme, Vlaeyen & Karoly, 2012). For example, it has been suggested that catastrophising thoughts about pain may be a precursor of fear of pain (Leeuw, Goossems, Linton, Crombez, Boersma & Vlaeyen, 2007; Vlaeyen et al., 2004b; Vlaeyen, Kohle-Snijders, Boeren & van Eek, 1995). Additionally, individual differences in attention to pain, such as pain hypervigilance (heightened levels of scanning for and facilitated processing of pain) have been considered as factors arising from fear of pain and contributing to pain perception (Leeuw, Goossems, Linton, Crombez, Boersma & Vlaeyen, 2007).

Building on fear-avoidance models, a variety of models and experiments have highlighted the central role of attention in the development and maintenance of chronic pain (Peters, Vlaeyen & Van Drunen, 2000; Eccleston & Crombez, 1999; Eccleston & Crombez, 2007; Aldrich, Eccleston & Crombez, 2000; Pincus & Morley, 2001; Rollman & Lautenbacher, 1993; Van Damme, Legrain, Vogt & Crombez, 2005; Van Damme, Crombez & Lorenz, 2007; Crombez, Eccleston, Van Damme, Vlaeyen & Karoly, 2012; Todd, Sharpe, Johnson, Nicholson Perry, Colagiuri & Dear, 2015). These studies attribute varying roles to attention,

and refer to different attentional constructs. For example, misdirected problem-solving models stress the importance of hypervigilance to pain (Aldrich, Eccleston & Crombez, 2000; Eccleston & Crombez, 2007), which results from increased worry and exacerbates the pain problem by increasing the patients' attentional focus on pain to the detriment of engagement in other activities. Other models have highlighted the interruptive effects of pain in terms of its ability to disrupt ongoing attentional processes by capturing selective attention, which results in difficulty disengaging from pain (cognitive-affective model; Eccleston & Crombez, 1999).

More recently, attentional biases have played a crucial role in models of chronic pain, such as the threat interpretation model (Todd, Sharpe, Johnson, Nicholson Perry, Colagiuri & Dear, 2015). Attentional biases refer to the systematic facilitation or suppression of cognitive processing for certain types of information, such as pain or threat, compared to others. This is characterised for example by faster attentional engagement (orientation) towards or disengagement from (avoidance) pain-related information. The threat interpretation model postulates that attentional processes are affected differently depending on the threat a pain stimulus presents; specifically, once stimuli are identified as pain-related, normal attentional processing is engaged if pain is considered non-threatening, while threatening pain stimuli elicit a biased pattern of cognitive responding characterised by enhanced early orientation followed by speeded disengagement (vigilance-avoidance). However, although a meta-analysis of 10 studies indicated the presence of greater attentional biases for pain in chronic pain patients compared to healthy individuals (Schoth, Nunes & Liossi, 2012), a larger meta-analyses comprising 50 studies concluded there was no difference in the magnitude of pain-bias between healthy individuals and chronic pain patients (Crombez, Van Ryckeghem, Eccleston & Van Damme, 2013). However, although future models of chronic pain should consider the possibility that chronic pain is not associated with attentional biases for pain-

related information, the authors argue that their findings are most likely the result of methodological challenges in assessing attentional biases reliably.

Taking a broader view of factors contributing to chronic pain, Linton, Flink &Vlaeyen (2018) proposed a comprehensive developmental model of chronic pain comprising four central tenets. Synthesising previous models and research in the clinical context of the disorder (i.e. its definition and treatment) and spanning a broad range of psychological processes thought to contribute to chronic pain, the authors argue that chronic pain must be considered 1) as a developmental process, 2) in light of responses to contextual cues, 3) transdiagnostically, as resulting from a set of underlying mechanisms which often simultaneously give rise to comorbid conditions such as depression and anxiety, and 4) as a product of interacting learning processes, through which pain experience and behaviours may have been linked with positive, or cessation of negative outcomes.

Illustrating the role of development in chronic pain, Linton, Flink and Vlaeyen reason that pain is inherently cyclical in nature, and coping strategies employed to deal with recurrent pain episodes may gradually, perhaps unnoticeably, change behaviour over long time periods (tenet 1). Which strategies are employed (e.g. avoidance) and how effectively they may guide behaviour and affect daily routines in the long term will differ greatly between individuals. Early life experiences are considered crucial in forming the bases for the strategies to which an individual might naturally resort.

The second tenet refers to the adaptiveness of an individual's response to pain in the context of internal (e.g. bodily sensation) and external (e.g. a doctor's prognosis for healing) cues. The authors argue that responses that are inappropriate in the context of available cues, for example due to insensitivity to contextual information, contribute to the development of chronic pain. According to the model, context sensitivity depends on attention. Individuals whose attentional resources are reduced are less likely to process and be able to respond to

situational cues, resulting in more maladaptive patterns of behaviour. This can occur for example as a result of pain-related fear or highly emotional responses to pain, which engage attentional processes, thus reducing attentional resources available to process contextual information that may have otherwise have guided behaviour.

Linton, Flink and Vlaeyen's third tenet acknowledges the complex nature of pain problems, highlighting the need to view chronic pain as the result of underlying cognitive and emotional risk factors which often also give rise to the development of comorbid conditions such as depression and anxiety. A complex pattern of four risk factors is proposed (temperament; childhood exposure to adverse, unpredictable environments; intolerance of uncertainty; helplessness, i.e. a sense of lack of control over environment during childhood), each associated with specific triggering, protective, catalytic and driving processes.

Learning is the final tenet featuring in Linton, Flink and Vlaeyen's model. The authors argue that learning affects pain perception and pain behaviours in a range of complex ways. Due to the variable nature of pain, the perceived effect of behaviours aimed at reducing pain (beneficial or detrimental) is not consistent. Pain may cease or worsen unrelated to pain behaviours, which the individual may interpret as the consequence of a pain behaviour rather than natural variation. Negative behaviours (e.g. over-resting) may therefore be reinforced, and positive behaviours (e.g. exercise) extinguished, inappropriately. This may depend on the frequency of pain episodes which give an opportunity for learning. Counter-intuitively, either highly frequent and very infrequent pain experience may not result in maladaptive learning according to the model, because single pain experiences would not provide enough opportunity for learning to occur, while extremely frequent pain experiences would provide sufficient learning repetitions for variability-based feedback errors to be compensated for. Inappropriate generalisations of learning are also considered as a potential mechanism through which learning may affect chronic pain development. For example, beneficial behaviours may be too

little generalised (e.g. limiting behaviours to one context, such as performing exercises during rehabilitation treatments but not at home), while detrimental behaviours may be over-generalised (e.g. avoiding movement altogether after one particular movement has been associated with pain).

1.2. The Challenge of Assessing Attention to Pain

Despite, or perhaps because of the crucial role attention to pain is thought to play in the psychopathology of pain, our ability to measure attention to pain effectively has recently been drawn into question. An extensive meta-analysis (Crombez, Van Ryckeghem, Eccleston & Van Damme, 2013) analysing the results of 50 studies that covered a total of 1023 chronic pain patients concluded that attention bias to pain did not differ between chronic pain patients and healthy controls, and was overall small. Further, pain-bias was not linked to individual differences in fear of pain, pain severity, anxiety or depression in chronic pain patients. The authors note that the lexical and pictorial stimulus material used in the paradigms predominantly covered in this meta-analysis (dot-probe, Stroop and modified spatial cueing task) may not be suitable to evoke pain-related cognitive processing. The authors note that some promising results have been reported for paradigms in which attention bias to pain is assessed using stimuli which have been associated with pain using conditioning (Van Damme, Crombez, Hermans, Koster & Eccleston, 2006). However, in their current version, these paradigms rely on pain induction which may not be viable for use with chronic pain patients. The development and validation of paradigms assessing attention bias towards pain is therefore recommended by the authors. In chapters 2-4 of this thesis, we adapt the recently developed Perceptual Matching Paradigm (PMP; Sui, He & Humphreys, 2012) to assess attentional bias for pain, and discuss the validity of this new pain-bias measure in the context of more established paradigms. The PMP operationalises attentional bias as the ease with which

participants can form novel associations between a label (e.g. ‘you’, ‘stranger’) with a neutral stimulus, such as a simple shape. In the context of Linton, Flink and Vlaeyen’s model (2018), this paradigm may capture not only the degree to which information relating to pain attracts and engrosses an individual’s attentional resources (related to tenet 3), but also the degree to which learning of pain-associations is facilitated (tenet 4). Consequently, the pain-bias (or pain-prioritisation) measure assessed by this paradigm may reflect individual differences in pain-related cognitive processes that predispose individuals to developing maladaptive pain responses in the context of triggering, catalytic and driving processes, and the in the absence of protective processes. Enhanced formation of novel associations between pain and neutral stimuli has, for example, been found in fibromyalgia patients (Meulders, Jans & Vlaeyen, 2015).

1.3. Distraction from Pain

One of the key themes in the relationship between pain and attention is the question whether distraction from pain can reduce perception of pain. The proposed mechanism for this is attention: If attention is engaged in a distraction task, less attention is available to process painful stimuli, and less pain is experienced (McCaul & Malott, 1984; Peters, 2015). This approach is based on the limited capacity or resource models of attention (Broadbent, 1958; Kahneman, 1973), and has been important in the treatment of chronic pain patients. Because distraction is a relatively intuitive coping strategy that can be easily learned and implemented by chronic pain patients, it has been incorporated into many psychological pain treatments (Morley, Shapiro & Biggs, 2004).

More recently, an increasing number of virtual reality treatments have been developed to treat pain in both paediatric and adult clinical populations (Hoffman et al., 2011; Carrougher et al., 2009; Jones, Moore & Choo, 2016; Trost & Parsons, 2014; Won, Bailey, Bailenson,

Tataru, Yoon & Golianu, 2017). The benefit of such treatments is thought to rely on the uniquely attention-capturing nature of immersive virtual game environments which act as a distraction from pain (Hoffman, Doctor, Patterson, Carrougher & Furness, 2000), although some have argued that mechanisms beyond distraction contribute to their effect (Trost & Parsons, 2014). Virtual reality protocols have generally focused on treating acute pain (Hoffman et al., 2000), although more recent reviews have argued that early findings indicate that immersive virtual reality shows promise as an intervention for chronic pain conditions, either in combination with other treatments or in their own right (Keefe et al., 2012).

Given the importance of distraction as a coping strategy in chronic pain, it is vital to learn more about the factors that influence the reduction of pain perception through distraction. Much research has been conducted on the effect of different pain characteristics (Crombez, Baeyens & Eelen, 1994; Crombez, Eccleston, Baeyens & Eelen, 1997; Crombez, Eccleston, Baeyens & Eelen, 1998; Eccleston, 1995; Legrain, Van Damme, Eccleston, Davis, Seminowicz & Crombez, 2009), showing that attentional capture by pain is increased when pain is novel, intense or threatening. Some researchers have argued that inter-personal differences, such as catastrophising thoughts about pain, also play a role in attentional processing and interpretation of pain experiences (Moore, Keogh & Eccleston, 2012; Sullivan, 2001; Verhoeven, Crombez, Eccleston, Van Ryckeghem, Morley & Van Damme, 2010). More recently, research has started to explore the characteristics of distraction tasks, and their influence on the effectiveness of distraction. For example, it has been demonstrated that more difficult distraction tasks are more effective at reducing concurrent pain perception (Bantick, Wise, Ploghaus, Clare, Smith & Tracey, 2002; Wiech, Seymour, Kalisch, Stephan, Koltzenburg, Driver & Dolan, 2005), both on a behavioural and a neural level. These findings support the approach of a limited attentional capacity model, because they show that highly attention-demanding tasks are more effective distractors.

One aspect of distraction from pain that has been little researched to date is the motivational component of distraction tasks. Although the relationship between reward and pain has received considerable attention at an abstract, computational level (Talmi & Pine, 2012; Talmi, Dayan Kiebel, Frith & Dolan, 2009), little research has experimentally investigated the impact of motivation on pain distraction. In 2010, Verhoeven, Crombez, Eccleston, Van Ryckeghem, Morley and Van Damme compared the effectiveness of a neutral and a motivated distraction task as distractors from experimentally induced pain. In their experiment, 3 groups of participants completed different distraction tasks (no distraction, neutral distraction, and motivated distraction in which participants received monetary rewards for good performance) while undergoing cold-pressor stimulation, and rating the painfulness and attention they were paying to the pain. The experiment showed that both the neutral and the motivated distraction task were effective distractors compared to the no-distraction control group, but the motivated distraction task was overall no more effective a distractor than the neutral task. However, when considering individuals high and low in pain catastrophizing separately, they found that low pain catastrophisers were effectively distracted from pain by the distraction-only task compared to no distraction, while high catastrophisers were distracted effectively only when performance was rewarded (motivated distraction) but not in the distraction-only condition. This indicates that high pain catastrophisers may benefit from more motivational distraction tasks. Pain catastrophising has frequently been implicated as a major factor associated with more negative outcomes in chronic pain patients (Turner, Jensen, Warms & Cardenas, 2002; Quartana, Campbell & Edwards, 2009; Sullivan et al., 2001; Vervoort, Goubert, Eccleston, Bijttebier & Crombez, 2006). Thus, identifying highly motivational characteristics that may increase the distractive value of cognitive tasks for high pain

catastrophisers could have valuable implications for pain treatments targeted at reducing perceived pain in high pain catastrophisers.

The motivational component of Verhoeven et al.'s motivated-distraction task was the monetary reward participants could earn for their performance. While reward-related stimuli have been demonstrated to capture attention very well (Anderson, Laurent & Yantis, 2011; Sui, He & Humphreys, 2012), an indirect association between monetary reward and a distraction task may not be the best way to achieve a motivational, inherently attention-capturing task. Recent research on the attentional salience of self- compared to reward-related information has shown that both types of stimuli are frequently prioritised in the competition for attentional resources (Bredart, Delchambre & Laureys, 2006; Cunningham, Turk, Macdonald & Macrae, 2008; Keenan, Nelson & O'Connor, 2001; Sui, He & Humphreys, 2012; Sui & Humphreys, 2015; Sui, Yankouskaya & Humphreys, 2015; Turk, Cunningham & Macrae, 2008). While there is some degree of overlap between the neural underpinnings of reward- and self-related processing (Enzi, de Greck, Prosch, Tempelmann & Northoff, 2009), the salience of these two types of stimuli is thought to rely on at least partially distinct mechanisms (Sui & Humphreys, 2015). Most recent studies suggest that reward-related stimuli are processed with limited attentional capacity compared to self-related stimuli, which are processed with super-capacity (Sui, Yankouskaya & Humphreys, 2015). Consequently, self-related stimuli may be uniquely suited to compete for attentional resources with pain stimuli, over and beyond the capacity of reward-related information.

1.4. Self-Pain Enmeshment and Chronic Pain

Chronic pain patients often experience pain on a daily basis for prolonged periods of time. This usually means that pain affects and interferes with many aspect of their lives, which can impact the individual's sense of self. The influence of repeated experience of pain in

chronic pain patients on the individual's self-concept (or self-schema) has received increasing interest in recent years. This idea is central to the schema enmeshment model of chronic pain (Pincus & Morley, 2001), which postulates that the repeated concurrent activation of an individual's self- and pain-schema which occurs in the context of pain experience leads to an increased association of self- and pain-schema in chronic pain patients. This increased self-pain enmeshment may contribute to the maintenance and exacerbation of pain symptoms and illness behaviours in chronic pain patients.

In their model, Pincus and Morley consider not only pain- and self-schema as contributing to pathological development, but illness-schema as well. Pincus and Morley's model originally suggested that enmeshment of pain- and illness-schema in particular is critical for a pathological development. Enmeshment of self- and pain-schemas without integration of illness is considered non-problematic enmeshment, while the integration of pain- and illness-schemas without increased association with the self-schema leads to adaptive coping with chronic pain. The model considers integration of all three schemas the worst possible outcome, resulting in distress and other negative affective outcomes. However, more recent research has considered enmeshment in the context of only pain- and self- schemas, showing that increased self-pain associations are found in chronic pain patients with more detrimental emotional and pain outcomes such as greater anxiety, depression or depressed mood, and decreased acceptance (Pincus & Morley 2007; Sutherland & Morley, 2008; Morley, 2010; Rusu & Pincus, 2012; Van Ryckeghem, De Houwer, Van Bockstaele, Van Damme, De Schryver & Crombez, 2013). Studies have therefore increasingly explored and focused on the relationship between self-pain enmeshment and chronic pain (Gumm, Erbe, von Collani & Nestler, 2008; Van Ryckeghem, De Houwer, Van Bockstaele, Van Damme, De Schryver & Crombez, 2013) without specific consideration of processes relating to the illness-schema.

The self-pain enmeshment model is also interesting to consider in light of the model which Linton, Flink and Vlaeyen (2018) recently proposed to elucidate the aetiology of chronic pain. Specifically, maladaptive learning processes (tenet 4) which favour the formation of new associations with pain may constitute a risk factor for the development of self-pain enmeshment and chronic pain in the context of repeated pain experience. Although Pincus and Morley conceptualise schemas as stable constructs which are generally resilient to change and only become enmeshed through a prolonged process of repeated co-activation, Linton, Flink and Vlaeyen's model highlights that some individuals may be more predisposed towards integrating self- and pain-schemas in the context of relevant pain experience. Enmeshment might for example occur faster (after fewer repetitions of pain experience), or in response to milder pain experience than in more resilient individuals. Pincus and Morley do consider and allow for the role of individual differences, though without specifically highlighting the potential role of associative learning.

Although a range of studies have provided evidence to support this model, most experiments in this area have focused on the effects of increased self-pain enmeshment within chronic pain patients (Pincus & Morley, 2001; Morley, Davies & Barton, 2005; Van Ryckeghem, Houwer, Van Bockaele, Van Damme, De Schryver & Crombez, 2013), or the comparison of self-pain association levels between chronic pain patients and healthy controls (Van Ryckeghem et al., 2013). As a result, we know little about the relationship between self and pain in non-clinical populations. Given its association with chronic pain characteristics such as depression and acceptance (Pincus & Morley, 2001; Morley, Davies & Barton, 2005; Sutherland & Morley, 2008) as well as detrimental pain outcomes (Van Ryckeghem et al., 2013), the enmeshment of self and pain has been proposed as a target for psychological chronic pain interventions (Van Ryckeghem et al., 2013). A more thorough understanding of this

relationship in a healthy population may provide a better basis to inform the development of such interventions.

The relationship between self and pain in chronic pain has mainly been investigated using explicit (e.g. self-report, interview) or semi-explicit measures (e.g. sentence completion test; Sutherland & Morley, 2008; Rusu & Pincus, 2012). These methods are of limited use in this research area. Their sensitivity is minimal, because only cognitive processes that the participant is consciously aware of will be reflected in their responses (Van Ryckeghem et al., 2013). Answers may also be influenced by response bias (De Houwer, 2002), which is particularly problematic when comparing chronic pain patients and healthy controls who may be affected by different response biases due to a range of individual differences (e.g. fear of pain, pain catastrophizing). It is thus vital that new paradigms are developed to investigate self- and pain-related cognitive processing on an implicit level.

To date, few studies have adopted implicit measures designs to avoid the problems associated with explicit study designs (Gumm, Erbe, von Collani & Nestler, 2008; Van Ryckeghem, De Houwer, Van Bockstaele, Van Damme, De Schryver & Crombez,2013). Van Ryckeghem et al. (2013) used a self-pain Implicit Associations Task (IAT) to compare enmeshment of self and pain in chronic pain patients and pain-free controls. They found not only an increased association of self and pain in chronic pain patients compared to healthy controls, but also a relationship between degree of self-pain association and pain severity, pain suffering, anxiety and helplessness within chronic pain patients. These findings indicate that self-pain association may indeed contribute to the maintenance of chronic pain, and play a role in exacerbating symptoms. The study strongly supports the enmeshment model of self and pain, and indicates the self-pain implicit associations task may be a useful and effective measure of self-pain enmeshment.

Van Ryckeghem et al. (2013) suggest that self-pain enmeshment could be a viable target for cognitive chronic pain interventions. Before such an intervention can be developed, a better understanding of the relationship between self and pain in healthy populations is needed. For example, it is possible that healthy individuals effectively distract themselves from painful experiences in everyday life with self-related thoughts. Self-related information is prioritised for cognitive processing to a similar degree as information relating to reward (Sui, He & Humphreys, 2012), although facilitation of the two information types seems to rely on at least partially distinct cognitive and neural mechanisms (Sui and Humphreys, 2015; Sui, Yankouskaya & Humphreys, 2015). An increased association of self and pain might reduce the effectiveness of self-related information as a distractor, and extend the facilitated cognitive processing which applies to self-related information to facilitate pain-related information also. This could constitute a putative mechanism which would explain findings of worse pain outcomes in individuals with increased self-pain associations. Linton, Flink and Vlaeyen (2018) note that chronic pain is characterised by coping strategies which are often beneficial for acute pain conditions (such as rest or medication), but paradoxically exacerbate the problem when pain persists. It is therefore plausible that, assuming that engaging in self-related thoughts as a distraction is a natural coping strategy individuals employ in response to acute pain, this behaviour may become detrimental in the context of repeated or persistent pain. Self-related thoughts would then be increasingly associated with pain (Pincus & Morley, 2001), and instead of reducing attention to pain may contribute to the increased and frequent activation of the pain schema through this association.

Given its potential clinical relevance, the validity of the self-pain IAT as a measure of self-pain enmeshment also needs to be established. Specifically, the relationship between implicitly assessed self-pain associations and other self- and pain-related cognitive constructs needs to be investigated to ensure the self-pain IAT measures a distinct psychological construct

rather than reflecting for example negative self-esteem. The relationship between self-pain associations and transient, non-clinical pain experiences such as occasional headaches or minor injuries also poses intriguing questions. Little is known about the process through which self- and pain-schema become enmeshed, such as which aspects of pain experience drive self-pain enmeshment, whether temporary increases in pain experience are reflected in self-pain enmeshment or whether this only occurs in response to pain intense and debilitating enough to be characterised as chronic pain, and whether certain inter-personal differences predispose individuals to associating self and pain more easily in response to pain experience. These questions are investigated in cross-sectional studies discussed in chapters 5 and 7.

1.5. Research Questions

The research described here addresses three main questions in a sample of healthy individuals:

1) Is a pain adaptation of the Perceptual Matching Paradigm (PMP) a valid measure of attentional prioritisation of pain?
2) Can self-related task content enhance the effectiveness of distraction from pain?
3) Does self-pain enmeshment measured by an Implicit Associations Task reflect transient pain experiences and inter-personal differences in self- and pain-related cognition?

Question 1 is addressed in chapters 2-5. These chapters also address question 2 in form of a proof of concept pilot, while chapter 6 represents the main investigation of question 2. Question 3 is addressed in chapters 5 and 7.

1.6. Research Overview

We performed four experimental studies which are described in chapters 2-7. Due to the breadth of questions addressed and analyses performed in the final two studies, each of these is segmented into two chapters. Chapters 4 and 5 as well as 6 and 7 describe data collected from the same participants in a single laboratory session (see table 1.1).

Table 1.1. Overview over studies discussed in this thesis, study samples and chapters in which each study is discussed. Different samples were recruited for each of the 4 studies; however, some studies contained several components of which not all were completed by all participants. Where this is the case (Study 1, Study 4), the total number of participants who completed the first component is given, and the subset of participants who completed the second component as well as the first is stated separately. There were no cases of participants completing only the second but not the first component. In studies 2 and 3, all participants completed all components of the study.

Study	Components	Participants	Thesis Chapter
Study 1: Deception	Bias Task	30 participants (opportunity sample)	Main analysis in chapter 2; compared with deception control in chapter 3
	Competition Task	24 participants (subset of the 30 participants who completed Study 1 Deception Bias task)	
Study 2: Deception Control	Bias Task, Competition Task	27 participants (opportunity sample including 12 undergraduates participating for course credits through the Research Participation Scheme)	Main analysis in chapter 3, including comparison with Study 1
Study 3: Painful Electric Stimulation	Bias Task, Competition Task	55 participants (opportunity sample)	Main analysis in chapter 4
	Individual Difference Measures		Main analysis in chapter 5
Study 4: Distraction and Individual Differences	Distraction (Cold Pressor)	163 participants (opportunity sample including 43 undergraduate students participating for course credits)	Main analysis in chapter 6
	Individual Differences	161 participants (subset of the 163 participants who completed the Study 4 Distraction task)	Main analysis in chapter 7

In our first three studies, we adapt the Perceptual Matching Paradigm (Sui, He & Humphreys, 2012), which has recently been developed to investigate the relationship between attentional biases for self- and reward-related information. As the term 'bias' traditionally may refer to either increased or decreased attention to a certain type of information, we will here use the term 'prioritisation' when referring to findings using the PMP Bias task adaptation to avoid ambiguity about the direction of the bias. In three studies (see chapters 2-4), two adaptations of the PMP are used to investigate cognitive processing of visual stimuli relating to self, pain and reward in different contexts. These adaptations are referred to as Bias and Competition task. The Bias task was designed to address research question 1, while the

competition task was designed to provide proof of concept for research question 2. In chapters 2-4, both tasks are applied in different contexts (deception, deception control and threat of experienced pain) to investigate their validity as a measure of attention to pain, and competition between cognitive resource allocation for self and pain, retrospectively. Data was collected from samples of 30, 27 and 55 participants respectively in chapters 2, 3 and 4.

In chapter 2, we aim to elicit pain-related cognitive processing by deceiving participants, who expect to receive painful electric stimulation at the end of the experiment depending on their performance to pain-related visual stimuli (deception). In chapter 3, their response patterns to the same stimuli are investigated when no deception is practiced (deception control). In chapter 4, painful electric stimulation is applied to participants before completing the Bias and Competition task and participants expect and receive additional performance-dependent painful stimulation at the end of the experiment (threat of experienced pain). By contrasting results from these three studies, we aim to establish whether

1) the cognitive prioritisation of pain-related stimuli as assessed by the Bias task constitutes a valid measure of attentional bias for pain (research question 1), and

2) self-related information is prioritised equally or more strongly for cognitive processing than pain-related information, even when pain outcomes are associated with performance to pain-related information (research question 2).

Chapter 5 addresses research question 1 by investigating the relationship between the Bias task measure of cognitive prioritisation of pain and individual differences in pain catastrophising, fear of pain, somatosensory amplification and recent pain experiences. One of the key findings in Crombez et al.'s (2013) meta-analysis was the lack of relationship between pain-bias and individual differences in fear of pain or pain severity, which cast doubt on the validity of pain-bias measures derived from traditional paradigms. In order to

investigate the validity of our pain-prioritisation measure compared to traditional pain bias measures, it is therefore essential to establish its relationship with individual differences in self-reported pain-related cognitive processing. The data analysed in this chapter were collected as part of the study outlined in chapter 4. The measure of pain-prioritisation discussed in chapter 5 therefore refers to the prioritisation of pain-related visual stimuli in the context of threat of experienced painful electric stimulation.

The research described in chapter 6 addresses research question 2 in a distraction paradigm. Closely following the method of Verhoeven et al. (2010), we devised a study design in which 5 distraction groups were compared on how effectively they reduced negative pain outcomes during a cold pressor pain induction. A total of 163 participants performed the pain induction while performing either

1) no distraction task (control),
2) a neutral distraction task (neutral distraction),
3) a distraction task containing self-related words (self distraction),
4) a neutral distraction task in which good performance was financially rewarded (neutral-rewarded), or
5) a distraction task containing self-related words in which good performance was financially rewarded (self-rewarded).

The study outlined in chapter 6 was designed predominantly to establish whether self-related task content would enhance the effectiveness of a distraction task in reducing negative pain outcomes, such as perceived pain intensity and negative pain affect. However, the chapter also explores the role of individual differences in pain catastrophising for the effectiveness of motivational components (self-related task content and expectation of performance-based reward).

Chapter 7 addresses research question 3 by investigating the relationship between implicitly assessed self-pain enmeshment and a range of individual differences in a healthy sample. The interactions between self-pain association and self-report measures of recent pain experiences, pain catastrophising, self-esteem, narcissism and locus of control subscales (internality, powerful others and chance) are explored. The data analysed in this chapter were collected as part of the study described in chapter 6, comprising a sample of 163 healthy participants.

A final chapter contains a summary and discussion of the research and findings presented in this thesis, its strengths and limitations, as well as directions for future research in the fields of research covered in this thesis.

Chapter 2

2

Self over Pain: The Relative Prioritisation of Self and Pain in a Deception Setting

2.1. Introduction

The research outlined in this chapter aimed to address two questions:

1) Can the Perceptual Matching Paradigm (PMP; Sui, He & Humphreys, 2012) be adapted to assess cognitive prioritisation of pain- as well as self- and reward-related information?
2) Is self-related information prioritised to the same degree as or more strongly than pain-related information?

The first question aims to address challenges in research on attention bias for pain, which have recently been highlighted in a meta-analysis of studies assessing attention bias to pain in chronic pain patients and healthy controls (Crombez, Van Ryckeghem, Eccleston & Van Damme, 2013). The second question aims to improve our understanding of the relationship between self- and pain-related cognitive processing in a healthy population, specifically the competition for cognitive resources between them. This may have implications for the schema enmeshment model of self and pain (Pincus & Morley, 2001), and the development of psychological treatments for chronic pain patients targeting self-pain enmeshment (Van

Ryckeghem, Houwer, Van Bockaele, Van Damme, De Schryver & Crombez, 2013). A better understanding of the competition for cognitive resources between self- and pain-related processing may also have applications in distraction from pain.

Cognitive biases for self and pain have both been studied extensively, with both self- and pain-related information considered highly salient (Crombez, Van Ryckeghem, Eccleston & Van Damme, 2013; Sui, He & Humphreys, 2012; Sui & Humphreys, 2015; Sui, Yankouskaya & Humphreys, 2015). Very different approaches and paradigms have been applied in the research areas of cognitive bias (prioritisation) towards self- and pain-related information. However, both fields have faced challenges in developing experimental paradigms and stimulus material suitable for assessing cognitive bias (Crombez, Van Ryckeghem, Eccleston & Van Damme, 2013; Sui, He & Humphreys, 2012). The research described in this chapter applied the Perceptual Matching Paradigm (Sui, He & Humphreys, 2012), which was recently developed to address methodological challenges in the field of self-bias research, to the field of pain-bias, aiming to address comparable challenges in this research area.

A recent meta-analysis on attention bias (Crombez, Van Ryckeghem, Eccleston & Van Damme, 2013) cast doubts on the capacity of paradigms (eg. Dot-probe, Stroop task) and stimulus materials (eg. lexical, pictorial) traditionally used in this area to activate pain memories / schemata in chronic pain patients. The study investigated common paradigms in pain research such as the Stroop task, the dot-probe task and the modified spatial cueing task. Another component included in this meta-analysis was a comparison of chronic pain patients with healthy controls. The study found that although overall a small attention bias to pain was displayed by chronic pain patients, they did not differ from healthy control groups. The study further suggests that the frequent use of linguistic and pictorial stimuli directly or indirectly related to pain is unfortunate, as it is not evident that they are suitable to activate pain memory

/ schema and therefore to assess pain-bias. In contrast, the authors point to promising results from a study investigating attentional bias towards signals of impending pain (Van Damme, Crombez, Hermans, Koster & Eccleston, 2006). This study showed attention bias towards pain stimuli in healthy participants using a conditioning paradigm. The authors of the meta-analysis point to this as a promising avenue, but concede that modifications would need to be made to adapt similar paradigms for use with chronic pain patients.

Given these problems with existing paradigms in the field of pain research, we decided to adapt a paradigm from self-bias research to assess pain-bias. Many studies have shown that social salience, such as a stimulus' relevance to ourselves, influences how strongly a stimulus is prioritised for cognitive processing, including attention, decision-making and memory (Bredart, Delchambre & Laureys, 2006; Cunningham, Turk, MacDonald & Macrae, 2008; Turk, Cunningham & Macrae, 2008; Keenan, Nelson & O'Connor, 2001). However, most of these studies have used stimuli which relied on learned associations, such as images of participants' own faces, or their names. Stimuli were thus impossible to standardise perceptually, and were necessarily more familiar in some ways than control stimuli (such as a friend's face or name) and associated with different memories and emotions. The Perceptual Matching Paradigm (PMP; Sui, He & Humphreys, 2012) was developed to address these concerns.

The PMP alleviates some of these problems by measuring not whether stimuli that are already naturally associated with oneself (e.g. one's own face or name) are prioritised for processing, but how quickly and accurately new associations are formed. To this end, participants are asked to associate an abstract geometric shape with a label referring to either themselves (e.g. 'you') or an unfamiliar other (e.g. 'stranger'). Participants are then presented with a series of shape-label pairs and tasked to judge whether they matched. The Perceptual Matching Paradigm successfully showed facilitated responding to self-shape pairs compared

to other-shape pairs. Several variations of the paradigm showed this cognitive prioritisation of self persisted even when contrasted with highly familiar and / or emotionally close others, such as 'mother' or 'best friend'. How quickly and accurately participants were able to identify matched self-shape associations compared to other-shape associations was considered self-bias.

The PMP is also referred to as Novel Associations Task. When it was first introduced by Sui, He and Humphreys (2012), a variant of the task was used in which visually degraded stimuli were utilised to show a perceptual advantage for stimuli associated with self relative to others. The term 'Perceptual Matching Paradigm' is derived from this context. Since, then, the term 'Novel Associations Task' has also been used to refer to versions of the task in which no perceptual manipulation (e.g. visually degraded stimuli) are used, but new associations are created between labels and neutral geometric shapes.

On a purely theoretical basis, the term 'Novel Associations task' would be more appropriate for the versions of the PMP used in this thesis as they contain no element of perceptual manipulation. Despite this, we will refer to the paradigm as PMP in this thesis to avoid confusion with the Implicit Associations Task used in later studies, and for the sake of consistency with the body of literature on self-bias, which has for the most part continued to refer to the paradigm as perceptual matching task. We note however that this is purely a question of labelling, and we make no claims about being able to measure or compare cognitive processes at the perceptual level with this variant of the task. The adaptation of the paradigm used in this thesis aims to test the relative ease of identifying correctly and incorrectly matched pairs of labels and shapes depending on the label content (e.g. self- or other-related). How quickly and accurately a participant can identify whether a briefly presented shape-label pair corresponds to a previously learned pair ('Match' for pairs that correspond to learned pair, 'Mismatch' for pairs that don't) is thought to indicate the degree of priority with which this

shape-label pair is processed. Geometric shapes are considered neutral and on average processed with the same degree of priority. Any differences in responding to different shape-label pairs are therefore considered the result of differences in the prioritisation for cognitive processing for the different labels, i.e. an individual who responds faster and more accurately to self-shape compared to stranger-shape pairs is thought to prioritise self-related information over stranger-related information for cognitive processing.

The PMP has also been used to investigate the relationship between self- and reward-bias, showing that both biases are similar in magnitude (Sui, He & Humphreys, 2012; Sui & Humphreys, 2015) and rely on overlapping but distinct neural processes (Sui, Yankouskaya & Humphreys, 2015; Sui & Humphreys, 2015). This means the paradigm is suitable to investigate differences between the cognitive prioritisation of two salient types of stimuli (e.g. self- or reward-related). To assess reward-bias, participants are asked to learn high reward-shape and low reward-shape stimulus pairs, and then judge whether a series of shape-label pairs match the learned pairs as described above. High and low reward labels have typically consisted of monetary amounts such as '£8' and '£0.5' respectively. In light of the methodological challenges in the field of pain bias, the PMP seemed a particularly appropriate experimental paradigm to use to investigate the relative prioritisation of self and pain considering the very similar challenges in self-bias research which the Perceptual Matching Paradigm was designed to alleviate.

Adapting the PMP to assess pain-bias as well as self- and reward-bias required the inclusion of stimulus material that represented high and low pain respectively to match the 'you', 'stranger', '£8' and '£0.5' labels used to assess self- and reward-bias. Considering the problems with pictorial and lexical pain stimuli (Crombez, Van Ryckeghem, Eccleston & Van Damme, 2013) and the promising results obtained with stimuli that were associated with impending pain, we chose symbols that were not related to pain through learned association or

past experience (e.g. pictures / words related to pain) but symbols that were linked to pain outcomes in the study. Specifically, two and one lightning bolt symbols were used to represent high and low pain respectively. Instead of creating an association between these stimuli and pain outcomes using conditioning, we linked these stimuli with pain outcome expectations. Participants were informed they would receive painful electric stimulation at the end of the experiment. They would receive a number of strongly and mildly painful electric shocks depending on their performance in trials containing high and low pain trials respectively. This approach allowed us to omit the pain induction all together, and although participants expected to receive painful electric stimulation at the end of the experiments, no pain induction was applied. This design is therefore potentially more viable for use with chronic pain patients than pain conditioning paradigms such as Van Damme, Crombez, Hermans, Koster & Eccleston (2006).

We decided to include a measure of reward-bias in all our computer tasks as a control. Reward-related stimuli could easily be linked to outcome measures, specifically differential amounts of monetary reward, and thus provide an effective comparison for the relationship between self-bias and a bias for information linked to a real-life outcome (i.e. reward / pain). The use of the PMP to measure reward-bias and compare self- and reward-bias was already established and therefore seemed beneficial and easy to implement.

Assuming that the PMP could effectively be adapted to measure cognitive bias towards pain as well as self and reward, we designed this study to test the following hypotheses:

1) Whether there were qualitative or quantitative differences between the prioritisation of self and pain when assessed independently (Bias Task), and
2) Whether self or pain would be prioritised more highly when directly competing for cognitive resources (Competition Task).

The Bias Task (Computer Task 1), compared participants' self-, pain- and reward-bias by contrasting how high vs. low priority shape-label pairs were prioritised in a Social, Pain and Reward block respectively. High and low priority stimuli respectively comprised self-shape and other-shape stimulus pairs in the Social block, high pain-shape and low pain-shape pairs in the Pain block and high reward-shape and low reward-shape stimulus pairs in the Reward block. If the PMP modification for pain-bias was successful, we expected to see a higher prioritisation of the high pain compared to the low pain shape-label pair, characterised by faster and more accurate responses to the high pain-shape than the low pain-shape stimulus display. This would be consistent with previous findings that a moderate pain-bias is present in healthy individuals as well as chronic pain patients (Crombez, Van Ryckeghem, Eccleston & Van Damme, 2013). We further expected that there would be no difference between responses to high compared to low priority shape-label pairs across blocks (i.e. no difference in self-, pain- and reward-bias). The magnitude of self- and reward-bias is generally comparable (Sui, He & Humphreys, 2012). There was little basis for any predictions about the relative prioritisation of self and pain in the literature. Studies investigating the relationship between self and pain focused on the association between self and pain rather than competition between them, and mostly employed explicit rather than implicit measures (Van Ryckeghem, Houwer, Van Bockaele, Van Damme, De Schryver & Crombez, 2013). These studies were therefore unsuitable to predict implicitly measured competition between self and pain. Studies investigating either self- or pain-bias (but not both) employed such vastly different approaches and paradigms that they could not be meaningfully compared. However, based on our theory that self-related information might be an effective distraction from pain, we formulated the tentative hypothesis that self-bias would be at least as great as pain-bias, or greater. Given the healthy population, we hypothesised that he magnitude of pain- and reward-prioritisation of pain and reward would not differ substantially.

The Competition Task (Computer Task 2) investigated the prioritisation of self, pain and reward when presented together and competing for cognitive resources. Labels / symbols relating to self, pain and reward were directly paired with each other instead of with simple shapes. Each of six blocks paired 2 types of stimuli (Social, Pain, Reward) either congruently (two high priority stimuli and two low priority stimuli as Match trials) or incongruently (one high and one low priority stimulus in each of two Match trials). We predicted that in all congruent blocks, responses to the label-label pair containing two high priority stimuli would be faster and more accurate than responses to the low priority stimulus pair. The incongruent blocks were crucial for investigating the competition between self, pain and reward. In line with our predictions for the Bias task, we expected that self and reward would be prioritised equally. In this case, we would find no difference in response speed and accuracy to you-low reward and stranger-high reward stimulus pairs. We further predicted, based on our hypothesis that self-related information could function as a distractor from pain, that the you-low pain stimulus pair would be prioritised at least equally to the stranger-high pain stimulus pair, or more. Finally, we hypothesised that the low pain-high reward and the high pain-low reward stimulus pairs would be prioritised equally, indicating comparable levels of prioritisation for reward and pain.

2.2 Method

Participants

Sample size. We calculated the required sample size for the Bias (computer task 1) and Competition task (computer task 2) using G*Power (Version 3.0.10). In order to detect within-subject effects with a medium effect size (f = 0.25) and a power of at least 0.8, samples of 28 and 24 participants were required for tasks 1 and 2 respectively.

Participants. We tested 30 (15f, 15m) healthy volunteers for the bias task. A subset of 25 (11f, 13m) also completed the Competition task. Participants were aged 18-35 years with normal or corrected-to-normal vision, and no current or history of neurological conditions. The study was approved by the Medical Sciences Interdivisional Research Ethics Committee (MS IDREC R45788/RE001) and advertised through posters, local newspaper advertisements, social media and word-of-mouth. Informed consent was obtained from all participants at the beginning of the experimental session. All participants were reimbursed for their time at the end.

Design and Procedure

Design and Procedure. All data was collected during a single laboratory session. At the beginning of the experimental session, participants were deceived concerning electroshocks and monetary rewards as described below. Participants then completed the Bias computer task first, which usually took 15-20 minutes. Then, participants completed the Competition computer task, which took 30-40 minutes. One they finished the computer tasks, participants were debriefed about the deception and received their reimbursement.

Deception. An association was created between visual stimuli intended to relate to pain (high pain, low pain) and physical pain, as well as visual representations intended to relate to

reward and monetary reward (high reward, low reward). We informed participants they would receive a number of painful electric shocks at the end of the experiment, based on their performance in the computer tasks (this included the Bias and Competition task – see chapter 3). Specifically, participants' performance in trials containing high pain stimuli (2 lightning bolts) would determine the number of strongly painful electric shocks they would receive, and their performance in trials containing low pain stimuli (1 lightning bolt) would determine the number of mildly painful electric shocks they would receive. Similarly, participants were informed that their performance in trials containing high reward stimuli ('£8') would affect the proportion of the £8 reward they would win, and their performance in trials containing low reward stimuli ('£0.5') would affect the proportion of the £0.50 reward they would win. Neither painful electric stimulation nor rewards were in fact given at the end of the experiment, and once both computer tasks (Bias and Competition) were completed, participants were debriefed about the deception.

Bias Task (Computer Task 1)

Stimuli. Each of six geometric shapes (a circle, a square, a triangle, a pentagon, a hexagon and a diamond) was assigned to one of six labels / symbols ('you', 'stranger', '£8', '£0.5', a single and a double lightning symbol). Shape-label pairings were pseudo-randomised across participants (see appendix A). Shapes, labels and symbols were centred at 150px above and below the fixation cross. Labels ('you', 'stranger', '£8', '£0.5') were fixed at a height of 75px. Lightning symbols and neutral shapes were fixed at a height of 122px. Stimuli differed in width (see appendix B for stimuli). All stimuli were processed using GIMP 2 (V 2.8.16) and presented on a 1920x1080 screen.

Task design. Participants performed 3 blocks of trials: The (i) Social block, which contained the labels 'you' and 'stranger' and paired geometric shapes, the (ii) Pain block

containing shapes paired with two or one lightning symbol, and the (iii) Reward block in which geometric shapes were paired with reward values (see table 2.1).

Table 2.1. Overview of high and low priority stimuli contained in each block (Social, Pain and Reward) in the Bias task. Neutral stimuli are not included.

	Social Block	***Pain Block***	***Reward Block***
High Priority Label / Symbol	'YOU'		'£8'
Low Priority Label / Symbol	'STRANGER'		'£0.5'

The order of the three blocks was randomised across participants. In each block, participants were asked to associate two labels or symbols with a geometric shape each. For example, in the Social block, participants' task was to associate a shape (e.g. a circle) and the word 'you', and another shape (e.g. a square) with the word 'stranger'. Participants had unlimited time to remember these pairings, but all participants spent less than 5 minutes memorising the stimulus pairs.

Immediately following this learning phase, participants were presented with a series of stimulus pairs. For each stimulus pair, participants' task was to press a key for 'Match' if the stimuli presented were one of the learned shape-label pairs, or a 'Mismatch' key if the shape and label had been paired differently in the learning phase. Each block contained 160 trials, 40 each of the two 'Match' trials, 40 'Mismatch' trials showing the label or shape from the first learned pair with the geometric shape from the second learned pair, and 40 'Mismatch' trials showing the label or shape from the second learned pair with the geometric shape from the first learned pair (see Table 2.2).

Table 2.2. Examples of 'Match' and 'Mismatch' shape-label pairs in Bias task.

Blocks	Match Pairs (example)	Mismatch Pairs (example)
Social Block	'You' – Circle 'Stranger' – Square	'You' – Square 'Stranger' – Circle
Reward Block	'£8' – Hexagon '£0.5' – Diamond	'£8' – Diamond '£0.5' – Hexagon
Pain Block	2 Lightning Bolts – Pentagon 1 Lightning Bolt – Triangle	2 Lightning Bolts – Triangle 1 Lightning Bolt – Pentagon

At the start of each trial, a fixation cross was presented for 500ms, followed by a 100ms stimulus presentation. A blank screen was then presented for up to 2000ms or until a response was made, followed by a feedback screen displaying accuracy and latency of participants' response presented for 500 ms (see Figure 2.1). Participants were also shown summary feedback about their performance at the end of the block.

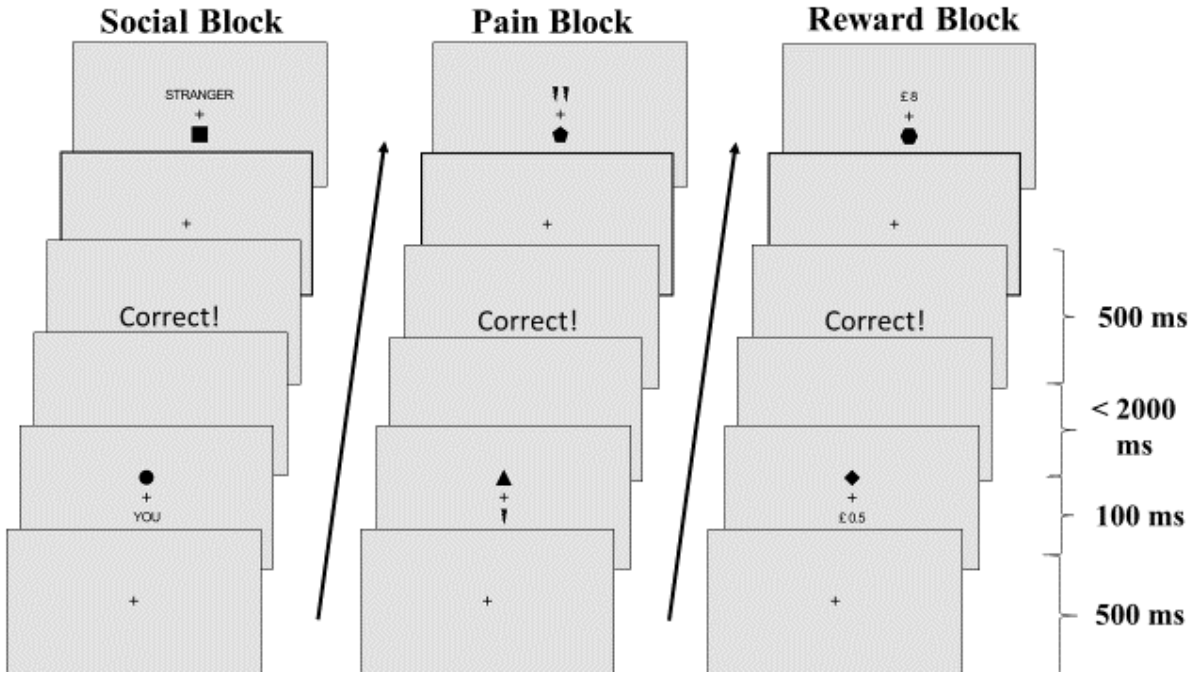


Figure 2.1. Example trial sequences in Social, Reward and Pain blocks in the Bias task. The stimuli displayed here are proportionate in size to the stimuli displays in the Bias task. The feedback display is simplified and enlarged here compared to the display in the Bias task for readability. The temporal sequence of displays remained constant across all blocks and conditions in the Bias task, as well as the Competition task.

Competition Task (Computer Task 2)

Stimuli. Each block contained four of six labels ('you', 'stranger', '£8', '£0.5', a single and a double lightning symbol) systematically paired with each other. These pairings were considered 'congruent' or 'incongruent' depending on the priority of stimuli that were paired. In 'congruent' blocks, one 'Match' pair comprised stimuli we expected to be processed with high priority ('you', '£8', double lightning) and the other stimuli we expected to be processed with low priority ('stranger', '£0.5', single lightning). In 'incongruent' blocks, each 'Match' pair contained one high and one low priority stimulus (see table 2.3). Stimuli were centred at 150px above and below the fixation cross on a 1920x1080 screen. Labels were fixed at a height of 75px. Lightning symbols were fixed at a height of 122px. Stimuli differed in width.

Procedure. Participants performed 6 blocks of 160 trials each: One congruent and one incongruent block each of (i) Self-Pain blocks, (ii) Self-Reward blocks, and (iii) Pain-Reward block. The order of these blocks was pseudo-randomised across participants, so that participants would never complete a congruent and incongruent block of the same type (Self-Pain, Self-Reward or Pain-Reward) consecutively.

In each block, participants were asked to associate two pairs of labels or symbols. For example, in the congruent Self-Pain block, participants' task was to associate a social label (e.g. 'you') and a pain-related symbol (e.g. a double lightning), and another social label (e.g. 'stranger') with another pain-related symbol (e.g. a single lightning). Participants had unlimited time to remember these pairings, but all participants spent less than 5 minutes memorising the stimulus pairs. Immediately following this learning phase, participants were then presented with a series of stimulus pairs. For each stimulus pair, participants' task was to press a key for 'Match' if the stimuli presented were one of the learned shape-label pairs, or a 'Mismatch' key if the shape and label had been paired differently in the learning phase. Each block contained

160 trials, 40 each of the two 'Match' and the two 'Mismatch' trials, with each Mismatch trial showing one label or symbol from the first learned Match pair with a label or symbol from the second learned Match pair (see Table 2.3). The timing and display sequence of each trial was identical to that in the Bias task (see figure 2.1).

Table 2.3. 'Match' and 'Mismatch' stimulus pairs in Competition Task (Computer Task 2).

Congruent Blocks	**'Match' Pairs**	**'Mismatch' Pairs**
Self-Pain (SP-C)	'You' – Two Lightning Bolts (HH) 'Stranger' – One Lightning Bolt (LL)	'You' – One Lightning Bolt (HL) 'Stranger' – Two Lightning Bolts (LH)
Self-Reward (SR-C)	'You' – '£8' (HH) 'Stranger'- '£0.5' (LL)	'You'- '£0.5' (HL) 'Stranger' – '£8' (LH)
Pain-Reward (PR-C)	Two Lightning Bolts – '£8' (HH) One Lightning Bolt – '£0.5' (LL)	Two Lightning Bolts – '£0.5' (HL) One Lightning Bolt – '£8' (LH)
Incongruent Blocks	**'Match' Pairs**	**'Mismatch' Pairs**
Self-Pain (SP-I)	'You' – One Lightning Bolt (HL) 'Stranger' – Two Lightning Bolts (LH)	'You' – Two Lightning Bolts (HH) 'Stranger' – One Lightning Bolt (LL)
Self-Reward (SR-I)	'You'- '£0.5' (HL) 'Stranger' – '£8' (LH)	'You' – '£8' (HH) 'Stranger'- '£0.5' (LL)
Pain-Reward (PR-I)	Two Lightning Bolts – '£0.5' (HL) One Lightning Bolt – '£8' (LH)	Two Lightning Bolts – '£8' (HH) One Lightning Bolt – '£0.5' (LL)

Data Analyses

Measures. We derived 3 performance measures for each condition (2 Match and 2 Mismatch pairs for each block) from each participant: Response time (RT), accuracy (ACC) and efficiency scores. Accuracy was calculated as proportion of correct responses and ranged from 0 to 1. We calculated mean response times (RT) from accurate responses made between 200 milliseconds and 1600 milliseconds after stimulus onset. The cut-off for premature responses was chosen based on Sui, He & Humphreys (2012). In this study, responses were made in a variable time interval between 800 and 1200 milliseconds after stimulus offset. We therefore chose the cut-off point of 1500 milliseconds after stimulus offset as a compromise between comparability with previous findings (e.g. cut-off at 800-1200 milliseconds) and removing too many trials from analysis. In both the Bias and Competition task, less than 1% of trials were removed as a consequence of setting the cut-off criterion at 1500 milliseconds.

From these measures we calculated the indirect performance measure of efficiency scores, as

$$efficiency = RT / ACC,$$

where RT was the response speed in milliseconds and ACC the proportion of correct responses. The efficiency measure was used to highlight overall performance and differentiate between true effects and cases of speed-accuracy trade-off (i.e. when participants responded faster but less accurately or vice versa to one trial type).

Previous studies using the PMP have frequently used the *d'* sensitivity index (Calculated as: *Hit Rate – False Alarm Rate*) as an additional measure to investigate the possibility of accuracy trade-offs between Match and Mismatch trials containing each label. We do not perform *d'* analyses in this or in subsequent chapters for the sake of brevity and clarity. Instead, the possibility of trade-offs between Match and Mismatch trials will be considered in the interpretation of accuracy data. Additionally, more substantial analyses of Mismatch data are reported here than in previous studies using the PMP to allow for an indirect comparison of Match and Mismatch trials.

Exclusion. No participants' data were excluded from either computer task on the basis of missing data or low accuracy.

Analyses. All analyses were performed on each of our three performance measures (reaction time, accuracy and efficiency). Separate analyses were conducted for Match and Mismatch trials. Repeated measures ANOVAs and paired samples *t*-tests were used to compare performance across different blocks and trial types.

2.3 Results

Bias Task (Computer Task 1)

Mean response times, accuracy and efficiency scores. Sample means for all performance measures are displayed in figure 2.2. Responses are on average faster, more accurate and more efficient in Match trials containing a high priority label (i.e. the self, high pain and high reward labels) compared to Match trials containing a low priority label (i.e. the stranger, low pain and low reward label). Differences between high and low priority labels are less pronounced and less consistent in Mismatch trials.

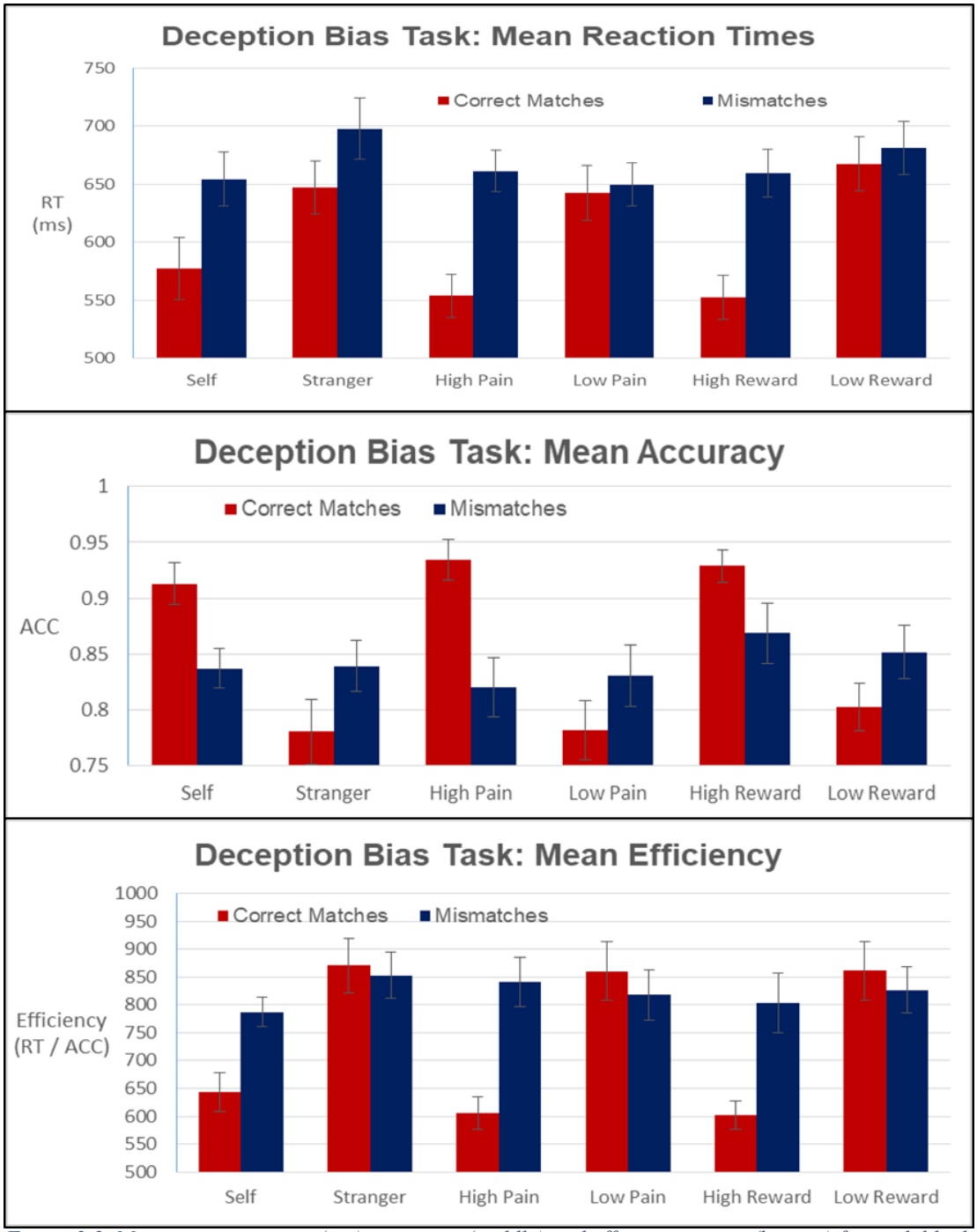


Figure 2.2. Mean response times (top), accuracy (middle) and efficiency scores (bottom) for each block and trial type in the Bias task (Deception study). Red bars represent means for Match trials, blue bars means of Mismatch trials. Error bars represent the standard error of the mean.

Analysis of Match trials. We performed 3x2 repeated measures ANOVAs with block (Social, Pain and Reward) and priority level (High, Low) as within-subject factors for reaction times, accuracy and efficiency scores. The results of these analyses are displayed in table 2.4.

The ANOVAs showed consistent effects across all 3 measures. There were no significant main effects of block (all $p > .05$), while all main effects of priority were significant (all $p < .001$). The interaction between block and priority was not significant for any of the measures (all $p > .05$).

We carried out a series of paired samples *t*-tests comparing high and low priority label-shape pairs in the Social, Pain and Reward blocks. The results of these analyses (performed on reaction times, accuracy and efficiency scores) are displayed in table 2.5. In line with the results of the ANOVAs, the differences between high and low priority label-shape pairs were significant across all blocks and all measures (all $p \leq .001$). The associated effect sizes indicate that the difference between high and low priority stimuli was greatest in the Reward block, somewhat smaller in the Pain block, and smallest in the Social block for all measures.

Table 2.4. Results of 3x2 repeated measures ANOVAs comparing main effects of block (Social, Pain and Reward) and label priority (high, low) in Match trials. Results are presented separately for reaction time (RT), accuracy (ACC) and efficiency scores. Measures reported refer to the F value (F), degrees of freedom (DF), p-value (p) and partial eta-squared values (N2P) associated with these comparisons. All values are rounded to 3 significant figures or 2 decimal points, excepting p-values which are rounded to 3 decimal points.

	RT				ACC				Efficiency			
	F	**DF**	***p***	**N2P**	***F***	**DF**	***p***	**N2P**	***F***	**DF**	***p***	**N2P**
Block	0.31	2, 58	.732	0.01	0.38	2, 58	.687	0.13	0.27	2, 58	.760	0.01
Priority	**96.3**	1, 29	< .001	0.77	**58.6**	1, 29	< .001	0.67	**56.3**	1, 29	< .001	0.66
Interaction	1.69	2, 58	.194	0.06	0.04	2, 58	.671	0.01	0.15	2, 58	.862	0.01

Table 2.5. Descriptive statistics and results of paired samples t-tests comparing high vs. low priority label-shape pairs (table refers to label only) Match trials within each block (Social, Pain, Reward). Values are presented separately for reaction times (RT), response accuracy (ACC) and efficiency scores. In order, the values given represent group means (M), standard deviations (SD), t-values (t), p-values (p), and Cohen's d (d) as a measure of effect size associated with the relevant significance test. All values are rounded to 3 significant figures or 2 decimal points, excepting p-values which are rounded to 3 decimal points.

	RT					ACC					Efficiency				
	M	***SD***	***t*(29)**	***p***	***d***	***M***	***SD***	***t*(29)**	***p***	***d***	***M***	***SD***	***t*(29)**	***p***	***d***
Self	577	146	**3.76**	.001	0.51	0.91	0.10	**5.10**	< .001	1.00	643	190	**4.67**	< .001	0.98
Stranger	647	127				0.78	0.16				870	268			
High Pain	554	101	**5.15**	< .001	0.76	0.93	0.10	**5.25**	< .001	1.23	606	164	**4.41**	< .001	1.08
Low Pain	642	130				0.78	0.15				861	292			
High Reward	553	103	**7.63**	< .001	0.92	0.93	0.08	**6.35**	< .001	1.25	602	136	**6.65**	< .001	1.15
Low Reward	668	144				0.80	0.12				861	288			

Mismatch trials. Paralleling our analyses of Match trials, we performed 3x2 repeated measures ANOVAs on reaction times, accuracy and efficiency scores with block (Social, Pain and Reward) and stimulus priority (High, Low) as within-subject factors (see table 2.6). Following the pattern of results from Match trials, there were no significant main effects of block. However, deviating from our results in Match trials, the main effect of priority was significant only for response times, but not accuracy or efficiency scores. Further, our analyses of Mismatch trials revealed a significant interaction between block and priority on reaction times, but not on accuracy or efficiency scores.

To further explore these effects, we performed paired-samples *t*-tests contrasting reaction times, accuracy and efficiency scores between high and low priority label-shape pairs in each block (see table 2.7). In Match trials, all these effects were significant. In contrast, in Mismatch trials, these analyses revealed no significant differences between high and low priority stimuli in the Pain block (all $p > .05$). Further, in the Reward block, high and low priority stimuli did not differ significant in accuracy and efficiency scores. For reaction times, the difference between high and low priority trials almost reached significance ($p = .054$). In the Social block, the difference between high and low priority stimuli was significant for reaction times and efficiency scores, but not accuracy.

Table 2.6. Results of 3x2 repeated measures ANOVAs comparing main effects of block (Social, Pain and Reward) and Priority (High, Low) in Mismatch trials. Results are presented separately for reaction time (RT), accuracy (ACC) and efficiency scores. Measures reported refer to the F value (F), degrees of freedom (DF), p-value (p) and partial eta-squared values (N2P) associated with these comparisons. All values are rounded to 3 significant figures or 2 decimal points, excepting p-values which are rounded to 3 decimal points.

	RT				ACC				Efficiency			
	F	**DF**	***p***	**N2P**	***F***	**DF**	***p***	**N2P**	***F***	**DF**	***p***	**N2P**
Block	0.69	2, 58	.504	0.02	0.82	2, 58	.446	0.03	0.05	2, 58	.950	0.00
Priority	**9.60**	1, 29	.004	0.25	0.02	1, 29	.878	0.00	1.92	1, 29	.176	0.06
Interaction	**6.67**	2, 58	.002	0.19	0.61	2, 58	.547	0.02	1.94	2, 58	.154	0.06

Table 2.7. Descriptive statistics and results of paired samples t-tests comparing high vs. low priority label-shape Mismatch pairs (table refers to labels only) within each block (Social, Pain and Reward). Separate analyses were performed for reaction times (RT), response accuracy (ACC) and efficiency. In order, the values given represent group means (M), standard deviations (SD), t-values (t) and degrees of freedom, p-values (p), and Cohen's d (d) as a measure of effect size associated with the relevant significance test. All values are rounded to 3 significant figures or 2 decimal points, excepting p-values which are rounded to 3 decimal points.

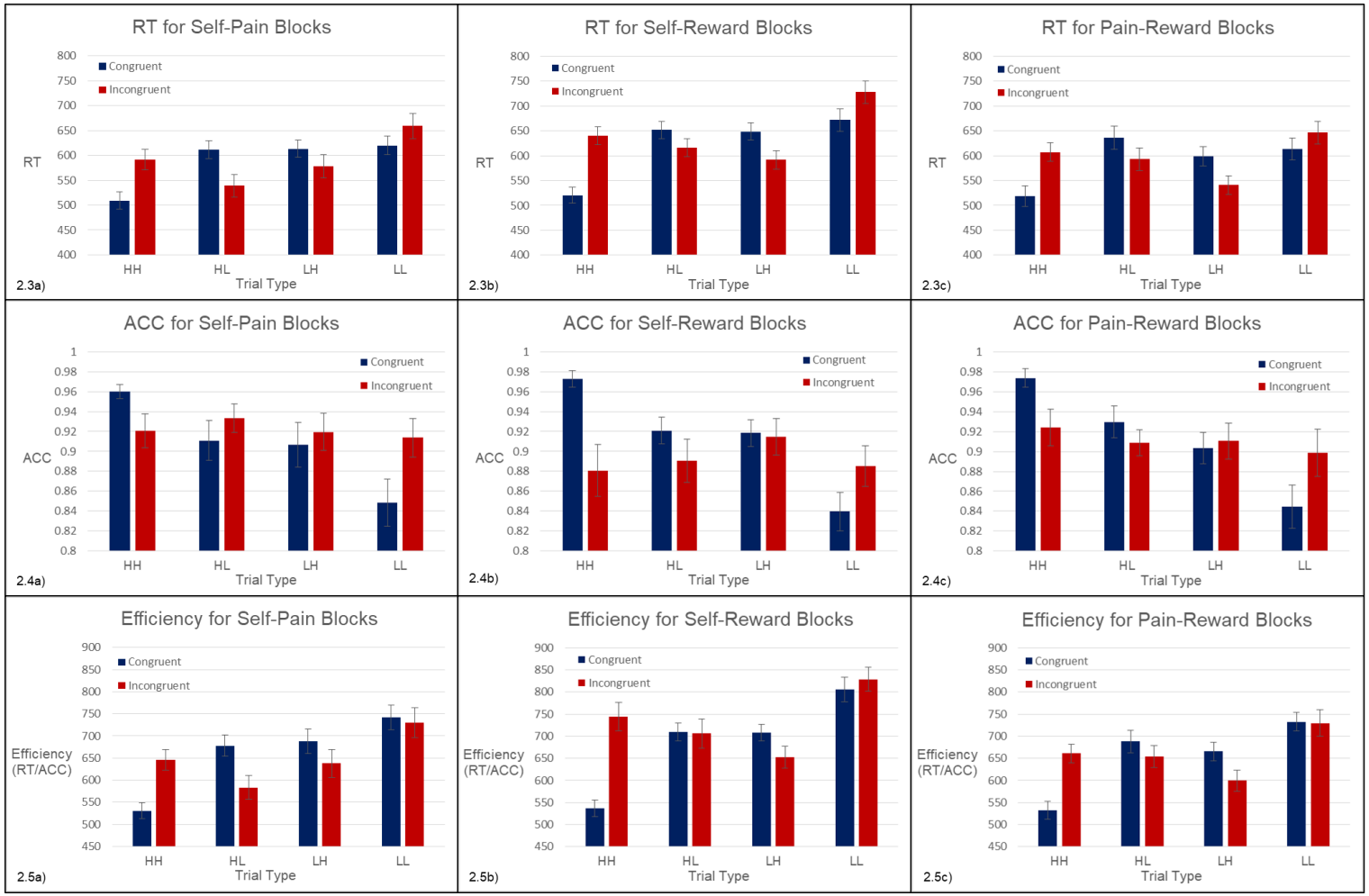
	RT					ACC					Efficiency				
	M	***SD***	***t*(29)**	***p***	***d***	***M***	***SD***	***t*(29)**	***p***	***d***	***M***	***SD***	***t*(29)**	***p***	***d***
Self	654	126	**4.08**	< .001	0.32	0.84	0.10	0.13	.901	0.02	787	146	**2.57**	.016	0.34
Stranger	698	145				0.84	0.13				852	227			
High Pain	661	97.0	1.18	.249	0.12	0.82	0.15	0.54	.596	0.07	841	238	0.63	.532	0.10
Low Pain	650	102				0.83	0.15				818	246			
High Reward	660	114	2.01	.054	0.18	0.87	0.08	1.04	.308	0.12	803	294	0.83	.412	0.09
Low Reward	681	125				0.80	0.12				827	227			

Competition Task (Computer Task 2)

Mean performance measures. We calculated mean response times, accuracy and efficiency scores for each of the 'Match' and 'Mismatch' trials in each of the 6 blocks (see figures 2.8, 2.9 and 2.10). In this task, Match and Mismatch trials comprised label-label stimulus pairs that were either congruent (high-high: HH, low-low: LL) or incongruent (high-low: HL, low-high: LH) for label priority. In congruent blocks (SPC, SRC, PRC), HH and LL were the Match trials and HL and LH were Mismatch trials. In incongruent blocks, HL and LH were the Match trials, and HH and LL were Mismatch trials. Stimulus pairs differed depending on block type: HH stimulus pairs contained two high priority labels, LL two low priority labels affiliated with the block type (e.g. in Self-Pain blocks, you-high pain was the HH label-label pair, stranger-low pain the LL label-label pair); HL and LH label-label pairs contained one high and one low priority stimulus each. The first letter indicates the stimulus type first named in the block type (i.e. in Self-Pain blocks, the first letter refers to the social label and the second letter to the pain label), and the second letter the stimulus type second named in the block type. H indicated this stimulus was high, L that it was low priority (e.g. in Self-Pain blocks, HL contained the 'you' and LH contained the 'stranger' stimulus).

The contrast between HL and LH label-label pairs in incongruent blocks was the crucial measure of the relative prioritisation of self-, pain- and reward-related stimuli. Mean reaction times, accuracy and efficiency scores for Self-Pain, Self-Reward and Pain-Reward blocks are displayed in figures 2.8-2.10 a-c. Our analyses for this task were focused on Match trials.

Deception Competition Task: Mean Performance Measures for Self-Pain, Self-Reward and Pain-Reward blocks



*Figures 2.3, 2.4 and 2.5 panels a, b and c. Mean response times (figure 2.3), accuracy (figure 2.4) and efficiency scores (figure 2.5) in the Competition task. Means are displayed for each trial type (HH, HL, LH, LL) in congruent (blue) and incongruent (red) blocks; each panel represents one block type (**a**: Self-Pain, **b**: Self-Reward, **c**: Pain-Reward). Error bars represent the standard error of the mean.*

Self-Pain Blocks

We conducted a series of 2x2 repeated measures ANOVAs with reaction times, accuracy and efficiency scores as dependent variables. Block congruency (Congruent: SPC-HH, SPC-LL; Incongruent: SPI-HL, SPI-LH) and self-priority (High: SPC-HH, SPI-HL; Low: SPC-LL, SPI-LH) were the within-subject factors (see table 2.8). Our analyses revealed consistent effects across all measures: There were no significant main effects of block congruency, but all main effects of self-priority as well as all interaction effects between block congruency and self-priority were significant.

To better understand these effects, we performed post-hoc repeated measures *t*-tests contrasting high and low self-priority stimulus pairs in congruent and incongruent Self-Pain blocks (see table 2.9).

In the congruent block (SPC), the difference between high (HH) and low (LL) self-priority stimuli was consistently significant across all measures (all $p < .05$). Responses were both faster and more accurate to the high (HH) than the low (LL) self-priority stimulus pair, and accordingly the effect was greater for efficiency scores ($d = 1.82$) than for reaction times ($d = 1.26$) or accuracy ($d = 1.30$) individually.

In the incongruent block (SPI), our results were inconsistent across measures. There was a significant difference between response times to high (HL) and low (LH) self-priority stimulus pairs, but not accuracy or efficiency. As in the congruent block, responses were faster to the high than the low self-priority stimulus pair; however, this effect was considerably smaller than any of the effects in the congruent block ($d = 0.37$).

Table 2.8. Results of 2x2 repeated measures ANOVAs comparing main effects of block congruency (Congruent: SPC-HH, SPC-LL; Incongruent: SPI-HL, SPI-LH) and self-priority (High: SPC-HH, SPI-HL; Low: SPC-LL, SPI-LH) in Match trials of Self-Pain blocks. Results are presented separately for reaction time (RT), accuracy (ACC) and efficiency scores as dependent variables. Measures reported refer to the F value (F), degrees of freedom (DF), p-value (p) and partial eta-squared values (N2P) associated with these comparisons. All values are rounded to 3 significant figures or 2 decimal points, excepting p-values which are rounded to 3 decimal points.

	RT				**ACC**				**Efficiency**			
	F	**DF**	***p***	**N2P**	***F***	**DF**	***p***	**N2P**	***F***	**DF**	***p***	**N2P**
Congruency	0.21	1, 23	.650	0.01	2.90	1, 23	.102	0.11	1.32	1, 23	.262	0.05
Self-Priority	**44.4**	1, 23	< .001	0.66	**17.0**	1, 23	< .001	0.43	**43.5**	1, 23	< .001	0.65
Interaction	**12.8**	1, 23	.002	0.36	**11.5**	1, 23	.003	0.33	**13.3**	1, 23	.001	0.37

Table 2.9. Descriptive statistics and results of paired samples t-tests comparing high and low self-priority Match trials in Self-Pain blocks (High self-priority: SPC-HH, SPI-HL; Low self-priority: SPC-LL, SPI-LH). Separate analyses were performed for reaction times (RT), response accuracy (ACC) and efficiency. In order, the values given represent group means (M), standard deviations (SD), t-values (t) and degrees of freedom, p-values (p), and Cohen's d (d) as a measure of effect size associated with the relevant significance test. All values are rounded to 3 significant figures or 2 decimal points, excepting p-values which are rounded to 3 decimal points.

		RT					**ACC**					**Efficiency**				
		M	***SD***	***t (23)***	***p***	***d***	***M***	***SD***	***t (23)***	***p***	***d***	***M***	***SD***	***t (23)***	***p***	***d***
SPC	**HH**	509	85.0	**8.21**	< .001	1.26	0.96	0.04	**5.04**	< .001	1.30	531	89.6	**7.36**	< .001	1.82
	LL	620	91.2				0.85	0.12				742	138			
SPI	**HL**	539	103	**2.40**	.025	0.37	0.93	0.07	0.70	.492	0.17	583	135	1.82	.083	0.38
	LH	579	113				0.92	0.09				638	156			

Self-Reward Blocks

We conducted a series of 2x2 repeated measures ANOVAs with reaction times, accuracy and efficiency scores as dependent variables. Block congruency (Congruent: SRC-HH, SRC-LL; Incongruent: SRI-HL, SRI-LH) and self-priority (High: SRC-HH, SRI-HL; Low: SRC-LL, SRI-LH) were the within-subject factors (see table 2.10).

Paralleling our results from the Self-Pain block, our analyses of the Self-Reward blocks revealed consistent effects across all measures: There were no significant main effects of block congruency, but all main effects of self-priority as well as all interaction effects between block congruency and self-priority were significant.

To better understand these effects, we performed post-hoc repeated measures *t*-tests contrasting high and low self-priority stimulus pairs in congruent and incongruent Self-Reward blocks (see table 2.11).

In the congruent block (SRC), the difference between high (HH) and low (LL) self-priority stimuli was consistently significant across all measures (all $p < .05$). Responses were both faster and more accurate to the high (HH) than the low (LL) self-priority stimulus pair, and accordingly the effect was greater for efficiency scores ($d = 2.29$) than for reaction times ($d = 1.58$) or accuracy ($d = 1.82$) individually. These results exactly match the pattern of results from the congruent Self-Pain block.

In the incongruent Self-Reward block (SRI), our results were also consistent across all measures: There were no significant differences between response times, accuracy or efficiency scores to high (HL) and low (LH) self-priority stimulus pairs. Our results differ from those in the incongruent Self-Pain block, in which responses were significantly faster to high than low self-priority stimulus pairs.

Table 2.10. Results of 2x2 repeated measures ANOVAs comparing main effects of block congruency (Congruent: SRC-HH, SRC-LL; Incongruent: SRI-HL, SRI-LH) and self-priority (High: SRC-HH, SRI-HL; Low: SRC-LL, SRI-LH) in Match trials of Self-Reward blocks. Results are presented separately for reaction time (RT), accuracy (ACC) and efficiency scores as dependent variables. Measures reported refer to the F value (F), degrees of freedom (DF), p-value (p) and partial eta-squared values (N2P) associated with these comparisons. All values are rounded to 3 significant figures or 2 decimal points, excepting p-values which are rounded to 3 decimal points.

	RT				ACC				Efficiency			
	F	**DF**	***p***	**N2P**	***F***	**DF**	***p***	**N2P**	***F***	**DF**	***p***	**N2P**
Congruency	0.47	1, 23	.500	0.02	0.08	1, 23	.780	0.00	0.21	1, 23	.650	0.01
Self-Priority	**26.5**	1, 23	< .001	0.54	**13.1**	1, 23	.001	0.36	**22.1**	1, 23	< .001	0.49
Interaction	**69.2**	1, 23	< .001	0.75	**34.8**	1, 23	< .001	0.60	**85.5**	1, 23	< .001	0.79

Table 2.11. Descriptive statistics and results of paired samples t-tests comparing high and low self-priority Match trials in Self-Reward blocks (High self-priority: SRC-HH, SRI-HL; Low self-priority: SRC-LL, SRI-LH). Separate analyses were performed for reaction times (RT), response accuracy (ACC) and efficiency. In order, the values given represent group means (M), standard deviations (SD), t-values (t) and degrees of freedom, p-values (p), and Cohen's d (d) as a measure of effect size associated with the relevant significance test. All values are rounded to 3 significant figures or 2 decimal points, excepting p-values which are rounded to 3 decimal points.

		RT					ACC					Efficiency				
		M	***SD***	***t (23)***	***p***	***d***	***M***	***SD***	***t (23)***	***p***	***d***	***M***	***SD***	***t (23)***	***p***	***d***
SRC	**HH**	520	77.7	**9.44**	< .001	1.58	0.97	0.04	**6.74**	< .001	1.82	537	94.0	**10.4**	<.001	2.29
	LL	672	111				0.84	0.10				806	137			
SRI	**HL**	616	89.6	1.51	.145	0.27	0.89	0.11	1.16	.260	0.24	706	164	1.68	.107	0.37
	LH	591	93.8				0.92	0.09				653	121			

Pain-Reward Blocks

We conducted a final series of 2x2 repeated measures ANOVAs on reaction times, accuracy and efficiency scores as dependent variables. Block congruency (Congruent: PRC-HH, PRC-LL; Incongruent: PRI-HL, PRI-LH) and pain-priority (High: PRC-HH, PRI-HL; Low: PRC-LL, PRI-LH) were the within-subject factors (see table 2.12).

Following the same pattern as the ANOVAs in Self-Pain and Self-Reward blocks, our analyses of the Pain-Reward blocks revealed no significant main effects of block congruency for any of the measures. The main effects of pain-priority as well as all interaction effects between block congruency and pain-priority were significant across all measures.

To better understand these effects, we performed a series of repeated measures *t*-tests contrasting high and low pain-priority stimulus pairs in congruent and incongruent Pain-Reward blocks (see table 2.13).

In the congruent block (PRC), the difference between high (HH) and low (LL) pain-priority stimulus pairs was consistently significant across all measures (all $p < .05$). Responses were both faster and more accurate to the high (HH) than the low (LL) pain-priority stimulus pair, and accordingly the effect was greater for efficiency scores ($d = 1.73$) than for reaction times ($d = 1.60$) or accuracy ($d = 0.91$) individually. These results exactly match the pattern of results from the congruent Self-Pain and Self-Reward blocks.

In the incongruent Pain-Reward block (PRI), our results were more mixed. There were no significant differences between accuracy or efficiency scores to high (HL) and low (LH) pain-priority stimulus pairs, although the difference between efficiency scores was near-significant ($p = .079$). Responses to high (HL) and low (LH) pain-priority stimulus pairs did differ significantly in mean reaction times, although this effect was smaller ($d = 0.50$) than any of the effects in the congruent Pain-Reward block (PRC). Responses were faster to low (LH)

than high (HL) pain-priority stimulus pairs. These results differ from those in the incongruent Self-Reward block in which neither stimulus type was prioritised over the other. They do however bear some similarity to the incongruent Self-Pain block, in which there was also no significant effect on response accuracy or efficiency, but responses were significantly faster to high than low self-priority stimulus pairs.

Table 2.12. Results of 2x2 repeated measures ANOVAs comparing main effects of block congruency (Congruent: PRC-HH, PRC-LL; Incongruent: PRI-HL, PRI-LH) and pain-priority (High: PRC-HH, PRI-HL; Low: PRC-LL, PRI-LH) in Match trials of Pain-Reward blocks. Results are presented separately for reaction time (RT), accuracy (ACC) and efficiency scores as dependent variables. Measures reported refer to the F value (F), degrees of freedom (DF), p-value (p) and partial eta-squared values (N2P) associated with these comparisons. All values are rounded to 3 significant figures or 2 decimal points, excepting p-values which are rounded to 3 decimal points.

	RT				ACC				Efficiency			
	F	**DF**	***p***	**N2P**	***F***	**DF**	***p***	**N2P**	***F***	**DF**	***p***	**N2P**
Congruency	0.01	1, 23	.927	0.00	0.00	1, 23	.965	0.00	0.13	1, 23	.724	0.01
Pain-Priority	**3.32**	1, 23	.082	0.13	**15.7**	1, 23	.001	0.41	**9.66**	1, 23	.005	0.30
Interaction	**41.2**	1, 23	< .001	0.64	**21.0**	1, 23	<.001	0.48	**51.8**	1, 23	< .001	0.69

Table 2.13. Descriptive statistics and results of paired samples t-tests comparing high and low pain-priority Match trials in Pain-Reward blocks (High pain-priority: PRC-HH, PRI-HL; Low pain-priority: PRC-LL, PRI-LH). Separate analyses were performed for reaction times (RT), response accuracy (ACC) and efficiency. In order, the values given represent group means (M), standard deviations (SD), t-values (t) and degrees of freedom, p-values (p), and Cohen's d (d) as a measure of effect size associated with the relevant significance test. All values are rounded to 3 significant figures or 2 decimal points, excepting p-values which are rounded to 3 decimal points.

		RT					ACC					Efficiency				
		M	***SD***	***t (23)***	***p***	***d***	***M***	***SD***	***t (23)***	***p***	***d***	***M***	***SD***	***t(23)***	***p***	***d***
PRC	**HH**	518	99.7	**5.90**	< .001	0.91	0.97	0.05	**5.84**	< .001	1.60	533	98.7	**6.95**	< .001	1.73
	LL	613	108				0.85	0.11				733	131			
PRI	**HL**	593	113	**3.13**	.005	0.50	0.91	0.06	0.08	.260	0.02	654	123	1.84	.079	0.46
	LH	541	93.3				0.91	0.09				599	116			

2.4. Discussion

Bias Task

The most important finding in the Bias task was the consistent prioritisation of high priority label-shape pairings over low priority label-shape pairings across all blocks (Social, Pain and Reward) in Match trials. These differences were significant for accuracy, reaction time and overall response accuracy, indicating a true effect rather than a speed-accuracy trade-off. This suggests that the paradigm was successfully adapted to show systematic prioritisation of pain for cognitive processing (or pain-bias) as well as self and reward. Further, the adaption of the PMP used here which contains only two shape-label pairs rather than three (Sui, He & Humphreys, 2012) seemed to be as effective as the established variant of the paradigm in creating a cognitive load that required participants to differentially allocate cognitive resources in order to optimally respond well to one shape-label pair. Had this not been the case, we would have expected optimal responding (100% response accuracy and fast response times) across all shape-label pairs without differentiation. The findings also indicate that the pain deception was successful, given that there was no reason to expect participants would prioritise the high pain-shape pair other than the fear of receiving painful electric stimulation after the experiment.

There were no overall differences between blocks, nor interactions between the degree of prioritisation of high vs. low priority label-shape pairings and blocks. We hypothesised that self-prioritisation would be at least as great as pain-prioritisation, if not greater. Our findings here suggest that they are prioritised to an equal degree, which is in line with our overall hypothesis that self-related information could constitute an effective distraction from pain. We further expected based on previous findings that self and reward would be prioritised equally, which was the case. We also tentatively expected comparable prioritisation of pain and reward

given that the healthy sample should not have an exacerbated pain-bias; this was also in line with our findings.

The lack of differences between the three biases could indicate a ceiling effect of the paradigm. When allocating cognitive resources to processing of the two Match shape-label pairs in this paradigm, there may be a maximum to processing of any stimulus pair can be prioritised. This would suggest that the Bias task is not suited to compare self-, pain- and reward-bias. The Competition task provided further information about the relative prioritisation of self, pain and reward when directly competing for cognitive resources which does indeed indicate that the Bias task may be limited in providing information about the relative magnitude of self-, pain- and reward-prioritisation due to a ceiling effect.

Although analyses found no differences between the degree of self-, pain- and reward-prioritisation, some differences can be seen in the effect sizes associated with the difference between high and low priority label-shape pairs in Social, Pain and Reward blocks. Specifically, prioritisation effects were consistently smallest in the Social block across all performance measures (d = 0.51-0.98), largest in the Reward block (d = 0.92-1.25) and in between in the Pain block (d = 0.76-1.23). This suggests that the prioritisation effect was largest in the Reward and smallest in the Social block in this study. Compared to the general standard for effect sizes, the prioritisation effect was medium to large in the Social and large in the Pain and Reward blocks.

In Mismatch trials, the pattern of findings was mixed and no significant effects were found for accuracy, indicating much less robust and clear effects. The main effect of priority was only significant for response times, suggesting there was overall less consistent prioritisation of high vs. low priority label-shape pairs than in Match trials. Post-hoc analyses showed that this difference only reached significance in the Social but not the Reward and Pain

block, and even then only for response times and efficiency scores. This difference between blocks was reflected in the significant interaction between block and stimulus priority found for response times.

These findings seems to be at odds with findings in Match trials, for which there were no interactions between block and stimulus priority and prioritisation effects were significant across all measures for all blocks. Moreover, effect sizes in Match trials seemed to indicate the self-prioritisation effect was smaller than pain- and reward-prioritisation. The lack of pain- and reward-prioritisation in Mismatch trials while self-prioritisation was at least found for response times and efficiency scores if not accuracy suggests there might be qualitative differences between self-, pain- and reward-prioritisation not evident from Match trials alone. For example, it is possible that self-prioritisation relies on more automatic[1] cognitive processes, while prioritisation of reward and pain depended on more strategic top-down mechanisms. This could be related to the outcome-based reward- and pain-prioritisation, while self-prioritisation was potentially less voluntary or intentional. Responses to Mismatch trials might reflect more automatic, bottom-up processing while responses to Match trials could be driven by more top-down strategic processes. However, these results are not in line with previous findings on self- and reward-bias (He, Sui & Humphreys, 2012). Taking a conservative view, these findings are most likely a chance result and will be treated as such unless replicated or supported in any of our next studies.

Competition Task

Across all congruent blocks and performance measures, high priority label-label stimulus pairs (HH) were prioritised over low priority label-label stimulus pairs (LL). This

[1] The term automatic is not used in the context of any specific framework of attention and refers only to a prioritisation for cognitive processing that does not rely on conscious effort or choice, but arises with little control on the side of the individual.

further supports our hypothesis that stimuli labelled as 'high priority', in line with our predictions, would be prioritised for cognitive processing compared to 'low priority' stimuli. Furthermore, the relative prioritisation of high-high compared to low-low stimulus pairs suggests that this adaptation of the PMP also effectively creates a cognitive load that forces participants to differentially allocate cognitive resources depending on stimulus priority, instead of responding to all stimuli with equally high accuracy and low speed.

Further validating this variation of the PMP, the interactions between block congruency and prioritisation effects were significant across all block types (Self-Pain, Self-Reward, Pain-Reward). However, there was no main effect of congruency, indicating same levels of overall performance in congruent and incongruent blocks of each type. Means of Match trials show that participants responded best to label-label pairs containing two high priority stimuli (HH in congruent blocks), and worst to pairs containing two low priority stimuli (LL in congruent blocks), while responses to label-label pairs that contained one low and one high priority stimulus were consistently in between these two extremes. This suggests that relative allocation of cognitive resources between the stimulus pairs (HH vs. LL and HL vs. LH) differed depending on block congruency. This supports the assumption that the participants' performance in this task is characterised by limited capacity, and relative prioritisation of one stimulus pair over another reflects its relatively higher priority for cognitive processing. The task should therefore be suitable to investigate the relative prioritisation of stimuli relating to self, pain and reward.

The crucial analyses to investigate competition between self, pain and reward was the relative prioritisation of Match trials in incongruent blocks. Analyses of the Self-Pain block revealed a prioritisation of the you-low pain compared to the stranger-high pain stimulus pair for response speed, but not accuracy or efficiency. This effect was associated with a small-medium effect size. This suggest that there may be a small prioritisation of self over pain for

response speed, but for accuracy and overall response efficiency, both are prioritised equally. These findings support our hypothesis that self would be prioritised to the same degree or more than pain. They are also a promising indication that self-related information may be an effective distraction from pain, although it is problematic to generalise from findings in this paradigm which uses visual stimuli relating to future pain to distraction paradigms in which pain is experienced concurrently.

Analyses of the Self-Reward block showed no significant differences between you-low reward and stranger-high reward stimulus pairs. This finding is in line with our hypothesis that self and reward would be prioritised equally, as well as previous research on the relationship and relative prioritisation of self and reward (Sui, He & Humphreys, 2012; Sui & Humphreys, 2015).

Finally, analyses of the Pain-Reward block showed prioritisation of the low pain-high reward over the high pain-low reward stimulus pair for reaction time, but not accuracy and efficiency. This effect was associated with a moderate effect size. This suggests that reward was prioritised over pain for response speed, while they were prioritised to the same degree for accuracy and overall response efficiency. Our hypothesis that pain and reward would be prioritised to the same degree was therefore supported for performance accuracy and efficiency, but not response speed.

The prioritisation of reward over pain for response speed is in line with the findings from Self-Pain and Pain-Reward blocks. Self was prioritised over pain, self was prioritised to an equal degree as reward and reward was prioritised over pain. The relative prioritisations of the three stimulus types are therefore internally consistent, i.e. self and reward are both prioritised equally and more highly than pain. These effects are only present for response speed however, and are not matched in accuracy and efficiency. This could suggest that response

times are the most sensitive out of our three performance measures. However, it certainly means that these effects are not large, and a larger sample may be required to verify these findings.

Limitations

Comparison of self-, pain- and reward-bias as well as competition between them in our study is circumstantial. Variations in the monetary amounts associated with reward labels and type and severity of pain linked to pain stimuli would most likely alter the magnitude of reward- and pain- bias and change the relationships between these stimuli. Our findings can therefore not easily be generalised to prioritisation of other amounts of reward, or other types and intensities of pain in a healthy population.

Though this is certainly a concern, it is indicative of methodological problems in this area. Previous studies investigating pain-bias have predominantly used lexical and pictorial stimuli expected to evoke pain-related processing due to learned associations. As discussed above, a recent meta-analysis has cast doubt on whether these stimuli are able to evoke pain-related processing (Crombez, Van Ryckeghem, Eccleston & Van Damme, 2013). Further, relying on learned associations to evoke pain-related processing necessarily results in individual differences in the degree to which each stimulus evokes pain-related processing in participants.

In our paradigm, participants were informed that high and low pain outcomes would be 'strongly' and 'mildly' painful respectively. Although the intensity of 'strong' and 'mild' pain imagined by each participant would likely vary depending on individual differences, they should be standardised to participants' individual pain scales, i.e. a participant who has a high tolerance for pain would imagine a more painful stimulus as the 'strong' pain outcome, while a participant with a low pain threshold would likely imagine a less intense pain stimulus in

absolute terms. Overall however, we would have expected each participant to imagine the strong pain stimulus as on the high end of their individual pain scale, and the mild pain stimulus as near the low end. If true, this would mean our study assessed bias towards a specific pain stimulus standardised for participants' subjective pain thresholds, an improvement compared to paradigms using stimuli that rely on inherently unstandardized learned associations to evoke pain-processing. However, as we did not measure the pain intensity participants expected based on the descriptors of 'strongly' and 'mildly' painful, we cannot know these expectations differed and were standardised across participants' pain scales. This could be addressed for example by asking participants at the end of the experiment to rate how painful they expected a) the mildly painful and b) the strongly painful electric stimulation would be.

Another problem is the efficacy of the deception used in this study. We concluded from the prioritisation of the 'high pain' over the 'low pain' stimulus that the deception was successful. However, it is possible that the 'high pain' stimulus was prioritised independently of the expected pain outcomes, for example due to perceptual properties. If the 'high pain' stimulus was simply more perceptually salient than the 'low pain' stimulus, we cannot assume that prioritisation of this stimulus is related to pain-processing. In this case we could not reasonably draw conclusions about the relationship between self and pain from our findings.

We cannot rule this out as we did not include a systematic deception check in this study. However, it should be considered that there was no outcome associated with self-related stimuli. Even if participants doubted the deception, the chance that poor performance might be penalised with pain outcomes should have caused them to prioritise the high pain-stranger over the low pain-you stimulus pair in the Competition task; instead, stimulus pairs containing the self-label were consistently highly prioritised. This must still be considered a positive indication for our hypothesis that self-related information could be an effective distractor from pain: It adds to findings on the strength and consistency of the self-prioritisation effect.

We recorded some spontaneous remarks made by participants, which suggested that some believed the deception, others did not, and others believed the deception in the beginning but began to believe during the experiment that they were unlikely to receive painful electric stimulation at the end. This suggests that more participants may have believed the deception during the first part of the experiment (Bias task) than the second part (Competition task). This could have affected the comparatively low prioritisation of pain relative to self and reward found in the Competition task, while all types of information were prioritised equally in the Bias task.

While future studies using this paradigm in a deception setting should take care to include a deception check, the present findings could by disambiguated by a control experiment employing the exact same procedure without including any deception for pain and reward outcomes (i.e. not linking pain / reward stimuli to any outcomes). If such a study found the same results as the present study, this would indicate that a) deception in this study was not successful, and b) responses to pain stimuli in this study were not determined by the association with pain outcomes but by perceptual or other characteristics.

Chapter 3

3

A No-Deception Control for the Pain Adaptation of the Perceptual Matching Paradigm

3.1. Introduction

Our first study adapted the Perceptual Matching Paradigm (PMP; Sui, He & Humphreys, 2012) to assess a) pain-bias as well as self- and reward-bias in the Bias task, and b) competition between self and pain, self and reward and pain and reward in the Competition task. The results of this study taken at face value were promising: Pain was prioritised to the same degree as reward and self in the Bias task, and in the Competition task, self and reward were both prioritised equally and both more strongly than pain for response speed, but to the same degree as pain for response accuracy and efficiency. This suggested that our Bias task adaptation of the PMP could be a useful measure of pain-bias. Further, the Competition task seemed effective in assessing the competition for cognitive resources between information relating to self, pain and reward, and seemed to indicate that healthy participants would prioritise both self and reward to the same degree as or more strongly than pain.

However, two key limitations prevented us from drawing strong conclusions from our findings. Firstly, we could not be certain that our deception was successful. The ability of our pain-stimuli to evoke pain-related processing depended on the association between those

stimuli and expected pain outcomes which was created by our deception manipulation. Our pain stimuli were not chosen for their inherent association with pain like a word or picture might be; although lightning bolt symbols could be associated with pain for some participants, we have no reason to suspect such an inherent relationship. Therefore, if participants did not expect to receive strongly or mildly painful electric stimulation depending on their performance in trials containing 'high pain' and 'low pain' stimuli respectively, the stimuli would likely not have evoked pain-related processing. We did not include a deception check in the study, and therefore have no way of knowing whether participants believed in the deception, or continued to believe in the deception throughout the experiment.

Secondly, even if participants did believe the deception, we cannot be certain that the high pain stimulus was prioritised due to the deception. Stimuli relating to self and reward were chosen based on previous studies, which have demonstrated that the self- and reward-bias effects can be shown using a variety of stimuli varying in word frequency and length for self-bias, and magnitude of reward for reward-bias (Sui, He & Humphreys, 2012; Sui & Humphreys, 2015). This makes it less probable that these prioritisation effects are the result of a purely perceptual advantage of for the example the 'you' over the 'stranger' stimulus. However, in our study, only one set of pain-related stimuli was tested. It is therefore possible that a purely perceptual advantage of the high pain over the low pain stimulus gave rise to the consistent prioritisation of one over the other.

To address both these limitations, we designed the control study reported here. We repeated the method as described in chapter 2 without applying any deception regarding pain and reward outcomes, i.e. no pain or reward outcomes were mentioned to participants and none were delivered. Although pain stimuli should now not be associated with pain, they will still be referred to as pain stimuli as they are identical to the stimuli that were used to represent pain in the deception study. We predicted that under these conditions, high pain label-shape pairs

would no longer be prioritised over low pain label-shape pairs in the Bias task while you-shape pairs would still be prioritised over stranger-shape pairs, and high reward-shape over low reward-shape pairs.

We expected the lack of outcome deception to affect prioritisation of pain-related shape-label pairs but not reward-related shape-label pairs based on previous studies which found reward-bias using the PMP without employing reward-related deception (Sui, He & Humphreys, 2012). Previous findings suggest that reward labels in the PMP inherently evoke reward-related processing, rather than acquiring this association through outcome expectations. However, it is possible that the deception enhanced reward-prioritisation, in which case we would expect a smaller degree of reward-prioritisation in the present study than in the deception design. Self-prioritisation should remain unchanged as this should not be affected by the outcome deception, and can be used as a fixed point for comparison. The previous study showed no difference between the prioritisation of self, pain and reward in the Bias task. As we expect a decreased prioritisation of pain and possibly reward in this study, we predict that pain-prioritisation in the Bias task of the present study will be decreased compared to self-prioritisation. Reward will be prioritised either to the same degree as self or lower, but more strongly than pain.

In the Competition task, we expect self and reward to be prioritised over pain stimuli. This was already the case for response speed in the deception study; however, if the deception was effective, the prioritisation of self and reward over pain stimuli should be greater in the present study. We further expected self to be prioritised to the same degree or more than reward.

Findings from this study will allow various conclusions. If our hypotheses regarding the decreased prioritisation of pain in the present study are met, we can infer that

1) the prioritisation in the deception study was not due to the perceptual salience of high vs. low priority pain stimuli and was indeed due to the differential pain associations of these stimuli, and

2) the deception in the previous study was successful.

This would address two key limitations of the previous study. However, there are also important conclusions to be drawn if the hypotheses for the present study are not supported. If the same pattern of pain-prioritisation is observed here without the deception setting, we can certainly conclude that a factor other than the pain deception gave rise to this relative prioritisation. This could be the relative perceptual salience of the high vs. low pain stimulus, or any number of other reasons. However, from such findings, we could not conclude that the deception failed. Although we could then be certain the deception did not cause the pain-prioritisation observed in the deception study, the deception may still have been successful but without causing any observable change. This would increase the importance of including a deception check in any future experiments employing a similar PMP deception paradigm.

3.2. Methods

Sample

Sample size. We aimed to match the sample size from the deception study, in which 30 participants completed the Bias task and 24 of those also completed the Competition task. This allowed sufficient power to conduct the same repeated measures analyses as performed in the deception study. Due to the post-hoc nature of the comparison between the deception and control studies, the between-subjects comparison across the samples is not covered by our power analysis and may be underpowered.

Participants. Twenty-seven (18f, 9m) healthy, young adults participated in this experiment. We invited individuals aged 18-35, with a good command of the English language, normal or corrected-to-normal vision, and no current or history of neurological condition to participate in this study. Participants were excluded if they had participated in the deception Study (see chapter 2). The study was advertised through posters, social media, word-of-mouth and the Research Participation Scheme (RPS) of the Department of Experimental Psychology (University of Oxford). Undergraduate psychology students who participated through RPS (n = 12) received course credits for their participation; all other participants (n = 15) were reimbursed for their time.

Sample comparisons. The Bias task was completed by 30 participants in the deception (15f, 15m) and 27 participants (18f, 9m) in the control study. The proportion of female participants who completed the Bias task differed significantly between the studies ($X^2(4, N = 84) = 86.39$, $p < .001$). Participants who completed the Bias task in the deception study were also significantly older than those in the control study ($M_D = 25.17$, $SD_D = 4.18$ $n_D = 29$; $M_C = 21.41$, $SD_D = 3.2$, $n_C = 27$; $t(54) = 3.77$, $p < .001$, $d = 1.01$).

The proportion of female participants who completed the Competition task was also significantly lower in the deception (11f, 13m) compared to the control study (18f, 9m), with $X^2(4, N = 84) = 87.70$, $p < .001$. Participants who completed the Competition task in the deception study were older than those in the control study ($M_D = 25.5$, $SD_D = 4.22$ $n_D = 24$; $M_C = 21.41$, $SD_D = 3.2$, $n_C = 27$; $t(49) = 3.93$, $p < .001$, $d = 1.09$).

Design & Procedure

Design & Procedure. Design, procedure and stimulus material of this study were identical to those in the deception study (see chapter 2) for the Bias and Competition computer tasks. In contrast to the deception study, participants were not deceived regarding

monetary reward or pain outcomes linked with performance in pain- and reward-related trials in the Bias and Competition tasks. Study advertisements did not mention pain or painful electric stimulation, participants were not lead to expect a monetary reward or painful electric stimulation depending on their performance in the computer tasks. As in the deception study, no monetary reward or painful electric stimulation outcomes were administered at the end of the experiment.

Data Handling

Measures. We derived 3 performance measures for each condition (2 Match and 2 Mismatch pairs for each block; see chapter 2) from each participant: Response time (RT), accuracy (ACC) and efficiency scores. Accuracy was calculated as proportion of correct responses and ranged from 0 to 1. We calculated mean response times (RT) from accurate responses made between 200ms and 1600ms after stimulus onset. The cut-off criterion for late responses was set to match that chosen in chapter 2. As in chapter 2, less than 1% of trials were removed in the Bias task due to slow responding, and approximately 1% in the Competition task.

From these measures, we calculated the indirect performance measure of efficiency scores as

$$efficiency = RT / ACC,$$

which was used to highlight overall performance and identify cases of speed-accuracy trade-off (i.e. when participants responded faster but less accurately or vice versa to one trial type).

Exclusion. No participants' data were excluded from either computer task on the basis of missing data or low accuracy; however, data from 2 participants was not collected for the Competition task due to technical failure.

3.3.1. Results: Bias Task

Bias Task (Computer Task 1): Control Study

Mean response times, accuracy and efficiency scores. Sample means for reaction times, accuracy and efficiency scores in each block (Social, Pain and Reward) and trial type (high vs. low priority) are displayed in figure 3.1.

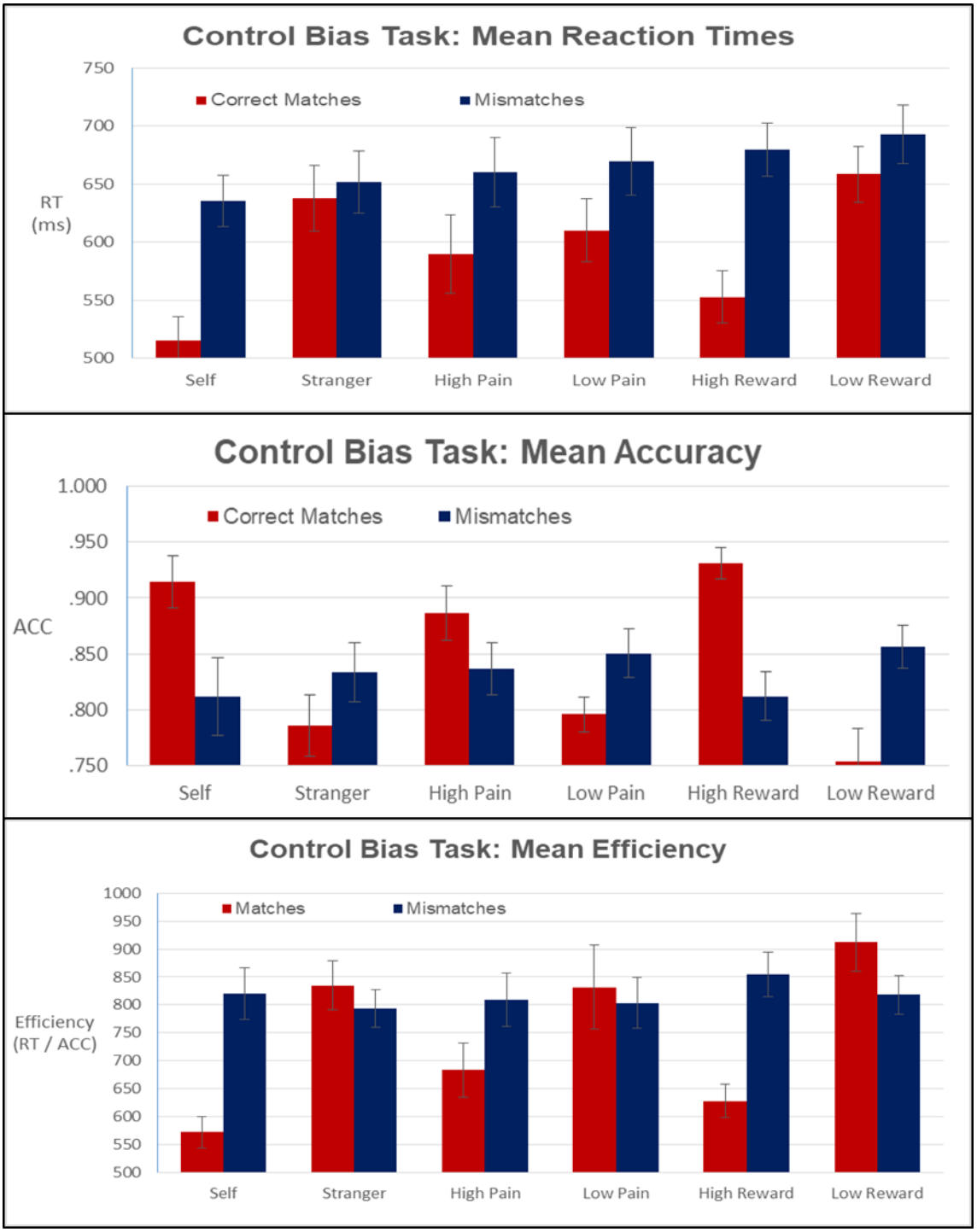


*Figure **3.**1. Mean response times (top), accuracy (middle) and efficiency scores (bottom) for each block and shape-label pair in the Bias task (control study). Figures display means for Match (red) and Mismatch (blue) shape-label pairs. Error bars represent the standard error of the mean.*

Match trials. We performed 3x2 repeated measures ANOVAs of reaction times, accuracy and efficiency scores with block (Social, Pain and Reward) and stimulus priority (High, Low) as within-subject factors (see table 3.1). Our analyses showed no significant main effects of block but significant main effects of stimulus priority across all performance measures, and a significant interaction between block and stimulus priority for reaction time, but not accuracy or efficiency. This suggests that prioritisation of high relative to low priority label-shape pairs differed between blocks for response speed, but not response accuracy or efficiency.

To further investigate this interaction effect, we used paired samples *t*-tests to compare high and low priority stimulus pairs within each block. Table 3.2 gives an overview of the relevant group means and results of associated significance tests. Our analyses show that self was consistently prioritised over stranger in the Social block, and high reward over low reward in the Reward block. However, in the Pain block, differences between high and low pain stimuli were not as clear or consistent. Reaction times to high and low pain stimulus pairs did not differ significantly, but responses were significantly more accurate to high pain compared to low pain label-shape pairs. This effect was associated with a much lower effect size ($d = 0.62$) than the equivalent effects in the Social ($d = 0.96$) and Reward ($d = 1.47$) blocks. Differences between high and low pain stimuli were near-significant for efficiency scores ($p = .053$), but again the effect was associated with a notably smaller effect size ($d = 0.45$) than the effects in the Social ($d = 1.38$) and Reward ($d = 1.32$) blocks.

Overall, differences between high and low priority stimuli were clearly pronounced and statistically significant across all measures in the Social and Reward blocks, while effects reached significance only for accuracy but not reaction times and efficiency in the Pain block. Effects in the Pain block were also consistently associated with smaller effect sizes than the corresponding values from Social and Reward blocks. These results indicate less consistent

and less strong differences between high and low priority stimuli in the Pain block compared to the Social and Reward blocks.

Table 3.1. Results of 3x2 repeated measures ANOVAs comparing main effects of block (Social, Pain and Reward) and priority (High, Low) in Match trials. Results are presented separately for reaction time (RT), accuracy (ACC) and efficiency measures. Values reported refer to the F value, degrees of freedom (DF), p-value (p) and partial eta-squared values (N2P) associated with these comparisons. All values are rounded to 3 significant figures or 2 decimal places, excepting p-values which are rounded to 3 decimal places.

	RT				ACC				Efficiency			
	F	**DF**	***p***	**N2P**	***F***	**DF**	***p***	**N2P**	***F***	**DF**	***p***	**N2P**
Block	1.88	2, 52	.163	0.07	0.70	2, 52	.930	0.00	1.50	2, 52	.232	0.06
Priority	**30.2**	1, 26	< .001	.54	**46.3**	1, 26	< .001	0.64	**41.4**	1, 26	< .001	0.61
Interaction	**8.23**	2, 52	.001	.24	2.03	2, 52	.142	0.07	1.75	2, 52	.184	0.06

Table 3.2. Descriptive statistics and results of paired samples t-tests for Match trials of the Bias Task. Values are presented for reaction times (RT), response accuracy (ACC) and efficiency. In order, the values given represent group means (M), standard deviations (SD), t-values (t) and degrees of freedom associated with the relevant significance test, p-values (p), and Cohen's d (d) as a measure of effect size. All values are rounded to 3 significant figures or 2 decimal places, excepting p-values which are rounded to 3 decimal places.

	RT					ACC					Efficiency				
	M	***SD***	***t*(26)**	***p***	***d***	***M***	***SD***	***t*(26)**	***p***	***d***	***M***	***SD***	***t*(26)**	***p***	***d***
Self	515	106	**7.34**	< .001	0.96	0.91	0.12	**5.96**	< .001	0.96	572	145	**6.34**	< .001	1.38
Stranger	538	147				0.79	0.15				835	228			
High Pain	590	175	0.82	.418	0.13	0.89	0.13	**2.51**	.019	0.62	683	154	2.03	.053	0.45
Low Pain	610	140				0.80	0.17				832	390			
High Reward	578	116	**4.68**	< .001	0.67	0.93	0.08	**5.04**	< .001	1.47	628	152	**5.23**	< .001	1.32
Low Reward	658	124				0.75	0.15				912	265			

Mismatch trials. We performed a series of 3x2 repeated measures ANOVAs with block (Social, Pain and Reward) and priority of the label contained in each shape-label pair (High, Low) as within-subjects factors and reaction times, accuracy and efficiency as dependent variables (see table 3.3). Our analyses showed no significant main effects of block, significant main effects of stimulus priority for accuracy and reaction times but not efficiency scores, and no significant interactions between block and stimulus priority. This suggests that there were some differences in response speed and accuracy between high and low priority label-shape pairs, but these differences did not depend on blocks and performance was overall comparable across blocks. The lack of main effect of priority in efficiency scores could indicate that speed-accuracy trade-offs caused priority effects in response speed and accuracy.

To disambiguate these findings, we carried out paired samples *t*-tests to compare high and low priority label-shape Mismatch pairs within each block (see table 3.4). There were no significant differences between high and low priority label-shape pairs in the Social or the Pain block. In the Reward block, response speed to high and low priority label-shape pairs did not differ significantly, but response accuracy and efficiency did. Notably, response accuracy was higher for the low reward than the high reward label-shape pair, but responses were more efficiency to the high compared to the low reward label-shape pair. This supports the suggestion of a speed-accuracy trade-off, which was already indicated by the results of our ANOVA (see table 3.3).

Table 3.3. Results of 3x2 repeated measures ANOVAs comparing main effects of block (Social, Pain and Reward) and priority (High, Low) in Mismatch trials. Results are presented separately for reaction time (RT), accuracy (ACC) and efficiency measures. Measures reported refer to the F value, degrees of freedom (DF), p-value (p) and partial eta-squared values (N2P) associated with these comparisons. All values are rounded to 3 significant figures or 2 decimal places, excepting p-values which are rounded to 3 decimal places.

	RT				ACC				Efficiency			
	F	**DF**	***p***	**N2P**	***F***	**DF**	***p***	**N2P**	***F***	**DF**	***p***	**N2P**
Block	2.29	2, 52	.111	0.08	0.38	2, 52	.680	0.02	0.38	2, 52	.685	0.01
Priority	**4.47**	1, 26	.044	0.15	**6.39**	1, 26	.018	0.20	1.69	1, 26	.205	0.06
Interaction	0.11	2, 52	.900	0.00	0.62	2, 52	.540	0.02	0.29	2, 52	.753	0.01

Table 3.4. Descriptive statistics and results of paired samples t-tests for Mismatch trials of the Bias Task. Values are presented for reaction times (RT), response accuracy (ACC) and efficiency. In order, the values given represent group means (M), standard deviations (SD), t-values (t) and degrees of freedom associated with the relevant significance test, p-values (p), and Cohen's d (d) as a measure of effect size. All values are rounded to 3 significant figures or 2 decimal points, excepting p-values which are rounded to 3 decimal points.

	RT					ACC					Efficiency				
	M	***SD***	***t*(26)**	***p***	***d***	***M***	***SD***	***t*(26)**	***p***	***d***	***M***	***SD***	***t*(26)**	***p***	***d***
Self	636	114	1.24	.225	0.12	0.81	0.18	0.90	.376	0.14	820	239	1.00	.515	0.13
Stranger	651	139				0.83	0.14				794	176			
High Pain	660	156	0.95	.350	0.06	0.84	0.12	0.79	.440	0.12	683	254	2.60	.053	0.45
No Pain	670	152				0.85	0.11				832	390			
High Reward	680	118	1.52	.140	0.10	0.81	0.11	**2.96**	.007	0.42	628	152	**4.24**	< .001	0.95
No Reward	693	132				0.86	0.10				776	158			

Bias Task: Deception Check

Analyses. To investigate whether deceiving participants about pain and reward outcomes (see chapter 2) impacted response patterns in the Pain and Reward blocks of the Bias task, we contrasted the results from this study (control: n = 27) with those from the previous study (deception: n = 30). Our analyses focused exclusively on Match rather than Mismatch trials. In the analyses of the deception and control study Bias tasks, we found more robust and consistent effects in Match than in Mismatch trials. We therefore expected that differences between the deception and control study, if present, would be more easily detectable in Match than Mismatch trials. We omitted to conduct analyses on Mismatch trials to reduce type I errors.

Match trials. First, we conducted mixed 2x3x2 ANOVAs with study design (deception, control) as between-subjects factor and block (Social, Pain, Reward) and stimulus priority (high, low) as within-subjects factors (see table 3.5). These ANOVAs revealed different patterns of responding across our three performance measures (response time, accuracy and efficiency).

There was a significant main effect of study design for reaction times, but not accuracy or efficiency scores. This indicates that response times differed between the deception and control study, but response accuracy and efficiency did not. There were no main effects of block, indicating overall comparable levels of performance in Social, Pain and Reward blocks. The main effect of stimulus priority was significant across all performance measures and associated with moderate-large effect sizes. This indicates there was overall differential prioritisation of shape-label pairs across blocks and study designs.

There was no significant interaction between study design and block (2x3), suggesting that overall performance in the Social, Pain and Reward block did not differ between the

deception and control study design. There was also no significant interaction between study design and priority (2x2), indicating that overall, differential prioritisation between shape-label pairs did not differ between the deception and control study design.

A significant interaction between block and stimulus priority (3x2) was found for response speed but not accuracy or efficiency, indicating that differential prioritisation of high and low priority label-shape pairs did differ between blocks for the speed of responses, but not accuracy or efficiency. The effect for response times, although significant, was small.

Another significant interaction was found between study design, block and stimulus priority (2x3x2) for response times but not response accuracy or efficiency. This suggests that for response speed, differences in differential prioritisation of high and low priority label-shape pairs between blocks depended on study design, i.e. the presence or absence of deception. However, this was not the case for response accuracy or efficiency, and the effect in response times was associated with a small effect size.

Table 3.5. Results of mixed 2x3x2 ANOVAs with study (deception, control) as between-subjects factor, and block (Social, Pain and Reward) and shape-label pair priority (High, Low) as within-subjects factors. Separate analyses were performed with reaction time (RT), accuracy (ACC) and efficiency scores as dependent variables. Measures reported refer to the F value (F), degrees of freedom (DF), p-value (p) and partial eta-squared values (N2P) associated with these comparisons. All values are rounded to 3 significant figures or 2 decimal points, excepting p-values which are rounded to 3 decimal points.

	RT				ACC				Efficiency			
	F	**DF**	***p***	**N2P**	***F***	**DF**	***p***	**N2P**	***F***	**DF**	***p***	**N2P**
Study	**1890**	1, 55	< .001	0.97	0.42	1, 55	.519	0.01	0.01	1, 55	.936	0.00
Block	1.05	2, 110	.354	0.02	0.06	2, 110	.938	0.00	0.3	2, 110	.740	0.01
Priority	**105**	1, 55	< .001	0.66	**104**	1, 55	< .001	0.65	**96.6**	1, 55	< .001	0.64
Study*Block	1.35	2, 110	.263	0.02	0.34	2, 110	.712	0.01	1.58	2, 110	.210	0.03
Study*Priority	1.07	1, 55	.306	0.02	0.04	1, 55	.848	0.00	0.1	1, 55	.752	0.00
Block*Priority	**3.83**	2, 110	.025	0.07	0.70	2, 110	.499	0.01	1.01	1, 55	.369	0.02
Study*Block*Priority	**6.22**	2, 110	.003	0.10	2.35	2, 110	.101	0.04	1.26	1, 55	.290	0.02

To explore the 3-way interaction between study design, block and stimulus priority in depth, we performed separate 2x2 mixed ANOVAs for each block (Social, Pain and Reward) with study design as the between-subjects variable (deception vs. control) and stimulus priority (high vs. low) as the within-subjects variable. The results of our analyses (see table 3.6) showed no significant main effects of study design, suggesting overall performance in each block type was comparable across the deception and control study. The main effect of priority was consistently significant across all measures, and associated with small-moderate effect sizes. This indicates overall differential prioritisation of one shape-label pair over another across study designs.

The interaction between study design and stimulus priority was significant for response times in the Social and Pain blocks, but not the Reward block. However, though significant, these interactions were associated with small effect sizes. For accuracy and efficiency, none of the interaction effects were significant as expected based on the lack of effects in the mixed 2x3x2 ANOVA.

Table 3.6. Results of mixed 2x2 ANOVAs comparing main effects of study design (Deception, Control) and stimulus priority (High, Low) in Match trials. Results are presented separately for reaction time (RT), accuracy (ACC) and efficiency measures. Measures reported refer to the F value (F), degrees of freedom (DF), p-value (p) and partial eta-squared values (N2P) associated with these comparisons. All values are rounded to 3 significant figures or 2 decimal points, excepting p-values which are rounded to 3 decimal points.

		RT			ACC			Efficiency		
		F (1,55)	***p***	**N2P**	***F(1,55)***	***p***	**N2P**	***F(1,55)***	***p***	**N2P**
Social	**Study**	1.18	.280	0.02	0.01	.920	0.00	1.30	.260	0.02
	Priority	**58.4**	< .001	0.52	**58.3**	< .001	0.51	**57.7**	< .001	0.51
	Interaction	**4.39**	.040	0.07	0.02	.900	0.00	0.30	.590	0.01
Pain	**Study**	0.00	.960	0.00	0.37	.550	0.01	0.17	.690	0.00
	Priority	**13.4**	.001	0.20	**28.0**	< .001	0.34	**19.1**	< .001	0.26
	Interaction	**5.24**	.026	0.09	1.83	.180	0.03	1.33	.250	0.02
Reward	**Study**	0.07	.790	0.00	1.15	.290	0.02	0.64	.430	0.01
	Priority	**73.8**	< .001	0.57	**59.4**	< .001	0.52	**68.0**	< .001	0.55
	Interaction	2.35	.130	0.04	1.70	.200	0.03	0.14	.710	0.00

We further explored these effects using independent samples *t*-tests to directly compare responses to each shape-label pair across studies (deception vs. control). The results of our analyses (see table 3.7) showed no significant differences between the two studies on any individual shape-label pair.

Given the significant interaction between study design and priority of shape-label pairs in the mixed 2x2 ANOVA of response times in the Pain block (see above), these results indicate that the small interaction effect revealed by the ANOVA is driven by a combination of both slightly faster responses to high pain label-shape pairs and slightly slower responses to low pain label-shape pairs in the deception compared to the control study. This suggests that prioritisation of high over low pain label-shape pairs was increased by a very small margin in the deception compared to the control study.

Superficially, the pattern of response times in the Social block seems similar to that seen in the Pain block. The mixed 2x2 ANOVA here also revealed a significant interaction effect of response times but not accuracy or efficiency (see table 3.6). Further, there are no significant differences when study designs are contrasted individually in independent samples *t*-tests of each trial type (see table 3.7). However, in the Social block, responses in the deception study were slower for both shape-label pairs compared to the control study. This affected the two shape-label pairs differentially: Responses were much slower for deception you-shape pairs and only a little slower for deception stranger-shape pairs than in the control study. This suggests that response speed in the Social block was overall slowed in the deception study, but more so in you-shape than stranger-shape trials.

The Reward block consistently showed no differences between study designs (deception vs. control) in either trial type. The mixed 2x2 ANOVA showed no significant interactions or main effects of study design for any of the measures (see table 3.6), and the

post-hoc *t*-tests showed no significant differences between the studies on any performance measures in either trial type (see table 3.7). This suggests that the study design (deception vs. control) had no detectable impact on performance in the Reward block.

Table 3.7. Descriptive statistics and results of independent samples t-tests comparing Match trials of each shape-label pair (labels: self, stranger, high pain, low pain, high reward, low reward) across study designs (deception, control). Values are presented for reaction times (RT), response accuracy (ACC) and efficiency. In order, the values given represent group means (M), standard deviations (SD), t-values (t) and degrees of freedom, p-values (p), and Cohen's d (d) as a measure of effect size associated with the relevant significance test. All values are rounded to 3 significant figures or 2 decimal points, excepting p-values which are rounded to 3 decimal points.

	RT					ACC					Efficiency				
	M	***SD***	***t*(55)**	***p***	***d***	***M***	***SD***	***t*(55)**	***p***	***d***	***M***	***SD***	***t*(55)**	***p***	***d***
Self	577	146	1.82	.074	0.49	0.91	0.10	0.04	.971	0.01	643	190	1.57	.122	0.42
Self (c)	515	106				0.91	0.12				572	145			
Stranger	647	127	0.26	.798	0.07	0.78	0.16	0.14	.892	0.04	870	268	0.53	.596	0.14
Stranger (c)	638	147				0.79	0.15				835	228			
High Pain	554	101	0.96	.344	0.25	0.93	0.10	1.61	.112	0.42	606	164	1.39	.172	0.36
High Pain (c)	590	175				0.89	0.13				683	254			
Low Pain	642	130	0.91	.369	0.24	0.78	0.15	0.34	.732	0.09	861	292	0.32	.75	0.08
Low Pain (c)	610	140				0.80	0.17				832	390			
High Reward	553	103	0.88	.384	0.23	0.93	0.08	0.12	.908	0.03	602	136	0.69	.495	0.18
High Reward (c)	578	116				0.93	0.08				628	152			
Low Reward	668	144	0.26	.797	0.07	0.80	0.12	1.37	.177	0.36	861	288	0.69	.491	0.18
Low Reward (c)	658	124				0.75	0.15				912	265			

3.3.2. Discussion: Bias Task

Bias Task: Indirect comparison of Deception vs. Control

Match trials in the control study showed strong prioritisation of high vs. low priority label-shape pairs in the Social and Reward block, while these differences were weaker and only significant for accuracy but not reaction times or efficiency scores in the Pain block. In contrast, in the deception study, differences between high and low priority stimuli were significant across all measures (reaction time, accuracy and efficiency scores) in the Pain block as well as the Social and Reward blocks. Further, in the deception study, the differences between high and low pain label-shape pairs were associated with large effect sizes (d = 0.76-1.23), while the corresponding effect sizes in the control study were much smaller (d = 0.13-0.62) and not significant for response times and efficiency. These finding seem to suggest that pain prioritisation was reduced in the control study compared to the deception study, supporting our hypothesis that prioritisation of high vs. low pain label-shape pairs in the deception study arose from participants' expectation of receiving strongly and mildly painful electric stimulation after the experiment depending on their performance in trials containing high and low pain label-shape pairs respectively.

The decrease in prioritisation in the control compared to the deception study was specific to the Pain block. Effect sizes in the Social block ranged between d = 0.51 - 1 in the deception and d = 0.98 – 1.38 in the control study, indicating a greater prioritisation of self in the control than the deception study. This might suggest resource allocation across blocks, i.e. strategic prioritisation of pain and reward to avoid / achieve pain / reward outcomes in the deception study could have reduced participants' capacity to allocate cognitive resources to you-shape pairs. However, this is not supported by the lack of interaction effects between block and shape-label pair priority in either the deception or control study. A more likely explanation

for these findings is a random sample difference in self-prioritisation between the deception and control study. This could skew the results of the Competition task, particularly if self is prioritised more strongly over pain and reward than expected in the control study.

In the Reward block, effect sizes ranged from $d = 0.92 – 1.25$ in the deception and $d = 0.61 – 1.47$ in the control study. This seems to indicate greater variability of effect sizes across different performance measures for reward-prioritisation in the control study, while the effect was more stable and consistent across accuracy, reaction time and efficiency in the deception study. It also suggests that Reward was prioritised strongly in both studies, even though participants expected to receive a performance-based monetary reward depending on their response to high and low reward label-shape pairs in the deception study, while participants in the control study did not expect to receive any reward. Performance patterns in the Reward block therefore did not seem to be driven by the expectation of performance-based reward outcomes. It is likely that the stimuli chosen, '£8' and '£0.5', were themselves sufficient to drive this effect without the addition of a performance-based reward due to their intrinsic association with reward (specifically, money). This could be an indication that in contrast, the stimuli chosen to represent high and low pain (2 and 1 lightning bolts respectively) did not have as strong an intrinsic association with strong vs. mild pain as the reward stimuli had with reward, and hence required the deception of performance-based pain outcomes to achieve the strong prioritisation seen in the deception study.

Responses to Mismatch trials also suggested differences between the control and the deception study. In the deception study, response times showed a significant main effect of stimulus priority and interaction between block and stimulus priority, but there were no significant effects for accuracy or efficiency scores. In the control study, there were no significant interactions between block and stimulus priority on any measure, but the main effect

of stimulus priority was significant for both reaction time and accuracy. Mismatch trials in either study showed no main effects of block.

Post-hoc paired samples *t*-tests in the deception study revealed self- but not pain- or reward-prioritisation (though only for response speed and efficiency). Mismatch trials in the control study showed significant differences between high and low priority label-shape pairs in the Reward but not the Social and Pain block for response accuracy and efficiency, but not speed. Notably, responses were more accurate to low compared to high reward label-shape pairs but more efficiently to high compared to low reward label-shape pairs, indicating a possible speed-accuracy trade-off or outlying variables affecting efficiency scores.

The inconsistency of these findings across measures suggests that effects in Mismatch trials are not as robust as the equivalent effects in Match trials, in which findings were on the whole more consistent across performance measures. Although these differences between the deception and control study could be a result of the study design, this is unlikely as the differences were observed in the blocks which we expected to be relatively unaffected by the deception (the Social and Reward block), and these hypotheses were supported in Match trials. We therefore conclude that results in Mismatch trials are more volatile and less robust than findings from Match trials, and should not be weighted highly.

Bias Task: Direct comparison of Deception vs. Control

The direct comparison between the control and deception study yielded informative results. Although no significant effects were found for response accuracy and efficiency other than an expected main effect of priority, several key interactions were detected for response times.

Most crucially, we found a significant 3-way interaction in a mixed 2x3x3 ANOVA comparing prioritisation of self, pain and reward across the two study designs. This indicates

that the presence or absence of deception affected differences between blocks in the degree to which high relative to low priority shape-label pairs were prioritised. Significant interactions in mixed 2x2 ANOVAs comparing study designs and differential prioritisation of high and low priority label-shape pairs in each block separately (Social, Pain and Reward) indicated that study design significantly impacted self- and pain-prioritisation, but not reward-prioritisation. Participants in the deception study responded both faster to high pain-shape pairs and slower to low pain-shape label pairs than participants in the control study, though differences in response speed to each individual shape-label pair between the deception and control study were not significant when contrasted in isolation (see independent samples t-tests, table 3.5). In contrast, self-prioritisation was reduced in the deception compared to the control study, specifically, responses were slowed greatly for you-shape pairs and a little for stranger-shape pairs.

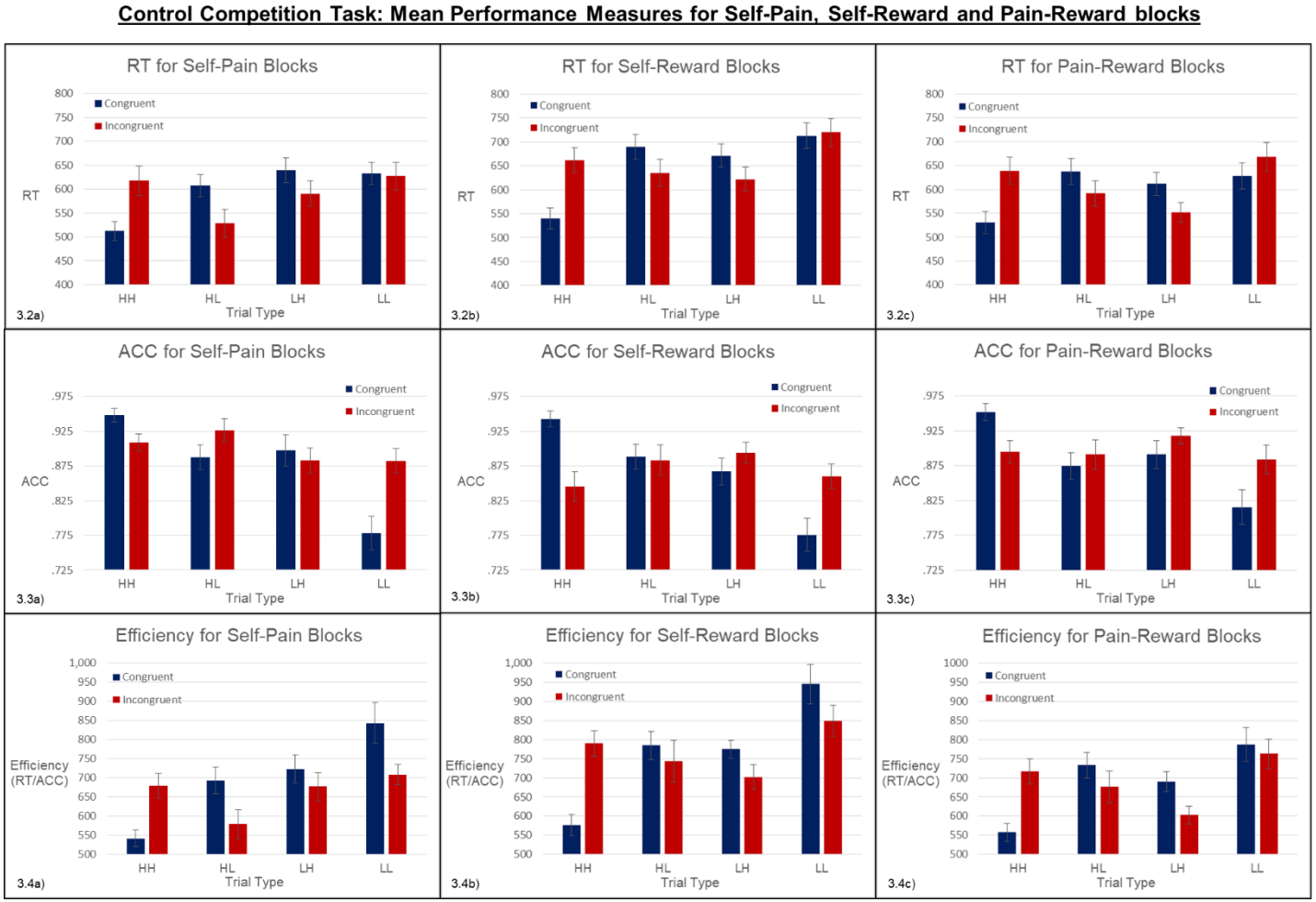
These findings on pain-prioritisation tentatively support our hypothesis that deception impacted the prioritisation of the high relative to the low pain-shape stimulus pair; however, they also show that deception did not solely drive pain-prioritisation. Based on the lack of effects for response accuracy and efficiency we must conclude that participants respond more accurately to the high vs. low pain label-shape pair irrespective of associated pain outcomes (i.e. deception). We can speculate that the high pain stimulus may have a perceptual advantage over the low pain stimulus and facilitate more accurate responding than the low pain stimulus, or alternatively the stimuli may bear intrinsic associations with high and low pain for participants. This could be investigated by including a self-report measure of each stimulus' relevance to pain in future studies employing this paradigm. However, we can also conclude that regardless of which intrinsic property of the pain-related stimuli may drive the baseline facilitation of the high pain stimulus, the pain deception at least added to and enhanced pain-prioritisation. This suggests that the deception was at least to some degree successful and

therefore pain-related stimuli were associated with pain outcomes in the deception task, which makes it probable that responses to pain-related stimuli reflect pain-related processing. This strengthens the conclusions we drew in the deception study regarding the relative prioritisation of self and pain, providing an abstract foundation for our hypothesis that self-related information may be effective as a distractor from pain.

3.4.1. Results: Competition Task

Competition Task (Computer Task 2): Control Study

Mean response time, accuracy and efficiency scores. Sample means for response time, accuracy and efficiency scores in each block and trial type are displayed in figures 3.2-4.6a-c. Each figure contains 3 panels (a, b and c), which display group means of all trial types for congruent and incongruent Self-Pain blocks (panel a), Self-Reward blocks (panel b) and Pain-Reward blocks (panel c). Our analyses of these data focus on Match trials. In congruent blocks (SPC, SRC, PRC), Match trials comprised HH and LL trials; in incongruent blocks (SPI, SRI, PRI), Match trials comprised HL and LH trials. Stimulus pairs differed depending on block type: HH stimulus pairs contained two high priority labels, LL two low priority labels affiliated with the block type (e.g. in Self-Pain blocks, you-high pain was the HH label-label pair, stranger-low pain the LL label-label pair); HL and LH label-label pairs contained one high and one low priority stimulus each. The first letter (H or L) indicates the stimulus type first named in the block type (i.e. in Self-Pain blocks, the first letter refers to the social label and the second letter to the pain label), and the second letter the stimulus type second named in the block type. H indicated this stimulus was high, L that it was low priority (e.g. in Self-Pain blocks, HL contained the ‘you’ and LH contained the ‘stranger’ stimulus).



Figures 3.2, 3.3 and 3.4 a-c. Mean response times (figure 3.2), accuracy (figure 3.3) and efficiency scores (figure 3.4) in the Competition task (control study). Means are displayed for each trial type (HH, HL, LH, LL) in congruent (blue) and incongruent (red) blocks; each panel represents one block type (a: Self-Pain, b: Self-Reward, c: Pain-Reward). Error bars represent the standard error of the mean.

Analyses. Analyses conducted match those performed in the Competition task in the deception study (see chapter 2). Repeated measures ANOVAs were used to investigate main effects of block congruency (congruent, incongruent) and priority of shape-label pairs (i.e. HH, HL, LH, LL). Given that priority of shape-label pairs differed on two levels (each of 2 stimuli could be either high or low priority), the decision was made to set the "priority" factor as the priority of the stimulus type named first in the block type, i.e. in Self-Pain and Self-Reward blocks, the 'stimulus priority' factor would refer to 'self-priority' and in Pain-Reward blocks it would refer to 'pain-priority'. As the two levels contained in this factor (e.g. self-priority and pain-priority in the Self-Pain block) were identical in congruent block Match trials and exactly reversed in incongruent block Match trials, this decision was statistically arbitrary as the same data are compared either way, but grouped differently. However, overall main effects of self-priority (Self-Pain and Self-Reward blocks) and pain-priority (Pain-Reward blocks) as well as interactions between self- / pain-priority and block congruency will be affected by this decision and will therefore be interpreted contextually.

Self-Pain Blocks (SRC, SRI)

We conducted a series of 2x2 repeated measures ANOVAs to investigate the effects of block congruency and self-priority on task performance (see table 3.8). The main effect of block congruency was significant for accuracy and efficiency scores, but not reaction times. The main effect of self-priority was significant across all measures, as was the interaction between block congruency and self-priority.

A set of post-hoc *t*-tests was carried out to better understand the effects revealed by these ANOVAs (see table 3.9). In the congruent Self-Pain block, responses to HH trials (self-high pain) were significantly faster, more accurate and overall more efficient than responses o LL trials (stranger-low pain). In the incongruent Self-Pain block, responses to HL (self-low

pain) stimulus pairs were significantly faster and more efficient than responses to LH (stranger-high pain) stimulus pairs. Responses were also more accurate in HL than LH trials, but at $p = .085$, this difference fell short of meeting our significance threshold of $\alpha < .05$.

Table 3.8. Results of 2x2 repeated measures ANOVAs comparing main effects of block congruency (Congruent: SPC-HH, SPC-LL; Incongruent: SPI-HL, SPI-LH) and self-priority (High: SPC-HH, SPI-HL; Low: SPC-LL, SPI-LH) in Match trials of Self-Pain blocks. Results are presented separately for reaction time (RT), accuracy (ACC) and efficiency scores as dependent variables. Measures reported refer to the F value (F), degrees of freedom (DF), p-value (p) and partial eta-squared values (N2P) associated with these comparisons. All values are rounded to 3 significant figures or 2 decimal points, excepting p-values which are rounded to 3 decimal points.

	RT				ACC				Efficiency			
	F	**DF**	***p***	**N2P**	***F***	**DF**	***p***	**N2P**	***F***	**DF**	***p***	**N2P**
Congruency	0.57	1, 24	.456	0.02	**9.16**	1, 24	.006	0.28	**7.64**	1, 24	.011	0.24
Self-Priority	**50.4**	1, 24	< .001	0.68	**85.8**	1, 24	< .001	0.78	**108**	1, 24	< .001	0.82
Interaction	**5.90**	1, 24	.023	0.20	**9.04**	1, 24	.006	0.27	**7.00**	1, 24	.014	0.23

Table 3.9. Descriptive statistics and results of paired samples t-tests comparing high and low self-priority Match trials in Self-Pain blocks (High self-priority: SPC-HH, SPI-HL; Low self-priority: SPC-LL, SPI-LH). Separate analyses were performed for reaction times (RT), response accuracy (ACC) and efficiency. In order, the values given represent group means (M), standard deviations (SD), t-values (t) and degrees of freedom, p-values (p), and Cohen's d (d) as a measure of effect size associated with the relevant significance test. All values are rounded to 3 significant figures or 2 decimal points, excepting p-values which are rounded to 3 decimal points.

		RT					ACC					Efficiency				
		M	***SD***	***t(24)***	***p***	***d***	***M***	***SD***	***t (24)***	***p***	***d***	***M***	***SD***	***t(24)***	***p***	***d***
SPC	**HH**	512	102	**10.2**	< .001	1.10	0.95	0.05	**7.20**	< .001	1.83	541	109	**7.28**	< .001	1.47
	LL	633	118				0.78	0.12				844	271			
SPI	**HL**	528	146	**2.80**	.009	0.44	0.93	0.08	1.80	.085	0.50	578	193	**2.23**	.036	0.53
	LH	591	135				0.88	0.09				678	184			

Self-Reward Blocks (SRC, SRI)

Another series of 2x2 repeated measures ANOVAs investigated effects of block congruency and self-priority on task performance in Self-Reward blocks (see table 3.10). These showed a significant main effect of block congruency for accuracy, but not response times or efficiency. The main effect of self-priority was significant across all performance measures, as was the interaction between block congruency and self-priority.

Another set of post-hoc *t*-tests was performed to further explore the effects highlighted by the ANOVAs (see table 3.11). In the congruent Self-Reward block, responses in HH trials (self-high reward) were significantly faster, more accurate and overall more efficient than responses o LL trials (stranger-low pain). These results match the ones from the congruent Self-Pain block, in which HH trials were also consistently prioritised over LL trials.

In the incongruent Self-Reward block, responses to HL (self-low reward) stimulus pairs did not differ significantly from responses to LH (stranger-high reward) stimulus pairs on any of our performance measures.

Table 3.10. Results of 2x2 repeated measures ANOVAs comparing main effects of block congruency (Congruent: SRC-HH, SRC-LL; Incongruent: SRI-HL, SRI-LH) and self-priority (High: SRC-HH, SRI-HL; Low: SRC-LL, SRI-LH) in Match trials of Self-Reward blocks. Results are presented separately for reaction time (RT), accuracy (ACC) and efficiency scores as dependent variables. Measures reported refer to the F value (F), degrees of freedom (DF), p-value (p) and partial eta-squared values (N2P) associated with these comparisons. All values are rounded to 3 significant figures or 2 decimal points, excepting p-values which are rounded to 3 decimal points.

	RT				ACC				Efficiency			
	F	**DF**	***p***	**N2P**	***F***	**DF**	***p***	**N2P**	***F***	**DF**	***p***	**N2P**
Congruency	0.02	1, 24	.887	0.00	**5.60**	1, 24	.026	0.19	1.66	1, 24	.209	0.07
Self-Priority	**33.8**	1, 24	< .001	0.58	**21.4**	1, 24	< .001	0.47	**25.8**	1, 24	< .001	0.52
Interaction	**85.9**	1, 24	< .001	0.78	**34.2**	1, 24	< .001	0.59	**62.7**	1, 24	< .001	0.72

Table 3.11. Descriptive statistics and results of paired samples t-tests comparing high and low self-priority Match trials in Self-Reward blocks (High self-priority: SRC-HH, SRI-HL; Low self-priority: SRC-LL, SRI-LH). Separate analyses were performed for reaction times (RT), response accuracy (ACC) and efficiency. In order, the values given represent group means (M), standard deviations (SD), t-values (t) and degrees of freedom, p-values (p), and Cohen's d (d) as a measure of effect size associated with the relevant significance test. All values are rounded to 3 significant figures or 2 decimal points, excepting p-values which are rounded to 3 decimal points.

		RT					ACC					Efficiency				
		M	***SD***	***t(24)***	***p***	***d***	***M***	***SD***	***t(24)***	***p***	***d***	***M***	***SD***	***t(24)***	***p***	***d***
SPC	**HH**	540	111	**9.85**	< .001	1.41	0.94	0.06	**7.66**	< .001	1.78	576	136	**8.63**	< .001	1.79
	LL	713	133				0.78	0.12				945	257			
SPI	**HL**	635	138	0.83	.415	0.10	0.88	0.11	0.44	.664	0.11	744	272	1.07	.297	0.19
	LH	622	127				0.89	0.08				702	166			

Pain-Reward Blocks (PRC, PRI)

A final series of 2x2 repeated measures ANOVAs investigated effects of block congruency and pain-priority on reaction times, accuracy and efficiency scores in Pain-Reward blocks (see table 3.12). These showed no significant main effect of block congruency. The main effect of pain-priority was significant across all performance measures, as was the interaction between block congruency and pain-priority. This indicates that there were no performance differences between the congruent and incongruent Pain-Reward blocks overall, and high pain was overall prioritised over low pain. However, the degree to which the high was prioritised compared to the low pain stimulus depended on the block, i.e. on whether high pain was paired with the high reward or the low reward stimulus.

A further set of post-hoc *t*-tests aimed to explore these effects in more detail (see table 3.13). In the congruent Pain-Reward block, responses in HH trials (high pain-high reward) were significantly faster, more accurate and overall more efficient than responses to LL trials (low pain-low pain). These results match the ones from the congruent Self-Pain and Self-Reward blocks, in which HH trials were also consistently prioritised over LL trials.

In the incongruent Pain-Reward block, responses to LH (low pain-high reward) stimulus pairs were significantly faster and more efficient than responses to HL (high pain-low reward) stimulus pairs. There was no significant difference between them on accuracy.

Table 3.12. Results of 2x2 repeated measures ANOVAs comparing main effects of block congruency (Congruent: PRC-HH, PRC-LL; Incongruent: PRI-HL, PRI-LH) and pain-priority (High: PRC-HH, PRI-HL; Low: PRC-LL, PRI-LH) in Match trials of Pain-Reward blocks. Results are presented separately for reaction time (RT), accuracy (ACC) and efficiency scores as dependent variables. Measures reported refer to the F value (F), degrees of freedom (DF), p-value (p) and partial eta-squared values (N2P) associated with these comparisons. All values are rounded to 3 significant figures or 2 decimal points, excepting p-values which are rounded to 3 decimal points.

	RT				ACC				Efficiency			
	F	**DF**	***p***	**N2P**	***F***	**DF**	***p***	**N2P**	***F***	**DF**	***p***	**N2P**
Congruency	0.36	1, 24	.554	0.02	2.24	1, 24	.148	0.09	2.81	1, 24	.107	0.11
Pain-Priority	**5.88**	1, 24	.023	0.20	**20.0**	1, 24	< .001	0.46	**17.8**	1, 24	< .001	0.43
Interaction	**29.6**	1, 24	< .001	0.55	**19.4**	1, 24	< .001	0.45	**25.8**	1, 24	< .001	0.52

Table 3.13. Descriptive statistics and results of paired samples t-tests comparing high and low pain-priority Match trials in Pain-Reward blocks (High pain-priority: PRC-HH, PRI-HL; Low pain-priority: PRC-LL, PRI-LH). Separate analyses were performed for reaction times (RT), response accuracy (ACC) and efficiency. In order, the values given represent group means (M), standard deviations (SD), t-values (t) and degrees of freedom, p-values (p), and Cohen's d (d) as a measure of effect size associated with the relevant significance test. All values are rounded to 3 significant figures or 2 decimal points, excepting p-values which are rounded to 3 decimal points.

		RT					ACC					Efficiency				
		M	***SD***	***t(24)***	***p***	***d***	***M***	***SD***	***t (24)***	***p***	***d***	***M***	***SD***	***t(24)***	***p***	***d***
PRC	**HH**	530	115	**5.70**	< .001	0.77	0.95	0.06	**5.64**	< .001	1.39	558	117	**6.88**	< .001	1.30
	LL	628	137				0.82	0.13				786	220			
PRI	**HL**	592	137	**2.22**	.036	0.33	0.89	0.10	1.33	.196	0.32	676	208	**2.01**	.036	0.44
	LH	552	104				0.92	0.58				603	114			

Competition Task: Deception Check

Self-Pain Blocks (SPC, SPI)

We conducted a 2x2x2 mixed model ANOVA on Match trials of Self-Pain blocks, with study design as between-subject variable, and block congruency and self-priority as within-subject factors. The results are shown in table 3.14.

There was no significant 3-way interaction between study design, block congruency and self-priority. There were no significant interactions between block congruency and study design. Interactions between self-priority and study design were significant for accuracy and efficiency but not reaction times. Interactions between self-priority and block congruency were significant across all measures.

The main effect of study design was significant for efficiency, but not accuracy or reaction times. The main effect of block congruency was significant for accuracy and efficiency, but not reaction times. The main effect of self-priority was significant across all measures.

Table 3.14. Results of 2x2x2 mixed model ANOVAs comparing main effects of study design (Deception, Control) as between-subjects factor and block congruency (Congruent: SPC-HH, SPC-LL; Incongruent: SPI-HL, SPI-LH) and self-priority (High: SPC-HH, SPI-HL; Low: SPC-LL, SPI-LH) in Match trials of Self-Pain blocks. Results are presented separately for reaction time (RT), accuracy (ACC) and efficiency scores as dependent variables. Measures reported refer to the F value (F), degrees of freedom (DF), p-value (p) and partial eta-squared values (N2P) associated with these comparisons. All values are rounded to 3 significant figures or 2 decimal points, excepting p-values which are rounded to 3 decimal points.

	RT				**ACC**				**Efficiency**			
	F	**DF**	***p***	**N2P**	***F***	**DF**	***p***	**N2P**	***F***	**DF**	***p***	**N2P**
Study[1]	3.59	1, 47	.876	0.07	3.59	1, 47	.064	0.07	**7.64**	1, 47	.011	0.24
Congruency[2]	0.77	1, 47	.390	0.02	**11.3**	1, 47	.002	0.19	**7.78**	1, 47	.008	0.14
Self-Priority[3]	**94.1**	1, 47	< .001	0.67	**79.8**	1, 47	< .001	0.63	**143**	1, 47	< .001	0.75
Interaction[4]: Con*Study	0.12	1, 47	.729	0.01	1.05	1, 47	.311	0.02	1.45	1, 47	.235	0.03
Interaction[5]: S-Pri*Study	0.91	1, 47	.346	0.02	**5.43**	1, 47	.024	0.10	**5.95**	1, 47	.020	0.11
Interaction[6]: Con*S-Pri	**17.1**	1, 47	< .001	0.27	**19.0**	1, 47	< .001	0.29	**16.3**	1, 47	< .001	0.26
Interaction[7]: Con*S-Pri*Study	0.17	1, 47	.682	0.01	0.00	1, 47	.581	0.01	0.28	1, 47	.600	0.01

To further explore the interaction between self-priority and study design found for accuracy and efficiency, we performed mixed 2x2 ANOVAs comparing self-priority between study designs in the congruent and incongruent Self-Pain blocks (see tables 3.15 and 3.16). Results from the congruent Self-Pain block show a main effect of study design for accuracy, but no significant interactions between study design and self-priority. The main effect of self-priority was significant across all measures.

In the incongruent Self-Pain block, the main effects of self-priority were significant for response times and efficiency, but not accuracy, and there were no significant main effects of study design nor any interactions between study design and self-priority.

Table 3.15. Results of 2x2 mixed model ANOVAs comparing main effects of study design (Deception, Control) as between-subjects factor and self-priority (High: SPC-HH; Low: SPC-LL) in Match trials of the congruent Self-Pain block. Results are presented separately for reaction time (RT), accuracy (ACC) and efficiency scores as dependent variables. Measures reported refer to the F value (F), degrees of freedom (DF), p-value (p) and partial eta-squared values (N2P) associated with these comparisons. All values are rounded to 3 significant figures or 2 decimal points, excepting p-values which are rounded to 3 decimal points.

	RT				ACC				Efficiency			
	F	**DF**	***p***	**N2P**	***F***	**DF**	***p***	**N2P**	***F***	**DF**	***p***	**N2P**
Study Design	0.09	1, 47	.765	0.00	**4.34**	1, 47	.043	0.09	1.88	1, 47	.177	0.04
Self-Priority	**167**	1, 47	< .001	0.78	**5.88**	1, 47	< .001	0.62	**102**	1, 47	< .001	0.68
Interaction	0.31	1, 47	.583	0.01	3.26	1, 47	.078	0.07	3.24	1, 47	.078	0.06

Table 3.16. Results of 2x2 mixed model ANOVAs comparing main effects of study design (Deception, Control) as between-subjects factor and self-priority (High: SPI-HL; Low: SPI-LH) in Match trials of the incongruent Self-Pain block. Results are presented separately for reaction time (RT), accuracy (ACC) and efficiency scores as dependent variables. Measures reported refer to the F value (F), degrees of freedom (DF), p-value (p) and partial eta-squared values (N2P) associated with these comparisons. All values are rounded to 3 significant figures or 2 decimal points, excepting p-values which are rounded to 3 decimal points.

	RT				ACC				Efficiency			
	F	**DF**	***p***	**N2P**	***F***	**DF**	***p***	**N2P**	***F***	**DF**	***p***	**N2P**
Study Design	0.00	1, 47	.983	0.00	1.40	1, 47	.243	0.03	0.19	1, 47	.669	0.00
Self-Priority	**13.6**	1, 47	.001	0.22	3.34	1, 47	.074	0.02	**8.06**	1, 47	.007	0.15
Interaction	0.68	1, 47	.413	0.01	0.91	1, 47	.350	0.02	0.67	1, 47	.416	0.01

To further investigate the main effect of study design in the congruent Self-Pain block, we performed a series of independent samples *t*-tests comparing responses to HH and LL stimulus pairs across the deception and control study (see table 3.17). As expected based on the results of the ANOVA, there were no significant differences in response speed and efficiency to HH or LL stimulus pairs between the deception and control study. However, responses to the LL stimulus pair were significantly more accurate in the deception than the control study, while there was no difference in response accuracy to the HH stimulus pair. This suggests the main effect of study design in the ANOVA (see table 3.14) was driven mainly by more accurate responding to LL stimulus pairs in the deception compared to the control study.

Table 3.17. Descriptive statistics and results of independent samples t-tests comparing Match trials in the congruent Self-Pain block between the deception and control study (c). Values are presented for reaction times (RT), response accuracy (ACC) and efficiency. In order, the values given represent group means (M), standard deviations (SD), t-values (t) and degrees of freedom associated with the relevant significance test, p-values (p), and Cohen's d (d) as a measure of effect size. All values are rounded to 3 significant figures or 2 decimal places, excepting p-values which are rounded to 3 decimal places.

	RT					ACC					Efficiency				
	M	***SD***	***t*(47)**	***p***	***d***	***M***	***SD***	***t*(47)**	***p***	***d***	***M***	***SD***	***t*(47)**	***p***	***d***
HH	509	85.0	0.12	.905	0.03	0.96	0.04	0.98	.335	0.28	531	89.6	0.36	.724	0.10
HH (c)	512	102				0.95	0.05				541	109			
LL	620	91.2	0.43	.666	0.12	0.85	0.12	**2.07**	.044	0.59	742	138	1.65	.106	0.47
LL (c)	633	118				0.78	0.12				844	271			

Self-Reward Blocks (SRC, SRI)

We conducted a 2x2x2 mixed model ANOVA on Match trials of Self-Reward blocks, with study design as between-subject variable, and block congruency and self-priority as within-subject factors. The results are shown in table 3.18.

There was no significant 3-way interaction between study design, block congruency and self-priority. There were no significant interactions between block congruency and study design or self-priority and study design. Interactions between self-priority and block congruency were significant across all measures.

The main effects of study design and block congruency were not significant. The main effect of self-priority was significant across all measures.

Table 3.18. Results of 2x2x2 mixed model ANOVAs comparing main effects of study design (Deception, Control) as between-subjects factor and block congruency (Congruent: SRC-HH, SRC-LL; Incongruent: SRI-HL, SRI-LH) and self-priority (High: SRC-HH, SRI-HL; Low: SRC-LL, SRI-LH) as within-subjects factors in Match trials of Self-Reward blocks. Results are presented separately for reaction time (RT), accuracy (ACC) and efficiency scores as dependent variables. Measures reported refer to the F value (F), degrees of freedom (DF), p-value (p) and partial eta-squared values (N2P) associated with these comparisons. All values are rounded to 3 significant figures or 2 decimal points, excepting p-values which are rounded to 3 decimal points.

	RT				**ACC**				**Efficiency**			
	F	**DF**	***p***	**N2P**	***F***	**DF**	***p***	**N2P**	***F***	**DF**	***p***	**N2P**
Study[1]	3.59	1, 47	.876	0.01	2.62	1, 47	.112	0.05	2.59	1, 47	.114	0.05
Congruency[2]	0.26	1, 47	.611	0.01	2.14	1, 47	.150	0.04	0.74	1, 47	.393	0.02
Self-Priority[3]	**59.9**	1, 47	< .001	0.56	**34.1**	1, 47	< .001	0.42	**46.4**	1, 47	< .001	0.50
Interaction[4]:Con*Study	0.08	1, 47	.780	0.00	3.48	1, 47	.068	0.07	1.77	1, 47	.190	0.04
Interaction[5]: S-Pri*Study	0.76	1, 47	.387	0.02	1.06	1, 47	.309	0.02	1.93	1, 47	.171	0.04
Interaction[6]: Con*S-Pri	**154**	1, 47	< .001	0.77	**68.2**	1, 47	< .001	0.59	**135**	1, 47	< .001	0.74
Interaction[7]: Con*S-Pri*Study	0.11	1, 47	.738	0.00	0.25	1, 47	.621	0.01	2.03	1, 47	.161	0.04

Pain-Reward Blocks (PRC, PRI)

We conducted a 2x2x2 mixed model ANOVA on Match trials of Pain-Reward blocks, with study design as between-subject variable, and block congruency and pain-priority as within-subject factors. The results are shown in table 3.19.

There was no significant 3-way interaction between study design, block congruency and pain-priority. There were no significant interactions between block congruency and study design or pain-priority and study design. Interactions between pain-priority and block congruency were significant across all measures.

The main effects of study design and block congruency were not significant. The main effect of pain-priority was significant across all measures.

Table 3.19. Results of 2x2x2 mixed model ANOVAs comparing main effects of study design (Deception, Control) as between-subjects factor and block congruency (Congruent: PRC-HH, PRC-LL; Incongruent: PRI-HL, PRI-LH) and pain-priority (High: PRC-HH, PRI-HL; Low: PRC-LL, PRI-LH) as within-subjects factors in Match trials of Pain-Reward blocks. Results are presented separately for reaction time (RT), accuracy (ACC) and efficiency scores as dependent variables. Measures reported refer to the F value (F), degrees of freedom (DF), p-value (p) and partial eta-squared values (N2P) associated with these comparisons. All values are rounded to 3 significant figures or 2 decimal points, excepting p-values which are rounded to 3 decimal points.

	RT				ACC				Efficiency			
	F	**DF**	***p***	**N2P**	***F***	**DF**	***p***	**N2P**	***F***	**DF**	***p***	**N2P**
Study[1]	0.10	1, 47	.753	0.00	0.83	1, 47	.368	0.02	0.61	1, 47	.439	0.01
Congruency[2]	0.12	1, 47	.728	0.00	1.56	1, 47	.217	0.03	2.28	1, 47	.138	0.05
Pain-Priority[3]	**9.03**	1, 47	.004	0.16	**34.7**	1, 47	< .001	0.43	**25.7**	1, 47	< .001	0.35
Interaction[4]:Con*Study	0.23	1, 47	.631	0.01	1.44	1, 47	.236	0.03	1.11	1, 47	.298	0.02
Interaction[5]: Pain-Priority*Study	0.22	1, 47	.639	0.01	0.19	1, 47	.666	0.00	0.03	1, 47	.875	0.00
Interaction[6]:Con*Pain-Priority	**69.3**	1, 47	< .001	0.60	**39.0**	1, 47	< .001	0.45	**63.4**	1, 47	< .001	0.57
Interaction[7]: Con*P-Pri*Study	0.08	1, 47	.785	0.00	0.48	1, 47	.491	0.01	0.45	1, 47	.505	0.01

3.4.2. Discussion: Competition Task

Competition Task: Indirect Comparison of Deception vs. Control

The strongest effect observed was the consistent prioritisation of the high priority stimulus pair (HH) compared to the low priority stimulus pair (LL) across all congruent blocks. This finding is in line with findings from the deception study reported in chapter 2, and indicated that the Competition task was successful in creating a cognitive load that required participants to de-prioritise responses to one label-label pair in order to maximise performance to another.

The main effect of stimulus priority (self-priority in Self-Pain and Self-Reward blocks, pain-priority in the Pain-Reward blocks) was significant across all block types. The post-hoc *t*-tests show that these main effects were driven predominantly by the difference between HH and LL stimulus pairs in congruent blocks, with smaller effects between HL and LH label-label pairs in congruent blocks (where present). Accordingly, interactions between block congruency and stimulus priority were also significant across all block types. However, the main effect of priority as well as interactions must be interpreted carefully, because both are impacted by the arbitrary choice to define the priority dimension as the different levels of priority in one stimulus type (i.e., self-priority in Self-Pain and Self-Reward blocks, pain-priority in Pain-Reward blocks) but not the other (see chapter 2). These findings are again in line with the results from the deception study, and indicate that participants allocated their cognitive resources differentially depending on the stimulus pairs presented, instead of responding equally well to all label-label pairs. This suggests that we may be able to draw valid conclusions about the relative importance of self, pain and reward from the results of this task.

To address our hypotheses, the most crucial comparisons were those between HL and LH stimulus pairs in incongruent blocks. In the Self-Pain block, the you-low pain stimulus pair

was significantly prioritised over the stranger-high pain stimulus pair for response speed and efficiency, with both effects associated with moderate effect sizes (d = 0.44; d = 0.51). The effect was near-significant for accuracy. This suggests that overall, self was prioritised more strongly than the pain stimulus. In the deception study, the you-low pain pair was prioritised for response time only, and this effect was associated with a slightly smaller effect size (d = 0.37). This suggests that overall, prioritisation of the you-low pain over the stranger-high pain stimulus pair was slightly enhanced in the control compared to the deception study. This was in line with our hypotheses that removing the association between pain stimuli and pain outcomes would reduce the prioritisation of pain stimuli relative to self-related stimuli, which were unaffected by the deception and should therefore have been responded to with equal degrees of prioritisation in the deception and control study.

In the incongruent Self-Reward block, there was no significant difference between you-low reward and stranger-high reward stimulus pairs. This finding matches the results from the deception study. This suggests that reward-prioritisation was not affected by the deception, and the prioritisation of high reward stimuli was still as strong as prioritisation of the self-stimulus in the absence of a reward outcome for good performance (i.e. in the control compared to the deception study). Our hypothesis was that reward-prioritisation would be little or not at all affected by the removal of the outcome-based incentive, certainly less than pain-prioritisation, due to the likely inherent association between reward stimuli with reward which was not present for pain stimuli. The findings support the conclusion that reward-prioritisation was not at all impacted by the deception.

In the incongruent Pain-Reward block, responses to the low pain-high reward stimulus pair were both faster and more efficient than responses to the high pain-low reward stimulus pair. These effects were associated with small-moderate effect sizes (d = 0.33; d = 0.44). These findings suggest that overall, reward was prioritised over pain. In the deception task, reward

was prioritised over pain for response speed only, but this effect was greater (d = 0.5) than the effects found in the control study. This could indicate that pain stimuli were de-prioritised and reward more generally prioritised for overall performance when removing the association between pain stimuli and pain outcomes. However, given that prioritisation of reward over pain for response efficiency was also near-significant in the deception study (p =0.079) and was associated with a greater effect size for response times, it would not be appropriate to draw strong conclusions from these differences between the deception and control study. Pain may have been slightly de-prioritised compared to reward in the control as oppose to the deception study on some performance measures, but these effects, if present, are highly negligible.

Overall, our hypotheses that the lack of deception would not impact prioritisation of self and reward were supported by these findings. They also indicate that prioritisation of pain relative to self and reward was reduced in the control compared to the deception study. Although this is in line with our hypotheses, we would have expected a stronger reduction in pain-prioritisation relative to self and reward. The results however indicate that prioritisation of the high pain stimulus was not entirely eradicated by removing the association between pain stimuli and pain outcomes. Had this been the case, we would not have expected to observe a significant interaction between block congruency and self-priority in Self-Pain blocks. We must therefore conclude that deception may have enhanced but was not the sole cause of the pain-prioritisation observed in the deception study.

Competition Task: Direct Comparison of Deception vs. Control

In the Self-Pain block, the main effect for study design was significant for efficiency and near-significant for accuracy, indicating some overall differences in performance in Self-Pain blocks between the deception and control study. Significant interactions between self-priority and study design for accuracy and efficiency suggested that deception impacted overall

self-prioritisation in Self-Pain blocks. However, as there was no 3-way interaction between study design, block congruency and self-priority, it seems self-prioritisation in the congruent and incongruent Self-Pain block was not differentially affected by the deception. Results of post-hoc 2x2 ANOVAs revealed no deception-dependent effect in the incongruent block, while a main effect of study design was found for accuracy in the congruent Self-Pain block. *T*-tests revealed that this effect was mainly driven by more accurate responses to low pain-stranger stimulus pairs in the deception study, while responses to all other stimulus pairs were unaffected by the deception.

These findings do not support our hypotheses. Although performance was apparently unaffected for social stimuli as predicted, we expected that removing the deception element in the control study would reduce performance to pain stimuli, in particular to high pain stimuli. In the Competition task of the deception study, self was prioritised over pain in the incongruent Self-Pain block. If performance to pain stimuli were reduced in the control study, the relative prioritisation of self over pain should be even more pronounced in the incongruent Self-Pain block in the control study. However, this was not the case. Instead there was only a relative de-prioritisation of the stranger-low pain stimulus pair in the congruent Self-Pain block of the control study. Although this could be interpreted as an indication of reduced performance to pain stimuli in the control study, it is not evident why performance to the low pain stimulus should have been affected by the deception but not performance to the high pain stimulus.

Differences between the self-low pain and stranger-high pain stimulus pair in the incongruent Self-Pain block of the deception study were associated with moderate effect sizes (d =0.37), and thus constituted a much smaller effect than those found in the Bias task or between HH and LL trials in congruent blocks. We may therefore conclude that the relative prioritisation assessed by incongruent blocks in the Competition task is a much smaller effect

than others revealed by our paradigm. Our sample size may not have been sufficient to detect between-sample differences in this small effect.

There were no main effects of study design in the Self-Reward and Pain-Reward blocks. Neither were there any significant 2-way or 3-way interactions between study design and the other variables in those blocks. These findings indicate that performance patterns in Self-Reward and Pain-Reward blocks did not differ between the deception and control study. We hypothesised that performance to social stimuli (you, stranger) would not be affected by the deception, i.e. we would see no difference in performance to you and stranger stimuli between the deception and control study. We further predicted that reward-prioritisation would be slightly reduced or not affected by removing the deception element.

Our findings from Self-Reward and Pain-Reward blocks broadly support these hypotheses. The results from the Self-Reward blocks indicate that response patterns to both social and reward-related stimuli were unaffected by the deception. However, these findings also indicate that performance patterns in Pain-Reward blocks were unaffected by the deception, suggesting that there was no difference in the relative prioritisation of pain and reward between the deception and control study. While this is in line with our hypothesis that responses to reward stimuli would be unchanged or only mildly affected by removing the reward deception, these findings are at odds with our hypothesis that pain stimuli would be de-prioritised in the control compared to the deception study. However, although not in line with our hypotheses, these findings are consistent with findings from the Self-Pain block, in which performance to pain stimuli also seemed mostly unaffected by the deception. This suggests that performance to none of our stimulus types (social, reward, pain) was notably affected by the deception, and overall performance in the Competition task did not differ between the deception and control study.

3.5. General Discussion

Limitations

Sample comparisons showed that the proportion of female participants completing the Bias and Competition task in the control study was higher than in the deception study. Further, participants completing the control study were younger than participants in the deception study for both tasks. This suggests any differences between the studies could be due to sample differences in gender or age rather than study design. We have no particular reason to expect gender differences to impact the results of this study, but the possibility should be taken into consideration when evaluating the findings. Although some research has found age differences in task performance, specifically reduced performance with increasing age (Salthouse, 1994), age groups in these studies differed by much greater margins than in our samples. Further, other findings (Allen, Lien, Murphy, Sanders, Judge & McCann, 2002) have suggested that older adults can perform parallel cognitive tasks at least as well as younger adults. These mixed findings indicate that the effect of age on task performance may depend on the specific task. To our knowledge, no studies have investigated the effect of age on performance in the PMP to date. We can therefore not determine whether the age difference between our sample is likely to have impacted our findings or if so, in which direction and to what degree.

For the direct comparison between the deception and control study Bias tasks, significant interactions between study design and differential prioritisation effects in the Social and Pain block were only detected for response times. The effect sizes associated with both interactions were both very small at $\eta^2_P \leq 0.10$. Combined with the inconsistency of these effects across performance measures, this indicates that these results may not be robust and larger samples would be required to validate the reliability of these effects.

Overall Conclusions

This study aimed to investigate whether performance patterns to pain stimuli in the deception study depended on the pain-related deception, i.e. whether the same patterns of prioritisation would be observed when the deception element was removed in the control study.

The results were overall mixed. The strongest support for our hypothesis was provided by the indirect comparison of the control and deception study in the Bias task, in which pain-prioritisation was drastically diminished in the control as opposed to the deception study. Findings from the direct comparison of Bias task performance between the deception and control study were also mildly in support of our hypothesis and indicated that the outcome deception both facilitated responding to high pain and reduced responding to low pain stimuli. However, differences between the deception and control study were overall very small, and even the results that most strongly support our hypotheses also suggested that at least some degree of pain-prioritisation was preserved in the control study. Overall, this suggests that

1) the deception enhanced pain-prioritisation in the Bias task, but
2) responses were prioritised for high compared to low pain stimuli independent of deception.

The combination of these findings indicates that pain-related processing contributed to the prioritisation of pain stimuli observed in the deception task, but was not the sole driver. The measure of pain-prioritisation used in the deception study may therefore not reflect pain-related processing particularly well, and conclusions about the relative prioritisation of self and pain drawn from this study may not be valid, or only to an uncertain degree.

Results from the Competition task suggest some small but overall negligible differences between the deception and control task. As there were at least some notable differences observed in the Bias task, these findings indicate that the deception affected performance more

strongly in the Bias than the Competition task. In chapter 2, we discussed the possibility that some participants may have stopped believing the deception halfway through the experiment (i.e. after completing the Bias task and at some point before or during the Competition task). Our comparisons of performance patterns in the deception and control study Competition task seem to support these findings, as deception seemed to impact responses far less than in the Bias task. This would mean that any conclusions drawn about the relative prioritisation of self and pain in the deception study may not be valid; if responses to pain-related stimuli were not driven by pain-related processing, which these findings make doubtful, they cannot be the basis of any inferences about pain-related processing.

Chapter 4

4

Prioritisation of Self and Pain: Threat of Experienced Pain

4.1. Introduction

Results from the deception study were promising for our hypotheses: Our findings were tentatively positive for our question whether the pain-adaptation of the Perceptual Matching Paradigm (PMP; Sui, He & Humphreys, 2012) could constitute a valid measure of pain-bias. They also suggested that self-related information could effectively compete for cognitive resources with pain, which provided some proof-of-concept support for our hypothesis that self-related content could increase the effectiveness of distraction from pain by reducing cognitive resources available to process pain. Overall, results from our deception study suggested that:

1) the Bias task adaptation of the PMP was successful in assessing pain-prioritisation as well as self- and reward-prioritisation;
2) pain-prioritisation is comparable in magnitude to self- and reward-prioritisation in a healthy sample;
3) The Competition adaption of the PMP was effective in assessing the relative prioritisation of self, pain and reward; and

4) Both self and reward were prioritised over pain to some degree by our healthy sample in the Competition task.

Despite these promising initial findings, several methodological weaknesses cast doubt on our conclusions. Most importantly, no check of whether participants were successfully deceived was included in the deception study. It was therefore uncertain whether participants expected to receive painful electric stimulation and monetary reward depending on their performance in the Bias and Competition task at the end of the experiment. This association, particularly between pain stimuli and pain outcomes was crucial to ensure responses to pain stimuli would be driven by pain-related cognitive processing. Without this association, the conclusions about pain-prioritisation or the relative prioritisation of self and pain based on the findings of this study were not valid.

The control study was designed as a comparison to show how participants would perform in the Bias and Competition task when no deception was applied and no performance-based pain or reward outcomes were expected by participants. Results of this study were mixed; although without the deception, pain was prioritised to a lesser degree in the Bias task, responses to the high pain-shape pair were still more accurate than responses to the low pain-shape pair. Further, in the Competition task, there was little difference in performance between the deception and control study.

Altogether, these findings drew into question whether the deception was successful in our first study, and therefore, whether our conclusions were valid. Although there was doubt as to whether pain stimuli used in the Bias and Competition task of the deception study were able to engage pain-related cognitive processing, findings from both the deception and control study support the effectiveness of our Bias and Competition task adaptations in creating a cognitive load which requires participants to selectively allocate cognitive resources between

the two Match pairs presented in each block. The findings further suggest that the relative prioritisation of Match pairs in the Competition task is internally consistent as well as to a reasonable degree stable across participants. We concluded that our adaptations of the PMP were in principle effective tools and could be used to investigate the relationship between self- and pain-related processing if the association between pain stimuli and pain outcomes can be improved. The present study was designed to address the limitations of our previous studies, and further investigate our hypotheses (outlined above). Specifically, we aimed to answer the question whether the finding of pain-prioritisation in the Bias task and prioritisation of self and reward over pain in our first study resulted only from a failed deception, or if the same pattern of responses would be found if pain stimuli were truly associated with pain outcomes.

To this end, we designed the present study with pain titration procedure at the start of the experimental session, in which participants' subjective pain thresholds would be determined and participants would experience examples of the painful electric stimulation they would receive again at the end of the testing session depending on their performance in the Bias and Competition task. Pain stimuli were then linked to pain outcomes anchored at participants' subject pain levels, i.e. participants expected to receive painful electric stimulation corresponding to an 8 on a scale from 0 to 10 based on their performance in the Bias and Competition task. With this design, performance in pain trials in the Bias and Competition task was not confounded by participants' sensitivity to pain, as it would have been had one standardised pain stimulus been applied to all participants. We expected this would increase the association between the pain stimuli in the Bias and Competition task and real pain.

Including a real pain outcome was one of the crucial changes in our methodological design compared to the deception study. To match the change from deception to real performance-based outcome for our control measure (reward), we also promised and delivered performance-based monetary reward. The inclusion of a real pain induction had great potential

to evoke pain-related cognitive processing in the computer tasks. However, despite its promise, it was not certain responses to pain stimuli would reflect pain-related cognitive processing in the context of experienced pain.

To test for the possibility that pain- and reward-prioritisation may not have reflected cognitive processing specific to pain and reward, we included a series of individual difference measures in this study. These measures served two purposes: Firstly, investigating the relationships between pain- and reward-prioritisation and established self-report individual difference measures related to pain and reward processing aimed to show indirectly whether pain- and reward-prioritisation reflected content-specific processing. We expected to find relationship between the implicit measures of self-, pain- and reward-bias assessed in the Bias task and explicit measures of cognition relating self, pain and reward respectively. Secondly, these data constituted a pilot for a future study (see chapter 7). A computerised Implicit Associations Task to assess overlap of self and pain was added, as well as a series of questionnaire measures assessing individual differences in cognition or experience related to self, pain and reward. The present chapter will focus exclusively on the results of the Bias and Competition task. Methods, findings and conclusions for these individual difference measures as well as the implications of these findings for the conclusions of the present chapter are discussed in chapter 5.

In the present study, we also implemented small changes to the Bias and Competition task stimulus material: “Low pain” and “low reward” stimuli were replaced with “no pain” and “no reward” stimuli. This deviates from previous experiments using the Perceptual Matching Paradigm (Sui, He & Humphreys, 2012). The decision was made to align stimulus levels across blocks (Social, Pain and Reward) more closely. The Social block contains a stimulus related to self, and a stimulus not related to self – a binary, categorical distinction. In contrast, in our first study, the Pain and Reward blocks contained stimuli relating to high and low levels of pain and

reward – both of which were somewhat arbitrarily chosen values on a continuous spectrum. Replacing the "low pain" and "low reward" stimuli with "no pain" and "no reward" meant that there was a categorical difference between the stimuli contained in each block (i.e., stimuli in the Pain block were now pain-related or not pain-related). We expected this would make the blocks more comparable.

We further adapted the pain stimuli to resemble more closely our reward stimuli. Results from the control study indicated that high pain stimuli used in the deception and control study might be more perceptually salient than low pain stimuli, which might to some degree drive the prioritisation of high compared to low pain stimuli. To match the design of our reward stimuli, the two lightning symbols which had been used as the high pain stimulus were replaced with a lightning and an 8. This symbol was used to signal the painful electric stimulation of participants' subjective pain rating '8' associated with poor performance in high pain trials. The 'lightning 8' combination was intended to match the '£8' combination comprising the high reward stimulus. The single lightning symbol previously used as the low pain stimulus was replaced with a lightning and a 0, matching the '£0' "no reward" stimulus label.

Based on these methodological changes, we expected that pain-prioritisation in the Bias task would be comparable in magnitude to self- and reward-prioritisation, as was found in the deception study. This would be consistent with our interpretation of the deception study findings that participants may have believed the deception during the Bias task, but ceased to believe it before or during the Competition task. We expected that as a result of the more realistic threat of pain outcomes through the experience of painful electric stimulation, self, reward and pain would now be prioritised equally in the Competition task. This would support our previous findings that the greater prioritisation of self and reward relative to pain in our first study may have resulted from the failure of deception in the Competition task. Equal prioritisation of self and pain in the Competition task of the present study would still support

our overall hypothesis that self-related information could function as an effective distraction from pain. As no pain or reward outcomes were associated with social stimuli, equal prioritisation of the self and high pain stimulus would support the hypothesis that self-related information could be an effective distractor from pain as such results would indicate that self-related stimuli are inherently prioritised for cognitive processing.

4.2. Method

Sample

Sample size calculation. We decided to increase the sample size compared to our previous studies. This was based on a) the small effects found in the Competition task in the deception and control study, specifically differences between Match pairs in incongruent blocks, which could be more reliably detected with a larger sample, and b) the planned correlational analyses between individual difference measures included in this study. Although a much larger sample would be necessary to detect small correlations reliably, we decided on a sample of 50 due to practical constraints. However, we increased this number to 55 after conducting an interim analysis of our preliminary data which suggested that data from around 10% of participants would have to be excluded from analysis due to poor performance or missing data. A post-hoc power analysis in R showed that a sample of 55 is large enough to detect correlations of $r = 0.367$ or larger at a significance level of $\alpha = 0.05$ with a power of 80%.

Participants. Fifty-five (27f, 28m) healthy volunteers aged 18-35 years ($M = 23.76$, $SD = 3.59$) were recruited for this experiment. We invited participants with no history of or current neurological conditions, and not currently taking any medications (excepting the contraceptive pill). Participants were excluded if they had any cuts or sores on the hand that the electrodes would be attached to. Good comprehension of the English language and normal or corrected-

to-normal vision were also required. The study was advertised through posters, university websites, social media and word-of-mouth. The study was approved by the Medical Sciences Interdivisional Research Ethics Committee (MS IDREC R45788/RE001) and sponsored by the Oxford University Clinical Trials and Research Governance (CTRG) team. Informed consent was obtained from all participants at the beginning of the experimental session. All participants were reimbursed for their time with at least £20 and up to £28, depending on their performance in the Competition task.

Design and Procedure

Design and Procedure. All data was collected during a single laboratory session. At the start of the experimental session, we used a thresholding procedure to calibrate participants' individual sensitivity to electroshocks, including their maximum pain tolerance and their subjective pain level 8. After the threshold was established, participants completed a standard set of computerised questionnaires (see chapter 5). Demographic sample characteristics (gender, age) were assessed with an ad hoc questionnaire. Then, participants completed the Bias and Competition tasks. We used pain and reward outcomes to create associations between the pain (lightning 8) and reward ('£8') stimuli used in the computer tasks and pain and monetary reward outcomes respectively. Before beginning the Bias task, participants were informed that their performance in both computer tasks would determine (i) the number of electric shocks on their subjective pain level 8 (as established in the electroshock thresholding procedure), and (ii) the amount of monetary reward they would receive at the end of the experiment. Specifically, in any block containing the pain stimulus (lightning 8), the speed and accuracy of responding to trials in which this stimulus was present would affect the number of electric shocks incurred at the end of the experiment. Equally, in any block containing the reward stimulus ('£8'), the speed and accuracy of responding to trials in which this stimulus was present would affect the amount of monetary reward earned at the end of the experiment.

Participants were informed the maximum number of electroshocks they could receive was 10, and the minimum 0. The maximum amount of reward that could be earned was £8, and the minimum 0. After completing the Competition task, participants completed the Implicit Associations Task (IAT) for self and pain (see chapter 5). We administered pain and reward outcomes once all computer tasks were completed. Participants received a number of repetitions of painful electric stimulation depending on their performance accuracy in pain-related trials during a block randomly chosen from the Competition task, and a monetary reward depending on their performance accuracy in reward-related trials in a randomly chosen block in the Competition task. Participants then received their full reimbursement and were thanked for their participation.

Painful electric stimulation titration. The procedure used to establish the current corresponding to participants' subjective pain level 8 closely followed that used by Crockett et al. (2014). All participants underwent individual pain titration procedures. Two experimenters were present during thresholding to ensure participant safety. A Digitimer DS5 electric stimulator was used to deliver shocks. After participants were given a brief overview of the equipment and calibration process, the experimenter asked participants to remove any items from their left wrist (e.g. watches, bracelets) and relax their left arm with the underside of their wrist facing up. The experimenter then prepared a patch of skin approximately 1cm above the wrist with an alcohol pad an exfoliating gel. Following this, an electrode was placed on the prepared patch on skin on the underside of the participant's left wrist. Thresholding began with a low-voltage electroshock (0.1mA) and increased in small increments. Participants were asked to rate their pain experience on an 11-point scale (rating from 0 = no pain / no sensation to 10 = intolerable). The first rating was followed by a series of shocks in small milliamp increments. Pain ratings were collected for every stimulation until a 10 rating was reached, which was recorded as the maximum threshold. This procedure was repeated twice more, resulting in 3

overall ratings of '10'. The maximum threshold obtained from the third titration was used as maximum threshold for the next set of shocks.

The next component of the thresholding process was designed based on the method of constant stimuli, with the aim to establish participants' subjective pain level 8. We generated a series of shocks ranging from 40% to 100% of the maximum current tolerated by the participant previously in 10% increments. This resulted in 7 shock intensities, each of which was delivered 3 times in random order, and rated in terms of painfulness by the participant. We statistically fit a sigmoid function to this set of shocks in order to generate an estimate of the participant's voltage-to-pain-rating response curve. From this derived function we extracted an estimate of the voltage corresponding to the participant's subjective pain level 8. This voltage was then used when the outcome of the perceptual matching tasks was delivered. This thresholding procedure also ensured that all participants had experienced the painful electric stimulation.

Bias Task (Computer Task 1)

Stimuli. Each of six geometric shapes (a circle, a square, a triangle, a pentagon, a hexagon and a diamond) was assigned to one of six labels / symbols ('you', 'stranger', '£8', '£0', a lightning symbol with an 8, and a lightning symbol with a 0). Shape-label pairings were pseudo-randomised across participants (see appendix A). Shapes, labels and symbols were centred at 150px above and below the fixation cross. Labels ('you', 'stranger', '£8', '£0') were fixed at a height of 75px. Lightning bolt symbols and neutral shapes were fixed at a height of 122px. Stimuli differed in width. All stimuli were processed using GIMP 2 (V 2.8.16) and were presented on a 1920x1080 screen.

Procedure. The procedure for the Bias task was identical to that used in the deception study (see chapter 2), excepting changes to the stimuli used. Examples of shape-label Match and Mismatch trials in this study are shown in table 4.1.

Table 4.1. 'Match' and 'Mismatch' shape-label pairs in the Bias task.

Blocks	Match Pairs (example)	Mismatch Pairs (example)
Social Block	'You' – Circle 'Stranger' – Square	'You' – Square 'Stranger' – Circle
Reward Block	'£8' – Hexagon '£0' – Diamond	'£8' – Diamond '£0' – Hexagon
Pain Block	Lightning Bolt 8 – Pentagon Lightning Bolt 0 – Triangle	Lightning Bolt 8 – Triangle Lightning Bolt 0 – Pentagon

Data Handling. Eight participants' data were excluded due to extremely low accuracy (below 10% correct responses in some conditions) in 'Match' trials containing the '£0' (in the Reward block) or the lightning bolt 0 (in the Pain block) symbol. All analyses were performed on the data from the remaining 47 participants.

Data Analyses. We performed a series of planned analyses to investigate the effects of priority (high, low) and block (Social, Pain and Reward). Separate analyses were conducted for Match and Mismatch trials. All analyses were performed on each of our three performance measures (reaction time, accuracy and efficiency). We conducted 3x2 repeated measures ANOVAs with 3 levels of block and two levels of shape-label pair priority as within-subject factors. Paired samples *t*-tests were performed to investigate the difference between high and low priority shape-label pairs within each block.

Competition Task (Computer Task 2)

Stimuli. Four of six labels ('you', 'stranger', '£8', '£0', a lightning symbol with an 8, and a lightning symbol with a 0) were systematically paired with each other either congruently or incongruently. Congruent stimulus pairs comprised either of two high salience stimuli (i.e. 'you', '£8', lightning 8; HH) or two low salience stimuli (i.e. 'stranger', '£0', lightning 0; LL). Incongruent stimulus pairs each comprised one high salience stimulus (i.e. 'you', '£8', lightning 8) and one low salience stimuli (i.e. 'stranger', '£0', lightning 0), and are referred to as HL and LH (high-low and low-high priority pairs). Stimuli were centred at 150px above and

below the fixation cross on a 1920x1080 screen. Labels were fixed at a height of 75px. Lightning bolt symbols were fixed at a height of 122px. All stimuli were presented on a 1920x1080 screen.

Procedure. The procedure for the Competition task was identical to that used in the deception study (see chapter 2) with the exception of the stimuli used. Label-label Match and Mismatch pairs in this study are shown in table 4.2.

Table 4.2. Overview of 'Match' and 'Mismatch' stimulus pairs in Competition task.

Congruent Blocks	**Match Pairs**	**Mismatch Pairs**
Self-Pain (SP-C)	'You' – Lightning Bolt 8 (HH) 'Stranger' –Lightning Bolt 0 (LL)	'You' –Lightning Bolt 0 (HL) 'Stranger' – Lightning Bolt 8 (LH)
Self-Reward (SR-C)	'You' – '£8' (HH) 'Stranger'- '£0' (LL)	'You'- '£0' (HL) 'Stranger' – '£8' (LH)
Pain-Reward (PR-C)	Lightning Bolt 8 – '£8' (HH) Lightning Bolt 0 – '£0' (LL)	Lightning Bolt 8 – '£0' (HL) Lightning Bolt 0 – '£8' (LH)
Incongruent Blocks	**Match Pairs**	**Mismatch Pairs**
Self-Pain (SP-I)	'You' – Lightning Bolt 0 (HL) 'Stranger' – Lightning Bolt 8 (LH)	'You' – Lightning Bolt 8 (HH) 'Stranger' – Lightning Bolt 0 (LL)
Self-Reward (SR-I)	'You'- '£0' (HL) 'Stranger' – '£8' (LH)	'You' – '£8' (HH) 'Stranger'- '£0' (LL)
Pain-Reward (PR-I)	Lightning Bolt 8 – '£0' (HL) Lightning Bolt 0 – '£8' (LH)	Lightning Bolt 8 – '£8' (HH) Lightning Bolt 0 – '£0' (LL)

Data Handling. Six participants' data were excluded completely from this task due to partially missing data or extremely low accuracy (below 10% correct responses in some conditions) in 'Match' trials containing the '£0' (in the Reward block) or the Lightning Bolt 0 (in the Pain block) symbol. All analyses were performed on the data from the remaining 49 participants.

Data Analyses. We performed a series of planned analyses to investigate the effects of block congruency (congruent, incongruent) and label-label pair priority (congruent blocks: high-high, low-low; incongruent blocks: high-low, low-high) for Match trials. Separate analyses were conducted for Self-Pain, Self-Reward and Pain-Reward blocks. All analyses

were performed on each of our three performance measures (reaction time, accuracy and efficiency). We conducted 2x2 repeated measures ANOVAs with 2 levels of block congruency and two levels of label-label pair priority (high, low) as within-subject factors. The different levels of label-label pair priority reflect the priority of only one of the labels. In congruent block Match trials, when one label is high priority (e.g. 'you') so is the other (e.g. '£8'). In incongruent block Match trials however, when one label is high priority (e.g. 'you'), the other is low priority (e.g. '£0'). The priority factor here reflects the priority of the label named first in the block type (e.g. in Self-Reward blocks, the priority factor reflects the priority of the Social label, i.e. 'you' or 'stranger'). This choice was arbitrary and has implications for the interpretation of results which will be taken into account. Paired samples *t*-tests were performed to investigate the difference between Match trial label-label pairs within each block.

4.3. Results

Measures. We derived 3 performance measures for each condition (2 Match and 2 Mismatch pairs for each block) from each participant: Response time (RT), accuracy (ACC) and efficiency scores. Accuracy was calculated as proportion of correct responses and ranged from 0 to 1. We calculated mean response times (RT) from accurate responses made between 200 milliseconds and 1600 milliseconds after stimulus onset. The cut-off for premature responses was chosen based on Sui, He & Humphreys (2012). The cut-off for late responses was chosen in accordance with the analyses in chapter 2. As in chapters 2 and 3, less than 1% of trials were excluded due to the response latency cut-off in the Bias and Competition task. From these measures we calculated the indirect performance measure of efficiency scores, as

$$efficiency = RT / ACC,$$

where RT was the response speed in milliseconds and ACC the proportion of correct responses. The efficiency measure was used to highlight overall performance and differentiate

between true effects and cases of speed-accuracy trade-off (i.e. when participants responded faster but less accurately or vice versa to one trial type).

Bias Task (Computer Task 1)

Mean response times, accuracy and efficiency scores. Sample means for all performance measures are displayed in figure 4.1. Responses are on average faster, more accurate and more efficient in shape-label Match pairs containing a high priority label (i.e. the self, pain and reward labels) compared to Match trials containing a low priority label (i.e. the stranger, no pain and no reward label). Differences between high and low priority label-shape pairs are less pronounced and consistent in Mismatch trials.

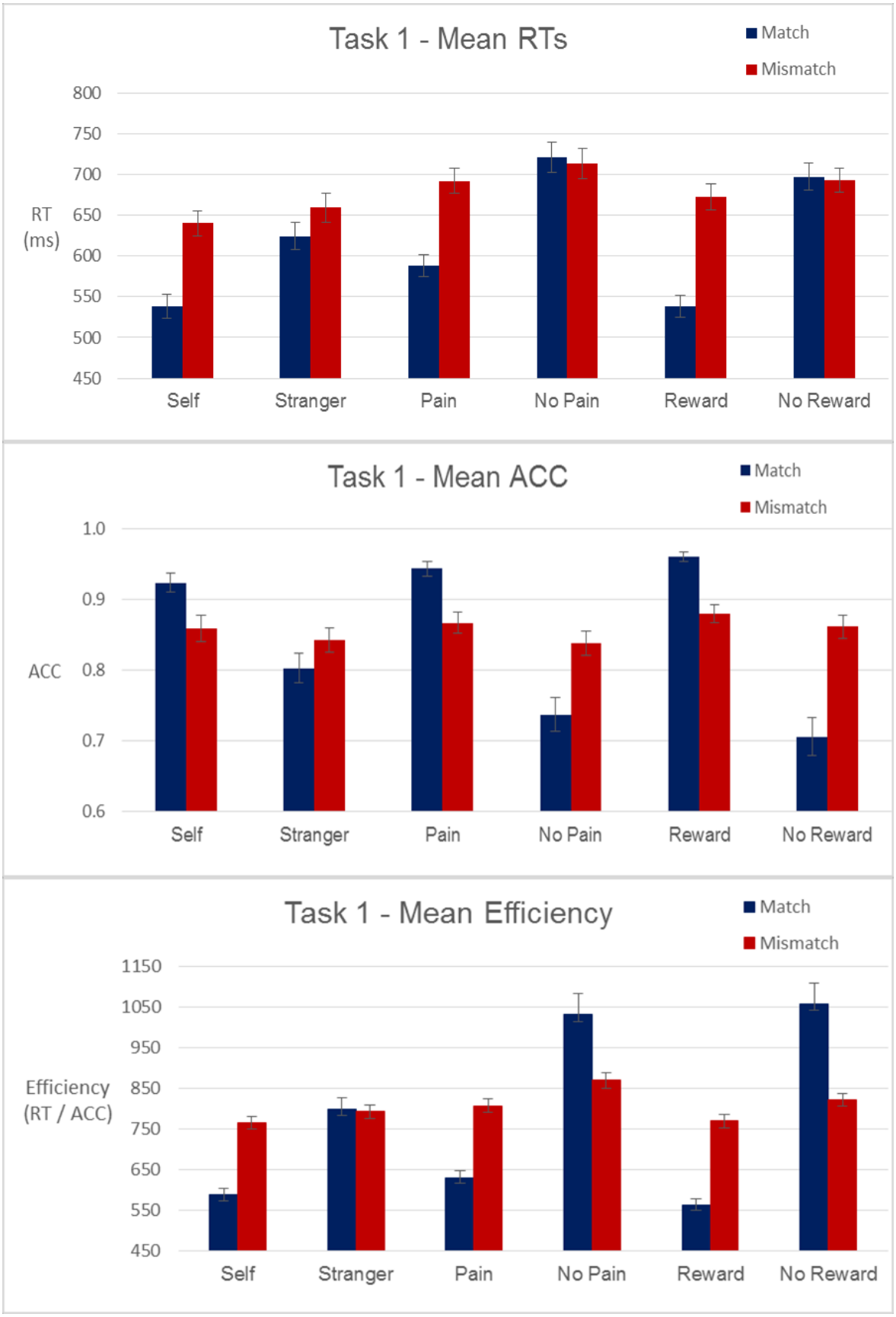


Figure 4.1. Mean Reaction Times, Accuracies and Efficiency measures for Match and Mismatch trials in high and low priority trials in Social, Pain and Reward blocks in the Bias Task. Error bars represent the standard error of each mean.

Analyses of Match trials. We conducted a series of 3x2 repeated measures ANOVAs with block (Social, Pain and Reward) and label-shape pair priority (high, low) as within-subject factors (see table 4.3), and reaction times, accuracy and efficiency as dependent variables. There were signifnicant small main effects of block for reaction times and efficiency but not accuracy, while the main effects of priority were significant across all performance measures and associated with very large effect sizes. The interaction between block and shape-label pair priority was significant across all performance measures and associated with moderate effect sizes. This indicated that the difference between high and low priority label-shape pairs depended on the block, i.e. whether stimuli were social, pain- or reward-related.

The main effect of block indicates that overall reaction times and efficiency were higher in some blocks than others, while accuracy remained relatively constant across all blocks. This could be the result of the nature of the accuracy measure, which is capped at 1.0 (100% correct performance) while reaction time and efficiency are more continuous.

We performed post-hoc paired samples *t*-tests to compare overall response speed and efficiency between the Social, Pain and Reward block. For reaction times, all blocks differed significantly. Responses were faster in the Social (M_{Social} = 581; SD_{Social} = 97.8; M_{Pain} = 655; SD_{Pain} = 100; M_{Reward} = 618; SD_{Reward} = 91.4) than the Pain ($t(46) = 4.23$, $p < .001$, $d = 0.74$) or the Reward block ($t(46) = 2.73$, $p = .009$, $d = 0.39$). Responses were also significantly faster in the Reward than the Pain block ($t(46) = 2.26$, $p < .014$, $d = 0.39$). For response efficiency, responses were more efficient in the Social (M_{Social} = 693; SD_{Social} = 122; M_{Pain} = 830; SD_{Pain} = 184; M_{Reward} = 811; SD_{Reward} = 177) than the Pain ($t(46) = 4.26$, $p < .001$, $d = 0.88$) or the Reward block ($t(46) = 3.8$, $p = .001$, $d = 0.79$). Response efficiency did not differ significantly between the Pain and Reward block ($p = .552$).

The significant main effects of shape-label pair priority indicated that task performance was affected by label priority. A series of repeated measures *t*-tests (table 4.4) was carried out to compare reaction times, accuracies and efficiency between high and low priority label-shape pairs within each block. Responses were significantly faster, more accurate and more efficient to high compared to low priority label-shape pairs across all blocks and all measures. Across all measures, the difference between high and low priority label-shape pairs was greatest in the Reward block with huge effect sizes, and smallest in the Social block with large to very large effect sizes. Effects in the Pain block were very large to huge. This suggests that overall the difference between high and low priority label-shape pairs was most pronounced in the Reward block, and smallest in the Social block.

The pattern of effect sizes for self-, pain- and reward-prioritisation seems to indicate that reward-prioritisation was the greatest effect. However, the mean response speed, accuracy and efficiency scores displayed in table 4.4 show that responses were similarly fast, accurate and efficient for high priority label-shape pairs (i.e. you, pain and reward) while responses were notably slower, less accurate and efficient towards no pain and no reward label-shape pairs. This could indicate that the greater prioritisation effects in the Reward and Pain compared to the Social block (see above) could be a result of de-prioritisation of low priority pain and reward labels rather than increased prioritisation of high priority pain and reward labels compared to social labels.

Table 4.3. Results of 3x2 repeated measures ANOVAs comparing main effects of block (Social, Pain and Reward) and label priority (high, low) in Match trials. Results are presented separately for reaction time (RT), accuracy (ACC) and efficiency scores. Measures reported refer to the F value (F), degrees of freedom (DF), p-value (p) and partial eta-squared values (N2P) associated with these comparisons. All values are rounded to 3 significant figures or 2 decimal points, excepting p-values which are rounded to 3 decimal points.

	RT				ACC				Efficiency			
	F	**DF**	***p***	**N2P**	***F***	**DF**	***p***	**N2P**	***F***	**DF**	***p***	**N2P**
Block	**11.8**	2, 92	< .001	0.20	1.69	2, 92	.191	0.04	**10.9**	2, 92	< .001	0.19
Priority	**244**	1, 46	< .001	0.84	**149**	1, 46	< .001	0.76	**146**	1, 46	< .001	0.76
Interaction	**8.56**	2, 92	< .001	0.16	**10.5**	2, 94	.001	0.19	**11.0**	2, 92	< .001	0.19

Table 4.4. Descriptive statistics and results of paired samples t-tests comparing high vs. low priority label-shape pairs (table refers to label only) Match trials within each block (Social, Pain, Reward). Values are presented separately for reaction times (RT), response accuracy (ACC) and efficiency scores. In order, the values given represent group means (M), standard deviations (SD), t-values (t), p-values (p), and Cohen's d (d) as a measure of effect size associated with the relevant significance test. All values are rounded to 3 significant figures or 2 decimal points, excepting p-values which are rounded to 3 decimal points.

	RT					ACC					Efficiency				
	M	***SD***	***t*(46)**	***p***	***d***	***M***	***SD***	***t*(46)**	***p***	***d***	***M***	***SD***	***t*(46)**	***p***	***d***
Self	538	100	**7.05**	< .001	0.81	0.92	0.10	**6.63**	< .001	1.01	587	109	**7.70**	< .001	1.34
Stranger	625	112				0.80	0.14				799	190			
Pain	588	94.0	**9.88**	< .001	1.21	0.94	0.07	**8.33**	< .001	1.67	629	124	**7.36**	< .001	1.53
No Pain	722	124				0.74	0.16				1031	351			
Reward	538	94.0	**11.7**	< .001	1.55	0.96	0.05	**9.72**	< .001	1.93	563	107	**9.25**	< .001	1.95
No Reward	698	111				0.71	0.18				1059	344			

Table 4.5. Results of paired samples t-tests comparing high priority label-shape pairs and low priority label-shape pairs (table refers to label only) Match trials with each other across block (Social, Pain, Reward). Values are presented separately for reaction times (RT), response accuracy (ACC) and efficiency scores. In order, the values given represent t-values (t), p-values (p), and Cohen's d (d) as a measure of effect size associated with the relevant significance test. All values are rounded to 3 significant figures or 2 decimal points, excepting p-values which are rounded to 3 decimal points.

	RT			**ACC**			**Efficiency**		
	***t*(46)**	***p***	***d***	***t*(46)**	***p***	***d***	***t*(46)**	***p***	***d***
Self vs. Pain	**-3.01**	.004	0.51	-1.17	.249	0.23	-1.87	.068	0.37
Self vs. Reward	0.01	.992	0.00	**-2.35**	.023	0.49	1.34	.188	0.22
Pain vs. Reward	**3.62**	.001	0.53	-1.44	.157	0.36	**-3.24**	.002	0.58
Stranger vs. No Pain	**-4.40**	< .001	0.82	**2.26**	.029	0.44	**-3.96**	< .001	0.83
Stranger vs. No Reward	**-4.22**	< .001	0.66	**2.95**	.005	0.61	**-4.39**	< .001	0.93
No Pain vs. No Reward	1.22	.230	0.20	1.40	.170	0.18	-0.45	.653	0.08

To investigate this possibility, we performed a series of post-hoc paired samples *t*-tests comparing high and low priority label-shape pairs across blocks (see table 4.5). You-shape stimulus pairs were responded significantly faster than pain-shape pairs, but not more accurately or efficiently. Responses to stranger-shape pairs were significantly faster, more accurate and more efficient than responses to no pain-shape pairs; these effects were also associated with larger effect sizes than differences between label-shape pairs containing the you and pain labels. This suggests that the larger response speed and accuray prioritisation effect in the Pain block (the difference between pain and no pain label-shape pairs) compared to the Social block outlined above was driven by the de-prioritisation of no pain compared to stranger label-shape pairs. The relatively lower prioritisation of pain compared to you label-shape pairs for response speed offset this effect.

T-tests comparing social and reward-related label-shape pairs (see table 4.5) showed that responses to you-shape Match pairs did not differ from reward-shape pairs for reaction time or efficiency, but responses were significantly more accurate towards reward-shape compared to you-shape stimulus pairs. In contrast, responses were significantly faster, more accurate and more efficient towards stranger-shape pairs compared to no reward-shape pairs. These results indicate that the larger prioritisation effect in the Reward block (the difference between reward and no reward label-shape pairs) compared to the Social block outlined above was driven by the de-prioritisation of no reward compared to stranger label-shape pairs. The relatively higher prioritisation of reward compared to you label-shape pairs for response accuracy also contributed slightly to this effect.

Finally, *t*-tests contrasting pain and reward label-shape pairs across blocks (see table 4.5) indicated that reward-shape pairs were responded to significantly faster and more efficiently than pain-shape pairs, but no more accurately. No differences were found between responses to no pain-shape and no reward-shape Match pairs for any of our performance

measures. This suggests that the greater prioritisation effect in the Reward block (the difference between reward and no reward label-shape pairs) compared to the Pain block was indeed driven by a greater prioritisation of reward than pain label-shape pairs, and not by any differences in responses to no pain and no reward label-shape pairs.

Analyses of Mismatch trials. We conducted a series of 3x2 repeated measures ANOVAs with block (Social, Pain and Reward) and high and low priority label-shape pairs as within-subject factors (see table 4.6), and reaction times, accuracy and efficiency as dependent variables. These analyses matched the ones performed for Match trials. There were signifnicant small main effects of block for reaction times and efficiency but not accuracy, matching results from Match trials. The main effect of priority was significant across all performance measures, but associated with much smaller effect sizes than the corresponding effects in Match trials. The interaction between block and shape-label pair priority was not significant for any performance measure.

The main effect of block indicates that overall reaction times and efficiency were higher in some blocks than others, while accuracy remained relatively constant across all blocks. As with Match trials, this could be the result of the nature of the accuracy measure, which is capped at 1.0 (100% correct performance) while reaction time and efficiency are more continuous.

A series of *t*-tests comparing high and low priority label-shape pairs within each block (see table 4.7) revealed that responses to high priority label-shape pairs were significantly faster compared to low priority label-shape pairs in every block. Performance accuracy did not differ significantly between high and low priority label-shape pairs in any of the blocks. Responses were more efficient towards high compared to low priority label-shape pairs in the Pain and Reward block, but not the Social block.

Table 4.6. Results of 3x2 repeated measures ANOVAs comparing main effects of block (Social, Pain and Reward) and label priority (high, low) in Mismatch trials. Results are presented separately for reaction time (RT), accuracy (ACC) and efficiency scores. Measures reported refer to the F value (F), degrees of freedom (DF), p-value (p) and partial eta-squared values (N2P) associated with these comparisons. All values are rounded to 3 significant figures or 2 decimal points, excepting p-values which are rounded to 3 decimal points.

	RT				ACC				Efficiency			
	F	**DF**	***p***	**N2P**	***F***	**DF**	***p***	**N2P**	***F***	**DF**	***p***	**N2P**
Block	**6.67**	2, 92	.002	0.13	0.65	2, 92	.520	0.01	**2.61**	2, 92	.080	0.05
Priority	**15.3**	1, 46	< .001	0.25	**6.63**	1, 46	.010	0.13	**16.4**	1, 46	< .001	0.26
Interaction	0.02	2, 92	.988	0.00	0.19	2, 92	.830	0.00	0.54	2, 92	.590	0.01

Table 4.7. Descriptive statistics and results of paired samples t-tests comparing high vs. low priority label-shape Mismatch pairs (table refers to labels only) within each block (Social, Pain, Reward). Values are presented separately for reaction times (RT), response accuracy (ACC) and efficiency scores. In order, the values given represent group means (M), standard deviations (SD), t-values (t), p-values (p), and Cohen's d (d) as a measure of effect size associated with the relevant significance test. All values are rounded to 3 significant figures or 2 decimal points, excepting p-values which are rounded to 3 decimal points.

	RT					ACC					Efficiency				
	M	***SD***	***t*(46)**	***p***	***d***	***M***	***SD***	***t*(46)**	***p***	***d***	***M***	***SD***	***t*(46)**	***p***	***d***
Self	640	107	**2.17**	.035	0.17	0.86	0.13	1.07	.292	0.13	766	195	0.97	.336	0.15
Stranger	660	121				0.84	0.12				792	152			
Pain	692	108	**2.55**	.014	0.18	0.87	0.10	1.73	.091	0.26	807	148	**2.59**	.013	0.36
No Pain	714	127				0.84	0.12				869	195			
Reward	673	109	**2.46**	.018	0.20	0.88	0.08	1.28	.208	0.18	769	127	**2.77**	.008	0.33
No Reward	693	101				0.86	0.11				821	183			

Competition Task (Computer Task 2)

Mean performance measures. Mean response times, accuracy and efficiency scores were computed for 2 'Match' and 2 'Mismatch' label-label pairs in each of the 6 blocks (see table 4.1). In this task, Match and Mismatch trials comprised label-label stimulus pairs that were either congruent (high-high: HH, low-low: LL) or incongruent (high-low: HL, low-high: LH) for label priority. In congruent blocks (SPC, SRC, PRC), HH and LL were the Match trials and HL and LH were Mismatch trials. In incongruent blocks, HL and LH were the Match trials, and HH and LL were Mismatch trials. Stimulus pairs differed depending on block type: HH stimulus pairs contained two high priority labels, LL two low priority labels affiliated with the block type (e.g. in Self-Pain blocks, you-high pain was the HH label-label pair, stranger-no pain the LL label-label pair); HL and LH label-label pairs contained one high and one low priority stimulus each.

The contrast between HL and LH label-label pairs in incongruent blocks was the crucial measure of the relative prioritisation of self-, pain- and reward-related stimuli. Mean reaction times, accuracy and efficiency scores for Self-Pain, Self-Reward and Pain-Reward blocks are displayed in figures 4.2, 4.3 and 4.4 panels a-c respectively. Our analyses for this task were focused on Match trials; Mismatch trials were not considered.

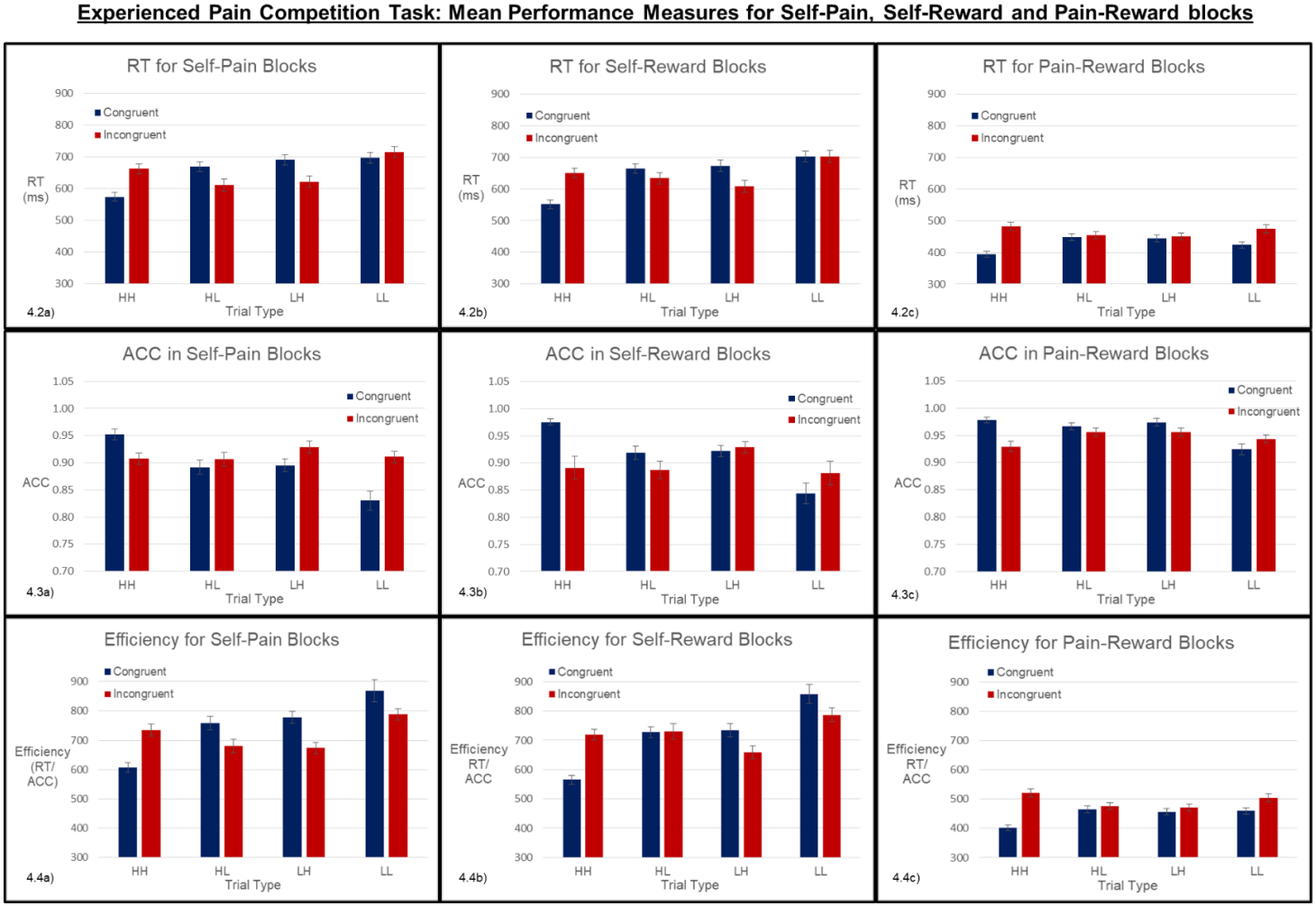


Figure 4.2., 4.3 and 4.4 panels a, b and c. Mean response times (figure 4.2), accuracy (figure 4.3) and efficiency scores (figure 4.4) in the Competition task. Means are displayed for each trial type (HH, HL, LH, LL) in congruent (blue) and incongruent (red) blocks; each panel represents one block type (a: Self-Pain, b: Self-Reward, c: Pain-Reward). Error bars represent the standard error of each mean.

Self-Pain Blocks

We conducted a series of 2x2 repeated measures ANOVAs with reaction times, accuracy and efficiency scores as dependent variables. Block congruency (Congruent: SPC-HH, SPC-LL; Incongruent: SPI-HL, SPI-LH) and self-priority (High: SPC-HH, SPI-HL; Low: SPC-LL, SPI-LH) were the within-subject factors (see table 4.8). Our analyses revealed consistent effects across all performance measures: There were significant main effects of block congruency and self-priority, as well as significant interactions between block congruency and self-priority. Effect sizes associated with the main effect of block were medium, while effect sizes for the main effect of self-priority and the interaction effects were very large (see table 4.8). The interaction effects were not followed up. Due to the arbitrary choice of defining the second factor in the ANOVA as self-priority rather than pain-priority, findings on the interaction are of limited meaning.

We carried out a series of paired samples *t*-tests comparing you-pain (HH) and stranger-no pain (LL) label-label pairs in the congruent, and you-no pain (HL) and stranger-pain (LH) label-label pairs in the incongruent block (see table 4.9). These tests showed that responses were significantly faster, more accurate and more efficient towards you-pain than stranger-no pain stimulus pairs in the congruent block for all performance measures. These effects were associated with very large effect sizes. No significant differences were found between responses to you-no pain and stranger-pain label-label pairs in the incongruent block.

Post-hoc paired samples *t*-tests comparing overall responses in the congruent and incongruent Self-Pain block showed that responses were significantly faster ($M_{Congruent}$ = 635; $SD_{Congruent}$ = 98.0; $M_{Incongruent}$ = 617; $SD_{Incongruent}$ = 114; $t(48) = 2.18$, $p = .034$, $d = 0.18$), more accurate ($M_{Congruent}$ = 0.89; $SD_{Congruent}$ = 0.08; $M_{Incongruent}$ = 0.92; $SD_{Incongruent}$ = 0.07; $t(48) = -3.11$, $p = .003$, $d = 0.36$), and more efficient ($M_{Congruent}$ = 738; $SD_{Congruent}$ = 161; $M_{Incongruent}$ =

677; $SD_{Incongruent}$ = 119; $t(48) = 3.41$, $p = .001$, $d = 0.43$) in the incongruent compared to the congruent Self-Pain block.

Table 4.8. Results of 2x2 repeated measures ANOVAs comparing main effects of block congruency (Congruent: SPC-HH, SPC-LL; Incongruent: SPI-HL, SPI-LH) and self-priority (High: SPC-HH, SPI-HL; Low: SPC-LL, SPI-LH) in Match trials of Self-Pain blocks. Results are presented separately for reaction time (RT), accuracy (ACC) and efficiency scores as dependent variables. Measures reported refer to the F value (F), degrees of freedom (DF), p-value (p) and partial eta-squared values (N2P) associated with these comparisons. All values are rounded to 3 significant figures or 2 decimal points, excepting p-values which are rounded to 3 decimal points.

	RT				ACC				Efficiency			
	F	**DF**	***p***	**N2P**	***F***	**DF**	***p***	**N2P**	***F***	**DF**	***p***	**N2P**
Congruency	**4.75**	1, 48	.034	0.09	**9.68**	1, 48	.003	0.17	**11.6**	1, 48	.001	0.20
Self-Priority	**56.0**	1, 48	< .001	0.54	**27.3**	1, 48	< .001	0.36	**42.1**	1, 48	< .001	0.47
Interaction	**20.4**	1, 48	< .001	0.30	**38.4**	1, 48	< .001	0.45	**32.5**	1, 48	< .001	0.40

Table 4.9. Descriptive statistics and results of paired samples t-tests comparing high and low self-priority Match trials in Self-Pain blocks (High self-priority: SPC-HH, SPI-HL; Low self-priority: SPC-LL, SPI-LH). Separate analyses were performed for reaction times (RT), response accuracy (ACC) and efficiency. In order, the values given represent group means (M), standard deviations (SD), t-values (t) and degrees of freedom, p-values (p), and Cohen's d (d) as a measure of effect size associated with the relevant significance test. All values are rounded to 3 significant figures or 2 decimal points, excepting p-values which are rounded to 3 decimal points.

		RT					ACC					Efficiency				
		M	***SD***	***t (48)***	***p***	***d***	***M***	***SD***	***t (48)***	***p***	***d***	***M***	***SD***	***t (48)***	***p***	***d***
SPC	**HH**	574	97.2	**9.32**	< .001	1.14	0.95	0.07	**7.41**	< .001	1.22	606	114	**7.41**	<.001	1.30
	LL	697	119				0.83	0.12				870	265			
SPI	**HL**	611	130	0.64	.527	0.09	0.91	0.09	1.69	.098	0.27	681	156	0.30	.765	0.05
	LH	622	128				0.93	0.08				673	140			

Self-Reward Blocks

We conducted a series of 2x2 repeated measures ANOVAs on reaction times, accuracy and efficiency scores as dependent variables. Block congruency (Congruent: SRC-HH, SRC-LL; Incongruent: SRI-HL, SRI-LH) and self-priority (High: SRC-HH, SRI-HL; Low: SRC-LL, SRI-LH) were the within-subject factors (see table 4.10). Results were consistent across all performance measures: There were no main effects of block congruency, but a significant main effect of self-priority, as well as a significant interaction between block congruency and self-priority. Both these effects were associated with large or very large effect sizes across all performance measures. The interaction effects were not followed up. Due to the arbitrary choice of defining the second factor in the ANOVA as self-priority rather than reward-priority, findings on the interaction are of limited meaning.

We carried out a series of paired samples *t*-tests (see table 4.11) comparing you-reward (HH) and stranger-no reward (LL) label-label pairs in the congruent, and you-no reward (HL) and stranger-reward (LH) label-label pairs in the incongruent block. These tests showed that responses were significantly faster, more accurate and more efficient towards you-reward than stranger-no reward stimulus pairs in the congruent block for all performance measures. These effects were associated with very large effect sizes. In the incongruent block, responses were significantly more accurate and efficient to stranger-reward than to you-no reward label-label pairs, but did not differ for response speed. This indicates that the reward label was prioritised more than the self label for response accuracy and efficiency. Effects in the incongruent block were associated with small-medium effects sizes.

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Table 4.10. Results of 2x2 repeated measures ANOVAs comparing main effects of block congruency (Congruent: SRC-HH, SRC-LL; Incongruent: SRI-HL, SRI-LH) and self-priority (High: SRC-HH, SRI-HL; Low: SRC-LL, SRI-LH) in Match trials of Self-Reward blocks. Results are presented separately for reaction time (RT), accuracy (ACC) and efficiency scores as dependent variables. Measures reported refer to the F value (F), degrees of freedom (DF), p-value (p) and partial eta-squared values (N2P) associated with these comparisons. All values are rounded to 3 significant figures or 2 decimal points, excepting p-values which are rounded to 3 decimal points.

	RT				ACC				Efficiency			
	F	**DF**	***p***	**N2P**	***F***	**DF**	***p***	**N2P**	***F***	**DF**	***p***	**N2P**
Congruency	0.39	1, 48	.535	0.01	0.04	1, 48	.837	0.00	1.25	1, 48	.270	0.03
Self-Priority	**52.7**	1, 48	< .001	0.52	**18.6**	1, 48	< .001	0.28	**39.0**	1, 48	< .001	0.45
Interaction	**44.6**	1, 48	< .001	0.48	**35.1**	1, 48	< .001	0.42	**46.5**	1, 48	< .001	0.49

Table 4.11. Descriptive statistics and results of paired samples t-tests comparing high and low self-priority Match trials in Self-Reward blocks (High self-priority: SRC-HH, SRI-HL; Low self-priority: SRC-LL, SRI-LH). Separate analyses were performed for reaction times (RT), response accuracy (ACC) and efficiency. In order, the values given represent group means (M), standard deviations (SD), t-values (t) and degrees of freedom, p-values (p), and Cohen's d (d) as a measure of effect size associated with the relevant significance test. All values are rounded to 3 significant figures or 2 decimal points, excepting p-values which are rounded to 3 decimal points.

		RT					ACC					Efficiency				
		M	***SD***	***t (48)***	***p***	***d***	***M***	***SD***	***t (48)***	***p***	***d***	***M***	***SD***	***t (48)***	***p***	***d***
SRC	**HH**	551	101	**12.3**	<.001	1.37	0.98	0.04	**7.04**	< .001	1.33	566	102	**9.23**	< .001	1.64
	LL	703	119				0.84	0.13				859	231			
SRI	**HL**	634	125	1.40	.169	0.21	0.89	0.11	**2.43**	.019	0.45	730	185	**2.18**	.034	0.41
	LH	608	130				0.93	0.07				659	156			

Pain-Reward Blocks

We performed a final series of 2x2 repeated measures ANOVAs on reaction times, accuracy and efficiency scores as dependent variables. Block congruency (Congruent: PRC-HH, PRC-LL; Incongruent: PRI-HL, PRI-LH) and pain-priority (High: PRC-HH, PRI-HL; Low: PRC-LL, PRI-LH) were the within-subject factors (see table 4.12). The main effect of block congruency was significant for reaction times and efficiency but not accuracy, and associated with medium-large effect sizes. The lack of effect on accuracy could indicate a ceiling effect, as accuracy was capped at 1.0 (100% accurate performance) while reaction times and efficiency were more continuous. The main effect of pain-priority was significant across all performance measures and associated with small effect sizes. The interaction between block congruency and pain-priority was also significant and associated with small effect sizes. The interaction effects were not followed up. Due to the arbitrary choice of defining the second factor in the ANOVA as pain-priority rather than reward-priority, findings on the interaction are of limited meaning.

We performed a series of paired samples *t*-tests (see table 4.13) comparing pain-reward (HH) and no pain-no reward (LL) label-label pairs in the congruent, and you-no reward (HL) and stranger-reward (LH) label-label pairs in the incongruent block. Responses were significantly faster, more accurate and more efficient towards pain-reward than no pain-no reward stimulus pairs in the congruent block for all performance measures. These effects were associated with medium-large effect sizes. No significant differences were observed between responses to pain-no reward and no pain-reward label-label pairs in the incongruent block.

Post-hoc *t*-tests comparing overall responses in the congruent and incongruent Pain-Reward block showed that responses were significantly faster ($M_{Congruent}$ = 409; $SD_{Congruent}$ = 66.5; $M_{Incongruent}$ = 452; $SD_{Incongruent}$ = 75.3; $t(48) = -5.66$, $p < .001$, $d = 0.61$) and more efficient ($M_{Congruent}$ = 431; $SD_{Congruent}$ = 65.4; $M_{Incongruent}$ = 473; $SD_{Incongruent}$ = 77.1; $t(48) = 4.58$, $p < .001$,

$d = 0.59$) in the congruent compared to the incongruent Pain-Reward block. Responses did not differ significantly for accuracy ($M_{Congruent} = 0.95$; $SD_{Congruent} = 0.04$; $M_{Incongruent} = 0.96$; $SD_{Incongruent} = 0.05$; $p = .539$).

Table 4.12. Results of 2x2 repeated measures ANOVAs comparing main effects of block congruency (Congruent: PRC-HH, PRC-LL; Incongruent: PRI-HL, PRI-LH) and pain-priority (High: PRC-HH, PRI-HL; Low: PRC-LL, PRI-LH) in Match trials of Pain-Reward blocks. Results are presented separately for reaction time (RT), accuracy (ACC) and efficiency scores as dependent variables. Measures reported refer to the F value (F), degrees of freedom (DF), p-value (p) and partial eta-squared values (N2P) associated with these comparisons. All values are rounded to 3 significant figures or 2 decimal points, excepting p-values which are rounded to 3 decimal points.

	RT				**ACC**				**Efficiency**			
	F	**DF**	***p***	**N2P**	***F***	**DF**	***p***	**N2P**	***F***	**DF**	***p***	**N2P**
Congruency	**32.0**	1, 48	< .001	0.40	0.38	1, 48	.539	0.01	**21.0**	1, 23	< 0.001	0.3
Pain-Priority	**13.5**	1, 48	.001	0.22	**25.0**	1, 48	<.001	0.34	**28.6**	1, 23	< 0.001	0.37
Interaction	**16.9**	1, 48	< .001	0.26	**21.3**	1, 48	< .001	0.31	**25.5**	1, 23	< 0.001	0.35

Table 1.13. Descriptive statistics and results of paired samples t-tests comparing high and low pain-priority Match trials in Pain-Reward blocks (High pain-priority: PRC-HH, PRI-HL; Low pain-priority: PRC-LL, PRI-LH). Separate analyses were performed for reaction times (RT), response accuracy (ACC) and efficiency. In order, the values given represent group means (M), standard deviations (SD), t-values (t) and degrees of freedom, p-values (p), and Cohen's d (d) as a measure of effect size associated with the relevant significance test. All values are rounded to 3 significant figures or 2 decimal points, excepting p-values which are rounded to 3 decimal points.

		RT					**ACC**					**Efficiency**				
		M	***SD***	***t (48)***	***p***	***d***	***M***	***SD***	***t (48)***	***p***	***d***	***M***	***SD***	***t (48)***	***p***	***d***
PRC	**HH**	394	67.3	**4.74**	< .001	0.42	0.98	0.03	**5.68**	< .001	1.00	403	68.3	**5.83**	< .001	0.77
	LL	424	72.5				0.92	0.07				460	78.7			
PRI	**HL**	454	75.2	0.85	0.401	0.05	0.96	0.05	0.03	.973	0.00	476	78.4	0.84	.406	0.05
	LH	450	78.4				0.96	0.05				471	80			

4.4. Discussion

Bias Task

The Bias task of this study revealed a similar pattern of responding as our first study: Shape-label pairs containing the you, reward and pain label were consistently prioritised over shape-label pairs containing the stranger, no pain and no reward label. In this study, these prioritisation effects were associated with large, very large or huge effect sizes across all performance measures, whereas the deception study found medium, large or very large prioritisation effects. This suggests that compared to the pain and reward outcome deception, the prioritisation effect was greater in the present study. This could be a result of either the alterations in pain and reward labels (the use of pain and no pain, as well as reward and no reward labels instead of high and low pain / reward labels which were used in the deception study), or the prior experience of the painful electric stimulation that was linked to the pain label in this study, or the increased sample size in the present compared to the deception study. Interestingly, the prioritisation effect was also larger for shape-label pairs containing the you compared to the stranger label (d = 0.81-1.24) compared to the deception study (d = 0.51-1). This could indicate that the more realistic threat of pain outcomes in the present study caused participants to respond more strategically across all blocks, resulting in enhanced responding to one and decreased prioritisation of another shape-label pair. However, this finding would also be consistent with the interpretation that the increased sample size gave rise to greater effect sizes, which is likely the most important factor contributing to this change.

Given the changes in the experimental paradigm, specifically the administration of electroshocks prior to the computer task and the replacement of “low pain” and “low reward” labels with “no pain” and “no reward”, we expected that the prioritisation of pain (compared to no pain) might now be increased relative to that of self over stranger. We expected this because the “pain” stimulus was associated with an outcome (poor performance on trials

containing this stimulus would be penalised with an increased number of electric shocks administered after the computer task), but there was no outcome benefit for responding well to the "self" stimulus. The results were surprising in this respect. The prioritisation of high compared to low priority stimulus pairs was greatest in the Reward block across all measures, and greater in the Pain than the Social block. This seemed to support our hypothesis that high priority stimuli associated with outcome measures (reward, pain) would be more highly prioritised over their respective low priority counterparts. However, this did not hold true. Instead, the greater apparent prioritisation of reward and pain labels appeared to be a result of de-prioritisation of stimulus pairs containing the low priority labels in the Reward and Pain blocks (i.e. no pain, no reward labels), which were responded to slower, less accurately and overall less efficiently than the stranger label-shape pair. Instead of greater prioritisation of the pain label compared to the you label, pain-shape stimulus pairs were in fact responded to less fast than you-shape labels. Our results overall indicated that de-prioritisation of no pain and no reward labels compared to the stranger label was the main factor driving the increased prioritisation of pain and reward compared to self in the Bias task.

We argue that the relative de-prioritisation of the no pain and no reward stimuli could be considered a within-block trade-off, and the result of strategic rather than automatic cognitive resource allocation in the Pain and Reward compared to the Social block. Participants could have strategically decided to maximise their response speed and efficiency to pain and reward labels in order to achieve the best possible pain and reward outcomes. To this end, they might have had to dedicate more cognitive resources to responding optimally to these labels (compared to the you label in the Social block, which was automatically prioritised for processing). This could have left fewer cognitive resources available to respond well to no pain-shape and no reward-shape stimulus pairs, while more resources were available to respond

to the stranger-shape stimulus pair because the you-shape stimulus pair was prioritised automatically rather than strategically.

It is also possible that the mere presence of incentives (performance outcomes) in the Reward and Pain block increased cognitive task demand, leading to the relative de-prioritisation of low priority label-shape pairs. The act of strategically directing attention to maximise responses to one shape-label pair in the Reward and Pain blocks could therefore have resulted in an overall poorer performance in those blocks. This is consistent with our observation that performance was overall faster and more efficient in the Social compared to the Pain and Reward block. Responses were also faster in the Reward than the Pain block, which could indicate a greater strain on cognitive resources from attempting to avoid pain outcomes in the Pain compared to the Reward block, in which participants attempted to gain reward outcomes.

The present study also showed stronger and more consistent effects in Mismatch trials which also indicated prioritisation of self, pain and reward compared to stranger, no pain and no reward respectively. This contrasts our results from the deception study, in which only the self-prioritisation effect was significant in Mismatch trials. It is possible that the pattern observed in this study is a result of increased sensitivity in the present study due to the much larger sample. The effects observed in Mismatch trials in the present study were small to medium, which is consistent with this explanation. It is possible that Mismatch trials overall reflect the same pattern of responding as Match trials but with notably decreased magnitude. These results support our approach to the Competition task, in which only Match trials were analysed. The effects shown in the Competition task, specifically in incongruent blocks, are already much smaller than those observed in the Bias task. An analysis of less sensitive Mismatch responses would likely merely unnecessarily increase the probability of finding type I errors.

Overall, it seems that our pain outcome manipulation did affect performance and produce a pattern of responding notably different to that observed in the deception study. However, the effects were not as we predicted. Our results suggest that pain- and reward-prioritisation in this study may reflect strategic response patterns aimed at minimising undesirable and maximising desired outcomes in the Pain and Reward block respectively. This would mean that the relative prioritisation of pain compared to no pain (or pain-bias) and reward compared to no reward (or reward-bias) might reflect a participants' ability to prioritise information strategically for cognitive processing, independent of informational content. These measures could then not be validly interpreted as measures of pain- and reward-bias, but rather as representing attentional control.

Individual differences in attentional control, pain experience, pain catastrophising, fear of pain and somatosensory amplification were assessed as part of this study. The nature of the pain- and reward-measure can be investigated indirectly through its relationship with these individual difference variables. This question will be addressed in chapter 5. If prioritisation of pain and reward did in fact reflect participants' ability to strategically allocate cognitive resources rather than content-specific inter-personal differences such as fear of pain or reward sensitivity respectively, we would expect pain- and reward-prioritisation to be positively correlated with each other, as well as attentional control. We would further expect no relationship between pain-prioritisation and pain-related cognition and pain experience, or reward-prioritisation and individual differences in behavioural inhibition and activation. Alternatively, if pain- and reward-prioritisation reflect content-specific individual differences, we expect to see no relationship between these measures and attentional control, but links between pain-prioritisation and pain-related individual differences as well as reward-prioritisation and variation in behavioural inhibition and activation.

We consider the validity of pain-prioritisation in this study as a measure of attentional bias doubtful due to the pattern of results above, which indicate that a more strategic, content-unspecific processing bias underlies both pain- and reward-prioritisation. Individual difference analyses outlined in chapter 5 will contribute to better informing our interpretation of the results presented here. Based on the present results, we tentatively conclude that pain stimuli in the present study may not have elicited pain-related but strategic, outcome-driven responding and may thus be no more suitable than existing paradigms (e.g. dot-probe, Stroop) as a valid measure of pain-bias.

Competition Task

Our hypotheses for the Competition task were partially met. The comparison of Match trials in incongruent blocks revealed no difference between the prioritisation of the you-no pain and the stranger-pain label-label pairs, suggesting that self and pain were prioritised to the same degree. This was in line with our hypothesis that the more realistic threat of pain outcomes, achieved through participants' experience of painful electric stimulation before preforming the computer tasks, would lead to greater prioritisation of the pain relative to the self label in this study compared to the deception study. In the deception study, self was prioritised over pain for one of our three performance measures. The results from the present study therefore indicate that the ability of self-related information to compete for cognitive resources with pain-related information is reduced when pain stimuli are more threatening, or more realistically associated with pain outcomes. However, in the present study, self-related information was still prioritised to the same degree as pain stimuli. The fact that self was not prioritised less than pain even though performance to pain stimuli was linked to pain outcomes while no outcomes were associated with performance to self-related labels still supports our hypothesis that self-related information can compete effectively for cognitive resources with information relating to pain.

This finding supports an interpretation suggested by the results in the Bias study: Self-related information may be prioritised for cognitive processing automatically, while prioritisation of pain and reward in this task may have been the result of strategic, goal-directed processes. If self-related information is processed with comparable cognitive resources as information which is associated with pain outcomes, this strongly suggests that self-related information is automatically prioritised and cannot be de-prioritised even at the cost of incurring pain outcomes.

Given that Match trials containing the no pain label in the Bias task were strongly de-prioritised, potentially in order to maximise performance to pain-shape Match trials, it is all the more significant that the self label was prioritised to the same degree as the pain label when competing for cognitive resources, especially when the self label was paired with the previously de-prioritised no pain label, while pain was paired with the comparatively highly prioritised stranger label. This result seems promising for our hypothesis that self-related task content may enhance the effectiveness of distraction from pain. This finding is particularly interesting considering that the deception study has previously shown the Competition task to be sensitive enough to show when one stimulus type (i.e. self-related information) is prioritised over another (i.e. pain-related information). The absence of prioritisation of pain over self in the present study is therefore unlikely to result from an insensitivity of this task, and is instead likely to result from comparable levels of prioritisation for cognitive processing of the self and pain labels.

In Self-Reward blocks, reward was prioritised over self. This finding contrasted with the results from our deception study, in which self and reward were prioritised equally. The comparatively increased prioritisation of reward relative to self in the present study may indicate that the more realistic pain outcomes associated with pain stimuli through prior experience of painful electric stimulation also made the association between reward stimuli

and reward outcomes more realistic. This is consistent with the fact that both pain and reward outcomes were in fact applied in the present study but not in the deception study, although there was no mechanism to make the reward outcomes more realistic prior to completing the computer tasks to match the pain experience manipulation. This finding may also indicate that participants stopped believing in the deception before or while completing the Competition task in the deception study. In this case, the results of the present study – greater prioritisation of reward relative to self – may represent what findings in the deception study would have been had participants truly believed they would receive financial reward based on their performance to reward labels. The findings would then present a challenge for our hypothesis that self-related task content may enhance the effectiveness of distraction from pain. Performance-based reward is of limited utility for the enhancement of distraction effects (Verhoeven et al., 2010). Therefore, if self-related information is prioritised for cognitive processing to a lesser degree than reward-related information, it may not perform better as a distractor. This is however an indirect and abstract comparison, and self-related information might still enhance the effectiveness of distraction through other mechanisms. Further, previous studies have generally shown equal levels of prioritisation for self- and reward-related stimuli (Sui & Humphreys, 2015). Our findings in on the relative prioritisation of self and reward may therefore more likely be the result of methodological limitations of this study (see limitations).

In Pain-Reward blocks, pain and reward were prioritised to the same degree. In combination with the equal prioritisation of self and pain observed in the incongruent Self-Pain block, this finding suggests that both self and reward may be effective at competing for cognitive resources with pain-related information. This pattern is consistent with our interpretation that the greater prioritisation of reward relative to self observed in the incongruent Self-Reward block may be an artefact of methodological constraints (see limitations); as both self- and reward-reward information were prioritised to the same degree

as pain, it is then inconsistent, though possible, for self and reward to differ in their relative levels of prioritisation in competition with each other. In the deception study, self and reward were both prioritised over pain to some extent. We argue the findings in the present study support the interpretation of enhanced prioritisation of pain stimuli compared to the deception study. This could be a result of the pain experience manipulation or the changes in stimulus material. However, the findings are inconsistent regarding the role of reward-related stimuli. The equal prioritisation of pain and reward in the incongruent Pain-Reward in the present study suggests that the prioritisation of pain was enhanced relative to reward, indicating that the prioritisation of reward was relatively unaffected. The increase in reward prioritisation compared to self in the incongruent Self-Pain block in the present compared to the deception study does not support this explanation, but we argue that our findings are overall in support of this interpretation.

In conclusion, the results of the Competition task indicate that both self- and reward-related information may be prioritised to the same degree, but not more strongly, than pain-related information. This supports our interpretation of the results from the deception study as well as the deception control, which lead us to conclude that participants may not have believed the deception regarding pain and reward outcomes while performing the Competition task, resulting in low prioritisation of pain stimuli relative to self and reward in the deception study. We argue that it is likely that participants did expect to receive pain and reward outcomes in the present study, and the increased prioritisation of pain relative to self and reward observed here is the result of this expectation.

In light of this, our findings seem to tentatively support our hypothesis that self- and reward-related cognitive processing may both be effective at competing for cognitive resources with pain. Self-related content might then enhance the effectiveness of distraction from pain. However, disappointingly, the results of the present study indicate that self-related content may

not be better than performance-based reward at enhancing distraction from pain, as both were prioritised to the same degree as pain in the present study, and reward-related information may have been prioritised more strongly than self-related information. These considerations are somewhat abstract, as prioritisation of pain-related information in the present study was operationalised as responding to visual stimuli linked to future pain outcomes, which may not be representative of processing physical sensations of pain. The hypothesis regarding the ability of self-related task content and performance-based reward to enhance the effectiveness of distraction from pain will therefore be tested more directly in a between-group distraction paradigm (see chapter 6). As the findings presented here cast some doubt on whether self-related information would be better than performance-based reward at enhancing the effectiveness of pain distraction, we included a condition in which the distraction contained both self-related content and performance-based reward in order to investigate whether these two factors may have additive effects that may, together, result in a more effective distraction.

Limitations and Future Directions

Matching our concerns in the deception study regarding the power of pain stimuli to elicit pain-related cognitive processing, it is unclear whether pain- or reward-processing was engaged in the present study. The validity of the Bias task pain-prioritisation measure, as well as our interpretations of the relative prioritisation of self, pain and reward in the Competition task, are all drawn into question by this. In themselves, the results of the present study afforded no investigation of this concern. The notable de-prioritisation of no pain and no reward stimuli in the Bias task leading to an overall performance decrease in Pain and Reward blocks raised our suspicions. We were further alerted by the unexpectedly high number of individuals who had to be excluded from analysis because they stopped responding to no pain and no reward stimuli entirely, disregarding the clear instructions for the task to try to respond as fast and as accurately as possible in all trials. This pattern of behaviour was notably different from responses in the deception and control study.

It is unclear what drove this effect. The threat of pain outcomes and the promise of reward in the present study may have been so great as to drive participants to break the social contract of performing the task which participants were reimbursed to do according to the instructions. The change in stimulus material may also have contributed to this pattern of responding; in the deception study, low priority pain and reward labels were still associated with an expected outcome, albeit a less painful / threatening one than high priority stimuli (mildly relative to strongly painful electric stimulation and £0.5 as opposed to £8). The replacement with no pain and no reward stimuli may have removed participants' incentive to respond; although, puzzlingly, participants still responded to stimulus pairs containing the self and stranger label. In the Bias task, this might have been explained by the absence of incentivised trials in the Social block: Because there was nothing to gain from responding to any trials, there was also nothing to lose by responding to all trials without focusing particularly on any on shape-label pair. However, in the Competition task, participants responded to the you-no pain label-label pair, which was associated with no outcomes, equally well as to the pain-stranger label. If the relative incentive explanation of the de-prioritisation of no pain and no reward stimuli had been true, this should not have been the case.

Another possible explanation is the sample of participants. Participants in the deception study also expected to receive painful electric stimulation, the studies were therefore likely to attract the same kind of volunteers. Further, our exclusion and inclusion criteria were identical, and both studies were advertised as including painful electrical stimulation. Consequently, it is unlikely that participants in the present study represent a different group of individuals because they volunteered to participate in a pain experiment (i.e. selection bias), or were recruited according to different criteria.

Finally, it is possible that the unexpectedly poor responding to no pain and no reward stimuli was driven by perceptual characteristics of these stimuli. Both the no pain and no reward label contained a '0' symbol; this may have automatically elicited de-prioritisation. The results of the deception control and deception study indicated that perceptual characteristics may have played a role in the relative prioritisation of pain and reward in the deception study. Although stimulus material in the present study was changed from the previous design in order to address this limitation, it is possible that this alteration

in fact attenuated the problem. We argue that this is the most likely explanation for the present findings. This interpretation would suggest that perceptual characteristics of pain and reward stimuli may have contributed substantially to the differential pattern of responding, which would drastically reduce the validity of any of our conclusions regarding pain- and reward-related processing. However, as no control study using the same stimulus material as the present study but without pain or reward outcomes was performed, this remains speculation. The relationships between pain- and reward- prioritisation and individual differences in pain- and reward-related cognition will however be investigated in chapter 5 and some indirect conclusions may be drawn from this about the degree to which response patterns to these stimuli reflect pain- and reward-related cognitive processing as opposed to perceptual characteristics of the stimulus material used.

The Competition task is limited by its inability to distinguish whether any differences between Match trials in incongruent blocks are driven by differential relative prioritisation of the high priority label contained in each Match trial (e.g. by greater prioritisation of reward compared to self in the incongruent Self-Reward block), or decreased de-prioritisation of the paired low priority label (e.g. lower de-prioritisation of the stranger compared to the no reward stimulus). This may have impacted the relative prioritisation of reward compared to self and pain in the Self-Reward and Pain-Reward blocks respectively. This is particularly plausible as an explanation of the findings from the Self-Reward block, considering that the results of the Bias task showed that both the no pain and no reward label were de-prioritised significantly compared to the stranger label. It is therefore possible that the increased prioritisation of reward relative to self observed in the incongruent Self-Reward block reflects enhanced processing of the stranger compared to the no reward stimulus, and does not indicate greater relative prioritisation of reward compared to self. This would be consistent with previous studies (Sui & Humphreys, 2015), which have shown the prioritisation of reward to be comparable to that of self.

As there was no difference between the degree to which the no pain and no reward labels were prioritised, it is unlikely that this effect impacted the results of the Pain-Reward block. Notably, in the Self-Pain block, this effect may have inflated the relative prioritisation of pain compared to self. As both were observed to be prioritised equally in this study, but self was prioritised over pain in the

deception study, this could mean that self was prioritised more than pain in the present study as well as the deception study, but this effect was offset by the de-prioritisation of the no pain label in the present study which was paired with the self stimulus in the incongruent Self-Pain block and thus may have offset the prioritisation effect of self compared to pain in this block. The increased de-prioritisation of low priority pain and reward stimuli may have been a result of the replacement of low pain and low reward labels with no pain and no reward. This interpretation is consistent with both the results of the Bias task and the interpretation above; however, given that this study introduced the threat of experienced pain as well as these changes in stimulus material, it is impossible to differentiate which of these factors drove these effects. However, it is highly likely that the level of self-prioritisation in competition with pain was either correctly estimated or underestimated in the Competition task of this study, not overestimated. Our findings therefore still support the hypothesis that self-related information can compete effectively for cognitive resources with pain-related stimuli.

There were also inconsistent effects of block congruency in this study. There was a significant cost of incongruent label-label pairings in the Pain-Reward block, while the incongruent pairings facilitated responding in the Self-Pain block and in the Self-Reward block, performance did not differ between congruent and incongruent blocks. These results differ from the deception study, in which congruent and incongruent blocks did not differ. In the deception study, we concluded that this supported the validity of the Competition task paradigm by indicating that overall block performance was capped, but cognitive resources differently allocated between the two Match pairs in the congruent compared to the incongruent block. This interpretation is in line with limited capacity models of attention (Broadbent, 1958). However, the overall performance difference between congruent and incongruent blocks in the present study, and in particular the inconsistent impact of incongruent pairings, raises questions about this interpretation. In combination with the findings on de-prioritisation of no pain and no reward labels, this suggests that the mechanisms underlying the relative allocation of cognitive resources in the Competition task in the present study may have differed from those in the deception task.

Chapter 5

5

Relationships between Self- and Pain-related Individual Differences

5.1. Introduction

In our previous chapters, we investigate the relationship between self- and pain-bias as well as the competition between self and pain using two novel adaptations of the Perceptual Matching Paradigm (PMP; Sui, He & Humphreys, 2012): The Bias and Competition task. We consider whether these tasks are appropriate to assess self-, pain- and reward-bias as well as competition between them, and highlight several limitations of our task design. One such limitation is the validity of our measure of pain-bias (or pain-prioritisation) as a reflection of pain-related cognitive processing. We designed three variations of our paradigm (deception, control and experienced pain) in an attempt to identify the pain-related situational factors driving pain-prioritisation as measured in the Bias and Competition task. However, despite these efforts it remains uncertain whether our measure of pain-prioritisation truly reflects pain-related cognitive processing instead of, for example, content-unspecific strategic cognitive processing to maximise reward and minimise pain outcomes.

The question whether implicit measures of pain-bias reflect pain-related processing is a common limitation in research on attention to pain. In a meta-analysis of 50 studies

comprising a total of 2035 participants, Crombez, Van Ryckeghem, Eccleston and Van Damme (2013) compared the impact of different tasks and stimulus material on findings of attentional bias towards pain. Their results showed overall no significant differences in pain-bias between healthy and control groups, which lead the authors to conclude that neither the lexical nor pictorial stimuli commonly used in this field may be able to activate pain schemata. This would mean measures of pain-bias that rely on such stimulus material do not reflect pain-related cognitive processing.

To address this question, we may explore the relationship between pain-bias and individual difference variables we believe to reflect pain-related thought processes, such as fear of pain. Crombez, Van Ryckeghem, Eccleston and Van Damme's (2013) meta-analysis considers this by investigating the relationship between pain-bias and explicitly assessed individual difference measures in chronic pain patients. The authors expected an increased magnitude of pain-bias in patients experiencing greater pain severity, pain-related fear, state or trait anxiety or depressive mood. In showing a relationship to other constructs thought to link to pain-related thought processes, such a finding would increase the validity of pain-bias measures. However, the meta-analysis showed no relationship between pain-bias and any of these individual difference measures, casting further doubt on the capacity of established methodological designs and stimulus material to assess pain-related cognitive processing.

In this chapter, we apply a similar approach by investigating the relationship between pain-bias and explicit measures of pain-related individual differences, such as pain experience, pain catastrophizing (Sullivan, Bishop & Pivik, 1995), fear of pain (McNeil & Rainwater, 1998) and somatosensory amplification (Barsky, Goodson, Lane & Cleary, 1988). These measures are thought to assess different but overlapping facets of individuals' sensitivity to and attentional focus on pain, and could therefore reasonably be expected to link to a valid measure of attentional prioritisation of pain for cognitive processing. We also investigated the

link between reward-bias and the questionnaire measure of behavioural inhibition and activation (Carver & White, 1994). The data analysed in this chapter were obtained from the same participants in the same experimental session as those analysed in chapter 4. Bias measures referred to in this chapter are derived from the Bias task adaptation of the PMP as detailed in chapter 4. The analyses reported here are exploratory. The PMP adaptation from which bias measures in this chapter are derived is novel, and this is the first study reporting on their relationship with questionnaire-based individual difference measures. We therefore form no specific hypotheses about the direction of relationships we expect to find. However, we expect to find a relationship between pain-prioritisation in the Bias task and pain-related individual difference measures if pain-prioritisation is a valid measure of pain-related cognitive processing.

We additionally explored the relationship between self-bias and self-related cognitive styles, specifically narcissism, self-esteem, generalised self-efficacy and locus of control. The relationship between implicit measures of self-bias and explicitly assessed self-related cognition is to date still poorly understood. Although a great deal of research has investigated self-bias (Bredart, Delchambre & Laureys, 2006; Cunningham, Turk, Macdonald & Macrae, 2008; Keenan, Nelson & O'Connor 2001; Turk, Cunningham & Macrae, 2008), and some studies have investigated the relationship between processing biases for self and reward (Enzi, de Greck, Prosch, Tempelmann & Horthoff, 2009; Sui, He & Humphreys, 2012; Sui & Humphreys, 2015; Sui, Yankouskaya & Humphreys, 2015), few studies have set out to improve our understanding of the relationship between self-bias and other self-related cognitive measures. Sui & Humphreys showed a link between decreased self-bias and increased personal distance to strangers, a questionnaire-based individual difference measure aiming to reflect how close participants perceived themselves to be to strangers as opposed to friends of themselves. However, this measure was only introduced recently by Sui and Humphreys

(2015). These findings contribute to our understanding of the construct of self-bias as assessed by the PMP; however, they do not allow us to relate implicit self-bias to other, more established, self-related cognitive constructs. The present study aims to address this gap in research and show whether PMP-based self-bias measures are related to individual differences in narcissism, self-esteem, self-efficacy, or locus of control. However, given the lack of previous research in this area, we again form no hypothesis about the direction of such effects.

Adding to the questions outlined above, this chapter will explore the relationship between implicit self-pain association and self- and pain-related individual difference measures. The schema enmeshment model of pain (Pincus & Morley, 2001) postulates that as chronic pain patients experience pain more frequently, pain becomes integrated into their self-concept. Increased enmeshment of self and pain then contributes to the maintenance and exacerbation of pain symptoms and illness behaviours in chronic pain patients. In support of this model, increased self-pain enmeshment in chronic pain patients has been linked to a variety of negative outcomes including increased disability, pain suffering, anxiety, depression or depressive mood as well as decreased acceptance (Pincus & Morley, 2001; Pincus, Santos & Morley 2007; Sutherland & Morley, 2008; Morley, 2010; Rusu & Pincus, 2012; Van Ryckeghem, De Houwer, Van Bockstaele, Van Damme, De Schryver & Crombez, 2013). Self-Pain associations are increased in chronic pain patients compared to healthy individuals (Van Ryckeghem, De Houwer, Van Bockstaele, Van Damme, De Schryver & Crombez, 2013).

Establishing links between individual differences and self-pain associations is important to better understand the role self-pain associations play in the maintenance and development of chronic pain. The increased self-pain enmeshment observed in chronic pain patients (Pincus & Morley, 2001; Van Ryckeghem, De Houwer, Van Bockstaele, Van Damme, De Schryver & Crombez, 2013) could however reflect differences in self-pain associations between healthy individuals and chronic pain patients which preceded the chronic pain

condition. Specifically, individuals with a greater tendency to integrate pain into their self-concept might be more likely to develop chronic pain conditions. To investigate these possibilities, it is vital to better understand the factors affecting variations in self-pain associations in healthy individuals.

The relationship between individual differences in self-pain enmeshment and self- and pain-related cognition in healthy individuals will be discussed in more depth in chapter 7. The present chapter constitutes a pilot for the methods and analyses used in chapter 7. We expect to find a link between pain experience and self-pain association, in line with predictions by the schema enmeshment model that more frequently experienced pain leads to greater enmeshment of self and pain in the transition from acute to chronic pain. Analyses of the relationship between self-pain enmeshment and self- and pain-related cognitions as well as self- and pain-bias measures are exploratory. We investigate whether self-pain enmeshment in healthy individuals is linked to self-bias, self-esteem (Rosenberg, 1965), narcissism (Ames, Rose and Anderson, 2006), locus of control (Levenson, 1972), pain-bias, pain catastrophizing (Sullivan, Bishop & Pivik, 1995), fear of pain (McNeil & Rainwater, 1998) or somatosensory amplification (Barsky, Goodson, Lane & Cleary, 1988).

5.2. Method

Participants. Participants in this study were 55 young, healthy individuals. The data analysed in this chapter were obtained as part of the study outlined in chapter 4. Details of the sample including recruitment, exclusion and inclusion criteria are given in chapter 4.

Self-report measures

Sample characteristics. Questionnaire data were collected online in anonymised digital format using LimeSurvey, and processed using Excel 2013. The characteristics of our sample (means, standard deviations, chronbach's α) as well as descriptors of the questionnaires used (range of scores, number of items or subscales) are displayed in table 5.1.

Table 5.1. Sample means, Standard deviations, number of items and subscales (where applicable) comprised, and chronbach's alpha coefficients for questionnaire measures.

	Sample Mean	SD	Range	n	Cronbach's α
Attentional Control	51.61	8.87	20-80	20	0.85
Pain Experience	-	-	-	10, 4	-
Pain Intensity	39.69	15.44	0-100	3	0.62
Disability Score	25.62	18.94	0-100	3	0.86
Disability Points	0.72	0.45	0-6	2	-
Grade	1.35	0.48	0-4	2	-
Pain Catastrophising	15.09	9.39	0-52	13	0.91
Fear of Pain	74.37	15.76	30-150	30, 3	0.90
Severe Pain	33.6	7.44	10-50	10	0.84
Minor Pain	17.47	5.28	10-50	10	0.81
Medical Pain	23.29	6.78	10-50	10	0.83
Somatosensory Amplification	26.78	6.45	10-50	10	0.71
Narcissistic Personality Inventory	4.75	2.59	0-16	16	0.61
Self-Esteem Scale	8.11	5.41	0-30	10	0.88
Locus of Control	-	-	-	24, 3	-
Internality	33.64	6.51	0-48	8	0.70
Powerful Others	18.49	8.37	0-48	8	0.82
Chance	20.49	7.94	0-48	8	0.74
Behavioural Inhibition and Activation Scale	-	-	-	24	-
Behavioural Inhibition	21.05	3.86	7-28	7	0.82
BAS Drive	11.70	2.33	4-16	4	0.76
BA Fun-Seeking	12.33	2.06	4-16	4	0.63
BA Reward Responsiveness	17.09	2.44	5-20	5	0.70

Attention Control Scale (ACS). Participants completed the Attention Control Scale (ACS; Derryberry & Reed, 2002). Each of 20 statements was rated on a 4-point scale for how often it applied to them (1 = almost never, 2 = sometimes, 3 = often, 4 = always). Some items were reverse scored. A mean attentional control score was calculated from these ratings, with higher scores indicating better ability to control attention. Where data was missing for any single item, the mean was calculated from the remaining items (1 case). Means were then multiplied by the number of items in the questionnaire (20) for comparability with previous studies. Our sample mean and standard deviation (M = 51.61; SD = 8.87) were close to those reported by Derryberry and Reed (2002; Study 3: M = 50.28; SD = 9.39; Study 4 M = 48.23; SD = 9.27). This measure of attentional control has previously been shown to be highly internally consistent (Derryberry & Reed, 2002) with Chronbach's α = 0.88. Internal consistency in our sample was equally good (α = 0.85).

Pain-related

Pain Experience (PE). Participants completed a pain experience questionnaire adapted from the graded Chronic Pain Scale (PE; von Korff, 0rmel, Keefe & Dworkin, 1992). Von Korff et al. showed the graded Chronic Pain Scale to be valid and reliable for several pain problems. The questionnaire comprises some general questions about pain experienced by participants over the preceding 6 months, and three 11-point numeric rating scales (0-10) each to assess pain intensity (present pain, worst and average pain over last 6 months) and disability (pain interference with daily, social and work activities). Participants also report the total number of disability days during the past six months (between 0-180). Overall intensity and disability scores range from 0 to 100 and are calculated as the average score across the 3 scales associated with pain intensity and disability respectively, multiplied by 10. Higher scores indicate higher pain intensity and disability. We then categorised participants as pain grades 0 ("pain-free), 1(low disability, low intensity), 2 (low disability, high intensity), 3 (high disability, moderately limiting), or 4 (high disability – severely limiting) according to the Graded Chronic Pain Scale scoring system.

In our sample, most participants (94.6%; $n = 55$) had experienced some pain in the last 6 months (i.e. headache, stomach ache, injury, illness, etc.). No participants were categorised as entirely pain free, but for all, pain was categorised as non-persistent (i.e. not persisting for the entire 6 months preceding the study). Most participants' pain was categorised as mildly or not at all disabling ($M = 25.62$, $SD = 18.94$) and of low or average intensity ($M = 39.69$, $SD = 15.44$). The majority of participants (96.4%) were categorised as grade 0-2: Thirty-five participants were categorised as grade 1, and 19 participants were categorised as grade 2. No participants were categorised as grade 3 or 4, consistent with our inclusion criteria and recruitment of 'generally healthy' participants. The internal consistency of pain intensity scores in our sample was questionable, that of disability scores was good (see table 5.1).

Pain catastrophizing (PC). Participants completed the 13-item Pain Catastrophising Questionnaire (PC; Sullivan, Bishop & Pivik, 1995). This scale measures catastrophic thoughts about pain, and is appropriate for both clinical and non-clinical samples. Reflecting on past pain experiences, participants rate the degree to which each of the 13 thoughts or feelings (e.g. "I worry all the time whether the pain will end") describes their experience. Ratings are given on a 5-point scale (0 = not at all, 1 = to a slight degree, 2 = to a moderate degree, 3 = to a great degree, 4 = all the time). We calculated a mean score for each participant and multiplied this by the number of items in the questionnaire, thus effectively calculating a sum score while replacing missing values on individual items (1 case) with the participants' mean score across all other items. Previous studies have shown the pain catastrophising scale to have good internal consistency (Sullivan et. al., 1995: $\alpha = 0.87$). In our sample, internal consistency was excellent (see table 5.1).

Fear of pain (FoP). Participants also completed the 30-item fear of pain questionnaire III (FPQ-III, McNeil & Rainwater, 1998). This questionnaire is suitable to assess fear of experiencing pain in both clinical and non-clinical populations, as demonstrated by McNeil and Rainwater (1998). Participants rated 30 items in terms of how fearful they are or would be of each event. Responses were given on a 5-point scale (1 = not at all, 2 = a little, 3 = a fair amount, 4 = very much, 5 = extreme). An overall measure of fear of pain was calculated, as well as subscale measures for fear of severe pain, minor pain and medical pain. For all measures, we calculated the mean for each participant first, then multiplied the mean by the number of items comprised in the measure. Measures were therefore effectively sum scores with any missing items (2 cases) replaced by the participants' mean on that measure calculated from the remaining items. The total fear of pain score as well as its subscales have been shown to have good – excellent internal consistency in previous studies (McNeil & Rainwater, 1998; Total fear of pain $\alpha = 0.92$, fear of severe pain $\alpha = 0.88$, fear of minor pain $\alpha = 0.87$, fear of

medical pain α = 0.87). In our sample, the overall scale had excellent internal consistency, while all subscales had good consistency (see table 5.1).

Somatosensory Amplification Scale (SAS). Participants completed the 10-item Somatosensory Amplification Scale (SAS; Barsky, Goodson, Lane & Cleary, 1988), which reflects individuals' tendency to experience somatic sensations as intense, noxious or disturbing. For each of 10 sentences, participants rated how much they applied to them on a 5-point scale ranging from 1 to 5. Overall scores between 10 and 50 were calculated for each participant by multiplying participants' average scores by the total number of items, thus obtaining a sum score with any missing items replaced by the participants' average across all other items (1 case). Higher overall scores indicated higher levels of somatosensory amplification. Previous studies have shown this scale to have good internal consistency (Barsky, Wyshak & Klerman, 1990; α = 0.82). In our sample, internal consistency of the scale was acceptable (see table 5.1).

Self-related

Narcissistic Personality Inventory (NPI). The 16-item Narcissistic Personality Inventory (NPI-16; Ames, Rose & Anderson, 2006) was used as a short measure of narcissism. Narcissism has received considerable attention in relation to a variety of sub-clinical populations in recent years, as a measure of enhanced perceptions of one's own behaviours and attitudes. Participants were given 16 pairs of sentences, and instructed to decide which of the two sentences in each pair described them better. Narcissism scores ranging from 0 to 16 were then calculated for each participant depending on their 16 choices, with one sentence from each pair considered the more, and one the less narcissistic option. Where participants did not follow instructions correctly and indicated that both sentences in the pair described them equally well or neither described them, 0.5 was added to their total score instead of either 1 or 0 (54 cases,

12 participants). The 16-item Narcissistic Personality Inventory has been shown to have acceptable internal consistency in previous studies (Ames, Rose & Anderson, 2006; $\alpha = 0.72$), and had questionable internal consistency in our sample (see table 5.1).

Self-Esteem Scale (SES). Rosenberg's (SES; Rosenberg, 1965) 10-item scale was used as a self-report measure of participants' positive self-esteem. Participants rated each of 10 statements based on how much they agreed with it on a 4-point scale (3 = strongly agree, 2 = agree, 1 = disagree, 0 = strongly disagree), with some items reverse scored. We calculated mean scores for each participant and multiplied these averages by 10 to obtain a sum score between 0 and 30, with missing items effectively replaced with the participant's mean from all other items (1 case). Higher scores indicated higher self-esteem, and scores below 15 indicated low self-esteem problems. This scale has previously shown to have good internal consistency (Bosson, Swann & Pennebaker, 2000; $\alpha = 0.87$), and had good internal consistency in our sample (see table 5.1).

Locus of Control Questionnaire (LoC). Participants completed the Locus of Control – Internality, Powerful Others and Chance scale (LoC; Levenson, 1972). Each of 24 items was rated on a 6-point scale depending on how strongly the participant agreed or disagreed with the statement (-3 = strongly disagree, -2 = moderately disagree, -1 = slightly disagree, 1 = slightly agree, 2 = moderately agree, 3 = strongly agree). We calculated sum scores for 3 subscales (Internality, Powerful Others and Chance). A constant of 24 was added to each participant's subscale scores, resulting in scores between 0 and 48 with higher scores indicating a stronger belief that the associated factor has a high degree of control over events in the individual's life (Internality = controlled by individual; Powerful Others = controlled by other individuals; Chance = controlled by external events, e.g. chance or fate). Previous studies have shown acceptable internal consistency across all subscales of this scale (Kourmousi, Xythali &

Koutras, 2015; Internality: α = 0.74, Powerful Others: α = 0.79, Chance: α = 0.79). In our sample, internal consistency was acceptable-good across all subscales (see table 5.1).

Reward-related

Behavioural Inhibition and Activation Scale (BIS/BAS). The Behavioural Inhibition and Activation Scale (BIS / BAS; Carver & White, 1994) was completed by participants as a self-report measure of susceptibility to positive and negative reinforcement. Participants rated each of 24 items on a 4-point scale for the degree to which it was true or false for them (1 = very true for me, 2 = somewhat true for me, 3 = somewhat false for me, 4 = very false for me), with some items reverse scored. Mean scores for behavioural inhibition (single factor) and three subscales of behavioural activation (Drive, Fun Seeking and Reward Responsiveness) were calculated from different subsets of items, with 4 filler items not contributing to any of the subscales. Mean scores were then multiplied by the number of items contributing to the subscale, resulting in sum scores in which any missing items were effectively replaced with the participant's average across the other items in that subscale (2 cases, 1 participant). Previous research has shown this scale to have questionable – acceptable internal consistency (Carver & White, 1994; Behavioural Inhibition: α = 0.74, BA Drive: α = 0.76, BA Fun Seeking: 0.66, BA Reward Responsiveness: α = 0.73). In our sample, the subscales had questionable – good internal consistency (see table 5.1).

Implicit Associations Test (IAT) Computer Task

Word stimuli. Each of the two categories in each dimension was represented by 3 words (see table 5.2). The 'self' category was represented by the words, 'my' and 'myself' 'self', while the 'other' category contained the words 'other', 'them' and 'their'. We derived this stimulus material from an experiment by Teachman, Marker & Smith-Janik (2009), but substituted the word 'myself' for 'I', and the word 'their' for 'they'. The 'pain' category was represented by the words 'excruciating', 'horrible' and 'exhausting', while the 'no pain'

category was represented by the words 'relieving' 'relaxing' and 'pleasant'. The stimulus material for this dimension was derived from a study by Van Ryckeghem et al., (2013), although we replaced the word 'lenitive' with 'pleasant'.

Table 5.2. List of words belonging to the pain, no pain, me and not me categories in the Self-Pain Implicit Associations task.

	Pain	**No Pain**	**Me**	**Not Me**
Stimuli	horrible excruciating exhausting	relieving relaxing pleasant	my myself self	other them their

Design. The Implicit Associations Test was initially developed by Greenwald, McGhee and Schwartz (1998). This version of the IAT was designed in line with Greenwald, Nosek and Banaji (2003) and closely following the method of Van Ryckeghem et al. (2013). The test comprised 7 blocks, of which the 3rd and 4th as well as the 6th and 7th were critical (see table 5.3). The order of blocks was semi-randomised across participants in line with Greenwald, Nosek and Banaji (2003), so that some participants completed the block sequence 1-2-3-4-5-6-7, while the rest completed the block sequence 1-5-6-7-2-3-4.

Procedure. At the beginning of each block, relevant category labels were presented for unlimited time along with the stimuli belonging to that category. Labels were 'Me' and 'Not me' for the self-other dimension, and 'pain' and 'no pain' for the pain-no pain dimension. The labels relevant for each block remained visible in the upper left and right corners of the screen throughout all the trials in that block. In each block, participants' task was to categorise stimuli appearing at the centre of the screen as quickly and accurately as possible in terms of the categories shown at the top of the display. At the beginning of each trial, a fixation cross was displayed for 500 milliseconds in the centre of the screen. This was followed by the presentation of the stimulus for up to 3000 milliseconds, or until a response was made. A feedback screen showing the words 'correct', 'incorrect' or 'no response detected' was presented after the stimulus screen. Responses were given by pressing the 'z' key on the left of

the keyboard for items belonging to either of the categories represented in the upper left corner of the screen, or the 'm' key for items belonging to the category represented in the upper right corner of the screen. In blocks 1, 2 and 5, categorisation on only one dimension was required (self-other or pain-no pain dimension). In blocks 3, 4, 6 and 7, stimuli of both dimensions were presented, and participants were instructed to press the 'z' key if the presently displayed stimulus corresponded to either of the two categories shown in the top left corner, or the 'm' key if the stimulus belonged to either of the categories displayed in the top right corner. Figure 5.1 shows examples of trial displays in each block type. An overview of the categorisations required in each block as well as response keys used is shown in table 5.3.

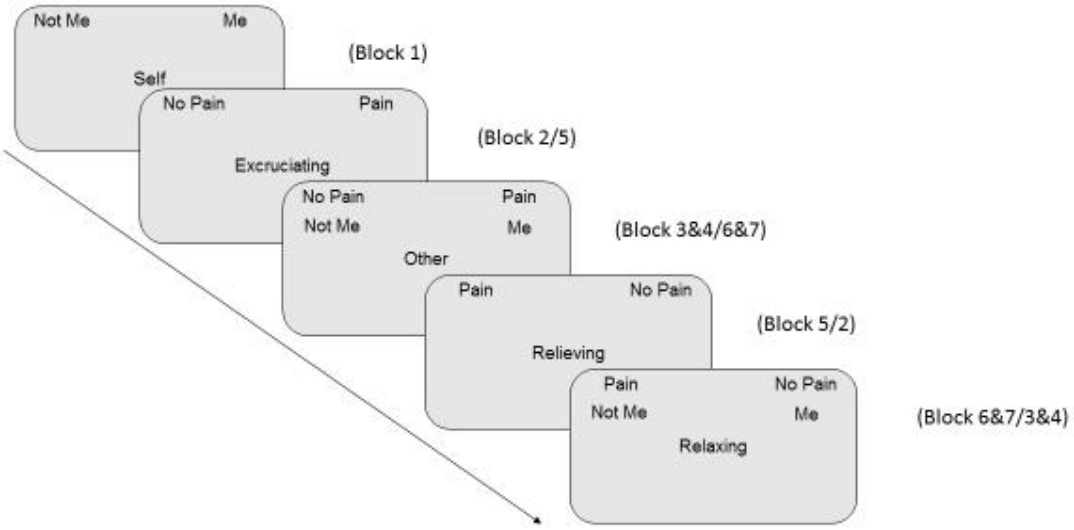

Figure 5.1 Schematic representation of the Implicit Associations Test (IAT).

In the first block, participants practised the discrimination between self and other stimuli. In the self-other discrimination block, each of the 'self' and 'other' stimulus words (6 stimuli) was presented 8 times (i.e., 48 trials). In the second block, participants practised the discrimination between 'pain' and 'no pain' stimuli. Each of the 'pain' and 'no pain' related words was presented 4 times (i.e. 24 trials). The third and fourth blocks were self-pain blocks.

In these blocks, all stimuli from each category (3 each for the 'self', 'other', 'pain' and 'no pain' categories) were presented 4 times in each of the pain blocks (i.e. 48 trials/block). The fifth block required categorisation only along the pain-no pain dimension. However, the response mapping for this categorisation was now reversed from previous blocks. During this block, each word was presented 4 times (i.e. 24 trials). In blocks 6 and 7, participants again categorised the words of all 4 categories as quickly and accurately as possible, but this time responses mapped together two different categories than in blocks 3 and 4. Blocks in which stimuli falling into the category of 'self' or 'pain' required the same response (stimuli falling into the categories of 'other' or 'no pain' required the same response also) were considered congruent blocks. Blocks in which stimuli categorised as 'other' and 'pain' required the same response, (those categorised as 'self' or 'no pain' also required the same response) were considered incongruent blocks. Faster responses in congruent blocks indicated greater ease mapping 'pain' and 'self' onto the same response, which indicates higher implicit self-pain association. Faster responses in incongruent blocks suggested greater ease mapping 'self' and 'no pain' onto the same response, indicating lower implicit self-pain association.

Table 5.3. Block and trial overview for the Implicit Associations Test (IAT).

Block nr.	Block name	Trials	Left key	Right key
1	Self-Other discrimination	48	Other	Self
2 (5)	Pain-No pain discrimination	24	No Pain	Pain
3 (6)	Self-pain practice block	48	Other + No pain	Self + Pain
4 (7)	Self-pain test block	48	Other + No pain	Self + Pain
5 (2)	No pain-Pain discrimination	24	Pain	No pain
6 (3)	Other-pain practice block	48	Other + Pain	Self + No pain
7 (4)	Other-pain test block	48	Other + Pain	Self + No pain

Data Handling. Greenwald, Nosek and Banaji (2003) developed a set of new measures (D1-D6) in addition to previously used measures (C1-4) that could be derived from IAT data. Based on an in-depth comparison of these measures on a wide range of criteria, they conclude that all of their novel measures (D1-6) outperform all of the conventional ones (C1-4). They further concluded that measures in which error penalties (error latencies replaced with penalty value (D3-6), or procedurally built-in error latency (D1-2)) were used to derive the IAT performance score outperformed measures in which error trial latencies were excluded. Of the measures which replaced error latencies with computed penalties (D3-6), they argued their observations very slightly favoured those measures which deleted latencies below 400ms (D5 & 6) over those measures which included latencies below 400ms in their calculation of the final IAT performance score (D3 &4), but conceded that this gain appeared so slight as to make the performance of these algorithms approximately equal. In our sample of young and healthy participants, reaction times were on average very low (M = 619.32, SD = 99.35, SEM = 13.40). Although the D-6 measure has been commonly used in recent studies using the IAT paradigm (e.g. van Ryckeghem, et al., 2013), we decided to use the D4 algorithm to calculate IAT scores in order to avoid excluding a high proportion of trials by excluding response latencies below 400ms. The D-4 and D-6 measures are identical other than the exclusion of response latencies below 400ms from calculation in the D-6 measure. Accordingly, we computed participants' D4 scores for blocks 3, 4, 6 and 7, including all trials but replacing latencies in error trials with the mean response time for that block plus a standard error penalty of 600ms. Matlab 2013 was used to perform these computations. Performance was then averaged across blocks 3 and 4 as well as 6 and 7 to give one D-4 score each for congruent and incongruent blocks.

Participants' overall IAT scores were calculated by subtracting incongruent block D-4 scores from congruent block D4 scores. Consequently, positive IAT scores indicate greater association with no pain than pain, while negative scores indicate greater association with pain than no pain. On average, participants' IAT scores were positive (M_{IAT} = 55.67, SD_{IAT} = 134.73). This suggests an overall tendency towards identifying with no pain rather than pain in our healthy sample.

In line with van Ryckeghem et al. (2013), we set our participant exclusion criterion at an error rate of 30% or higher. Participants' responses were consistently highly accurate (*M* = .93, *SD* = .05, *SEM* = .01), and thus no participants were excluded on this basis.

Counterbalancing. Thirty-four participants (*M* = -.03, *SD* = 126.85, *SEM* = 21.76) completed the congruent blocks first, 21 participants (*M* = 146.62, *SD* = 92.19, *SEM* = 20.12) completed the incongruent blocks first. We performed an independent samples *t*-test to compare IAT scores across the two groups. D4 IAT scores were significantly higher ($t(53) = -4.59$, $p < .001$, $d = 1.32$) in the group that completed incongruent blocks first.

5.3. Results

Analyses. All analyses were performed using IBM SPSS Statistics (Version 22).

Implicit Bias Measures

Bias measures. We computed self-, pain- and reward-bias measures from participants' performance in the Bias task (see chapter 4). Bias measures were calculated by subtracting response efficiencies for high from efficiency for low priority label-shape Match pairs. For example, the pain bias score was calculated by subtracting each participant's efficiency responding to pain-shape stimulus pairs from their efficiency responding to the no pain-shape stimulus pair. Higher bias scores reflect both faster and more accurate responses to the high

pain-shape stimulus pair and slower and less accurate responses to the no pain-shape stimulus pair.

Correlations between bias measures. We performed bivariate correlational analyses between all three bias measures (see table 5.4). Self-bias was not significantly correlated with either pain- or reward-bias; however, pain- and reward-bias were significantly correlated with each other ($r(45) = .35$, $p = .016$).

Table 5.4. Means, standard deviations and correlations of self, pain and reward bias measures. Numbers reported reflect Pearson's r coefficient for each correlation. All values are rounded to 3 significant figures or 2 decimal points.

	Mean	SD	Self Bias	Pain Bias
Self Bias	212	27.6	-	
Pain Bias	402	54.7	0.00	-
Reward Bias	496	53.6	.08	**.35***

* significant at α = 0.05
** significant at α = 0.01

Correlations of bias measures with attentional control. We performed bivariate correlations between self-reported attentional control and each bias measure (self-, pain- and reward-bias). Attentional control was not significantly correlated with self-bias ($r(45) = .04$, $p = .814$), pain-bias ($r(45) = .11$, $p = .467$) or reward-bias ($r(45) = .05$, $p = .728$).

Pain-bias and self-reported individual differences

Correlations between implicit pain-bias and self-reported pain experience. We performed bivariate correlational analyses to explore the relationships between implicit pain-bias and self-reported pain experience in the 6 months preceding the testing session (see table 5.5). A Spearman's correlation showed pain-bias was strongly negatively correlated with the average duration of pain experienced in preceding months ($r_S(45) = -.38$, $p = .009$). This indicates that participants who had experienced longer periods of ongoing pain in the preceding 6 months displayed a decreased attentional focus on pain stimuli in the Bias task. Notably, pain bias was only linked to the average duration of pain, but not any measure of the intensity of the

pain experienced, nor the degree to which that pain interfered with any aspect of daily functioning. Several aspects of pain experience were positively correlated (see table 5.5).

Table 5.5. Bivariate correlations between implicit pain-bias and self-reported pain experience in the 6 months preceding the study. Pain experience comprised pain frequency and duration, intensity of pain at the time of testing (current pain), at its worst (worst pain) and on average (average pain), and the degree to which pain interfered with participants' overall life (interference overall), their social life (social interference) and work (interference work). All variables were continuous excepting frequency and duration of pain. Values reported in this table represent Pearson's r coefficients associated with each correlation, excepting values associated with pain duration and frequency. These variables were ordinal rather than continuous and therefore Spearman's r coefficient is reported instead.

	PE							
	F	***D***	***P-C***	***P-W***	***P-A***	***I-O***	***I-S***	***I-W***
Pain-Bias	*.05*	***-.38****	*-.04*	*-.26*	*-.16*	*-.16*	*-.05*	*-.21*
Frequency	*-*	*-.10*	***.30****	*.15*	*-.02*	*.20*	*.25*	*.20*
Duration		*-*	*.11*	***.32****	***.40****	***.30****	*.24*	***.30****
Current Pain			*-*	*.09*	*.13*	*.23*	*.12*	*.24*
Worst Pain				*-*	***.69****	***.48****	***.51****	***.48****
Average Pain					*-*	***.40****	***.44****	***.44****
Interference (overall)						*-*	***.71****	***.77****
Interference (social)							*-*	***.57****
Interference (Work)								*-*

** = significant at α = 0.05*
*** = significant at α = 0.01*

Correlations between implicit pain-bias and pain-related cognitions. We performed bivariate correlations between pain-bias and pain-related cognitions (see table 5.6). Pain-bias was not significantly correlated with any of the pain-related cognitions included in the analyses. Pain catastrophizing was significantly correlated with total fear of pain score ($r(53) = .64$, $p < .001$), fear of minor pain ($r(53) = .35$, $p = .009$) and fear of severe pain ($r(53) = .45$, $p = .001$), and fear of medical pain ($r(53) = .31$, $p = .02$) as well as somatosensory amplification ($r(53) = .64$, $p < .001$). This suggests that individuals who reported greater pain catastrophizing also reported higher fear of pain overall as well as fear of minor, severe and medical pain, and greater awareness of somatosensory information. Fear of pain total and subscales were also highly positively correlated with each other and somatosensory amplification.

Table 5.6. Bivariate correlations between implicit pain-bias and self-reported pain-related cognitions. Pain-related cognitions comprised pain catastrophizing (PC), a total fear of pain score (FoP-T) as well as minor pain (FoP-M), severe pain (FoP-S) and medical pain (FoP-Me) subscales. Values given represent Pearson's r coefficient.

	PC	*FoP-T*	*FoP-M*	*FoP-S*	*FoP-Me*	*SAS*
Pain-Bias	*- .04*	*.02*	*- .01*	*.11*	*.06*	*.12*
Pain Catastrophising	*-*	***.46*****	***.35*****	***.45*****	***.31****	***.46*****
Fear of Pain (Total)		*-*	***.76*****	***.80*****	***.86*****	***.38****
Fear of Pain (Minor			*-*	***.36*****	***.58*****	***.43*****
Fear of Pain (Severe)				*-*	***.69*****	***.48*****
Fear of Pain (Medical)					*-*	***.49*****
Somatosensory Amplification						*-*

** = significant at α = 0.05*
*** = significant at α = 0.01*

Self-bias and self-reported individual differences

Correlations between implicit self-bias and self-related cognitions. We performed bivariate correlations between self-bias and self-reported narcissism, self-esteem and locus of control internality, powerful others and chance subscales (see table 5.7). Implicit self-bias was strongly positively correlated with narcissism ($r(45) = -.44$, $p = .002$) and the locus of control internality subscale ($r(45) = .35$, $p = .016$) but was not linked to self-esteem or the Powerful Other or Chance subscales of locus of control. These results suggest that individuals who showed a greater self-bias in the Bias task also scored higher on narcissism and Internality locus of control scales. Further, self-bias appears to be unrelated to self-esteem and the Powerful Others and Chance subscales of locus of control. Narcissism was positively correlated with self-esteem ($r(53) = .30$, $p = .028$) and the Internality subscale of locus of control ($r(53) = .3$, $p = .028$). This suggests individuals categorised as more narcissistic also achieve higher scores on self-esteem and internal locus of control scales. The locus of control Powerful Others and Chance subscales were also strongly positively correlated ($r(53) = .51$, $p < .001$).

Table 5.7. Bivariate correlations between implicit self-bias and self-reported self-related cognitions. Self-related cognitions comprised narcissism, self-esteem and locus of control internality, powerful others and chance subscales. Values given represent Pearson's r coefficient.

	NPI	*SES*	*LoC-I*	*LoC-PO*	*LoC-C*
Self-Bias	***.44****	*- .10*	***.35****	*- .17*	*-.08*
Narcissism (NPI)	*-*	***.30****	***.30****	*.11*	*-.03*
Self-Esteem (SES)		*-*	*- .21*	*.23*	*.09*
Locus of control – Internality (I)			*-*	*.02*	*-.24*
Locus of control – Powerful Others (PO)				*-*	***.51****
Locus of control – Chance (C)					*-*

** = significant at α = 0.05*
*** = significant at α = 0.01*

Reward-bias and self-reported individual differences

Correlations between implicit reward-bias and self-reported behavioural inhibition and activation. We performed bivariate correlations between reward-bias and behavioural inhibition, as well as well as three subscales of behavioural activation (drive, fun-seeking and reward-responsiveness). The results of these correlational analyses are displayed in table 5.8. Reward-bias was not significantly correlated with either behavioural inhibition or any subscale of behavioural activation. Behavioural activation subscales were all positively correlated with each other.

Table 5.8. Bivariate correlations between implicit reward-bias and self-reported behavioural inhibition and activation. Behavioural activation comprised the subscales drive, fun-seeking and reward-responsiveness. Values given represent Pearson's r coefficient.

	Reward-Bias	*BI*	*Behavioural Activation*		
			Drive	*Fun-Seeking*	*Reward-Responsiveness*
Reward-Bias	*-*	*- .14*	*.01*	*.01*	*.02*
Behavioural Inhibition (BI)		*-*	*.12*	*.09*	*.13*
BA Drive			*-*	***.34****	***.43****
BA Fun-Seeking				*-*	***.39****
BA Reward-Responsiveness					*-*

** = significant at α = 0.05*
*** = significant at α = 0.01*

Self-Pain Implicit Associations (IAT scores)

Correlation with implicit measures of self- and pain-bias. Bivariate correlations were performed between implicit self-pain associations and self- and pain-bias measures (derived from efficiency scores in the Bias task). Neither self-bias ($r(45) = -.26$, $p = .080$) nor pain-bias ($r(45) = .11$, $p = 0470$) were significantly correlated with implicit associations of self and pain.

Correlation with pain experience. We performed bivariate correlations between participants' self-pain IAT scores and self-report measures of pain experience (see table 5.9). Implicit self-pain associations were significantly negatively correlated with average intensity of pain experienced in the 6 months preceding the study ($r(53) = -.26$, $p = .047$) but not the average duration, frequency, current or worst pain intensity nor the degree to which pain interfered with participants' overall activity, social life or work. As lower IAT scores indicate greater self-pain association, the negative correlation with average pain levels suggests that participants who reported having experienced more intense pain on average in the 6 months preceding the study had higher levels of self-pain association at the time of testing.

Table 5.9. Bivariate correlations between implicit self-pain associations and self-reported aspects of pain experience in the 6 months preceding the testing session. Pain experience measures refer to the frequency and average duration of the pain experienced, intensity of current, worst and average pain experienced, and the degree to which pain interfered with participants' overall activity, social life and work during this time period. Values given represent Pearson's r coefficients for each correlation, excepting correlations with pain frequency and duration. These variables were ordinal, the values reported here therefore represent Spearman's correlation coefficient.

	Pain Experience							
	Frequency	*Duration*	*Current Pain*	*Worst Pain*	*Average Pain*	*Overall Interference*	*Social Interference*	*Work Interference*
IAT	*-.10*	*-.04*	*-.11*	*-.18*	***-.27****	*-.02*	*-.00*	*.08*

* significant at a significance level α = 0.05
** significant at a significance level α = 0.01

Correlation with explicit pain-related cognitions. We performed bivariate correlations between implicit self-pain associations and explicit pain-related cognitions, namely pain catastrophizing, fear of pain (total as well as minor, severe and medical pain subscales) and

somatosensory amplification (see table 5.10). There were no significant correlations between implicit self-pain associations and any of our self-report measures of pain-related cognitions.

Table 5.10. Bivariate correlations between implicit self-pain associations and explicit pain-related cognitions. Pain-related cognitions comprised pain catastrophising, fear of pain (total and fear of minor, severe and medical pain subscales) and somatosensory amplification. Values given represent Pearson's r coefficients for each correlation.

	Pain Catastrophising	***Fear of Pain***				*Somatosensory Amplification*
		Total	*Minor*	*Severe*	*Medical*	
IAT	*-.02*	*-.07*	*-.11*	*-.00*	*.06*	*-.04*

* significant at a significance level α = 0.05
** significant at a significance level α = 0.01

Correlation with explicit self-related cognitions. Bivariate correlations were performed to explore the relationship between implicit self-pain associations and explicit self-related cognitions (self-esteem, narcissism, and three locus of control subscales). The results of these analyses are presented in table 5.11. Self-Pain Implicit Associations Test scores were significantly correlated with the Internality subscale of locus of control ($r(53) = -.32$, $p = .019$), but not with self-esteem, narcissism or the Powerful Others or Chance subscales of locus of control. As lower IAT scores indicate greater self-pain association, the negative correlation with the Internality subscale of locus of control suggests that participants who were categorised as having a more internal locus of control based on their questionnaire answers had higher levels of self-pain associations.

Table 5.11. Bivariate correlations between implicit self-pain associations and explicit self-related cognitions: Narcissism, self-esteem, and the Internality, Powerful Others and Chance subscales of locus of control. Values given represent Pearson's r coefficients for the given correlation.

	Narcissism	*Self-esteem*	***Locus of Control***		
			Internality	*Powerful Others*	*Chance*
IAT	*-.06*	*-.05*	***-.32****	*-.07*	*-.13*

* significant at a significance level α = 0.05
** significant at a significance level α = 0.01

5.4. Discussion

Pain-bias and Individual Difference Measures

Our main aim was to investigate whether our pain-bias measure reflects pain-related cognitive processing or rather a content-unspecific strategic allocation of cognitive resources. We addressed this question from different angles by investigating the relationship between pain-bias and several other individual difference variables.

First, we investigated the relationship among the three biases derived from the Bias task described in chapter 4: Self-, pain- and reward-bias. Our analyses revealed that individuals who displayed greater pain-bias also had a higher reward-bias. This link between pain- and reward-bias could indicate that the two measures may well be driven at least to a certain degree by a common underlying factor. For example, it could reflect participants' ability to allocate cognitive resources strategically and maximise task outcomes (in this case, increase monetary reward and reduce painful electric stimulation). In contrast, self-bias was not linked to pain- or reward-bias, suggesting that self-bias scores were driven by different factors than pain- and reward-bias. As there were no performance-based outcomes associated with self-prioritisation, this could be considered a further indicator that the link between pain- and reward-bias reflects outcome-based attention allocation.

To further investigate this possibility, we explored the relationship between our bias measures and attentional control. If pain- and reward-bias measures reflected merely content-unspecific strategic allocation of attentional resources, both should be positively correlated with attentional control. However, we found no correlations between attentional control and any of the bias measures. This could mean that our pain- and reward-bias measures are not affected by participants' ability to allocate attention strategically. In this case, pain- and reward-bias could both be driven by a different underlying factor.

Alternatively, the two biases might be directly linked in that participants who focus more on reward also focus more on pain irrespective of their ability to control attention. However, it seems unlikely that participants' ability to allocate attention effectively was unrelated to participants' pain- and reward-bias given that our pain- and reward-bias measures necessarily rely to some degree on participants' ability to selectively allocate cognitive resources. We therefore suggest that the self-report measure of attentional control in this study may reflect a different construct, or a different facet of an attentional control construct than the one driving our implicit bias measures. For example, when completing the attentional control questionnaire, participants may think about how they direct attention in more long-term goal-directed situations such as studying for exams instead of going out with friends. This may then reflect a different level on the spectrum of attentional control processes than the ability required to respond fast and accurately in our computer task. Future research should investigate whether a relationship between attentional control and pain- and reward-bias as assessed by the Bias task PMP adaptation can be shown when attentional control is assessed implicitly rather than explicitly, as for example with the attention network task (Fan, McCandliss, Sommer, Raz and Posner, 2002).

Finally, we investigated the relationship between our implicit bias measures and self-reported individual differences in self-, pain- and reward-related processing. This line of analysis aimed to improve our understanding of each bias measure in the context of related traits and constructs that are more established.

For pain-bias, we found no relationship with any pain-related cognitions such as pain catastrophizing, fear of pain and somatosensory amplification. There are several possible explanations for this finding. First, there may be a weak relationship between pain-bias and self-reported pain-related cognitions which our study was underpowered to detect. We cannot rule out this possibility, and future research could investigate this using larger samples. Second,

implicit pain-bias may reflect a different facet of pain-related processing than our self-report measures of pain processing. It is not uncommon that explicit and implicit measures, even if they aim to assess the same construct, do not in fact overlap strongly. A similar problem was highlighted for explicit vs. implicit measures of self-pain association (Van Ryckeghem, Houwer, Van Bockstaele, Van Damme, De Schryver & Crombez, 2013). This problem is common for attentional biases to pain; in their meta-analysis of pain-bias, Crombez, Van Ryckeghem, Eccleston and Van Damme (2013) also found no relationship between implicitly measured pain-biases and self-reported individual differences in fear of pain. A third possible explanation for the lack of relationship between pain-bias and self-report measures of pain-related processing is that implicit measures of pain do not reflect pain-related cognitive processing but content-unspecific attentional processes. This explanation is in line with the correlation between pain- and reward-bias in this study discussed above, but it is not supported by the lack of relationship with self-reported attentional control.

Although pain-bias was not linked to pain-related cognitions, stronger pain-bias was found in participants who had experienced shorter periods of pain in the 6 months leading up to the study. This suggests that there may be at least some relationship between our measure of pain-bias and pain-related processing. It is possible that certain aspects of pain experience cause subtle changes in pain-related processing which self-report measures of pain-related thoughts are not sensitive enough to pick up. For example, experiencing pain for more prolonged periods of time could de-sensitise participants to pain, thus reducing pain-bias. Participants might not be consciously aware of this change, in which case it would not be reflected in their self-reported pain-related thoughts, but our implicit measure of pain-bias might be impacted by these subtle changes. However, there is very little evidence to support this interpretation, and given our small sample this should be replicated before any strong conclusions can be drawn.

Overall, our measure of pain-bias seems to interact with self-reported individual difference measures in much the same way as pain-biases in Crombez, Van Ryckeghem, Eccleston and Van Damme's (2013) meta-analysis did. There is no evidence that our pain-bias links to any self-reported individual differences in pain-related processing. The correlation with reward-bias provides some evidence that our pain-bias measure reflects general rather than pain-specific attentional processes, but this is not supported by a link with self-reported attentional control. There was a slight indication that our pain-bias measure may be impacted by the duration of recent pain episodes, but future research will need to validate this finding in a larger sample.

Self-bias and Individual Difference Measures

Self-bias was not associated with pain- or reward-bias. This suggests that our self-bias measure reflects a different construct than pain- and reward-bias. Self-bias was also not linked to self-reported attentional control, indicating that the measure reflects a content-specific bias rather than a general ability to direct attention effectively. Participants who displayed a greater self-bias also displayed greater narcissism and a more internal locus of control in their responses to self-report measures. However, self-bias was not related to self-esteem, the powerful others or chance subscales of locus of control.

These findings give an interesting insight into the underlying psychological construct assessed by the PMP. Although the use of the PMP to measure and investigate self-bias has increased in recent years (Sui, He & Humphreys, 2012; Sui & Humphreys, 2013; Sui & Humphreys, 2015), to our knowledge no study has reported relationships between its self-bias measure and self-report-based measures of self-related individual difference. Our study suggests that self-bias is not an implicit way of measuring self-esteem as might have been suggested, but rather reflects facets of narcissism and a high estimation of the individual's

control over events in their life. Given the nature of the self-bias measure – the difference between responding to self-referent rather than other-referent stimuli – it is hardly surprising that it reflects self-report measures in which the individual is compared to others (i.e. narcissism and locus of control) rather than measures which assess the individual's thoughts about themselves without reference to others (e.g. self-esteem) or thoughts about others / situations without reference to the individual (e.g. powerful others / chance subscale of locus of control). Our findings will be particularly valuable for the interpretation of future research investigating self-bias using the PMP.

Reward-bias and Individual Difference Measures

We investigated the relationship between reward-bias and self-reported behavioural inhibition and activation to better understand the context of our reward-bias measure. Reward-bias was not associated with either behavioural inhibition or any facet of behavioural activation, including reward-responsiveness. This was surprising, and as with the findings on pain-bias, it cast doubt on whether reward-bias as assessed by the PMP Bias task did indeed measure content-specific rather than general attentional processes. Reward-bias was also not related to self-reported attentional control. There are several possible explanations for this as discussed above for pain-bias. Based on our study, we cannot draw a strong conclusion either way and can only suggest that future research should investigate the nature of reward-bias as assessed by the PMP using larger samples.

Self-Pain Association and Pain Experience, Pain- and Self-related Individual Differences

Self-pain associations were not related to self- and pain-biases derived from the PMP Bias task. This suggests that the Bias and Implicit Associations Task measured different, non-overlapping constructs, which supports the validity of the self-pain IAT as a measure of self-pain enmeshment. Individuals who displayed greater self-pain associations had experienced

more intense pain on average in the 6 months preceding the study. A more internal locus of control was also associated with increased self-pain associations.

These findings suggest that self-pain associations in healthy individuals depend on recent pain experience. This is an important finding, as it suggests that self-pain integration is a fluid process that adapts to pain experience over a prolonged period of time. It is important to note that self-pain associations were not related to current pain levels, nor to the intensity of the worst pain experienced in the preceding months. This indicates that isolated painful incidents that do not cause prolonged pain (e.g. stubbing one's toe) do not notably affect self-pain associations. Neither were self-pain associations impacted by how frequently participants experienced pain, or how long the pain persisted on average. These findings seem to support the self-pain enmeshment model and its proposed mechanism of developing self-pain association through repeated painful experience.

In our relatively small sample, it is possible that the relationship between self-pain association and average pain experienced is a chance finding. A significant difference in implicit self-pain associations was also found between individuals who completed the congruent and individuals who completed the incongruent blocks of the IAT first; it is therefore probable that our findings were impacted by the decision to counterbalance block order across participants. If this finding is replicated in our final study (see chapter 7) with a larger sample and improved methodological design, this would constitute a valuable enhancement to the self-pain enmeshment model. Specifically, these findings could help identify exactly which aspects of pain experience drive the integration of pain into the self-concept. It seems surprising that self-pain association would be driven by average pain levels rather than factors such as the frequency of painful experiences or the impact pain had on participants' daily lives. However, this finding could be extremely useful in the early identification of individuals at risk of

developing self-pain enmeshment and chronic pain due to increased pain experience over a prolonged period of time.

Finally, our findings also suggested that individuals with a more internal locus of control associated self and pain more easily. If replicated in a larger sample, this finding could be another valuable piece in the puzzle of chronic pain development. Unlike pain experience which is transient and depends on situational factors, locus of control is considered a relatively stable trait (Levenson, 1972). Our findings indicate that individuals who consider themselves as more in control of events in their lives had also increasingly integrated pain into their self-concepts. Based on these findings, a highly internal locus of control could therefore comprise a risk factor for self-pain integration and chronic pain development. Though counter-intuitive at first glance, it is plausible that individuals who believe they have more control over life events find pain a more difficult experience. Pain forces individuals to confront their limitations, particularly when it impedes individuals' ability to go about their daily lives. The exact mechanisms by which a more internal locus of control puts participants at risk of integrating pain into their self-concept would need to be carefully investigated. However, the identification of internal locus of control as a potential factor contributing to self-pain integration and chronic pain is a useful step in understanding who develops chronic pain and why.

Chapter 6

6

The Impact of Self-related Content and Performance-based Reward on Distraction from Pain

6.1. Introduction

In our previous chapters, we have explored the competition for attentional resources between visual information relating to self and pain using a novel adaptation of the Perceptual Matching Paradigm (PMP; Sui, He & Humphreys, 2012). Our studies have consistently shown that self-related information is prioritised to the same degree as (chapter 4) or more than pain-related information (see chapter 2). These findings generally support our hypothesis that self-related information could constitute an effective distraction from pain. This could be an important mechanism in the role of self-pain association in chronic pain development and maintenance, for example if focus on self-related information constitutes an automatic distraction for healthy individuals, and integration of pain- and self-schema disturbs this coping mechanism, resulting in worse pain outcomes (see chapter 1). However, we cannot draw strong conclusions from our findings due to various methodological constraints (see chapters 2, 3, 4 and 5). We have considered whether our measure of pain-prioritisation / pain-bias indeed reflects pain-related processing (see chapter 3, chapter 5), but cannot reject the possibility that it may reflect content-unspecific cognitive processes instead.

The current study aims to investigate the hypothesis that self-related information may function as an effective distraction from pain. In this study, self-related information directly competes with pain for cognitive resources in a distraction paradigm. Distraction is a common strategy for coping with pain, and constitutes part of many psychological treatments targeting pain (Morley, Shapiro & Biggs, 2004) including novel applications such as, for example, virtual reality interventions (Trost & Parsons, 2014; Won, Bailey, Bailenson, Tataru, Yoon & Golianu, 2017). Limited attentional capacity (Broadbent, 1958) has been suggested as the mechanism underlying the effectiveness of distraction in reducing pain. When limited cognitive resources are available to process painful stimulation, pain is thought to be perceived as less intense (McCaul & Malott, 1984; Villemure & Bushnell, 2002; Verhoeven, Crombez, Eccleston, Van Ryckeghem, Morley & Van Damme, 2010). Assuming a limited capacity model of attention, the more cognitive resources are dedicated to another activity such as a distraction task, the fewer resources are available to process pain thereby reducing the perceived intensity of pain.

Employing a distraction paradigm addresses several of the methodological concerns raised in our previous chapters. In the present study, participants experience pain concurrently with performing a distraction task. This paradigm is therefore highly likely to engage pain-related processing. In one of our previous studies, painful electric stimulation was applied to engage pain-related processing (see chapter 4). Although this was a more promising approach than relying on deception (see chapter 2), the temporal distance between task performance and pain experience still proved problematic for linking performance-based measures of pain-bias to pain-related processing (see chapter 5). In the current study, pain experience was assessed more directly through self-reports completed immediately after pain experience. Our measure is therefore very likely to reflect pain-related processing.

This study was designed based on a recent experiment (Verhoeven, Crombez, Eccleston, Van Ryckeghem, Morley & Van Damme, 2010) that investigated the role of motivation in the effectiveness of distraction. Specifically, the authors investigated whether a distraction task reduced pain perception more effectively when performance in the distraction task was rewarded with small monetary amounts. Participants held their hand in a cold water bath (12°C) for 1 minute while performing a sound discrimination Random Interval Repetition (RIR) task. Participants were randomly assigned to a no-distraction control, a non-rewarded distraction group, or the rewarded distraction group in which performance was rewarded with €3, €4 or €5. Participants reported less intense pain in both distraction groups than the no-distraction control group. The rewarded and non-rewarded distraction groups did not differ overall in their ratings of pain intensity.

Despite the disappointing findings related to the main hypothesis of the study, an effect of individual differences in pain catastrophizing was revealed: High pain catastrophisers did not benefit from the distraction compared to the no-distraction control, but did benefit from the rewarded distraction. In contrast, low pain catastrophisers did not benefit from the rewarded distraction compared to the no-distraction control, but did benefit from the non-rewarded distraction. The authors conclude that distraction task characteristics, specifically motivational content, may differentially affect individuals with certain patterns of pain-related cognitive processing. However, these findings should be interpreted cautiously given the small sample size (n = 73), which is particularly problematic when investigating individual differences in a between-group design.

In the present study, participants were randomly assigned to one of five distraction groups. Matching Verhoeven, Crombez, Eccleston, Van Ryckeghem, Morley & Van Damme's (2010) design, we included a no distraction control group, a non-rewarded (neutral distraction) and a rewarded distraction group (neutral-reward distraction). The distraction task in our

experiment was a simple word discrimination task in which participants saw two stimulus words presented one at a time and pressed one of two response keys to identify which word had been displayed. Participants in the neutral and neutral-rewarded conditions performed the same task, but in the neutral-rewarded condition, participants received money as a performance-based reward. These conditions were included to a) establish whether the distraction task used in this study effectively reduces pain, and b) replicate Verhoeven and colleague's findings on the impact of pain catastrophizing on the effectiveness of rewarded vs. un-rewarded distraction in a larger sample.

Critical for our hypothesis was the additional inclusion of a self-related distraction condition (self-distraction). In this group, the distraction task contained self-related words but was otherwise identical to the task performed by participants in the neutral and neutral-reward condition. We expected that self-related task content would make distraction more effective than neutral task content. Based on our previous findings that self and reward are prioritised for cognitive processing to a comparable degree (see chapters 2-4), we expected that distraction would be equally effective when task content was self-related (self distraction) and when task content was neutral but performance was rewarded (neutral-reward distraction).

We further included a self-reward distraction group, in which participants performed the self-related distraction task and were rewarded for their performance. We aimed to investigate whether, if present, any impact of self-related task content and performance-based reward on pain reduction was additive, i.e. whether a self-related rewarded task would reduce pain perception more effectively than either self-related task content or performance-based reward individually. Alternatively, if no pain reduction was observed from either self-related content or performance-based reward compared to the neutral distraction condition, we expected that the self-rewarded condition would reveal whether there were small improvements

in pain reduction through self-related distraction content and performance-based rewards that were too small to be detected when considering each individually.

This question could have important implications for distraction-based psychological pain treatments (Morley, Shapiro & Biggs, 2004; Trost & Parsons, 2014; Won, Bailey, Bailenson, Tataru, Yoon & Golianu, 2017). For example, it is possible that both self-related task content and performance-based reward increase the motivational relevance of a distraction task, but that there is a ceiling effect on the impact of motivation on distraction effectiveness. In this case, designing distraction-based treatments that contain both self-related and reward features would be superfluous. If both are equally effective individually as we predict, manipulating motivational relevance of distraction tasks through self-related content should be more feasible in a real life setting, although there may be concerns for some patient groups such as chronic pain patients, for whom self-related distraction might be less effective due to an enmeshment between self and pain (Pincus & Morley, 2001). Both reward- and self-related manipulations would be feasible to implement for example in virtual reality treatments. The inclusion of an avatar that can be named and customised to resemble the patient could for example engage the patient's self-related processing in response to the virtual environment. Reward mechanisms such as receiving virtual currency could also be employed. A better theoretical understanding of how such manipulations might interact may therefore better inform the development of such treatments.

6.2. Method

Study Design

Design. We used a between-subjects design with 5 groups. Participants were randomly allocated to one of five pain distraction conditions (see table 6.1). Participants in the active distraction conditions (neutral, self, neutral-rewarded, self-rewarded) performed a computer

task concurrently with a pain induction. Participants in the no distraction control condition performed the pain induction without a distraction task. Individual difference self-report measures were collected after the pain induction was completed. Participants also completed an Implicit Associations Task of self and pain. Sample means, methods and analyses of these individual difference data are presented in chapter 7. All data were collected in a single one hour laboratory testing session.

Table 6.1. Overview of the 5 distraction conditions: Neutral, self, neutral-rewarded, self-reward and no distraction (control). The table shows which stimulus words were used and whether participants expected to receive a performance-based reward for good performance in each active distraction task.

	Neutral Distraction	Self Distraction	Neutral-Reward Distraction	Self-Reward Distraction	No Distraction
Stimulus words	"HEAR", "BUILDING"	"MINE", "YOURSELF"	"HEAR", "BUILDING"	"MINE", "YOURSELF"	N /A
Performance-based monetary reward	No	No	Yes	Yes	N /A

Sample

Power calculation. We performed an a priori power analysis using G*Power (Version 3.0.10) to determine our sample size. To detect a moderate-sized effect ($f = 0.25$) in a between-subjects ANOVA with 5 groups at a significance level of $\alpha = 0.05$ and with 80% power, a sample of 200 participants was required. This was however not deemed feasible with the resources available. The maximum number of participants we expected to be able to test was 165. According to a second power analysis, a sample of 165 would allow us to detect effects slightly larger than moderate ($f = 0.275$) in a between-subjects design with 5 groups ($\alpha = 0.05$, 80% power). This sample size was accepted as a realistic compromise between statistical power and availability of resources.

Participant recruitment. Participants were invited if they were generally in good health, aged 18-35, had no current or history of neurological conditions and were not currently taking any medication (excepting the contraceptive pill), were fluent English-speakers with normal or

corrected-to-normal vision. To satisfy our general good health criterion, participants were screened for any history of chronic pain, heart problems, fainting, seizures, frostbite or Reynaud's phenomenon. Volunteers were excluded from participating if they had any open cuts, sores, bruises or fractures on their non-dominant hand on the day of testing to avoid risk of infection from the cold pressor pain induction. The study was advertised through posters, university websites, social media and word-of-mouth. Ethical approval for the study was granted by the Medical Sciences Interdivisional Research Ethics Committee (MS IDREC; R51264 / RE001). All participants gave informed consent at the beginning of the testing session. All participants were fully debriefed at the end of the experiment. Participants were compensated for their time with £10. Undergraduate psychology students who participated through the Research Participation Scheme were rewarded with 8 course credits instead.

Sample characteristics. We tested 163 healthy, young (M = 24.08, SD = 4.87) participants who met our eligibility criteria. Three participants' data were excluded from our analyses because equipment failure led to inconsistent water temperature measurements and we could not be certain the actual water temperature met our study requirements. All analyses were conducted on the remaining 160 participants' data. Mean ages and proportion of female participants in our overall sample as well as each distraction group are displayed in table 6.2. A univariate ANOVA of mean age as dependent variable and group (Control, Neutral, Self, Neutral-Rewarded, Self-Rewarded) showed no significant age differences across the groups ($F(4,158) = 0.378$, $p = .824$, $\eta^2_P = 0.01$). A X^2 test showed there was no significant association between group and proportion of female participants (X^2 (4) = 0.06, $p = .999$).

Table 6.2. Sample sizes, mean ages and proportion of female participants within each distraction group and counterbalancing version, as well as in the total sample.

		Total	Control (No Distraction)	Neutral	Self	Neutral-Rewarded	Self-Rewarded
Total	***n***	163	33	33	33	32	32
	Age	24.04 (4.88)	24.88 (4.64)	24.24 (4.98)	23.73 (4.27)	23.69 (5.25)	23.66 (5.37)
	Proportion Female	55%	55%	55%	55%	56%	53%
Version 1	***n***	65	-	16	16	16	17
	Mean Age (SD)	23.85 (4.87)	-	24.13 (5.48)	24.25 (4.25)	23.75 (5.35)	23.29 (4.75)
	Proportion Female	55%	-	56%	56%	56%	53%
Version 2	***n***	65	-	17	17	16	15
	Age	23.82 (5.02)	-	24.35 (4.64)	23.24 (4.25)	23.63 (5.33)	24.07 (6.15)
	Proportion Female	54%	-	53%	53%	56%	53%

Pain experience characteristics. Pain experience over the 6 months preceding our study was assessed using a version of the Chronic Graded Pain scale (PE; von Korff, 0rmel, Keefe & Dworkin, 1992) adapted for healthy participants. Details of this measure as well as sample characteristics are given in chapter 7. The majority of participants in our sample who completed this questionnaire (n = 161) were characterised as either grade 0 (pain-free; 1.86%), 1 (low disability and low intensity; 81.4%) or grade 2 (low disability and high intensity, 9.31%). However, 13 participants (8.07%) were classified as grade 3 (high disability and moderately limiting). Pain grades were evenly distributed between distraction groups (X^2 (12) = 10.88, p = 0.539). It is therefore unlikely that these unexpectedly high levels of pain and pain-related disability affected our results.

Pain catastrophising characteristics. Participants completed the 13-item Pain Catastrophising scale (PC; Sullivan, Bishop & Pivik, 1995) as a measure of the degree to which individuals engage in catastrophising thoughts about pain. Sample means, a description of the questionnaire and scoring algorithms used as well as the relationship between pain catastrophising and other individual difference measures in our sample are discussed in detail

in chapter 7. In the present chapter, pain catastrophising is included as a covariate in some of our analyses in line with previous findings (Verhoeven et al., 2010), which suggested that the impact of motivational characteristics of distractions tasks on pain reduction may depend on individual differences in pain catastrophising.

Procedure

Procedure. Each participant completed a one hour laboratory session individually. Following the procedure of Verhoeven et al. (2010), participants in this study were not aware that the study investigated the effectiveness of distraction. Instead, participants were informed that the aim of the study was to investigate the impact of pain on cognitive performance. This information was consistent with study advertisements and participant information sheets, which listed the study title as *'The effect of pain on cognitive performance'* and referred to the purpose of the individual difference measures included in this study as investigating whether pain impacts some individuals' cognitive performance more than others'. Participants were not aware that the study contained a between-groups manipulation until the debriefing at the end of the experiment.

At the beginning of the testing session, participants completed a cold pressor pain induction (see pain induction). Some participants performed a distraction task concurrently with the pain induction, depending on which distraction group they had been allocated to (see experimental manipulation). After the pain induction and distraction task, participants completed a brief questionnaire rating their pain experience during the pain induction (see measures of pain experience). Participants then completed a set of standard computerised questionnaires, followed by a brief computerised Implicit Association Test (IAT) for self and pain. Details of these individual difference measures and their analyses are outlined in chapter 7. After completing all the individual difference measures, participants were thanked and

debriefed and received reimbursement for their participation as well as performance-based monetary rewards, where applicable.

Experimental Manipulation

Distraction groups. Each participant was randomly assigned to one of five experimental conditions: No distraction (control), neutral distraction, self-related distraction (Self), motivated neutral distraction (Neutral-Rewarded), or motivated self-related distraction (Self-Rewarded) (see table 6.1). Participants completed identical computer tasks in the neutral distraction and neutral-rewarded distraction groups, as well as the self distraction and the self-rewarded distraction groups.

Performance-based rewards. Participants who were randomly assigned to either of the two motivated distraction groups were informed they could earn a reward for performing well in the computer task (performed concurrently with the cold pressor pain induction). Specifically, they were told they could earn between £3 and £5 depending on how fast and accurately they responded. In reality, the reward was randomly chosen and amounted to £3, £4 or £5 following the procedure of Verhoeven and colleagues (2010). These rewards were not mentioned in the study advertisements and participants in the no distraction control, neutral and self distraction conditions received no information about additional reward, nor the reward itself.

Distraction tasks. We adapted the auditory Random Interval Repetition (RIR) task used by Verhoeven et al. (2010) into a visual task to allow for the presentation of self-related vs. neutral content in different distraction groups. The auditory RIR task has been shown to be effective as a distraction from pain in multiple studies (Verhoeven et al., 2010; Goubert, Crombez, Eccleston & Devulder, 2004; Van Damme, Crombez, Van Nieuwenborgh-De Wever & Goubert, 2008). The task was programmed and presented via E-Prime (V2.0, Schneider,

Eschman & Zuccolotto, 2002) and took 1 minute to complete. Participants were required to respond to two words presented one at a time above or below the fixation cross. Different stimulus words were used in the neutral and self-related distraction conditions (see table 6.1). Stimulus words were presented for 150 ms and followed by a randomised inter-trial interval of 900 or 1500ms during which responses were made while a blank screen was displayed. Participants responded by pressing '1' or '2' on the keyboard depending on the word presented.

Counterbalancing stimulus-response pairings. Stimulus-response pairings were counterbalanced across participants within each distraction condition, resulting in two versions of each distraction task (neutral and self-related). In both tasks, version 1 linked the shorter word (Neutral: 'HEAR'; Self: 'MINE') with response key 1 and the longer word (Neutral: BUILDING; Self: 'YOURSELF') with response key 2. In version 2 of each task, the longer word was linked to response key '1' and the shorter word to response key '2'. Gender proportions and mean ages of participants who completed version 1 and version 2 in each distraction group are displayed in table 6.4. A Chi-squared test showed that there was no association between gender and counterbalancing version across distraction groups (X^2 (1) = 0.03, p = .860). A univariate ANOVA with age as dependent variable and counterbalancing version (1 or 2 across all distraction conditions) showed no significant difference between distraction task versions (F(1,128) = 0.00, p = .972, η^2_P = 0.00). Different stimulus-response pairings did not result in differences in pain ratings within any of the distraction groups (see appendix C).

Stimulus Material. We selected the words for the neutral distraction task ('HEAR' and 'BUILDING') to match the self-related words chosen for the self-related task ('MINE' and 'YOURSELF') as closely as possible. Specifically, we tried to find words that matched self-related words for written and verbal frequency, concreteness and familiarity. The aim of this was to control for factors other than the self-related vs. neutral content of the words that might

affect how much attention participants paid to the computer task, how difficult participants found the task to perform and how motivated they were to perform the task well. The words 'MINE' and 'YOURSELF' were chosen as self-related words that were not contained in any of the other computer tasks in this study (self-bias task, self-pain Implicit Associations Task). The words 'MINE' (Greenwald & Farnham, 2000; Zeigler-Hill, 2006) and 'YOURSELF' (Sui, He & Humphreys, 2012) have both been used to elicit self-related processing in previous studies. For each self-related word, we identified its log transformed Hyperspace Analogue to Language frequency norms (HAL), Brown verbal frequency, concreteness and familiarity ratings, Kucera-Francis and Thorndike-Lorge written frequency indices using the MRC Psycholinguistic Database and the English Lexicon Project (Balota et al., 2007; http://elexicon.wustl.edu/). We then used the English Lexicon Project's website to find words that matched the characteristics of either the word 'MINE' or 'YOURSELF'. We excluded words that were unsuitable (see appendix D for selection). Out of the list of remaining possible words, we chose the word 'HEAR' as the optimal match for the word 'MINE', and the word 'BUILDING' as the most suitable match for the word 'YOURSELF'.

Pain Induction

Cold pressor material. A cold pressor apparatus was constructed from two 32l plastic containers (Thermos Cool Boxes; External dimensions (length x width x height): 43 x 30 x 45cm; Internal dimensions: 33 x 20 x 43cm), a Hailea Ultra Titan 150 water chiller (Aquatuning HC-130A), two 1 meter tubes (19.5mm inner diameter), a Hailea HX4500 submersible water pump (flow rate: 2000 litre per hour), and an AQC-200 submersible water pump (flow rate: 200 litre per hour). Each 32 litre plastic container was filled with 20 litre of water. The water in one of the containers was kept at room temperature (21°C), the water in the other was cooled to 12°C by the water chiller, and kept constantly circulating by the HX4500 and AQC-200 submersible water pumps.

Temperatures. Water temperature in both containers was controlled to within ±0.6°C. The set-up and temperatures were chosen based on recommended guidelines (Von Baeyer, Piira, Chambers, Trapanotto, & Zeltzer, 2005) and standards from previous studies (Verhoeven et al., 2010). Additionally, a small pilot study (n = 23) was conducted to test the cold pressor equipment, instructions and self-reported pain measures. (see table 6.3) The pilot study received ethical approval from the Medical Sciences Inter-Divisional Research Ethics Committee (MS IDREC; R51166 / RE001). Participants immersed their hands in the room temperature water for 1 minute, and then the cold water container as long as they could, up to 5 minutes. The results were overall inconclusive. Univariate ANOVAs suggested there were no significant differences in self-reported attention to pain, pain intensity or pain affect between participants who completed the pain induction at 11°C, 12°C, 13°C or 14°C (all $p > .05$).

Table 6.3. Pain ratings and drop-out numbers by cold pressor temperature in pilot study.

	11°C	**12°C**	**13°C**	**14°C**
N (total)	8	11	2	2
Number of drop-outs before 1 min	2	5	0	0
Number of drop-outs between 1 and 5 minutes	2	0	1	0
Self-reported attention to pain: Mean (Standard Deviation)	-2.38 (4.93)	-0.82 (4.96)	-4.5 (3.54)	-5.5 (0.71)
Self-reported pain intensity: Mean (Standard Deviation)	10.4 (4.1)	10.1 (3.78)	9.00 (4.24)	5.00 (1.41)
Self-reported pain affect: Mean (Standard Deviation)	14.00 (5.48)	13.00 (4.49)	7.5 (2.12)	6.00 (4.24)

Cold pressor pain induction. Participants received all instructions relating to the cold pressor pain induction and distraction task prior to commencing the procedure. Participants were informed that they would immerse their hand in room temperature water (21°C ± 0.6°C) for 1 minute first, then transfer their hand to the container with cold water (12°C ± 0.6°C). All participants were made aware of their right to withdraw their hand from the cold water at any point without giving a reason, but informed that this would constitute their withdrawal from the study. Participants were instructed to immerse their hand in the water up to their wrist. Non-dominant hands were used for the immersion, and participants were asked to keep their hand

still and relaxed once immersed in the water. For participants who completed a distraction task simultaneous with the pain induction, instructions for the distraction task were given before beginning the pain induction. Participants were asked to start the distraction task as soon as they immersed their hand in the cold water. The task took 1 minute to complete and ended with a screen instructing participants to remove their hand from the water. Participants were asked to take their hand out of the water as soon as the task finished. Immersion time was therefore fixed to a 1 minute interval, so that immersion duration was not a confounding factor in self-reported pain experience. Participants were then asked to complete a set of self-report measures assessing their immersion experience.

Self-reported Pain Ratings (Pain Induction)

Self-report pain ratings. Immediately after the cold pressor pain induction, participants completed a 13-item paper-based questionnaire assessing their subjective pain and distraction task experience. Following the method of Verhoeven et al. (2010), we assessed pain experience with 7 items measuring attention to pain, pain intensity, and pain affect. Distraction task experience was measured with six items assessing task difficulty, interest in the task, amount of attention paid to the task, amount of effort put into the task, importance of performing well in the task, and belief about the effectiveness of the task in distracting from the pain.

Attention to pain during cold pressor pain induction. Attention to pain was assessed with 2 items. On an 11-point scale ranging from 0 to 10 (0 = “not at all”; 10 = “very much”), participants rated 1) how much attention they had paid to the pain, and 2) how well they had been able to distract themselves from the pain. These items aimed to assess the same underlying construct (attention to pain). Verhoeven et al. (2010) argue that the opposite formulation of the two items controls for participants’ response tendency. We then calculated a total attention to

pain score by subtracting item 2 from item 1, resulting in overall scores between -10 and 10, with higher scores representing greater attention paid to pain.

Self-reported pain intensity during cold pressor pain induction. Following the method of Verhoeven et al. (2010), we distinguished between pain intensity and pain affect. Pain intensity was assessed with 2 items: On an 11-point scale ranging from 0 to 10 (0 = "no pain"; 10 = "the worst imaginable pain"), participants rated 1) the worst pain experienced during immersion, and 2) the pain just at the end of the immersion. We then calculated a total pain intensity score by adding the two items, resulting in scores between 0 and 20 with higher scores indicating more intense pain experienced. Kahneman, Fredrickson, Schreiber and Redelmeier (1993) suggest that the peak-and-end pattern of participants' discomfort during cold pressor pain induction predicts participants' retroactive evaluation of the experience. We therefore considered participants' reports of their pain intensity at the worst point and the end of the cold pressor immersion good indicators of their pain experience.

Self-reported pain affect during cold pressor pain induction. We used 3 items to assess pain affect. On an 11-point scale ranging from 0 to 10 (0 = "not at all anxious /tense / unpleasant"; 10 = "very anxious / tense / unpleasant"), participants rated the level of anxiety and tenseness they experienced and how unpleasant the immersion was. We then calculated a total pain affect score by adding all 3 items, resulting in sum scores ranging from 0 to 30. Higher scores indicated more negative affect experienced as a consequence of the pain induction.

Data Analysis

Measures and Statistical Analyses. Data were pre-processed using Microsoft Excel 2013. All analyses were conducted in IB SPSS Statistics (Version 22.0). Our main outcomes were composite measures of self-reported pain intensity and negative pain affect, which were

compared between all 5 distraction groups in univariate ANOVAs. Where data were not normally distributed or did not meet the equal variances assumption, this is highlighted and appropriate alternative statistical analyses were conducted. Where univariate ANOVAs indicated a significant difference between distraction groups, post-hoc *t*-tests were performed to further explore these effects. We also performed matching ANCOVAs with pain catastrophizing as a covariate, matching the analyses performed by Verhoeven et al. (2010). Additionally, we carried out a series of manipulation checks investigating whether our distraction tasks successfully reduced attention to pain, and whether task engagement was enhanced by self-related task content and performance-based reward. A composite measure of self-reported attention to pain was compared between all 5 distraction groups using a univariate ANOVA, as well as an ANCOVA with pain catastrophizing as covariate. Self-reported task engagement characteristics were compared between the four active distraction groups (Neutral, Self, Neutral-rewarded and Self-rewarded) using a MANOVA (multivariate analysis of variance).

In several instances, the analyses performed here include multiple comparisons. Traditionally, the increased chance of committing type I errors has been addressed by applying significance level adjustments (Rice, 1989) such as the Bonferroni correction (Cabin & Mitchell, 2000). However, this procedure is highly conservative, and though effectively reducing the likelihood of committing type I errors (rejecting a null hypothesis even though it's true), it drastically increases the likelihood of committing type II errors (accepting a null hypothesis when it is not true) and results in a reduction of power. The use of Bonferroni corrections, particularly in fields in which it is often not possible to obtain large data sets due to practical constraints, such as behavioural testing, has therefore been criticised on both mathematical and pragmatic grounds (Wright, 1992; Nakagawa, 2004). A further problem consists in the lack of clarity for when such adjustments would be appropriate to perform

(Perneger, 1998). For example, a researcher performing 100 experiments which contain one single comparison each would mathematically have the same chance of committing a type I error in one of these experiments as a researcher performing 1 experiment containing 100 comparisons. Yet, significance level adjustments are hardly required across studies, resulting in mathematically inconsistent application. As a solution to these problems, Nakagawa (2004) suggested that effect sizes and confidence intervals (CIs) associated with each comparison should be reported instead of applying significance level adjustments. Effect sizes represent the magnitude of an experimental effect standardised for factors such as sample size. Their presentation therefore allows readers to determine the statistical significance of an effect in comparison with other studies and effects, and gives a more nuanced, contextual perspective on the effects in question. Confidence intervals additionally aid the interpretation of nonsignificant results (Jennions & Møller, 2003). Where multiple comparisons are performed in this study, we will therefore present effect sizes and confidence intervals of effects instead of performing significance level adjustments, and discuss these effects in the context of their magnitude as highlighted by their effect sizes.

6.3. Results

Effect of Distraction on Self-Reported Pain

Pain Intensity. Mean self-reported pain intensity scores were calculated for each distraction group (see figure 6.1). Pain intensity was greatest in the no distraction control group, while perceived pain intensity was lowest in the self and self-rewarded distraction group. In the neutral-rewarded group, pain intensity levels were a little higher than in the self and self-rewarded distraction groups. In the neutral distraction group, perceived pain intensity was highest of all active distraction groups, but still lower than in the no distraction control.

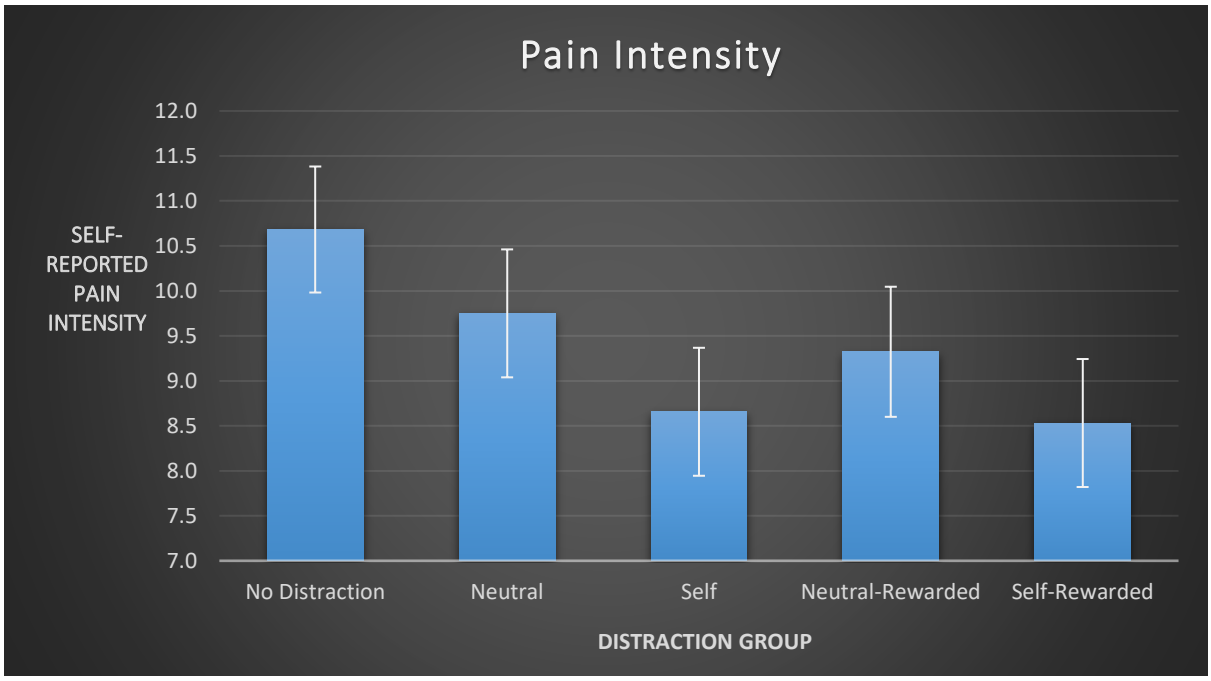

Figure 6.1. Mean self-reported pain intensity (combined measure) for each distraction group (no distraction control, neutral, self, neutral-rewarded and self-rewarded distraction). Error bars represent the standard error of each mean.

A univariate ANOVA with distraction group as between-subjects factor and combined pain intensity scores as dependent variable did not reveal any significant differences between distraction groups (see table 6.4). A univariate ANCOVA with distraction group (5 levels) as between-subjects factor, pain catastrophizing as covariate and pain intensity as dependent variable showed no main effect of distraction group ($F(4, 152) = 1.52$, $p = .197$, $\eta_2P = 0.04$). There was no main effect of pain catastrophizing and no interaction between pain catastrophizing and group on pain intensity (all $p > .05$).

Table 6.4. Sample means and results of significance test on pain intensity by distraction group. Data represent group means (M), standard deviations (SD), lower and upper bound of confidence intervals (Lower CI, Upper CI), the F value and degrees of freedom (F), p-value (p) and partial eta squared (N2P) associated with a univariate ANOVA with pain intensity as dependent variable and distraction group as between-subjects factor. All values are given to 3 significant figures or 2 decimal points, excepting p-values which are always given to 3 decimal points.

	n	*M*	*SD*	Lower CI	Upper CI	*F*(4,155)	*p*	N2P
Control	33	10.7	3.54	9.43	11.9	1.55	.191	0.04
Neutral	32	9.75	4.50	8.13	11.4			
Self	32	8.66	3.84	7.24	10.1			
Neutral-Reward	31	9.32	3.56	8.03	10.6			
Self-Reward	32	8.53	4.50	6.91	10.2			
Total	160	9.40	4.05	8.76	10.0	-	-	-

To investigate whether these findings were the result of using the composite pain intensity measure rather than original ratings of the worst pain intensity and pain intensity at the end of the pain induction, univariate ANOVAs were also performed separately for the original measures (see tables 6.5 and 6.6). There were no significant differences between distraction groups on either pain intensity measure when analysed separately.

Table 6.5. Sample means and results of significance test on worst pain ratings by distraction group. Data represent group means (M), standard deviations (SD), lower and upper bound of confidence intervals (Lower CI, Upper CI), the F value and degrees of freedom (F), p value (p) and partial eta squared (N2P) associated with a univariate ANOVA with worst pain ratings as dependent variable and distraction group as between-subjects factor. All values are given to 3 significant figures or 2 decimal points, excepting p-values which are always given to 3 decimal points.

	n	M	SD	Lower CI	Upper CI	F(4,155)	p	N2P
Control	33	5.56	1.88	4.90	6.23			
Neutral	32	5.06	2.33	4.22	5.90			
Self	32	4.59	2.03	3.86	5.33	1.82	.127	0.04
Neutral-Reward	31	4.74	1.91	4.04	5.44			
Self-Reward	32	4.25	2.30	3.42	5.08			
Total	160	4.85	2.12	4.51	5.17	-	-	-

Table 6.6. Sample means and results of significance test on ratings of pain at the end of pain induction by distraction group. Data represent group means (M), standard deviations (SD), lower and upper bound of confidence intervals (Lower CI, Upper CI), the F value and degrees of freedom (F), p value (p) and partial eta squared (N2P) associated with a univariate ANOVA with ratings of pain at the end of immersion as dependent variable and distraction group as between-subjects factor. All values are given to 3 significant figures or 2 decimal points, excepting p-values which are always given to 3 decimal points.

	n	*M*	*SD*	Lower CI	Upper CI	*F*(4,155)	*p*	N2P
Control	33	5.12	1.88	4.39	5.85			
Neutral	32	4.69	2.32	3.95	5.43			
Self	32	4.06	2.18	3.33	4.80	1.19	.316	0.03
Neutral-Reward	31	4.58	1.79	3.83	5.33			
Self-Reward	32	4.28	2.33	3.54	5.02			
Total	160	4.55	2.12	8.8	10	-	-	-

Pain Affect. Mean self-reported negative pain affect scores were calculated for each distraction group (see figure 6.2). Negative pain affect was greatest in the no distraction control group and lowest in the neutral distraction group. In the self and self-rewarded distraction group, negative pain affect was slightly lower than in the neutral-rewarded group. Negative pain affect was higher in the rewarded version of both neutral and self distraction.

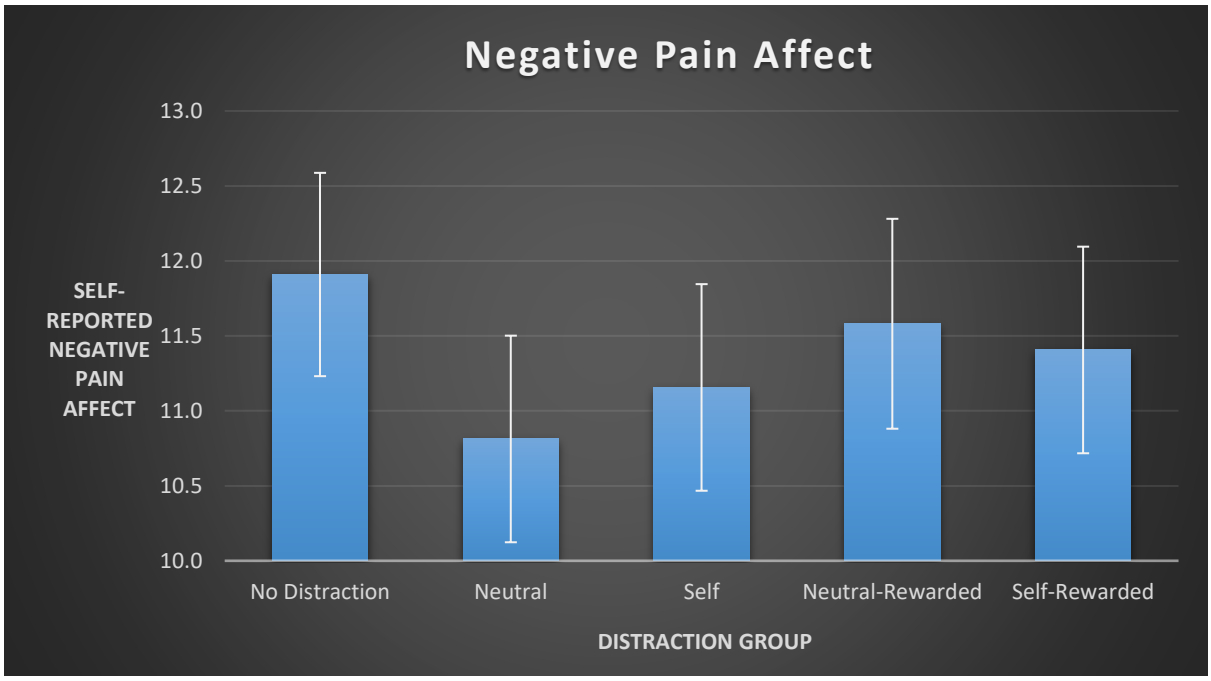

Figure 6.2. Mean self-reported negative pain affect (combined measure) for each distraction group (no distraction control, neutral, self, neutral-rewarded and self-rewarded distraction). Error bars represent the standard error of each mean.

A univariate ANOVA with distraction group as between-subjects factor and combined pain affect score as dependent variable did not reveal any significant differences between distraction groups (see table 6.7). An ANCOVA with distraction groups as between-subjects factor, pain catastrophizing as covariate and pain affect as dependent variable also revealed no significant main effect of group ($F(4, 152) = 0.10$, $p = .983$, $\eta_2 P = 0.00$) nor a main effect of pain catastrophizing or interaction between group and pain catastrophizing (all $p > .05$).

Table 6.7. Sample means and results of significance test on pain affect by distraction group. Data represent group means (M), standard deviations (SD), lower and upper bound of confidence intervals (Lower CI, Upper CI), the F value and degrees of freedom (F), p value (p) and partial eta squared (N2P) associated with a univariate ANOVA with pain affect as dependent variable and distraction group as between-subjects factor. All values are given to 3 significant figures or 2 decimal points, excepting p-values which are always given to 3 decimal points.

	n	*M*	*SD*	Lower CI	Upper CI	*F*(4,155)	*p*	N2P
Control	33	11.9	5.50	9.91	13.9			
Neutral	31	10.8	6.41	8.79	12.8			
Self	32	11.2	5.12	8.79	13.2	0.17	.955	0.00
Neutral-Reward	31	11.6	5.48	9.13	13.6			
Self-Reward	32	11.4	6.39	9.52	13.4			
Total	160	11.4	5.74	10.5	12.3	-	-	-

To investigate whether using the composite pain affect measure rather than original ratings of pain unpleasantness, anxiousness and tenseness during immersion, we carried out

separate univariate ANOVAs on all 3 original pain affect measures. There were no significant differences between distraction groups on pain unpleasantness ($F(4,155) = 0.67$, $p = .617$, $\eta_2 P = 0.02$), pain-related anxiousness ($F(4,155) = 0.14$ $p = .966$, $\eta_2 P = 0.00$) and tenseness ($F(4,155) = 0.52$, $p = .724$, $\eta_2 P = 0.01$).

Manipulation Checks

Distraction task engagement. We calculated mean task engagement measures for each active distraction group (Neutral, Self, Neutral-Reward, Self-Reward). We then performed a MANOVA with distraction group as between-subject variable and task engagement measures (attention to task, task difficulty, interest in task, effort to perform well, importance of performing well and belief about distraction task effectiveness) as dependent variables. For all dependent variables, the assumption of equal variances was tested with Levene's test of homogeneity of variance. The assumption of equal variances was violated for self-reported importance of performing well but not any other dependent variables. Therefore, for importance of performing well, a Welch test was performed. There were no significant differences between the groups on any of the task engagement measures (see table 6.8).

Table 6.8. Descriptive statistics and results of a MANOVA comparing task engagement measures between active distraction groups (Neutral, Self, Neutral-Reward and Self-Reward). Values given represent the means (M), standard deviations (SD), and lower and upper bound of confidence intervals of the mean, as well as results of the significance test associated with each dependent variable: F-values (F) with associated degrees of freedom, p-values (p), and partial eta-squared (N2P). All values are given to 3 significant figures or 2 decimal points, excepting p-values which are always given to 3 decimal points.

				Confidence Interval				
		M	**SD**	**Lower**	**Upper**	***F*(3,123)**	***p***	**N2P**
Attention to task	*Neutral*	7.48	1.86	6.96	8.01	1.94	.126	0.05
	Self	7.73	1.7	7.2	8.26			
	Neutral-Reward	7.87	1.31	7.34	8.41			
	Self-Reward	8.37	1.16	7.84	8.91			
	Total	7.86	1.55	7.6	8.13	-	-	-
Task difficulty	*Neutral*	3.7	2.39	2.88	4.51	1.13	.339	0.03
	Self	4.27	2.3	3.46	5.09			
	Neutral-Reward	4.47	2.7	3.64	5.3			
	Self-Reward	4.69	2.02	3.86	5.52			
	Total	4.28	2.37	3.87	4.87	-	-	-
Interest in task	*Neutral*	5.88	2.79	5.04	6.71	0.91	.440	0.02
	Self	5.67	2.46	4.83	6.5			
	Neutral-Reward	5.66	2.46	4.81	6.5			
	Self-Reward	6.63	1.88	5.78	7.47			
	Total	5.95	2.43	5.54	6.38	-	-	-
Effort to perform	*Neutral*	7.76	1.42	7.25	8.63	1.90	.133	0.04
	Self	8.52	1.33	8.01	9.02			
	Neutral-Reward	7.91	1.89	7.39	8.42			
	Self-Reward	8.28	1.14	7.77	8.8			
	Total	8.12	1.48	7.86	8.37	-	-	-
Importance of performing well[1]	*Neutral*	8.39	1.32	7.88	8.91	1.58	.203	0.04
	Self	8.85	1.09	7.54	8.59			
	Neutral-Reward	8.06	2.08	7.79	8.84			
	Self-Reward	8.31	1.33	8.33	9.37			
	Total	8.41	1.51	8.14	8.66	-	-	-
Belief about distraction task effectiveness	*Neutral*	6	2.21	5.26	6.74	2.02	.115	0.05
	Self	6.42	2.18	5.69	7.16			
	Neutral-Reward	6.44	2.33	5.69	7.19			
	Self-Reward	7.25	1.81	6.5	8			
	Total	6.52	2.17	6.16	6.9	-	-	-

[1] = values represent results of a Welch test due to unequal variances between distraction groups

Attention to Pain. Mean self-reported attention to pain scores were calculated for each distraction group (see figure 6.3). Attention to pain was greatest in the no distraction control group, while least attention was paid to pain in the self and self-rewarded distraction group. In the neutral-rewarded group, attention to pain was almost at the same level as in the self and self-rewarded distraction groups, but in the neutral distraction group, attention to pain was notably higher (though still lower than in the no distraction control).

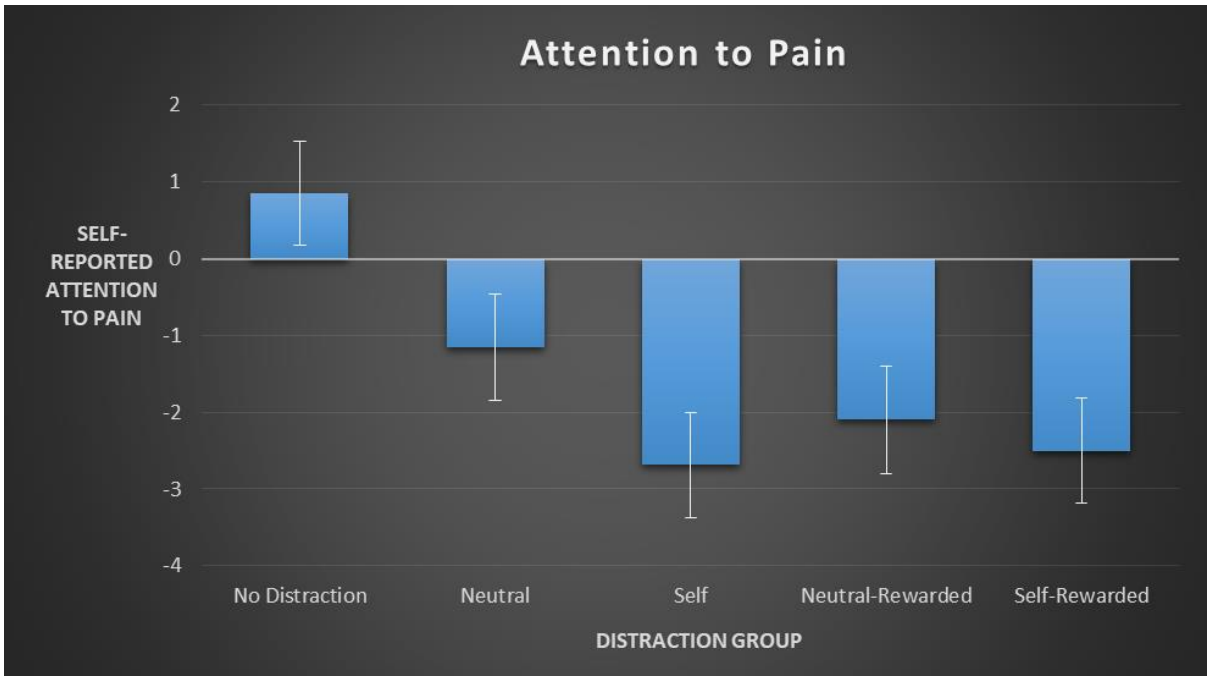

Figure 6.3. Mean self-reported attention to pain (combined measure) for each distraction group (no distraction control, neutral, self, neutral-rewarded and self-rewarded distraction). Error bars represent the standard error of each mean.

A univariate ANOVA with distraction group as between-subjects factor (5 levels) and combined attention to pain scores as dependent variable revealed a significant difference between the groups (see table 6.9). An ANCOVA with pain catastrophizing as a covariate revealed a main effect of distraction group ($F(4, 152) = 3.91$, $p = .005$, $\eta_2 P = 0.09$), but no main effect of pain catastrophizing or interaction between group and attention to pain (all $p > .05$).

Table 6.9. Sample means and results of significance test on attention to pain by distraction group. Data represent group means (M), standard deviations (SD), lower and upper bound of confidence intervals (Lower CI, Upper CI), the F value and degrees of freedom (F), p-value (p) and partial eta squared (N2P) as a measure of effect size associated with a univariate ANOVA with attention to pain as dependent variable and distraction group as between-subjects factor. All values are given to 3 significant figures or 2 decimal points, excepting p-values which are always given to 3 decimal points.

	n	M	SD	Lower CI	Upper CI	*F*(4,155)	*p*	N2P
Control	33	0.85	4.04	-0.49	2.19			
Neutral	32	-1.16	4.08	-2.52	0.21			
Self	32	-2.69	3.64	-4.05	-1.33	**4.51**	0.002	0.10
Neutral-Reward	31	-2.10	3.87	-3.48	-0.71			
Self-Reward	32	-2.50	3.84	-3.86	-1.14			
Total	160	-1.51	4.03	-2.13	-0.91	-	-	-

To further investigate this effect, we performed independent samples *t*-tests on attention to pain scores between all groups (see table 6.10). These analyses revealed differences between

the control group (no distraction) and some of the active distraction groups that were significant at the level of α = 0.05, but no significant differences among any of the active distraction groups. Neutral distraction did not differ significantly from the no distraction control group, although the difference was very near-significant (p = .051). All other active distraction groups differed significantly from the no distraction control. The differences were most pronounced between the control group and the self distraction and the self-reward distraction. Both differences were significant at a level of α = 0.001 and associated with higher effect sizes (d_{Self} = 0.92; $d_{Self\text{-}Reward}$ = 0.85) than the differences between the control group and the neutral distraction and the neutral-reward distraction ($d_{neutral}$ = 0.49; $d_{neutral\text{-}reward}$ = 0.75).

Table 6.10. Results of independent samples t*-tests on attention to pain by distraction group. Data represent the* t*-values and degrees of freedom (DF), p-values (p) and Cohen's* d *measures of effect size associated with these significance tests, as well as lower and upper bound of confidence intervals (Lower CI, Upper CI) of each effect. All values are given to 3 significant figures or 2 decimal points, excepting p-values which are always given to 3 decimal points.*

		t	DF	*p*	*d*	Confidence Interval	
						lower	upper
Control	Neutral	1.99	63	.051	0.49	0.01	4.02
	Self	**3.70**	62	< .001	0.92	1.63	5.44
	Neutral-Reward	**2.98**	62	.004	0.75	0.97	4.92
	Self-Reward	**3.43**	63	.001	0.85	1.40	5.30
Neutral	Self	1.58	62	.118	0.40	-0.40	3.46
	Neutral-Reward	0.94	61	.352	0.24	-1.06	2.95
	Self-Reward	1.36	62	.180	0.34	-0.64	3.32
Self	Neutral-Reward	0.62	61	.535	0.16	-2.48	1.30
	Self-Reward	0.20	62	.842	0.05	-2.06	1.68
Neutral-Reward	Self-Reward	0.42	61	.679	0.11	-1.54	2.34

6.4. Discussion

Summary

We investigated the hypotheses that pain intensity and negative pain affect would be reduced by 1) a performance-based reward in high pain catastrophisers and 2) self-related task content for all participants. We also expected to see the greatest reduction of pain intensity and negative pain affect in the self-rewarded distraction group, which performed the task containing

self-related content and expected to receive a performance-based reward. None of these hypotheses were supported by our findings, which showed no significant differences among any of the distraction groups, including no reduction in self-reported pain intensity or negative pain affect in any of the distraction compared to the no distraction control group. Manipulation checks indicated that our experimental manipulation did reduce attention to pain in the self, neutral-rewarded and self-rewarded distraction groups compared to the control group, but not in the neutral distraction group. However, neither self-related content nor performance-based reward successfully impacted task engagement in active distraction groups.

Distraction effect

We found no significant differences among distraction groups on self-reported pain intensity and negative pain affect, which were the main outcome variables in this experiment. Based on findings by Verhoeven et al. (2010), we expected that perceived pain intensity would be reduced in active distraction groups compared to the no distraction control. This was not the case either when no covariate was included or when individual differences in pain catastrophizing were considered to match Verhoeven et al.'s analyses. The results on pain affect are in line with Verhoeven et al.'s findings, and suggest that negative affect induced by pain is not a suitable measure to assess distraction task effectiveness in laboratory settings such as this. However, the results on pain intensity are unexpected and problematic, because they suggest our distraction task did not successfully reduce perceived pain intensity.

There are several possible explanations for this finding. Firstly, it is possible that our distraction task failed to draw participants' attention. We chose to adapt the paradigm employed by Verhoeven et al. from an auditory to a visual stimulus discrimination task. It is possible that discriminating between visual rather than auditory stimuli requires less attention, and therefore failed to distract participants from pain. This is unlikely however, as we found increased self-reported attention to pain in the no distraction control group compared to some

of the distraction groups. It is possible that we did not find a difference between the no distraction control and the neutral distraction group because, unlike Verhoeven and colleagues, we did not explicitly instruct participants in the no distraction control group to focus on and attend to the pain. This may have reduced the attention participants in the no distraction group allocated to pain and thus diminished the differences between the control group and active distraction groups. Given this methodological difference between the studies, our findings indicate that performing a distraction task with self-related content of performance-based reward reduced attention to pain more than any natural coping techniques individuals in the no distraction control group may have employed. At least for the self, neutral-rewarded and self-rewarded conditions, it is therefore unlikely that the failure to demonstrate reduced perceived pain intensity in distraction groups compared to the no distraction control group was a result of our distraction task's failure to draw participants' attention.

These findings pose a problem for the assumption that reducing attention to pain reduced perceived pain intensity. This could indicate that the efficacy of distraction in reducing perceived pain may be limited. Eccleston and Crombez (1999) suggested that distraction may not be effective for example when pain is intense. It is possible that our pain stimulus was not suitable. Although we aimed to match Verhoeven et al.'s (2010) design in which distraction was effective, our studies differed in several key aspects. In particular, the water temperature was less closely controlled: Verhoeven et al. were able to regulate water temperature to within ± 0.01°C, while variability using our less expensive equipment was at ±0.6°C, a variability increase factor of 60. Due to this variability in water temperature, it is possible that some participants found the water intensely painful, reducing the effectiveness of distraction. Pain perception does not linearly relate to physical parameters of the noxious stimulus, and small variations in water temperature may therefore have resulted in a disproportionate increase in perceived pain intensity for those individuals who experienced water temperatures colder than

12°C. Although our temperature control was within the standard of ±1°C recommended by Von Baeyer, Piira, Chambers, Trapanotto and Zeltzer, 2005, it may have introduced an additional element of measurement variability that reduced the sensitivity of our study to detect distraction effects compared to Verhoeven et al. (2010). However, our study also had a larger sample ($31 \geq n \leq 33$) than Verhoeven et al., who reported 23 participants in the smallest distraction group and 26 in the largest. Our larger sample may have compensated for the reduced reliability of measures in our study. Further, our overall measures of pain intensity were in a comparable range (M = 8.53-10.7) as that reported by Verhoeven et al. (M = 8.48-11.0). This suggests that perceived pain should not have been any more intense in our study that Verhoeven et al.'s, and distraction therefore should have been effective. Additionally, our pilot study, though small and likely unable to detect small or medium effects, indicated that perceived pain intensity did not vary significantly between individuals who completed the immersion at 11°C or 12°C.

We argue that the most likely explanation for our finding is that the benefit of distraction on perceived pain is a small and not robust effect. Our sample was powered to detect effects larger than moderate only (f = 0.275). We would therefore not have expected to be able to show a small effect. As discussed above, between-subject variability in our pain stimulus may have contributed to poor reliability of self-reported pain intensity and pain affect measures, and therefore poor sensitivity to detect subtle between-group effects. Our findings suggest that large samples and extremely carefully controlled pain stimulation are required to show this effect reliably.

Effectiveness or Performance-based Reward as Distraction

We predicted that perceived pain intensity would differ among distraction groups. Specifically, based on Verhoeven et al.'s findings, we expected to find reduced pain intensity

in the neutral-reward compared to the neutral distraction group dependent on individual differences in pain catastrophizing. This was not the case, as pain intensity did not differ between any of our distraction groups. Analyses were performed both with and without pain catastrophizing as a covariate. This did not affect the results, indicating that individual differences in pain catastrophizing did not impact self-reported pain intensity in our study. This draws into question Verhoeven et al.'s findings, which may represent a type I error rather than a robust effect. To our knowledge, no study has replicated their findings to date. It is however difficult to estimate whether our findings are more likely to be reliable than theirs; while our study was better powered than Verhoeven et al.'s experiment, their pain induction method was more carefully controlled and their outcome measures were therefore likely more reliable than ours. The findings in our study may have been the result of a type II error. Future research is needed to address this question, ideally with a much larger sample than either study in order to detect small effects reliably, and using a carefully controlled pain stimulus.

There are other possible explanations for the differences in findings between our study and Verhoeven et al.'s. Specifically, it is possible that our performance-based reward manipulation failed to impact task engagement. This interpretation is supported by manipulation checks in our study: There were no significant differences among distraction groups in self-reported attention to the task, task difficulty, interest in the task, importance to perform, effort to perform, beliefs about the effectiveness of the task in distracting from pain, or attention to pain. In contrast, in Verhoeven et al.'s experiment, participants in the neutral (distraction only) distraction group reported less interest in the task and expended less effort to perform well than participants in the neutral-rewarded (motivated distraction) distraction task. These different patterns of results suggest that differences in the implementation of the distraction task between the studies may have contributed to the difference in findings.

In Verhoeven et al.'s experiment, performance-based reward was implemented slightly differently than in our study. Although in both, participants were rewarded with randomly chosen monetary rewards of £3-5 / €3-5, participants in Verhoeven et al.'s study were additionally informed they could earn 10 eurocents for every correct response. Participants also received performance feedback after every response in Verhoeven et al.'s experiment, but not it ours. This more explicit link between every response and reward in Verhoeven et al.'s experiment may have been more effective in manipulating distraction task engagement. Our findings indicate that the effectiveness of performance-based reward in enhancing distraction from pain may be dependent on specific methodological implementation, namely performance feedback. This would suggest the underlying effect is neither strong nor robust. Future research is needed to isolate factors that are crucial to the success of performance-based reward manipulation and its role in distraction from pain, and explore its interaction with individual differences such as pain catastrophizing.

Effectiveness of Self-related Distraction Content

Our hypothesis that self-related distraction task content would enhance the effectiveness of distraction from pain was not supported by our findings. The same considerations of the effectiveness of our distraction task and suitability of our pain stimuli as discussed above apply here. However, it should be noted that our self-related distraction groups reported less attention to pain than participants in the no distraction group, indicating that self-related distraction content was as effective in drawing attention away from pain as neutral-rewarded and more effective than the neutral distraction task. Moreover, effect sizes indicated that attention to pain was reduced more drastically by the self-distraction ($d = 0.92$) and self-rewarded distraction ($d = 0.85$) than the neutral-rewarded ($d = 0.77$) distraction. These findings indicate that attention to pain may be more effectively reduced by self-related content than neutral content, and similarly well as by a performance-based reward manipulation. However,

if there is such an effect it would be small. A much larger sample with a more carefully controlled pain induction would be needed to detect this effect and establish whether a reduction in attention to pain also leads to a corresponding but smaller reduction in perceived pain intensity, which may be too small to have been detected in our study.

Limitations and Future Directions

Our results highlight several of the difficulties in researching distraction from pain. Firstly, between-group designs require large samples to produce reliable results. We argue that experiments conducted in this area including the present study are typically underpowered to detect small effects reliably, and much larger-scale studies are needed to establish whether previous findings represent robust effects or type I errors. Secondly, we suggest that pain stimulation must be more tightly controlled, or variabilities in pain stimulation compensated for with a further increase in sample size, as this is likely to reduce measurement reliability of perceived pain. Recommendations put forward by Von Baeyer, Piira, Chambers, Trapanotto, & Zeltzer (2005) were a great step in the right direction, but we argue that these do not go far enough. Where it is not possible to apply a carefully controlled and standardised pain induction, pilot studies and larger samples should be used to address this issue, as such designs are otherwise unlikely to produce robust results. Finally, we question the utility of negative pain affect as a measure in the context of laboratory pain experiments. Neither Verhoeven et al. (2010) nor our study found any differences between groups in self-reported pain affect, and it is doubtful whether this measure is likely to produce notable findings in future studies. Given the safe and controlled environment, participants' experience of the induced pain as increasing tenseness, anxiety or feeling unpleasant may reflect individual differences in pain tolerance, anxiety or other factors rather than variations in the pain experience itself. We recommend that no great importance should be attributed to this measure until more research has been conducted into the relationship between negative pain affect and pain stimulation in a

laboratory setting, and the sensitivity of this measure to reflect minor differences in pain experience.

Chapter 7

7

Self-Pain Enmeshment and Individual Differences in Self- and Pain-related Cognition and Experience

7.1. Introduction

Self-pain enmeshment is one of the mechanisms proposed for the maintenance and development of chronic pain (Pincus & Morley, 2001; Van Ryckeghem, De Houwer, Van Bockstaele, Van Damme, De Schryver & Crombez, 2013). Self-pain enmeshment refers to the integration of pain into the individual's self-concept. Such increased associations between self and pain are observed in chronic pain patients compared to healthy individuals (Pincus & Morley, 2001; Compan, Feixas, Varlotta-Dominguez, Torres-Vinals, Aguilar-Alonso & Dada, 2011; Van Ryckeghem, De Houwer, Van Bockstaele, Van Damme, De Schryver & Crombez, 2013). Within chronic pain patients, increased self-pain associations have been linked to more negative emotional and pain outcomes such as greater anxiety, depression or depressive mood, decreased acceptance and increased disability as well as pain suffering (Pincus & Morley, 2001; Pincus & Morley 2007; Sutherland & Morley, 2008; Morley, 2010; Rusu & Pincus, 2012; Van Ryckeghem, De Houwer, Van Bockstaele, Van Damme, De Schryver & Crombez, 2013). Conversely, the improvement of chronic pain in response to treatment has been linked to reductions in self-pain associations (Gumm, Erbe, von Collani & Nestler, 2008).

Various authors have highlighted the importance of researching the role of self-related cognitions such as identity and self-respect in the development and maintenance of chronic pain (Morley & Eccleston, 2004; Compan, Feixas, Varlotta-Dominguez, Torres-Vinals, Aguilar-Alonso & Dada, 2011). Self-pain enmeshment has also been identified as a potential target for psychological treatments of chronic pain (Van Ryckeghem, De Houwer, Van Bockstaele, Van Damme, De Schryver & Crombez, 2013). Given the attention self-pain associations have received in this clinical context, it is vital to improve our understanding of the relationship between self-pain associations and other self- and pain-related cognitive styles, as well as the measures typically employed to assess these constructs.

Research on self-pain enmeshment has mostly employed qualitative, explicit measurements of self-pain integration such as interviews (Osborn & Smith, 2006; Smith & Osborn, 2007; Sutherland & Morley, 2008). Some studies also used quantitative semi-explicit measures such as sentence completion tests (Morley, Barton & Davis, 2005; Rusu, Pincus & Morley, 2012). Although these studies highlight the importance of better understanding the relationship between self and pain in order to devise effective treatments for pain conditions, the use of explicit measures is problematic in this context. Response tendencies related to participant characteristics other than pain (e.g. depression) may influence participants' responses in the sentence completion test (Rusu, Pincus & Morley, 2012) and interviews. Additionally, because these measures rely on participant self-reports, they can only reflect cognitive processes the participant is consciously aware of and willing to report (Van Ryckeghem, De Houwer, Van Bockstaele, Van Damme, De Schryver & Crombez, 2013).

To address these limitations, recent studies (Gumm, Erbe, von Collani & Nestler, 2008; Van Ryckeghem, De Houwer, Van Bockstaele, Van Damme, De Schryver & Crombez, 2013) have adapted an implicit associations test (IAT; Greenwald, MCGhee & Schwartz, 1998) to assess the degree to which participants' self- and pain-schema were integrated. Grumm, Erbe,

von Collani & Nestler showed that implicitly-assessed self-pain associations were reduced in chronic pain patients (n = 25) over the course of a 4 week cognitive-behavioural pain treatment compared with a healthy control group (n = 27) who did not receive any treatment, and whose self-pain associations did not change over the course of the 4 weeks. In a sample of 73 chronic pain patients and 53 matched healthy controls, Van Ryckeghem and colleagues demonstrated 1) increased self-pain association in individuals with chronic pain compared to the healthy control group, and 2) a link between increased self-pain association and detrimental affective and pain outcomes in chronic pain patients, including higher pain severity, pain suffering, anxiety and helplessness. These findings support the schema-enmeshment model of self and pain, and constitute a valuable addition to previous research using explicit measures of self-pain enmeshment. The validation of the IAT to assess self-pain enmeshment offers important possibilities for future research on self-pain enmeshment. The IAT is quick and easy to administer to both healthy and clinical populations, and as a measure of self-pain associations more sensitive to subtle effects and less likely to be influenced by response bias than explicit measures.

Although Van Ryckeghem et al.'s study represents an important milestone in research on self-pain enmeshment, the importance of its conclusions are limited by several factors. Due to the cross-sectional design, their study did not allow any conclusions about the directionality of the relationship between self-pain enmeshment, chronic pain and detrimental affective and pain outcomes. Further, the relationships between individual differences in self-pain association and pain and affective outcomes were investigated in the chronic pain group only. Although this provided a detailed picture of the psychopathology of self-pain enmeshment in chronic pain patients, it did not enhance our understanding of the relationship between self and pain schema in healthy individuals any further than that they are less enmeshed than in chronic pain patients.

The self-pain enmeshment model proposes repeated co-activation of the self- and pain-schema as the mechanism leading to their increased integration in chronic pain patients. This suggests that self- and pain-schema should become increasingly associated as the individual experiences more pain. However, the exact process is still very poorly understood. For example, it is not clear which aspects of pain experience contribute to increased self-pain enmeshment. Pain frequency, duration, intensity and disability caused by pain are all plausible as factors driving the integration of self and pain. The present study aims to address this gap by investigating which aspects of pain experience co-vary with changes in self-pain enmeshment in healthy young adults. If self-pain enmeshment plays a role in chronic pain development, isolating the specific factors that drive self-pain integration could be crucial for identifying individuals at risk of developing chronic pain. Additionally, investigating the impact of sub-clinical pain experience on self-pain associations will further illuminate the process through which self- and pain-schema become enmeshed in chronic pain patients and advance our understanding of how adaptively self-pain associations change as a result of transient pain.

Although the self-pain IAT is a promising new measure of self-pain enmeshment, it is important to establish its validity and relation to other constructs. The task operationalises self-pain enmeshment as the ease with which participants map responses to self- and pain-related stimuli to one response key and other- and no pain-related stimuli to another response key, compared to the reverse (mapping self- and no pain-related vs. other- and pain-related information to one response key each). Participants categorise stimulus words on one of two dimensions: Me vs. not me, and pain vs. no pain. Each stimulus word belongs to one dimension and one category only (e.g. the word ‘self’ can be categorised on the ‘me vs. not me’ dimension, but not on the ‘pain vs. no pain’ dimension). In separate blocks, the same response is required for stimuli categorised as 1) ‘me’ and ‘pain’ as well as ‘not me’ and ‘no pain’ (congruent) and

2) 'me' and 'no pain' as well as 'not me' and 'pain' (incongruent). Faster and more accurate responses in congruent blocks reflect greater ease associating self and pain, while better performance in incongruent blocks indicates that participants associate self and no pain more. Pain-related processing in this context is indicated by categorising words relating to pain (e.g. 'excruciating') as belonging to the 'pain' or 'no pain' category. However, as pain-related words are generally associated with negative concepts, it is uncertain whether this implicit self-pain associations measure truly reflects overlap between self- and pain-schema, or the degree to which both concepts are familiar (Van Ryckeghem et al., 2013), or a general association between self and negative concepts not specific to pain. In the latter case, self-pain associations should be strongly related to other self-related constructs such as self-esteem or narcissism in a healthy sample, without being related to pain experience measure. Self-esteem has been considered related to chronic pain independently of self-pain enmeshment (Gumm, Erbe, von Collani & Nestler, 2008). Consequently, it is important to establish that self-esteem and implicitly measured self-pain associations do not merely reflect the same construct. This is easier to establish in healthy individuals; if both self-esteem pathology and self-pain associations independently impact chronic pain, both will be observed in chronic pain patients, making it impossible to distinguish whether the two measurements reflect the same underlying construct or occur independently. The present study explores the relationship between implicitly assessed self-pain associations and self-reported pain experience, pain catastrophizing, self-esteem, narcissism and locus of control in a healthy sample using a cross-sectional design. In line with the schema enmeshment model of self and pain, we expect that individual differences in pain experience in a healthy sample will be linked to variations in self-pain associations. Pincus and Morley (2001) argue that schemas are relatively stable, which suggests that they may be resilient to enmeshment in the context of pain experience characterised by short duration, low intensity or low disability. If this is the case, we may not

observe a link between pain experience and self-pain enmeshment in our healthy sample, who may not have experienced 'sufficient' degrees of pain to affect self-pain enmeshment. However, the model is not specific with respect to the level of pain experience that would be expected to drive enmeshment. Further, the model highlights the inherently associative nature of schemas, which might be expected to facilitate more dynamic than stagnant adaptation to pain experience. The current study aims to improve our understanding of the characteristics and degree of pain experienced by healthy individuals which may give rise to potentially transient changes in self-pain enmeshment.

If present, a relationship between pain experience and self-pain enmeshment could mediated by individual differences in pain catastrophizing. The schema enmeshment model postulates that affective aspects of pain such as distress are relevant for whether pain experience leads to self-pain enmeshment. Individuals who catastrophise more about pain may perceive pain as worse and therefore be more likely to develop self-pain enmeshment in the context of pain experience. Pain catastrophizing was therefore included to investigate its relationship with self-pain enmeshment.

Measures of self-esteem, narcissism and locus of control were included to explore the relationship between implicitly assessed self-pain association and other facets of self-related processing. Constructs such as narcissism related to a more fragile self-esteem have been linked to poor psychological adjustment (Zeigler-Hill, 2005), and locus of control has been associated with adjustment to illness and health outcomes (Crisson & Keefe, 1988; Burker, Evon, Galanko & Egan, 2005; Pucheu, Consoli, D'Auzac, Francais, & Issad, 2004). Due to the cross-sectional designs of studies showing a link between implicit self-pain associations and chronic pain or more negative pain outcomes, we cannot reject the possibility that the self-pain implicit associations measure reflects maladaptive self-related processing which predates the development of chronic pain. This study will fill an important gap in our understanding of how

the self-pain IAT measure relates to self-esteem, narcissism and locus of control in a healthy sample. If the self-pain IAT measures a distinct construct (i.e. the degree to which self- and pain-schema are enmeshed) rather than more general maladaptive self-related processing, we expect to see little or no correlation between self-pain association and self-reported self-related cognitions. Strong links between these measures in a healthy sample would suggest that 1) they may measure the same construct, and 2) self-pain IAT scores may not reflect an increase in self- and pain-schema overlap that occurs in response to pain experience in chronic pain patients, but rather pre-existing individual differences in maladaptive self-related processing which predispose individuals to develop chronic pain if exposed to certain pain experiences. In either case, our findings will have important implications for the future use of the self-pain IAT in a clinical context.

7.2. Method

Design and Procedure

In a cross-sectional design, individual differences in implicit self-pain associations and self-reported pain experience, pain catastrophizing, self-esteem, narcissism and locus of control were collected in a single laboratory session. Measures included in this study were chosen based on the findings presented in chapter 5. Questionnaires were presented in computerised format and data was collected through LimeSurvey. All participants completed all questionnaires and the self-pain IAT in the same order. This order was randomly determined.

Sample

Participants. Participants in this study were the same as participants described in chapter 6. Of the 163 participants who completed the distraction experiment (see chapter 6), 161 completed the present study immediately afterwards. The remaining 2 participants

withdrew after completing the distraction experiment and are therefore not included in this study. All other participants (n = 161) completed all individual difference measures. Inclusion and exclusion criteria, method of recruitment and compensation are described in chapter 6. Ethical approval for the study was granted by the Medical Sciences Interdivisional Research Ethics Committee (MS IDREC; R51264 / RE001). All participants gave informed consent at the beginning of the testing session. All participants were fully debriefed at the end of the experiment.

Self-report measures

Pain-related

Pain Experience (PE). Participants completed a pain experience questionnaire adapted from the graded Chronic Pain Scale (PE; von Korff, 0rmel, Keefe & Dworkin, 1992). Further details of the questionnaire are given in chapter 5. We categorised participants as pain grades 0 (pain-free), 1 (low disability, low intensity), 2 (low disability, high intensity), 3 (high disability, moderately limiting), or 4 (high disability – severely limiting) according to the Graded Chronic Pain Scale scoring system.

In our sample, most participants (96.25%; n = 160; 1 case of missing response) had experienced some pain in the last 6 months (i.e. headache, stomach ache, injury, illness, etc.). For all participants, pain was categorised as non-persistent (i.e. not persisting for 6 months), although two participants reported experiencing pain most days of the week and 6 participants reported experiencing pain several days of the week. Mean pain intensity and disability scores as well as disability points and pain grades are reported in table 7.1. The internal consistency of pain intensity and disability scores in our sample was good (see table 7.1).

Most participants' pain was categorised as mildly or not at all disabling (91.9%; n = 161), with 13 participants' disability scores indicating high disability levels. Pain intensity was

characterised as mild for most participants (88.19%; n = 161), high for a few participants (6.21%), and on the border between mild and high (pain intensity = 50) for 5.59% of participants. The majority of participants (91.9%) were categorised as grade 0-2: Three participants were categorised as entirely pain free (1.86%), 130 participants as grade 1 (81.4%), and 15 participants as grade 2 (9.31%). An additional 13 participants (8.07%) were categorised as grade 3 based on their high disability points. Participants scoring more than 3 points based on their self-reported number of disability days, i.e. days off work due to disability, and disability score based on the degree to which pain had interfered with their general, social and work activities, are characterised as grade 3 or higher regardless of pain intensity. Interestingly, those participants self-identified as 'healthy' in our study exclusion questionnaire.

Pain catastrophizing (PC). Participants completed the 13-item Pain Catastrophising Questionnaire (PC; Sullivan, Bishop & Pivik, 1995). This scale measures catastrophic thoughts about pain, and is appropriate for both clinical and non-clinical samples. Reflecting on past pain experiences, participants rate the degree to which each of the 13 thoughts or feelings (e.g. "I worry all the time whether the pain will end") describes their experience. Ratings are given on a 5-point scale (0 = not at all, 1 = to a slight degree, 2 = to a moderate degree, 3 = to a great degree, 4 = all the time). We calculated a mean score for each participant and multiplied this by the number of items in the questionnaire, thus effectively calculating a sum score while replacing missing values on individual items (7 instances, 4 participants) with the participants' mean score across all other items. Previous studies have shown the pain catastrophising scale to have good internal consistency (Sullivan et. al., 1995: α = 0.87). In our sample, internal consistency was excellent (see table 7.1).

Table 7.1. Sample descriptives for self-report measures of pain experience, pain catastrophising, narcissism, self-esteem, and locus of control (Internality, Powerful Others and Chance subscales). Measurement reliability is reported as Chronbach's alpha. Number of participants who did not complete every question of the questionnaire is reported as Missing (n), although total scores were successfully calculated for each participant on each measure, excepting 1 participant who did not complete the pain experience questionnaire at all (n=160; this is not treated as a case of missing data but rather as a different number of total participants for this questionnaire). Range of each measure (Range) and number of items (and subscales, where applicable) included in each measure (n) are also reported.

	Missing (n)	Sample Mean	SD	Range	n	Cronbach's α
Pain Experience		-	-	-	10	-
Pain Frequency	0	3.71	0.09	1-9	1	-
Pain Duration	0	4.65	0.22	1-14	1	-
Pain Intensity	0	9.41	4.26	0-100	3	0.7
Disability Score	0	5.98	6.28	0-100	3	0.91
Disability Points	0	0.51	0.96	0-6	2	-
Grade	0	1.24	0.62	0-4	2	-
Pain Catastrophising	4	17.93	9.31	0-52	13	0.91
Narcissistic Personality Inventory	1	3.83	2.83	0-16	16	0.69
Self-Esteem Scale	3	18.82	4.71	0-30	10	0.85
Locus of Control	8	-	-	-	24, 3	-
Internality	4	31.83	6.17	0-48	8	0.62
Powerful Others	6	19.05	7.19	0-48	8	0.69
Chance	2	20.64	6.96	0-48	8	0.67

Self-related

Narcissistic Personality Inventory (NPI). The 16-item Narcissistic Personality Inventory (NPI-16; Ames, Rose & Anderson, 2006) was used as a short measure of narcissism. Narcissism has received considerable attention in relation to a variety of sub-clinical populations in recent years, as a measure of enhanced perceptions of one's own behaviours and attitudes. Participants were given 16 pairs of sentences, and instructed to decide which of the two sentences in each pair described them better. Narcissism scores ranging from 0 to 16 were then calculated for each participant depending on their 16 choices, with one sentence from each pair considered the more (1 point), and one the less (0 points) narcissistic option. We calculated a total narcissism score for each participant by calculating an average from their responses, which was then multiplied by 16 thereby effectively replacing any missing responses with the participant's mean (1 case, 1 participant). The 16-item Narcissistic Personality Inventory has been shown to have acceptable internal consistency in previous studies (Ames, Rose &

Anderson, 2006; α = 0.72), and had questionable internal consistency in our sample (see table 7.1).

Self-Esteem Scale (SES). Rosenberg's (SES; Rosenberg, 1965) 10-item scale was used as a self-report measure of participants' self-esteem. Participants rated each of 10 statements based on how much they agreed with it on a 4-point scale (3 = strongly agree, 2 = agree, 1 = disagree, 0 = strongly disagree), with some items reverse scored. We calculated mean scores for each participant and multiplied these averages by 10 to obtain a sum score between 0 and 30, with missing items effectively replaced with the participant's mean from all other items (4 cases, 3 participants). Higher scores indicated higher self-esteem, and scores below 15 indicated low self-esteem problems. This scale has previously shown to have good internal consistency (Bosson, Swann & Pennebaker, 2000; α = 0.87), and had good internal consistency in our sample (see table 7.1).

Locus of Control Questionnaire (LoC). Participants completed the Locus of Control – Internality, Powerful Others and Chance scale (LoC; Levenson, 1972). Each of 24 items was rated on a 6-point scale depending on how strongly the participant agreed or disagreed with the statement (-3 = strongly disagree, -2 = moderately disagree, -1 = slightly disagree, 1 = slightly agree, 2 = moderately agree, 3 = strongly agree). We calculated sum scores for each of the 3 subscales (Internality, Powerful Others and Chance) by multiplying the mean for each participant by the number of items in the subscale (8), thus effectively replacing missing responses with the participant's mean (9 cases, 8 participants). A constant of 24 was added to each participant's subscale scores, resulting in scores between 0 and 48 with higher scores indicating a stronger belief that the associated factor has a high degree of control over events in the individual's life (Internality = controlled by individual; Powerful Others = controlled by other individuals; Chance = controlled by external events, e.g. chance or fate). Previous studies have shown acceptable internal consistency across all subscales of this scale (Kourmousi,

Xythali & Koutras, 2015; Internality: $\alpha = 0.74$, Powerful Others: $\alpha = 0.79$, Chance: $\alpha = 0.79$). In our sample, internal consistency was questionable for all subscales (see table 7.1).

Data handling

All self-report data was pre-processed using Excel 2013, including reverse scoring, replacement of missing values with participants' mean, and calculation of subscales and composite measures.

Implicit Associations Test (IAT) Computer Task

Design. The Implicit Associations Test was initially developed by Greenwald, McGhee and Schwartz (1998). This version of the IAT was designed in line with Greenwald, Nosek & Banaji (2003) and closely following the method of Van Ryckeghem et al. (2013). The test comprised 7 blocks, of which the 3rd and 4th as well as the 6th and 7th were critical (see table 7.3). In chapter 5, the order of blocks was semi-randomised across participants in line with Greenwald, Nosek and Banaji (2003). This resulted in significant differences in overall IAT scores between participants who had completed blocks in different orders, which posed a problem for using IAT scores as an individual difference measure. Therefore, in this study, all participants completed congruent blocks first (see table 7.3).

Word stimuli. Each of the two categories in each dimension was represented by 3 words (see table 7.2). The 'Me' category was represented by the words, 'my', 'myself' and 'self', while the 'Not Me' category contained the words 'other', 'them' and 'their'. We derived this stimulus material from an experiment by Teachman, Marker & Smith-Janik (2008), but substituted the word 'myself' for 'I', and the word 'their' for 'they'. The 'pain' category was represented by the words 'excruciating', 'horrible' and 'exhausting', while the 'no pain' category was represented by the words 'relieving' 'relaxing' and 'pleasant'. The stimulus material for this dimension was derived from a study by Van Ryckeghem et al., (2013), although we replaced the word 'lenitive' with 'pleasant' due to concerns that the word 'lenitive', used in the original Dutch ('verzachtend') by Van Ryckeghem and colleagues, might not be known to all participants. 'Pleasant' was chosen as a substitution from the stimulus material used in Gumm, Erbe, von Collani and Nestler (2008). At the end of the Implicit Associations Task, participants rated each of the 12 word stimuli for how relevant they found them for themselves on a scale from 1 (not at all relevant) to 7 (completely relevant), matching the manipulation check performed by Van Ryckeghem et al. (2013).

Table 7.2. List of words belong to the pain, no pain, me and not me categories in the Self-Pain Implicit Associations task.

	Pain	**No Pain**	**Me**	**Not Me**
Stimuli	excruciating exhausting horrible	relieving relaxing pleasant	my myself self	other them their

Procedure. At the beginning of each block, relevant category labels were presented for unlimited time along with the stimuli belonging to that category. Labels were 'Me' and 'Not me' for the self-other dimension, and 'pain' and 'no pain' for the pain-no pain dimension. The labels relevant for each block remained visible in the upper left and right corners of the screen throughout all the trials in that block. In each block, participants' task was to categorise stimuli appearing at the centre of the screen as quickly and accurately as possible in terms of the

categories shown at the top of the display. At the beginning of each trial, a fixation cross was displayed for 500ms in the centre of the screen. This was followed by the presentation of the stimulus for up to 3000ms, or until a response was made. A feedback screen showing the words 'correct', 'incorrect' or 'no response detected' was presented after the stimulus screen. Responses were given by pressing the 'z' key on the left of the keyboard for items belonging to either of the categories represented in the upper left corner of the screen, or the 'm' key for items belonging to the category represented in the upper right corner of the screen. In blocks 1, 2 and 5, categorisation on only one dimension was required (self-other or pain-no pain dimension). In blocks 3, 4, 6 and 7, stimuli of both dimensions were presented, and participants were instructed to press the 'z' key if the presently displayed stimulus corresponded to either of the two categories shown in the top left corner, or the 'm' key if the stimulus belonged to either of the categories displayed in the top right corner.

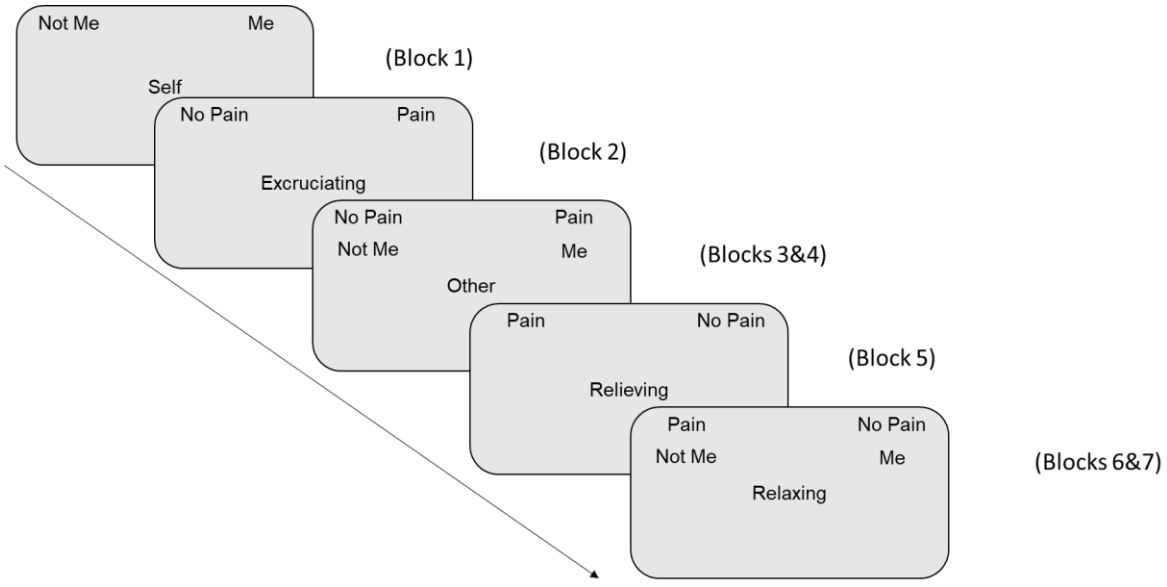

Figure 7.1. Schematic representation of the Implicit Associations Test (IAT).

The relative number of trials presented in each block was adjusted compared to the Implicit Associations Task in chapter 5. The number of presentations for each stimulus in this study followed the procedure of Van Ryckeghem, De Houwer, Van Bockstaele, Van Damme,

De Schryver and Crombez (2013). This design was specifically adapted to produce IAT scores that could be used in individual difference analyses.

In the first block, participants practised the discrimination between self and other stimuli. In the self-other discrimination block, each of the 'self' and 'other' stimulus words (6 stimuli) was presented 4 times (i.e., 24 trials). In the second block, participants practised the discrimination between 'pain' and 'no pain' stimuli. Each of the 'pain' and 'no pain' related words was presented 4 times (i.e. 24 trials). The third and fourth blocks were congruent self-pain blocks. In these blocks, all stimuli from each category (3 each for the 'self', 'other', 'pain' and 'no pain' categories) were presented 4 times (i.e. 48 trials/block). Stimuli categorised as 'self' and 'pain required the same response in the congruent self-pain blocks. The fifth block required categorisation only along the pain-no pain dimension. However, the response mapping for this categorisation was now reversed from previous blocks. During this block, each word was presented 6 times (i.e. 36 trials). In blocks 6 and 7, participants again categorised the words of all 4 categories as quickly and accurately as possible, but this time responses mappings were incongruent: Stimuli categorised as 'other' and 'pain' required the same response (see table 7.3). Faster responses in congruent blocks indicated greater ease mapping 'pain' and 'self' onto the same response, which indicates higher implicit self-pain association. Faster responses in incongruent blocks suggested greater ease mapping 'self' and 'not pain' onto the same response, indicating lower implicit self-pain association.

Table 7.3. Block and trial overview for the Implicit Associations Test (IAT).

Block nr.	Block name	Trials	Left key	Right key
1	Self-Other discrimination	24	Other	Self
2	Pain-No pain discrimination	24	No Pain	Pain
3	Self-pain practice block	48	Other + No pain	Self + Pain
4	Self-pain test block	48	Other + No pain	Self + Pain
5	No pain-Pain discrimination	36	Pain	No pain
6	Other-pain practice block	48	Other + Pain	Self + No pain
7	Other-pain test block	48	Other + Pain	Self + No pain

Data Handling. All IAT scores were computed using Matlab 2013. We intended to compute total IAT measures as D-400 (Greenwald, Nosek and Banaji, 2003) in line with the calculation of total IAT scores in chapter 5. However, the IAT design here resembles more closely the design of Van Ryckeghem, De Houwer, Van Bockstaele, Van Damme, De Schryver and Crombez (2013), who used the D-600 measure. We therefore calculated D-600 as well as D-400 measures to investigate the impact of our choice to align our computations with those used in our previous chapter or those used in previous literature. Both measures were identical for all participants, indicating that no participant made a correct response faster than 400ms after stimulus onset, with mean response times over 600 milliseconds ($M_{RT} = 661$, $SD_{RT} = 139$). We will here continue to refer to the D-400 measure to ensure continuity from chapter 5.

A D-400 score was calculated for congruent and incongruent blocks separately. Inaccurate responses were replaced with a penalty latency, consisting of the participant's mean response latency added to an error penalty of 600 milliseconds. The D-400 comprised the average of response latencies for correct responses and penalty latencies for incorrect responses. Overall IAT scores were calculated for each participant as

$$IAT\ score = D\text{-}400_{Congruent} - D\text{-}400_{Incongruent},$$

where $D\text{-}400_{Congruent}$ was the D-400 score associated with the participant's performance in congruent blocks, and $D\text{-}400_{Incongruent}$ the D-400 score associated with the participant's performance in incongruent blocks. Both practice and test blocks were used to calculate mean D-400 scores for congruent and incongruent blocks, in line with Van Ryckeghem et al (2013). On average, participants' IAT scores were positive ($M_{IAT} = 63.5$, $SD_{IAT} = 116$). This suggests D-400 scores were higher in the congruent than the incongruent block, which is consistent with an overall tendency towards identifying with no pain rather than pain in our healthy sample. Negative IAT scores indicate greater association with pain.

In line with van Ryckeghem et al. (2013), we set our participant exclusion criterion at an error rate of 30% or higher. Participants' responses were consistently highly accurate (M = 0.94, SD = 0.05), and thus no participants were excluded on this basis.

7.3. Results

Manipulation Check: Relevance Ratings for Word Stimuli (Self-Pain IAT)

Mean relevance ratings for each category are presented in table 7.4. Ratings were given on a Likert scale from 1 to 7, with higher scores indicating higher relevance. We performed paired samples t-tests to investigate which category (Me, Not Me, Pain, No Pain) was more relevant to participants in each dimension (self-other, pain-no pain). Participants rated words belonging to the 'Me' category as significantly more relevant to themselves than words that belonged to the 'Not Me' category ($t(160) = 13.33$, $p < .001$, $d = 1.54$), while words belonging to the 'No Pain' category were rated as more relevant by participants than words in the 'Pain' category ($t(160) = 13.33$, $p < .001$, $d = 1.39$). Both effects were very large based on their effect sizes. Ratings for the different words within each category had questionable ('No Pain') to acceptable ('Pain', 'Me', 'Not Me') internal consistency. This indicates that there was a substantial degree of variation in self-relevance between the words in each category. This variation was greatest in the 'No Pain' category and smallest in the 'Not Me' category.

Table 7.4. Mean relevance ratings and internal consistency of ratings for words belonging to each category.

	Mean (SD)	Chronach's Alpa
Me	5.61 (1.05)	0.71
Not Me	3.79 (1.30)	0.79
Pain	3.52 (1.25)	0.70
No Pain	5.04 (0.92)	0.63

Pain Experience, Pain Catastrophising and Self-Pain Associations

Correlations of pain catastrophizing and pain experience with self-pain associations. We performed bivariate correlations between participants' self-pain associations (IAT) and participants' self-report measures of pain catastrophizing and pain experience (see table 7.4). Implicit self-pain associations did not correlate with pain catastrophizing. Of the various aspects of participants' pain experience, only participants' disability grade was linked to self-pain associations. A Spearman's correlation showed a weak negative correlation between self-pain IAT scores and disability grade ($r(160) = -.16$, $p = .038$). As lower IAT scores reflect increased self-pain association, this negative correlation indicates that participants with higher disability grades (increased disability) also showed increased self-pain association. Notably, although disability grade is derived from pain intensity and disability points, neither of these measures taken individually correlated with IAT scores.

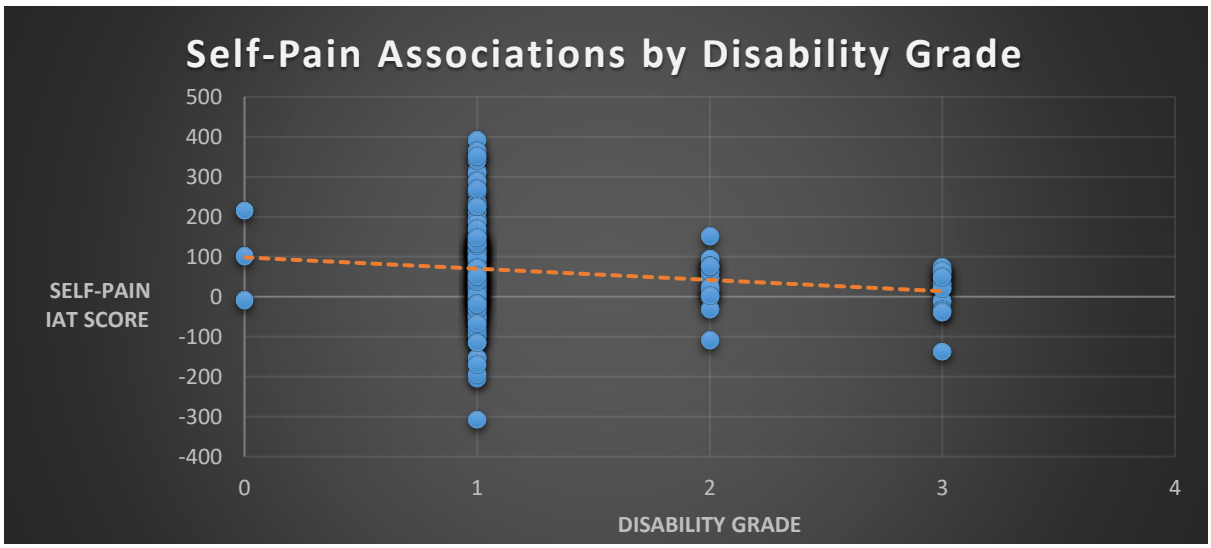

Figure 7.2. Implicit self-pain associations by disability grade. Positive self-pain IAT scores indicate greater association between self and not pain, while negative IAT scores indicate greater association between self and pain. Higher disability grades indicate a greater degree of disability. A trendline indicates the weak negative relationship between self-pain implicit associations and disability grade.

Table 7.4. Bivariate correlations between implicit self-pain associations (1 = IAT), pain catastrophizing (2 = PC) and pain experience (PE). Pain experience comprised several aspects of pain experience in the 6 months preceding the study, specifically pain frequency (3), pain duration (4), current pain levels (5), worst pain (6), average pain (7), the degree to which pain interfered with participants' lives (8 = PE Interference), the degree to which pain interfered with participants' social lives (9 – PE Interference (Social)) and work (10 – PE Interference (Work)), overall pain intensity (11), disability score (12), disability points (13) and disability grade (14). Pain Intensity (11), disability score (12), disability points (13) and disability grades (14) are composite measures computed based on participants' self-reported pain experience (see table 7.1). Overall pain intensity is computed from overall pain interference (8), social (9) and work (10) interference, disability score is computed from current(5), worst (6) and average pain (7), disability points are awarded based on disability score and number of days participants reported having missed work, and disability grades were categorised based on overall pain intensity and disability points. Values given represent Pearson's r correlation coefficient, excepting values associated with pain frequency (3) and duration (4), disability points (13) and grade (4). As those measures represent ordinal data, Spearman's correlation coefficient is reported for correlations with these variables.

	2	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
IAT[1]	-.03	-.01	-.14	-.07	-.13	-.04	-.10	-.10	-.12	-.10	-011	-.01	**-.16***
PC[2]	-	**.26****	**.18***	.10	**.19***	.10	**.28****	**.26****	**.27****	**.17***	**.29****	**.24****	.11
PE Frequency[3]	**.26****	-	.06	**.17***	**.19***	.08	**.28****	**.33****	**.28****	.14	**.34****	**.20****	.14
PE Duration[4]	**.18***	.06	-	.13	**.42****	**.37****	**.53****	**.45****	**.50****	**.43****	**.52****	**.44****	**.43****
PE Current Pain[5]	.10	**.17***	.13	-	**.22****	**.32****	**.34****	**.37****	**.35****	**.49****	**.39****	**.28****	**.30****
PE Worst Pain[6]	**.19***	**.19***	**.42****	**.22****	-	**.74****	**.40****	**.36****	**.36****	**.91****	**.40****	**.34****	**.52****
PE Average Pain[7]	.10	.08	**.37****	**.32****	**.74****	-	**.40****	**.40****	**.37****	**.91****	**.42****	**.40****	**.54****
PE Interference[8]	**.28****	**.28****	**.53****	**.34****	**.40****	**.40****	-	**.81****	**.79****	**.47****	**.94****	**.75****	**.43****
PE Interference (Social)[9]	**.26****	**.33****	**.45****	**.37****	**.36****	**.40****	**.81****	-	**.72****	**.46****	**.92****	**.73****	**.45****
PE Interference (Work)[10]	**.27****	**.28****	**.50****	**.35****	**.36****	**.37****	**.79****	**.72****	-	**.44****	**.91****	**.66****	**.46****
PE Pain Intensity[11]	**.17***	.14	**.43****	**.49****	**.91****	**.91****	**.47****	**.46****	**.44****	-	**.49****	**.42****	**.58****
PE Disability Score[12]	**.29****	**.34****	**.52****	**.39****	**.40****	**.42****	**.94****	**.92****	**.91****	**.49****	-	**.76****	**.47****
PE Disability Points[13]	**.24****	**.20****	**.44****	**.28****	**.34****	**.40****	**.75****	**.73****	**.66****	**.42****	**.76****	-	**.56****
PE Disability Grade[14]	.11	.14	**.43****	**.30****	**.52****	**.54****	**.43****	**.45****	**.46****	**.58****	**.47****	**.56****	-

* = significant at $\alpha = 0.05$

** = significant at $\alpha = 0.01$

Correlations between pain catastrophizing and pain experience. Bivariate correlation analyses (see table 7.4) revealed positive Spearman's correlations between pain catastrophizing and frequency ($r_S(160) = .26$, $p = .001$) and duration ($r_S(160) = .18$, $p = .023$) of pain experienced in the 6 months preceding the study. Pearson's correlations showed a link between pain catastrophizing and worst pain experienced ($r(160) = .19$, $p = .018$), but not average or current pain levels. Pain catastrophizing was also weakly correlated with overall pain intensity scores ($r(160) = .17$, $p = .036$). This suggests participants who catastrophise more about pain reported experiencing pain more frequently and for longer, as well as more intense worst pain and overall more intense pain experiences.

Positive Pearson's correlations were also found between pain catastrophizing and the degree to which pain interfered with participants' overall activities ($r(160) = .28$, $p < .001$), social activities ($r(160) = .26$, $p = .001$) and work ($r(160) = .27$, $p = .001$). Participants' overall disability scores computed from overall, social and work interference scores also correlated positively with pain catastrophizing ($r(160) = .29$, $p < .001$). A Spearman's correlation (r_S) showed a positive correlation between pain catastrophizing and disability points derived from disability scores ($r_S(160) = .24$, $p = .002$). Disability grade was not linked with pain catastrophizing. These results suggest that individuals who catastrophise more about pain also report that pain interfered to a greater degree with their overall and social activity as well as work . Consequently high pain catastrophisers achieve greater overall disability scores (derived from overall, social and work interference scores) and scored more disability points (derived from disability scores and number of days participants reported missing work due to pain). However, pain catastrophizing did not affect which disability grade participants were categorised as.

Correlations between pain experience measures. Spearman's rank correlations (r_S) revealed that the frequency with which participants experienced pain in the 6 months preceding

the study was linked current ($r_S(160) = 0.17$, $p = 0.031$) and worst ($r_S(160) = .19$, $p = .018$) but not average pain levels or overall pain intensity scores. Pain frequency also positively correlated with pain interference with overall ($r_S(160) = .28$, $p < .001$) and social activities ($r_S(160) = .33$, $p < .001$) as well as work ($r_S(160) < .28$, $p = .001$). Consequently, pain frequency was also correlated with disability score ($r_S(160) = .34$, $p < 0001$) and disability points ($r_S(160) = .20$, $p = .010$), but not with disability grade. This suggests individuals who experienced pain more frequently in the 6 months preceding the study experienced more pain at the time of the study as well as more intense worst pain in the preceding 6 months, but not more intense pain on average or overall. The more frequently participants reported having experienced pain, the more they reported pain having interfered with their overall and social activity as well as work in the preceding 6 months, and consequently the higher their disability scores and points were. However, which pain grade participants were categorised as was not linked to how frequently participants had experienced pain.

Spearman's rank correlations with pain duration revealed links with worst ($r_S(160) = .42$, $p < .001$) and average ($r_S(160) = .37$, $p < .001$) but not current pain. Overall pain intensity was also positively correlated with average pain duration ($r_S(160) = .43$, $p < .001$). This suggests that participants who experienced longer periods of pain in the 6 months preceding the study also reported experiencing more intense worst, average and overall pain during this period, although pain duration was not related to participants' pain levels at the time of the study. Pain duration was also positively correlated with the degree to which participants reported pain interfered with their overall ($r_S(160) = .53$, $p < .001$) and social ($r_S(160) = .45$, $p < .001$) activity as well as work ($r_S(160) = .50$, $p < .001$), and consequently their overall disability score ($r_S(160) = .52$, $p < .001$) and disability points ($r_S(160) = .44$, $p < .001$). Pain duration was also positively correlated with pain grade ($r_S(160) = .43$, $p < .001$). This suggests that individuals who experienced pain for longer periods at a time also reported that pain

interfered more with their overall, social and work activities and therefore had higher disability scores. Experiencing longer periods of pain was also linked to greater disability points as well as higher disability grades.

All pain intensity and disability scores, as well as composite measures of overall pain intensity, disability score, disability points and disability grade were positively correlated (see table 7.4). The magnitude of these associations ranged from weak ($r \sim .3$) to strong ($r \sim .7$), with some of the composite scores reaching almost a perfect linear relationship with some of their compound variables. These results suggest that participants who reported having experienced more intense pain on one measure (on average, at its worst or at the time of testing) also reported experiencing more intense pain in the other measures, and consequently received higher overall pain intensity scores. Similarly, participants reporting that pain interfered to a greater degree with their overall, social or work activities also reported greater interference with the other aspects of their lives and consequently received higher disability scores. Further, higher pain intensity ratings were also associated with higher disability ratings and scores. This indicates that participants reporting experiencing more intense pain generally also reported higher disability due to the pain and vice versa.

Self-related Cognitions and Self-Pain Associations

Correlations of self-related cognition with self-pain associations. We performed bivariate correlations between self-pain associations and self-related cognitions, comprising narcissism, self-esteem, and locus of control subscales Internality, Powerful Others and Chance (see table 7.6). Implicit self-pain associations were not correlated to narcissism, self-esteem or the Internality subscale of locus of control. However, Powerful Others ($r(161) = -.19$, $p = .016$) and Chance ($r(161) = -.17$, $p < .034$) subscales of locus of control were weakly negatively correlated with self-pain associations (see figures 7.3 and 7.4, respectively). This suggests that

individual differences in self-esteem, narcissism and internal attribution of control did not affect self-pain associations, but attributing control over events in participants' lives to powerful others or chance did to a small degree. As lower IAT scores indicate higher self-pain association, greater attribution of control to powerful others and chance was linked to increased self-pain associations.

Table 7.6. Bivariate correlations between implicit self-pain associations (IAT) and self-reported self-related cognitions comprising narcissism, self-esteem and locus of control Internality, Powerful Others and Chance subscales. Values given represent Pearson's r coefficient.

	IAT	NPI	SES	Locus of Control		
				Internality	Powerful Others	Chance
Self-Pain Associations	-	.03	.07	-.04	**-.19***	**-.17***
Narcissism (NPI)	.03	-	**.19***	.09	-.03	-.07
Self-esteem Scale (SES)	.07	**.19***	-	**.38****	**-.23****	**-.21***
LOC Internality	-.04	.09	**.38****	-	-.07	**-.33****
LOC Powerful Others	**-.19***	-.03	**-.23****	-.07	-	**.46****
LOC Chance	**-.17***	-.07	**-.21***	**-.33****	**.46****	-

* = significant at $\alpha = 0.05$
** = significant at $\alpha = 0.01$

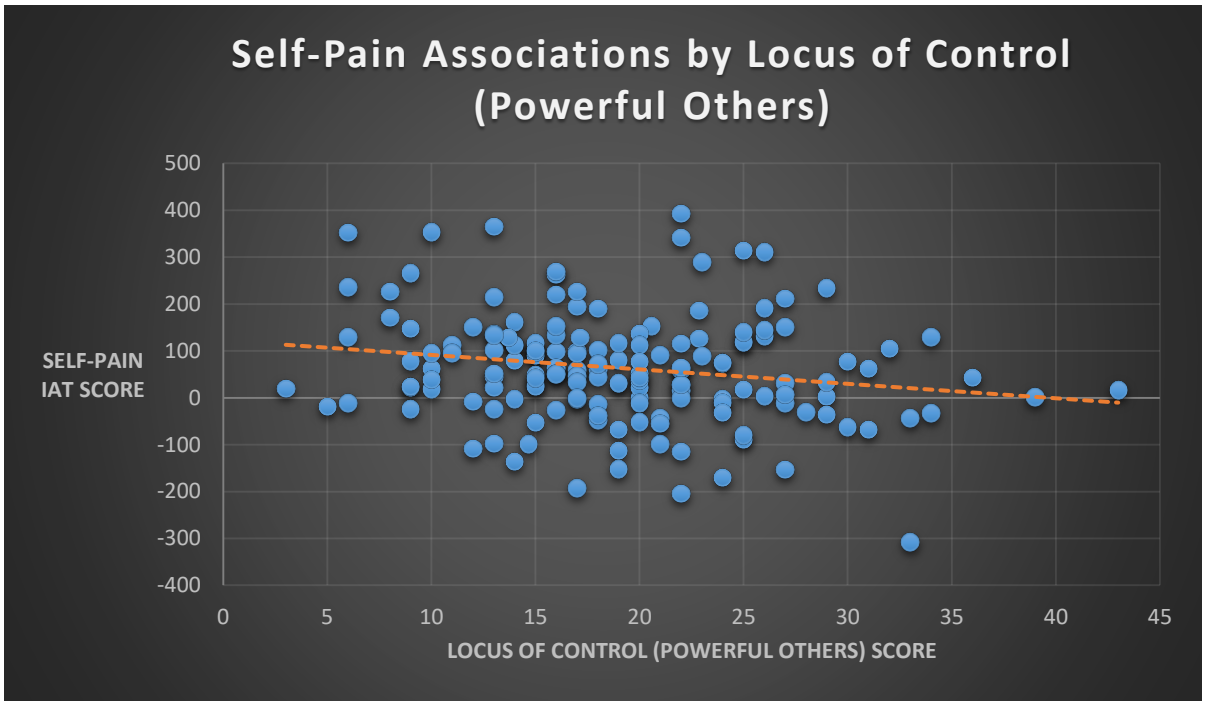

Figure 7.3. Implicit self-pain associations by locus of control (Powerful Others). Positive self-pain IAT scores indicate greater association between self and not pain, while negative IAT scores indicate greater association between self and pain. Higher locus of control (Powerful Others) scores indicate greater belief that events in participants' lives are controlled by powerful others. A trendline indicates the weak negative relationship between self-pain implicit associations and locus of control (Powerful Others).

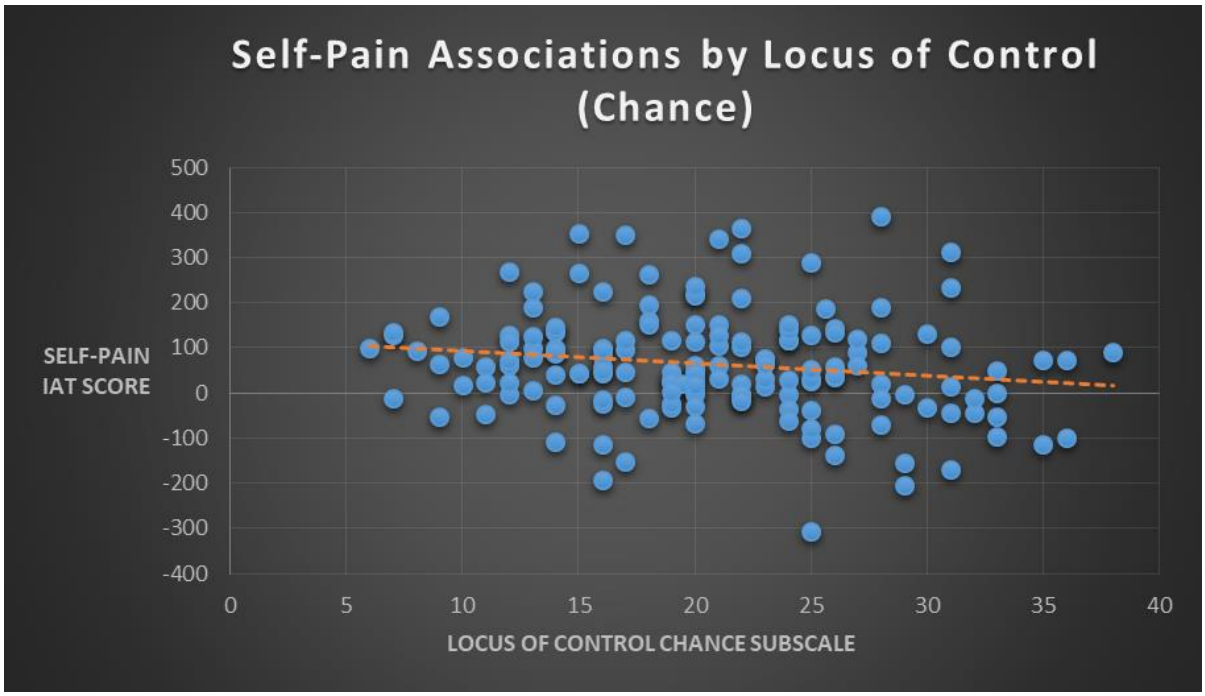

Figure 7.4. Implicit self-pain associations by locus of control (Chance). Positive self-pain IAT scores indicate greater association between self and not pain, while negative IAT scores indicate greater association between self and pain. Higher locus of control (Chance) scores indicate greater belief that events in participants' lives are controlled by chance. A trendline indicates the weak negative relationship between self-pain implicit associations and locus of control (Chance).

Correlations between self-related cognitions. Bivariate correlations among self-related cognitions (see table 7.6) revealed a weak positive correlation between narcissism and self-esteem ($r(161) = .19$, $p = .019$). Self-esteem was also weakly positively correlated with the internality subscale of locus of control ($r(161) = .38$, $p < .001$), and negatively with the powerful others ($r(161) = .23$, $p = .003$) and chance ($r(161) = .21$, $p < .009$) subscales. This suggests that individuals high in self-esteem were also high in narcissism, had a more internal locus of control and attributed less control over events in their lives to powerful others or chance. Narcissism was not associated with any of the locus of control subscales. Internal locus of control was negatively correlated with chance ($r(161) = -.33$, $p < .001$) but not the powerful others subscale, while attribution of control to powerful others was linked to attributing control to chance ($r(161) = .46$, $p < .001$). This suggests there was no link between narcissistic personality and locus of control, but individuals with a more internal locus of control attributed less control over events in their lives to chance while those attributing more control to powerful others also attributed more control to chance.

Predicting Self-Pain Associations from Disability Grades and Locus of Control (Powerful Others and Chance)

Regression Analysis. Hierarchical multiple regression was performed to predict implicit self-pain association with disability grade as an explanatory variable after controlling for individual differences in locus of control powerful others and chance. Preliminary analyses were conducted to ensure the assumptions for normality, linearity and homoscedasticity were met. The multicollinearity assumption of multiple regression was tested, showing no strong correlations between disability grade and powerful others ($r_S(161) = .07$, $p = .36$) or chance ($r_S(161) = .08$, $p = .33$) locus of control. Chance and powerful others subscales of locus of control were moderately but not strongly correlated (see table 7.6), which suggests

multicollinearity is unlikely to be problematic for this analysis (see Tabachnick & Fidell, 2007). All predictor variables were correlated with implicit associations of self and pain (see tables 7.5, 7.6) which indicated a multiple hierarchical regression was suitable to perform on these data.

In the first step, Powerful Others and Chance scales of locus of control were entered as predictors. This produced a significant model which explained 4% of the variance in self-pain associations ($R^2 = 0.04$, $F(1, 159) = 5.90$, $p = .016$). The only predictor in this model was the Powerful Others subscale of locus of control ($\beta = -0.19$, $p = .016$), while the Chance subscale of locus of control was not significant ($\beta = 0.10$, $p = .246$).

Disability grade was then entered as a predictor variable in step 2. The resulting model explained 6% of the variance in self-pain associations ($R^2 = 0.06$, $F(1, 158) = 4.60$, $p = .011$). Model 2 therefore explained 2% more variance in self-pain associations than model 1, a 50% increase in variance explained. In this model, only Powerful Others locus of control was a significant predictor variable ($\beta = -0.18$, $p = .021$), with disability grade just below the threshold for significance ($\beta = -0.14$, $p = .074$).

7.4. Discussion

Summary

We found weak correlations between self-pain associations and disability grade, powerful others and chance attributions of control. Higher disability grades (indicating greater pain-related disability) were linked to greater associations between self and pain, consistent with the self-pain enmeshment model of chronic pain. Self-pain associations were not linked to other pain experience measures such as frequency, duration, intensity or pain-related disability, suggesting that a combination of these factors (i.e. our compound measure of disability grade) rather than any individual factor was driving self-pain enmeshment. Self-pain

enmeshment was not linked to participants' pain levels at the time of testing, suggesting the self-pain implicit associations measure was unaffected by the degree of pain participants experienced while performing the task.

There was also no relationship between self-pain associations and individual differences in self-esteem and narcissism, indicating that the self-pain implicit associations measure does not reflect general associations between self and negative content, but a specific, distinct construct of self-pain enmeshment. Individuals higher in self-pain associations also attributed more control over events in their lives to powerful others or chance. Powerful others locus of control was a better predictor of self-pain associations than chance attributions of control, or disability grade.

This finding poses some problems for the construct of self-pain enmeshment and the schema enmeshment model of chronic pain, which conceptualises self-pain enmeshment as a cognitive change in response to a situational change (increased pain experience), rather than reflecting individual trait differences that predispose individuals to develop chronic pain and self-pain enmeshment. Our findings indicate that trait differences in powerful others attributions of control may be more important for self-pain enmeshment than pain experience. This could mean the self-pain enmeshment model needs to consider the contribution of stable inter-individual differences as well as situational differences in pain experience for the development of self-pain enmeshment and chronic pain. It is possible that individuals who attribute more control to powerful others develop self-pain enmeshment more easily when confronted with pain experience, which could put them at higher risk of developing chronic pain according the self-pain schema enmeshment model. The role of individual differences in locus of control for self-pain enmeshment could have important implications for chronic pain treatments targeting the relationship between self- and pain-schema.

Self-Pain Associations, Pain Experience and Pain Catastrophising

Implicit self-pain associations were weakly related to disability grade, but not any other aspects of self-reported pain intensity such as pain frequency, duration, intensity or pain-related disability. Participants categorised into higher disability grades also showed higher enmeshment of self and pain in the self-pain implicit associations task. Disability grades were categorised based on participants' self-reported pain intensity and the degree to which they reported pain had interfered with their lives in the 6 months preceding the study. Self-pain associations were linked to disability grades but not individual measures of self-reported pain intensity or pain-related disability, which suggests that neither experiencing more intense pain nor increased disability as a result of pain is sufficient by itself to drive self-pain enmeshment; instead, a combination of both more intense pain and increased disability are necessary for pain to become integrated into one's self-schema.

More frequent or longer pain experiences alone also did not lead to an increase of self-pain associations. In our generally healthy sample, it is possible that this was due to a lack of variance in pain experience. However, our descriptive analysis of the pain experience in our sample suggests that only 3 of our participants had been entirely free of pain in the 6 months preceding the study, while all others had experienced some pain, with a few participants even experiencing very frequent or long periods of pain, very intense pain and substantial degrees of pain-related disability. This suggests some variance in pain experience in our sample, although none of our participants were characterised as suffering from chronic pain. These findings indicate that self-pain enmeshment may occur slowly and only through prolonged periods of experiencing both intense pain and high disability as a result of pain, rather than transiently in response to short periods of intense pain and / or high disability.

The lack of relationship between self-pain enmeshment and specific characteristics of pain experience (e.g. frequency) highlights the complex, interactive impact of pain, with multiple factors contributing to the development of maladaptive response patterns such as self-pain enmeshment. This view of the pathology of pain is also consistent with a recent model of chronic pain (Linton, Flink & Vlaeyen, 2018), which highlights that numerous factors may interact non-linearly to influence the pathology of chronic pain development. Our study considered the contribution of individual factors such as frequency of pain in a linear sense only. The broader measure of disability grade may therefore have been better-suited to investigate the relationship between self-pain enmeshment and pain experience. Future research on the enmeshment of self and pain should consider the potential non-linear relationship between pain experience and pain outcomes; for example, Linton, Flink and Vlaeyen's model would predict that variable and unpredictable pain experience, rather than frequency, duration or intensity, may reinforce maladaptive pain responses. If self-pain enmeshment were considered such a maladaptive cognitive response, it may be expected that individuals reporting more unpredictable and variable pain may also display increased self-pain enmeshment. Future research could show a link between these two models by investigating whether self-pain enmeshment is linked to the schedule of pain experienced by individuals suffering from pain.

Also notable was our finding that participants' pain levels at the time of testing were not linked to their performance in the self-pain Implicit Associations Task. One concern with using an implicit measure of self-pain enmeshment as opposed to the previously used explicit measures was that, although less affected by response tendencies, it might be confounded by factors such as current pain levels. A participant in pain at the time of performing the self-pain IAT might find it easier to associate self and pain in the task irrespective of their longer-term self-pain enmeshment. Due to the implicit nature of the task, the participant would not be able

to put their current experience into a wider context, as they might be able to in an explicit assessment relying on their conscious reports. Our results indicate that this is not the case. Instead, the self-pain implicit associations task seems robust to both current and transient pain experiences. These results indicate that the IAT is indeed a valid measure of self-pain associations.

Self-Pain Associations, Self-esteem and Narcissism

We found no relationship between implicit self-pain associations and self-esteem or narcissism, although self-esteem was associated with narcissism. The link between self-esteem and narcissism supports the view of narcissism as related to self-esteem but representing a less stable and more fragile component or discrepant self-esteem (Zeigler-Hill, 2005). This study aimed to test whether the self-pain IAT measures a construct specific to the association between self- and pain-schema and distinct from a more general association between self and negative information. These findings suggest that the self-pain IAT measure does not reflect the same construct as either self-esteem or narcissism. Combined with our finding that disability grade was linked to self-pain associations, it therefore seems likely that the self-pain IAT does not reflect and is not confounded by individual differences in self-esteem or narcissism, but is indeed associated with an increase in pain-related disability. This suggests that 1) the self-pain IAT is a useful measure of self-pain enmeshment independent from individual differences in self-related cognition, and 2) self-pain enmeshment depends on a combination of pain-related experience, but not individual differences in self-esteem or narcissism.

Self-Pain Associations, Locus of Control and Disability Grade

We found a weak link between self-pain associations and powerful others or chance orientation of locus of control, but not internal locus of control. Individuals attributing more control over events in their lives to chance or powerful others also showed slightly higher self-

pain enmeshment in the self-pain associations task. Previous research has linked viewing outcomes as controlled by external factors such as chance to poor pain coping strategies (Crisson & Keefe, 1988). Our finding could therefore suggest that individuals higher in external attributions of control could develop self-pain enmeshment more easily when confronted with pain experience. We tested this hypothesis in a hierarchical multiple regression. In a first model, we investigated the variance in self-pain associations explained by attributions of control to powerful others and chance. The results indicated that the variance explained by these two factors overlapped, and attribution of control to powerful others remained the only significant predictor of self-pain associations, explaining a small but significant proportion of variance (4%). In a second model, the additional contribution of disability grade in explaining the variance in self-pain associations was tested. The resulting model was also significant and explained 6% of the variance in self-pain association, but attribution of control to powerful others remained the only significant predictor variable while disability grade was just shy of being a significant predictor ($p = 0.074$).

These results have several implications. Firstly, they suggest that attributing control to powerful others is a better predictor of increased self-pain associations than attributing control to chance, though both factors are related and explain an overlapping portion of the variance in self-pain associations. Secondly, they indicate that powerful others attributions of control are a better predictor of self-pain associations than pain-related disability grade. Although both factors together can predict self-pain associations better than powerful others attributions of control alone, disability grade did not add significantly to the predictive power of individual differences in powerful others.

This pattern of results poses a problem in the context of the self-pain enmeshment model of chronic pain, which postulates that pain experience drives changes in self-pain association. Our findings indicate that, although pain experience (specifically disability grade)

is linked to self-pain association, enmeshment is better predicted by individual differences in attributing control to powerful others. This could mean that self-pain enmeshment, rather than reflecting a change in the relationship between self- and pain-schema resulting from pain experience, simply measures individual differences in powerful others attributions of control. External locus of control has been linked to maladaptive pain coping strategies before (Crisson & Keefe, 1988). Locus of control has generally been considered a stable construct reflecting inter-personal differences (Levenson, 1972; Roberts & Nesselroade, 1986), although there is some evidence for situation-dependent changes in locus of control (Roberts & Nesselroade, 1986). It is therefore likely that, if measures of self-pain enmeshment reflect individual differences in powerful others attribution of control, they assess individual differences pre-disposing individuals to developing chronic pain rather than a transient construct that changes in response to experiencing pain. Our results indicate that this is the case to a small degree, with trait differences in powerful others attribution of control contributing to 4% of the variance in self-pain enmeshment. If self-pain enmeshment reflects a construct that is at least to some degree a stable trait difference between individuals rather than a maladaptive response to pain experience, this could mean the self-pain enmeshment model needs to be expanded to allow or both stable trait factors and pain experience to contribute to self-pain enmeshment and chronic pain.

Given our cross-sectional design and overall healthy sample, we cannot exclude the possibility that the relative contribution of stable individual differences and situational pain experience to the degree of self-pain association changes depending on the degree to which pain experience in present. The link between pain experience and self-pain associations may increase with prolonged, more intense or more debilitating pain experience. In a sample experiencing higher levels of pain, pain characteristics might be a better predictor of self-pain associations than powerful others attributions of control. However, these findings highlight the

need for future research to adopt longitudinal designs to establish temporal and causal relationships between pain experience, self-pain enmeshment and individual differences in locus of control. It is essential to investigate the role individual trait differences in locus of control play in the enmeshment of self and pain, and whether they reflect a risk factor for chronic pain development due to a predisposition to enmesh self- and pain-schema more easily. The role of trait differences in powerful others attributions of control in developing enmeshed self- and pain-schema could have important implications for chronic pain treatments targeting the self-pain enmeshment.

Limitations and Future Directions

One limitation of our study was that pain experience was assessed retrospectively through self-reports only, and may therefore not be highly reliable. Pain experience reports were highly inter-related, indicating that individuals who reported experiencing pain more frequently and more longer periods also experienced more intense pain and increased disability as a result of pain. This could be a result of the all-encompassing nature of pain, or it might reflect some degree of response bias. Individuals who reported more pain were generally also higher in pain catastrophizing. Given that pain experience reports were retrospective and not validated by external sources such as medical practitioners or observer ratings, it is plausible that pain catastrophizing impacted participants' self-reports of pain experience. Pain catastrophizing was however not related to self-pain associations. This suggests that the self-pain Implicit Associations measure is not confounded by individual differences of pain catastrophizing, while self-reported measures of pain experience may be. If pain catastrophizing impacted our self-reported measures of pain experience, it is possible this is the reason that no relationship was found between implicit self-pain associations and some of our pain experience measures, such as pain frequency and duration. However, although this may have affected the reliability of our pain experience measures, this should have been

compensated for by our large sample. The relationships between pain catastrophizing and pain experience measures were overall weak, suggesting that pain catastrophizing may have impacted, but not entirely determined self-reports of pain experience. We conclude that our findings are likely valid despite this limitation, although future research would benefit from including measures of pain experience less compounded by reporting bias or pain catastrophizing.

We also need to consider whether the Self-Pain Implicit Associations Task used in this study was a valid measure of self-pain enmeshment. The design used here was much improved from the one described in chapter 5, using a standardised rather than randomised block order with appropriately adjusted number of trials per block, adapted to investigate individual differences rather than between-group differences. However, is it uncertain whether the word stimuli used were entirely suitable for our purpose. Our manipulation check indicates that the words used for the self-other dimension were appropriate choices: Participants rated words in the 'Me' category as more relevant to themselves than words in the 'Not Me' category. Previous studies using the Self-Pain IAT employed words specific to each participant (e.g. participants' own first and last name, place of birth) as opposed to someone else (e.g. someone else's names, birth place) as stimuli in the self-other dimension (Van Ryckeghem et al., 2013; Grumm, Erbe, von Collani & Nestler, 2008). This personalised method is substantially more effortful than our standardised words, and potentially confounded by participants' past associations (Sui, He & Humphreys, 2012). Previous research has demonstrated the efficacy of non-personalised self-related words in an IAT design (Teachman, Marker & Smith-Janik, 2008), and recent research (Sui, He & Humphreys, 2012) as well as our manipulation checks indicate that these word stimuli are capable of evoking self-related cognitive processing. We consider the use of this standardised stimulus material as both increasing the validity and

improving the ease of administering the Self-Pain IAT, and recommend its use in future research on self-pain enmeshment.

In comparison, we are less confident in the suitability of the stimulus material used for the pain-no pain dimension. Our manipulation check indicated that our healthy sample identified more strongly with words belonging to the 'No pain' compared to the 'Pain' category, in line with findings by Van Ryckeghem et al. (2013) and our expectations. However, a check of how relevant participants found the words for their respective category was not included for the pain-no pain dimension. We can therefore not verify whether the increased self-relevance reported for words in the 'No pain' category reflects a heightened association between self and no pain compared to self and pain. Although these word stimuli were based on previous studies (Van Ryckeghem, 2013; Grumm, Erbe, von Collani & Nestler, 2008), our reliability analysis suggests that there was a substantial deal of variation in how self-relevant words in the 'No pain' category were considered by participants. This suggests that not all of the word stimuli included may adequately represent this category. We recommend that future research should establish reliable standardised stimulus material to ensure the validity of the self-pain IAT as a measure of self-pain enmeshment before expanding its use in a clinical context.

The Implicit Associations Task was chosen because it is one of the most widely used indirect measure of attitudes (De Houwer, 2003), particularly easy to implement, and has already been used as a measure of self-pain enmeshment (Gumm, Erbe, von Collani & Nestler, 2008; Van Ryckeghem, De Houwer, Van Bockstaele, Van Damme, De Schryver & Crombez, 2013). Consequently, in using this task, we were able to draw on a set of stimulus words and a methodological set-up which had been demonstrated by previous studies to yield a measure of self-pain enmeshment which varies between healthy individuals and chronic pain patients, as well as within chronic pain patients depending on their pain severity, pain suffering, anxiety

and helplessness. However, as discussed above, the stimulus material may nevertheless have been sub-optimal.

In addition to the benefits outlined before, the IAT is also generally associated with large effect sizes allowing findings to be easily replicated, as well as robust individual differences (De Hower, 2003). This made the IAT particularly suitable for the present study, which focused on individual differences within a limited sample. However, alternative tasks might have been used, such as the affective Simon task (De Houwer & Eelen, 1998; De Houwer, Crombez, Baeyens & Hermans, 2001). In the affective Simon task, participants respond to valenced words (e.g. 'FRIEND', 'ENEMY') depending on a non-evaluative feature (e.g. whether a person or animal is presented), giving a positive or negative response (e.g. respond: "Good" for person, "Bad" for animal). Responses are faster when the correct response matches the intrinsic valence of the word presented (e.g. responding "Good" to the "FRIEND" stimulus). This task thus shares many similarities with the IAT (De Houwer, 2001), but differs crucially because responses are intrinsically valenced unlike in the IAT. The IAT has been criticised on the basis that performance may be impacted by non-associative factors such as recoding. De Houwer (2003) argues that participants may categorise stimuli according to different criteria than instructed whenever possible. For example, in an IAT that requires categorisation of stimuli as flowers or insects on one dimension, and positive and negative on another, participants may simply ignore the flowers – insects dimension and simply think of flowers as positive, insects as negative, and then respond only in terms of the positive – negative dimension. This is a notable deficit of the IAT, particularly where dimensions are used which can easily be grouped according to some task-irrelevant characteristic (e.g. being positive, being a certain shape, colour, etc.). We do not believe that this is likely to have occurred in the present study due to the particular dimensions used. However, the findings

reported here would be strengthened if future research using alternative tasks such as the affective Simon task that avoid this methodological constraint found similar results.

The IAT also measures associations on a relative scale in that associations between self and pain are defined in contrast to the association between self and no pain, and not self and pain. The task thus contains an inherent confounding factor, as the IAT measure does differentiate whether participants with unusually high self-pain associations found it easy to link self and pain, or hard to link self and no pain, or both. In the context of this study, we considered this an acceptable limitation, because either abnormally high identification with pain or low identification with no pain might indicate problematic pain-related processing that could constitute a risk factor. However, further research could explore the exact underlying cognitive pattern in more detail using the affect Simon task. For example, participants could be instructed to say "Me" any time a yellow word was presented, and "Not Me" any time a green word was shown. The different speeds in responding to a pain-related word shown in yellow (response: "Me") or green (response: "Not Me" could then be directly compared without the need to contrast these responses with responses to not pain-related stimuli.

A further limitation was the cross-sectional design of our study. We have made some assumptions about the directionality of the effects in our study based on the nature of our measures (e.g. self-reported pain experienced in the 6 months preceding the study) and previous research using these measures (e.g. locus of control as a stable trait measure; Levenson, 1972). However, ideally, the time-course and directionality of the relationship between pain experience, implicit self-pain associations and individual differences which may constitute risk factors for chronic pain or heightened self-pain associations should be established in a large-scale longitudinal study following healthy individuals who develop chronic pain. Designing such a study is challenging considering that a large number of individuals have to be followed for a notable portion of them to develop chronic pain, which would be crucial for obtaining

statistically meaningful results. However, this can be achieved by recruiting healthy participants scheduled to receive medical procedures which are often painful and are associated with high rates of chronic pain development, such as caesarean (Weibel et al., 2016). We predict that such a study would show trait measures of powerful others attribution of control predicting self-pain associations more strongly than pain experience before the painful procedure, but to a much smaller degree than pain experience after the pain procedure. This would be consistent with a change in relative contribution of interpersonal differences (e.g. locus of control) and situational factors (e.g. pain experience) to self-pain associations depending on the situation, i.e. how much pain an individual has experienced. Baseline differences in self-pain associations in a healthy sample may reflect cognitive traits such as locus of control, but intense and debilitating pain experience would likely cause more extreme changes in self-pain association, consistent with the self-pain enmeshment model of chronic pain.

Chapter 8

8

Summary, Discussion and Future Directions

8.1. Assessing Pain-Prioritisation with the Perceptual Matching Paradigm

Chapters 2-5 in this thesis aimed to investigate whether a pain adaptation of the Perceptual Matching Paradigm (PMP; Sui, He & Humphreys, 2012) could constitute a valid measure of prioritised cognitive processing for pain-related information. The development and validation of new paradigms and measures assessing cognitive bias for pain has been called for in a recent meta-analysis on attentional bias for pain (Crombez, Van Ryckeghem, Eccleston & Van Damme, 2013). This study found that pain-bias as assessed by traditional paradigms such as the dot-probe, Stroop and modified spatial cueing tasks did not differ between chronic pain patients and healthy individuals, and reaction-time-based measures of pain-bias were not related to individual differences in fear of pain, pain severity, anxiety or depression in chronic pain patients. These findings pose problems for a series of models of chronic pain in which cognitive bias for pain plays an important role in the development and / or maintenance of chronic pain, including fear-avoidance models (Lethem, Slade, Troup & Bentley, 1983; Leeuw, Goossems, Linton, Crombez, Boersma & Vlaeyen, 2007; Vlaeyen, Kole-Snijders, Boeren & Van Eek, 1995; Vlaeyen & Linton, 2000; Asmundson, Norton & Vlaeyen, 2004; Vlaeyen & Linton, 2012; Crombez, Eccleston, Van Damme, Vlaeyen & Karoly, 2012), misdirected problem-solving models (Aldrich, Eccleston & Crombez, 2000; Eccleston & Crombez, 2007)

and the schema enmeshment model (Pincus & Morley, 2001). The authors argue that their findings are likely the result of methodological issues related to the assessment of pain-bias. They conclude that measures of pain-bias based on current paradigms are not sufficiently reliable, and the linguistic and pictorial stimulus material these paradigms rely on may not elicit pain-related processing effectively, to produce a valid measure of pain-bias which is useful in a clinical context.

Given the importance of measuring pain-bias effectively to inform models and treatments of chronic pain, we adapted the PMP, which had been developed to assess self- and reward-bias, for pain-related information. This Bias task adaptation of the PMP was performed in 3 different contexts using samples of healthy individuals. Pain stimuli were linked to pain outcomes

1) in a deception setting, in which participants expected to receive performance-based painful electric stimulation but did not (chapter 2),

2) in a deception control in which participants performed the same task but did not expect to receive pain outcomes (chapter 3), and

3) in an experienced pain setting in which participants not only expected to receive performance-based painful electric stimulation which was administered after task performance, but had experienced this painful electric stimulation prior to performing the Bias task (chapter 3).

This variation of context aimed to establish whether pain-bias as assessed by the Bias task adaptation of the PMP would vary depending on the pain outcome expectations linked to pain stimuli in the Bias task. We further explored the relationship between the pain-bias measure and individual differences in pain catastrophizing, fear of pain, somatosensory

amplification and pain experience (see chapter 5). These lines of investigation aimed to establish whether prioritised responding to pain stimuli in the Bias task reflected pain-related cognitive processing, rather than pain-unspecific individual differences such as for example strategic ability to direct attention to maximise desired outcomes. In order to overcome problems with existing measures of pain-bias, new measures should demonstrate that they elicit pain-related processing and relate to existing individual difference measures of pain-related cognition such as fear of pain.

The results from our studies were mixed. Our deception study (chapter 2) showed overall strong prioritisation of high relative to low pain stimuli. This pain-prioritisation or pain-bias did not differ from the self- and reward-bias assessed in separate blocks, indicating that the pain adaptation of the PMP was successful. As healthy individuals generally display pain-bias as well as chronic pain patients (Crombez, Van Ryckeghem, Eccleston & Van Damme, 2013), these findings suggest the pain adaptation of the PMP might constitute a valid measure of pain-bias. However, we failed to include a manipulation check for our deception, as a result of which we were unable to determine whether participants really did expect to receive performance-based painful electric stimulation. Further, the stimuli linked to pain outcomes through deception were chosen arbitrarily; we could thus not be certain response patterns to pain-related stimuli were caused by the link to expected pain outcomes rather than for example perceptual characteristics of the stimuli themselves. Our findings, though seemingly promising, thus required further research.

The deception control study (chapter 3) was designed to address the problems outlined above. Participants performed an identical Bias task adaptation of the PMP, but pain stimuli were not linked to any performance-based pain outcomes. This aimed to investigate whether prioritisation of pain stimuli observed in the deception study was caused by the association with pain outcomes, or a result of the stimuli and paradigm used. The results indicated that the

association with pain outcomes had enhanced the prioritisation of pain stimuli in the deception study, but pain stimuli were still prioritised significantly without this association for response accuracy and efficiency, though not speed. This suggests that prioritisation of pain stimuli in the deception study could only partly be attributed to the association with pain stimuli. It was impossible to determine why pain stimuli were prioritised in the absence of an association with pain outcomes in the deception control from our findings. It is possible that perceptual characteristics of the pain stimuli drove this pattern of responding. Further, these results may indicate that deception was not effective in the deception study, and participants might have prioritised pain-related stimuli more strongly had they truly believed they were going to receive performance-based pain outcomes. However, although we could not determine the exact mechanism underlying the prioritisation of pain stimuli not associated with pain outcomes, we were able to conclude that the prioritisation of pain stimuli in the deception study was partly to be attributed to factors not specific to the association of pain stimuli with pain outcomes. Prioritisation of pain stimuli in the deception study therefore only partially reflected pain-related processing, with unknown factors likely unrelated to pain contributing to the pattern of responding observed. The deception control study therefore on the whole did not support the utility of the Bias task adaption of the PMP as a valid measure of pain-bias.

Our third study (chapter 4 & 5) was designed to investigate pain-prioritisation in the Bias task adaptation of the PMP when pain stimuli were linked to performance-based pain outcomes which participants had experienced, thus had specific expectations for. We hypothesised that having experienced the painful electric stimulation associated with pain stimuli before performing the Bias task would make the threat of the performance-based pain outcome more realistic and more specific, and thereby elicit more pain-related processing in response to pain stimuli in the Bias task. The pain induction addition meant this particular paradigm would be no more suitable for use with chronic pain patients than existing paradigms

which utilise conditioning to establish associations between visual stimuli and nociception to elicit pain-related cognitive processing in response to visual stimuli (Van Damme, Crombez, Hermans, Koster & Eccleston, 2006).

This study was nevertheless useful in determining whether increasing participants' belief in the performance-based pain outcomes would result in pain-prioritisation measures which more strongly reflect pain-related processing. Individual differences in pain catastrophizing, fear of pain, somatosensory amplification and pain experience were assessed to investigate whether individuals reporting more fear, catastrophizing and sensitivity to pain or more intense, frequent, debilitating or longer episodes of pain in their lives also displayed greater pain-prioritisation in the Bias task adaptation of the PMP. Such a relationship would be consistent with pain-bias scores reflecting a detectable degree of pain-related cognitive processing.

Findings from our third study were mixed. Pain-prioritisation was greater than self-prioritisation, which seemed promising. In the deception study, self- and pain-prioritisation in the Bias task did not differ significantly. It therefore appeared that linking pain stimuli to the threat of experienced pain as opposed to the threat of unknown pain (deception) enhanced pain-prioritisation compared to self-prioritisation, which should have remained unaffected by the change in performance-based outcome associations (deception vs. experienced pain). However, upon closer examination, it became apparent that this change reflected changes in responding to stimuli associated with no pain outcomes, which were used as a baseline to calculate pain-prioritisation. This was unexpected and disappointing, as it indicated that prioritisation of pain stimuli had not been enhanced by increasing the credibility and specificity of the threat of pain associated with pain stimuli through a pain induction. However, the findings could be indicative of a ceiling effect of performance to pain stimuli, due to which

greater cognitive prioritisation of pain stimuli was reflected in decreased prioritisation of baseline stimuli (stimuli associated with no pain outcome).

We were unable to determine whether these changes were a result of participants associating pain stimuli more strongly with performance-based pain outcomes due to experiencing pain before performing the Bias task compared to the deception study, or whether they were the result of changes in the stimuli material. The control study indicated that high pain stimuli were prioritised compared to low pain stimuli independent of their association with pain outcomes. In study 3, we attempted to address these issues by changing the stimulus material from two and one lightning bolt representing high and low pain respectively to a single lightning bolt combined with an 8 or a 0 to indicate painful electric stimulation at participants' subjective pain level 8 (high pain) or 0 (no pain). This meant our stimulus material was more comparable to traditional paradigms, which typically assess pain-bias as the difference in responding to stimuli related to pain and stimuli not related to pain. In our first two studies, pain-prioritisation was assessed as the difference between responses to high and low pain stimuli. As a result, our measure was confounded by participants' relative concern over less intense compared to more intense pain, which could have impacted the validity of the measure as an assessment of pain-bias. However, as a result of these changes, it is impossible to determine whether poorer responding to stimuli associated with no pain in study 3 compared to the deception study (chapter 2) was a result of changing the visual stimulus, replacing the baseline condition 'low pain' with 'no pain' (associated with mildly painful outcomes in the deception, and no pain outcomes in the experienced pain setting), or introducing pain experience prior to the Bias task.

The final test of the pain-bias measure derived from the Bias task adaptation of the PMP was its relationship with individual differences in pain-related cognition and pain experience (chapter 5). Although notable variation between explicit, self-report based measures and

implicit, reaction-time-based measures has been observed for many constructs in various studies (Bosson, Swann & Pennebaker, 2000; Van Bockstaele, Verschuere, Koster, Tibboel, De Houwer & Crombez, 2011), a relationship between implicitly assessed pain-bias and self-report measures of increased attending to, worrying about and sensitivity to pain would strengthen the credibility such a pain-bias measure as validly reflecting pain-related cognitive processing (Crombez, Van Ryckeghem, Eccleston & Van Damme, 2013).

Disappointingly, no relationship was observed between pain-bias and fear of pain, pain catastrophizing or somatosensory amplification in our healthy sample. This finding is not quite consistent with predictions by fear-avoidance models of pain that stress the role of attentional bias in pain processing (Vlaeyen, Kole-Snijders, Boeren & Van Eek, 1995; Vlaeyen & Linton, 2000; Asmundson, Norton & Vlaeyen, 2004; Vlaeyen & Linton, 2012; Crombez, Eccleston, Van Damme, Vlaeyen & Karoly, 2012). However, these models generally highlight the relationship between attention to and fear of pain in the context of psychopathology; potential covariations between these constructs may therefore not have been great enough to be detected in our healthy sample.

Our results also showed that all self-report measures of cognitive focus on pain were strongly associated with each other, indicating the existence of an underlying construct of focus on pain which all self-report measures reflected, but implicitly assessed pain-bias did not. It is however possible that this was a result of reporting bias, and the shared construct underlying scores on these individual difference measures reflects a subjective self-perception of pain sensitivity which is not in fact indicative of objective interpersonal differences, which may be better reflected by implicitly assessed pain-bias. This hypothesis is entirely speculative, but given existing divergence between implicit and explicit measures of cognitive focus on pain (Crombez, Van Ryckeghem, Eccleston & Van Damme, 2013), future research should investigate this possibility.

In support of the PMP-based pain-bias measure, we found a moderate relationship to self-reported pain duration. Participants who reported having experienced longer periods of pain in the 6 months preceding the study displayed reduced pain-bias in the PMP Bias task adaptation. This is consistent with either de-sensitisation to pain following prolonged exposure, or pain avoidance caused by experiencing long periods of pain, which would be consistent for example with the threat interpretation model if pain-bias in this task were interpreted as a later rather than earlier stage effect of cognitive processing (Todd, Sharpe, Johnson, Nicholson Perry, Colagiuri & Dear, 2015). This finding gives some support to the validity of our pain-bias measure as reflecting pain-related processing.

The fact that no relationship was found between pain-bias and other pain experience measures such as pain intensity or frequency may be considered in the light of Linton, Flink & Vlaeyen's recent model (2018) of chronic pain. The model highlights the complex role of learning in chronic pain, specifically the importance of frequency and schedule of opportunities to reinforce behavioural responses to pain (i.e. pain occurrence), in their fourth tenet. The authors argue that variable schedules of pain experience, rather than increased frequency or intensity of pain, may drive mal-adaptive pain behaviours and chronic pain. Based on this model, increased vigilance towards pain as a potential mal-adaptive coping strategy might be expected to result from irregular and unpredictable pain, rather than depending on its frequency or intensity. Future research might consider to explore such aspects of pain experience in addition to the ones included here.

Finally, we investigated the possibility that our PMP-based pain-bias measure reflected participants' ability to strategically direct attention to maximise desirable outcomes rather than pain-specific patterns of cognitive processing. Pain-bias was positively correlated with reward-bias, which indicated that both these bias measures might reflect an underlying ability to direct cognitive resources strategically. However, if this was the case, we would have expected to

observe a relationship between pain- and reward-bias and self-reported attentional control, which was not the case. It is possible that the self-report measure attentional control does not accurately reflect participants' ability to direct attention in a reaction-time-based task. Implicit measures of attentional control such as the Attention Network Task (ANT; Fan, McCandliss, Sommer, Raz & Rosner, 2002) may have been more suitable to assess this construct. Given the information at hand we can only conclude that it is possible our measures of pain- and reward-bias at least partially reflected participants' ability to direct attention strategically to maximise desirable outcomes rather than content-specific information processing biases. This does not support the validity of our PMP-based pain adaptation as a useful alternative to existing paradigms assessing pain-bias.

To conclude, there were some indications that the Bias task adaptation of the PMP was a useful measure of pain-bias, but its advantage over existing paradigms and measures of pain-bias is doubtful. A strong attention bias to pain was observed consistently in our healthy samples, in line with findings from previous studies (Crombez, Van Ryckeghem, Eccleston & Van Damme, 2013). However, it is unclear whether this observed pain-prioritisation was specific to pain content or a methodological artefact resulting for example from perceptual differences between high and low pain (or pain and no pain) stimuli. A relationship between pain- and reward-bias indicates that both may reflect participants' ability to direct attention effectively in order to maximise desired outcomes, although this was not supported by a relationship between self-reported attentional control and pain- and reward-bias measures. Pain-bias was linked to individual differences in the duration of recently experienced pain which seems to indicate that pain-bias reflected pain-related cognitive processing. However, pain-bias was not linked to inter-personal differences in pain catastrophising, fear of pain, somatosensory amplification or other aspects of recent pain experience such as pain intensity or frequency, or pain-related disability. Theoretical models of pain such as the fear-avoidance

model, the misdirected problem-solving model or models of psychopathology predict a relationship between pain-bias and pain-related fear, anxiety and catastrophising thoughts, and one of the key limitation of existing pain-bias measures is that they have not consistently been shown to be related with individual differences in pain-related cognitive styles (Crombez, Van Ryckeghem, Eccleston & Van Damme, 2013). Our data indicate that the PMP-based pain-bias measure is no better than existing paradigms in this respect.

8.2. Competition between Self and Pain and the Effectiveness of Self-related Distraction Tasks in Reducing Attention to Pain

We investigated the competition for cognitive resources between self- and pain-related processing aiming to determine whether self-related task content could enhance the effectiveness of distraction tasks in reducing perceived pain. Distraction is a theme of many psychological pain treatments (Morley, Shapiro & Biggs, 2004). The mechanism thought to underlie the effectiveness of distraction is limited attentional capacity: If more cognitive resources are dedicated to another task (e.g. a distraction), less attention is available to process pain, resulting in the perception of pain as less intense (Verhoeven, Crombez, Eccleston, Van Ryckeghem, Morley and Van Damme, 2010).

Previous studies have demonstrated that distraction is less effective when pain is intense, novel or threatening (Crombez, Baeyens & Eelen, 1994; Crombez, Eccleston, Baeyens & Eelen, 1997; Crombez, Eccleston, Baeyens & Eelen, 1998; Eccleston, 1995; Legrain, van Damme, Eccleston, Davis, Seminowicz & Crombez, 2009) and more effective when the distraction task is more difficult (Bantick, Wise, Ploghaus, Clare, Smith & Tracey, 2002; Wiech, Seymour, Kalisch, Stephan, Koltzenburg, Driver & Dolan, 2005). However, little is known about how motivational characteristics of distraction tasks can affect pain perception, although the results of one study indicate that individuals high in pain catastrophizing benefit

from linking performance in a distraction to reward incentives (Verhoeven, Crombez, Eccleston, Van Ryckeghem, Morley and Van Damme, 2010). In the field of self-bias research, many studies have shown that self-related information is prioritised for cognitive processing in a similar way as reward-related information (Sui, He & Humphreys, 2012; Sui & Humphreys, 2015; Sui, Yankouskaya & Humphreys, 2015), relying on distinct but overlapping neural circuits as reward processing (Enzi, de Greck, Prosch, Tempelmann & Northoff, 2009; Sui & Humphreys, 2015) which has lead to the suggestion that self-related information is intrinsically rewarding (Humphreys & Sui, 2015). Based on these findings, we hypothesised that self-related task content may enhance the effectiveness of distraction tasks for high pain catastrophisers better than performance-based reward because its salience depends on inherent rather than outcome-based association with reward.

To test this hypothesis, we first explored the competition between self, pain and reward at an abstract level (chapter 2-4), utilising the Competition task adaptation of the Perceptual Matching Paradigm (PMP; Sui, He & Humphreys, 2012) in which pain and reward stimuli were associated with pain and reward outcomes respectively in 1) a deception setting (chapter 2), 2) a no deception control (chapter 3), and 3) a realistic outcome setting in which participants experienced a pain induction before completing the computer task, and received performance-based pain and reward outcomes as expected after performing the Competition task. This variation of context allowed us to understand how the competition between self- and pain-related information was affected by the association between pain stimuli and outcomes, enabling us to draw more general conclusions.

The initial results from the deception study (chapter 2) seemed promising for our hypothesis. The Competition task adaptation of the PMP seemed effective in reflecting competition for cognitive resources between stimuli relating to self, pain and reward. The results of the deception study indicated that both self- and reward-related information were

prioritised to the same degree as, or prioritised over, pain-related stimuli, while self and reward were prioritised equally in competition with each other. This suggested both self- and reward-related stimuli might be equally effective at reducing attention to pain in a pain distraction setting, in line with our hypothesis as well as previous findings on the relationship between pain and reward (Verhoeven, Crombez, Eccleston, Van Ryckeghem, Morley and Van Damme, 2010). Notably, self-related stimuli were prioritised to the same degree as pain for response accuracy and efficiency and more for response speed even though no outcomes were associated with performance to self-related stimuli, which seemed to suggest a strong, automatic prioritisation of self-related stimuli for cognitive processing supportive of our hypothesis.

The results from the deception control study (chapter 3) were less promising. We aimed to investigate whether removing the association between pain and reward stimuli and pain and reward outcomes respectively would alter their relative prioritisation in the Competition task. This was not observed, and results overall indicated that pain and reward stimuli were prioritised no less than when associated with pain and reward outcomes respectively. We concluded that it was likely that responses to pain stimuli in our first study did not reflect pain-related processing. Participants may not have believed in the deception in our first study, or the deception was insufficient to elicit pain-related cognitive processing. Irrespective of the reason, these results suggested that responses in our deception study did not reflect pain-related processing; consequently, any conclusions about the relative prioritisation for cognitive processing of pain-related information cannot be validly applied to pain processing. We can therefore no longer consider the findings from our deception study as in support of our hypothesis that self-related content may be able to effectively compete for cognitive resources with pain-related information, although the findings also do not refute our hypothesis.

In our third study (chapter 4), participants performed a variant of the Competition task in which pain stimuli were linked to performance-based pain outcomes which participants had

experienced before they completed the computer task. We hypothesised that this more realistic association between pain stimuli in the Competition task and pain outcomes would result in response patterns that were reflective of pain-related cognitive processing. Our findings suggested that reward and self were both prioritised to the same degree as pain, while reward was prioritised over self. These results indicated that both self-related content or performance-based reward could compete effectively for cognitive resources with visual stimuli relating to pain. Although this was promising for our hypothesis that self-related task content might enhance the effectiveness of pain distraction, it was not consistent with our hypothesis that such a distraction might be more effective than a reward-based motivated distraction. Despite these seemingly promising results, it is unclear whether response patterns in the Competition task in this study truly reflected pain-related processing. In chapter 5, we showed that the pain-prioritisation measure (derived from the Bias task in the experienced pain setting) correlated with reward-prioritisation, which may suggest that response patterns reflect participants' ability to strategically direct attention as opposed to pain-related cognitive processing. This was not supported by a relationship between pain- or reward-prioritisation and self-reported attentional control however. We can therefore not draw any strong conclusions about the relative cognitive prioritisation of self, pain and reward, as the ability of our stimuli and paradigm to elicit pain-related cognitive processing remains uncertain.

Finally, we compared the effectiveness of self-related content and performance-based reward in enhancing the effectiveness of pain distraction directly (chapter 6). In 4 distraction groups, participants performed a pain induction concurrently with a distraction task that had neutral or self-related content, and in which performance was linked to a performance-based reward or not. In a no distraction control group, participants performed only the pain induction without distraction. The results were unexpected. Although all but the neutral distraction effectively reduced attention to pain, none of them reduced perceived pain intensity, nor

negative pain affect. Individual differences in pain catastrophizing did not affect any of our outcomes. The fact that we were unable to replicate even a basic distraction effect draws into question the fundamental principles thought to be underlying distraction from pain.

The parameters of our pain induction were well in accordance with guidelines in the field (Von Baeyer, Piira, Chambers, Trapanotto, & Zeltzer, 2005), and our sample size per group larger than that of previous studies which successfully demonstrated distraction from pain (Verhoeven et al., 2010; Moore, Stewart, Barnes-Holmes, Barnes-Holmes & McGuire, 2015). Further, our manipulation check of attention indicated that distraction tasks with self-related content or performance-based reward did reduce attention to pain effectively compared to the no distraction control. The neutral distraction task also reduced attention to pain, but this effect fell just short of reaching significance and was associated with a smaller effect size than those of the self, neutral-rewarded and self-rewarded distraction.

The failure to demonstrate the reduction in perceived pain intensity or negative pain affect that would be expected to accompany this reduction in attention to pain based on limited capacity models of attention and pain therefore suggests that our models of the mechanisms underlying distraction may need to be revised, or the effects in question are smaller than is generally thought. It is possible that the link between attention to pain and perceived pain intensity is less direct or large than assumed, with a great decrease in attention to pain required to observe a reduction in pain intensity, or that the effect underlying distraction is much smaller than generally understood. It is also possible that our findings were a result of unfortunate randomisation, and our groups were unevenly matched for pain sensitivity. However, the mean ratings of pain intensity in our groups as well as their standard deviations are comparable to those of previous studies (Verhoeven et al., 2010) and our groups did not differ in mean age or gender proportions. We therefore have no reason to suspect this was the case. We conclude that it seems the effect underlying distraction from pain is less robust and strong than previously

thought, and future research should use large samples as well as highly controlled and standardised pain induction procedures to achieve adequate power to detect this effect reliably.

We were nevertheless able to draw some conclusions regarding the relative efficacy of our distraction task manipulations from our findings. Neither self-related task content nor performance-based reward significantly impacted attention to pain, task engagement, perceived pain intensity or negative pain affect compared to the neutral distraction task. Our study was powered to detect medium-large effects only. Therefore, if our self-related content or performance-based reward manipulations did improve the effectiveness of our distraction task, this effect was small. From these findings we can certainly conclude that such an effect could not be moderately-sized or large, but we cannot determine whether a small effect is present or not. The fact that attention to pain was effectively reduced by distraction tasks with self-related content and / or performance-based reward is however a promising step. Perhaps this phenomenon could be investigated more effectively in the context of a virtual reality-based pain treatment. For example, future research could determine the efficacy of treatments in which patients see an avatar with features relating to themselves (e.g. name, appearance), or receive performance-based reward (e.g. virtual currency or experience to reward performance of certain actions).

Overall, our research gives little support to the hypothesis that self-related content or performance-based reward may be effective distractions from pain. There was however also no evidence to suggest that self-related content or performance-based reward would decrease the effectiveness of distraction, providing a potential basis for future research to investigate the efficacy of pain treatments with self or reward content without concern that this might reduce the effectiveness of the treatment. Due to a series of methodological limitations, we cannot draw strong conclusions from our findings. We do however highlight a series of methodological challenges both in our research as well as the field of pain research, and

recommend the adoption of more standardised procedures and larger samples in future research on distraction from pain in order to establish the true effect size of distraction from pain, detect existing effects more reliably and reduce the likelihood of Type I errors.

8.3. Self-Pain Enmeshment and Pain Experience, Pain- and Self-related Interpersonal Differences in Healthy Individuals

Self-pain enmeshment as outlined by the schema enmeshment model of chronic pain has received increasing interest as an important factor in chronic pain in recent years (Pincus & Morley, 2001; Morley, Davies & Barton, 2005; Rusu & Pincus, 2012; Sutherland & Morley, 2008; Van Ryckeghem, Houwer, Van Bockaele, Van Damme, De Schryver & Crombez, 2013). Given the association between increased self-pain enmeshment and chronic pain, as well as its link to increased pain severity, pain suffering, anxiety and helplessness in chronic pain patients (Van Ryckeghem, Houwer, Van Bockaele, Van Damme, De Schryver & Crombez, 2013), self-pain enmeshment has been proposed as a potential target for psychological pain treatments. In light of these clinical applications, it is essential to improve our understanding of current measures of self-pain enmeshment, their limitations and relationships with state and trait differences between individuals in a healthy population.

Our second study (chapter 5) aimed to address this gap in research by exploring the relationship between implicitly assessed self-pain associations, self- and pain-bias, recent pain experience, and explicitly measured individual differences in self- and pain-related cognitive styles (e.g. pain catastrophizing, self-esteem, locus of control). The self-pain Implicit Associations Task (IAT) has been introduced recently as a measure of self-pain enmeshment (Gumm, Erbe, von Collani & Nestler, 2008; Van Ryckeghem, Houwer, Van Bockaele, Van Damme, De Schryver & Crombez, 2013) due to concerns that explicit measures (e.g. sentence completion, structured or semi-structured interviews) can only reflect processes participants

are aware of, and are likely confounded by response bias, which is particularly problematic when comparing patient and non-patient populations as they are likely to differ in their response biases.

Our study (chapter 5) showed no relationship between self-pain implicit associations, self- and pain-bias. This indicates the self-pain IAT reflects a cognitive construct distinct from self- and pain bias despite the similarity in their assessments, which supports the validity of the self-pain IAT as a measure of self-pain enmeshment. We also found a link between increased self-pain associations and more intense pain experiences in the 6 months preceding the study, which supports the schema enmeshment model's proposed mechanism of self- and pain-schema becoming increasingly enmeshed through repeated co-activation of both schemas. Individuals with a more internal locus of control also showed increased self-pain associations. This is a novel finding, and indicates that some individuals may be predisposed to develop self-pain enmeshment, potentially through heightened sensitivity to pain experience. However, we did not test for such potential mediating effects in this study as the sample was too small to allow for such analyses, and the version of the self-pain IAT used was not optimally adapted as a measure of individual differences. Due to this limitation in our measure, we did not consider it appropriate to draw strong conclusions based on this study. However, given the interesting questions raised by these findings, we replicated part of this study in a much larger sample using a self-pain IAT better adapted for use with individual difference analyses.

Our replication study (see chapter 7) comprised 163 participants, who performed a version of the self-pain IAT more suitable for individual difference analyses as well as questionnaire measures of pain catastrophising, pain experience in the 6 months preceding the study, self-esteem, narcissism and locus of control. Our results revealed that increased self-pain associations were linked to higher disability grades, which were assessed based on participants' self-reported pain-related disability scores and days as well as pain intensity

ratings. However, self-pain associations were not linked to any individual measures of pain experience, and the link to disability grades was of small magnitude. These findings contrasted our earlier findings (chapter 5), but given the larger sample and improved methods in this study, we consider these results as more valid. These results indicate that variations in comparatively transient and low-impact pain our healthy sample reported to have experienced are not strongly reflected in changes in self-pain enmeshment. This enhances our understanding of the mechanisms underlying self-pain enmeshment, as they point towards a slow, inert process of integration between self- and pain-schema rather than a flexible, dynamic process that quickly and easily adapts to new experiences and situations. We conclude that self-pain associations do not simply reflect aspects of pain experience such as the amount of time for which an individual has experienced pain recently, or how intense this pain was, but are linked to a complex combination of these factors in which individuals experience both intense and debilitating pain which limits their ability to work. This is consistent with the schema enmeshment model, which considers self-pain enmeshment as the response to pain experience which is perceived by the individual to impede their ability to achieve their full potential, resulting in a greater discrepancy between their actual and ideal self (Morley, 2010).

Our study (chapter 7) further explored the link between self-pain associations and self- and pain-related cognitive styles. Self-pain enmeshment was shown not to be related to pain catastrophising, self-esteem or narcissism. This was consistent with our previous findings, and supports our earlier conclusion that the self-pain IAT measures a construct separate from self-esteem. It further suggests that trait differences in narcissism and pain catastrophising do not drive self-pain enmeshment. In our larger sample, we found no relationship between self-pain associations and internal locus of control, indicating that the findings from our previous study (chapter 5) were a type I error or perhaps the result of flaws in our method of assessing self-pain enmeshment. However, the replication showed a link between self-pain enmeshment and

powerful others as well as chance subscales of locus of control, which had not been shown by the previous study. Individuals attributing more control over events in their lives to powerful others or chance also showed higher self-pain enmeshment. As locus of control is considered a stable trait (Levenson, 1973), these findings may indicate that interpersonal differences in external locus of control predispose individuals to develop self-pain enmeshment.

External locus of control has been linked to maladaptive coping strategies by previous research (Crisson & Keefe, 1988). Our finding therefore raises the question whether self-pain enmeshment occurs in the context of repeated and debilitating pain experience as postulated by the self-pain enmeshment model, or whether it is a result of an external locus of control. Using a hierarchical regression analysis, we showed that, when controlling for individual differences in powerful others attributions of control, disability grade did not significantly contribute to predicting self-pain associations. This suggests that interpersonal differences in locus of control play a greater role in self-pain enmeshment than pain experience, which is inconsistent with the schema enmeshment model. It is possible that this finding is an artefact of our assessment methods of both self-pain enmeshment and pain experience; pain experience was assessed using retrospective self-reports, which may have been confounded by reporting bias. Self-pain enmeshment was measured using a self-pain Implicit Associations Task, which is inherently confounded by individuals' views of other people's relationship with pain as their identification with pain is contrasted with their ease of associating pain with others. Our findings therefore highlight the need for future research to investigate the relationship between self-pain enmeshment and interpersonal differences in external locus of control. Given the potential utility of the self-pain IAT in clinical contexts, its relationship with locus of control should be contrasted with explicit measures of self-pain enmeshment to identify whether any potential confounding impact of locus of control is attributable to this particular measurement, or the construct of self-pain enmeshment. Further, we conclude that longitudinal research

investigating the role of locus of control, pain experience and self-pain enmeshment in the development of chronic pain is needed. In light of our findings, it is vital to show whether self-pain enmeshment occurs in response to complex and debilitating pain experience leading to chronic pain as suggested by the schema enmeshment model, or whether self-pain association reflects individual differences that precede chronic pain development. Understanding the timeline and direction of these effects as well as the relative contribution of each factor is crucial to inform our approach to self-pain enmeshment in a clinical context, specifically whether it should be treated as a risk-factor, a target for intervention or a psychological marker that is a result, but not a driving factor, of chronic pain.

8.4. Limitations, Implications and Future Directions

Although the work presented here addresses some important gaps in previous research, it is characterised by a set of methodological limitations. Some of these limitations reflect challenges generally encountered in the relevant field of research, while others are specific to our work. In this section, we will discuss the lessons that can be learned from our work, and how future research could improve upon our studies in their approach to the questions at hand.

Our first few studies outline our attempt to adapt the Perceptual Matching Paradigm (PMP) for pain-bias. Addressing recommendations in Crombez et al.'s (2013) meta-analysis, we hypothesised that outcome-based associations between pain stimuli and pain content might be more effective in eliciting pain-related processing than stimuli that rely on previous associations or abstraction (e.g. lexical, pictorial stimuli). Although some of our findings seemed to support this hypothesis, there were also concerns that pain-bias measures in this task reflected strategic, content unspecific cognitive processing instead of pain-bias.

In our design, responses to pain stimuli were associated with reducing undesirable outcomes. As a consequence, participants' ability to direct cognitive resources strategically

was conflated with prioritised processing of pain-related information. Future research could avoid this problem by utilising paradigms in which pain-bias is operationalised as the power of pain-related stimuli to disrupt and interfere with task performance. However, this is challenging to achieve while linking visual pain stimuli to pain outcomes. It may be more beneficial to pursue paradigms in which tactile stimuli are applied, and bias for processing physiological sensations is assessed rather than visual stimuli linked to the sensation of pain. Our studies rigorously investigated all the possible explanations for participants' relative prioritisation of pain stimuli. We argue that comparable or greater rigour is needed in any future studies attempting to develop new paradigms to assess pain-bias. Pain research cannot advance until pain-bias can be aptly and reliably assessed. The introduction of new paradigms which have not been rigorously and critically tested may slow down progress towards this goal. We therefore recommend that future studies consider whether their measures 1) reflect pain-related cognitive processing, or whether responses can be explained by any mechanisms not specific to pain, and 2) relate to existing self-report measures of individual differences in pain-related cognition. On the latter consideration, it is possible that differences between implicit and explicit assessments underlie the existing gap between pain-related cognitive factors. If this is the case, future research will need to determine which measures are more meaningful in a clinical context.

Each of our studies contained a component investigating the competition between self and pain. In our first studies, this was investigated using the Competition task adaptation of the PMP. Our studies suggested the Competition task is an effective measure of the relative prioritisation of two stimulus types consistent with limited capacity models of attention (Broadbent, 1958). Because the ability of our pain stimuli to elicit pain-related processing was questionable, our findings are limited in their applicability to pain processing. However, the

Competition task adaptation of the PMP may be useful for future research aiming to investigate the competition for cognitive resources between two stimulus types (e.g. self and reward).

In our investigation of the competition between self and pain, we encountered further challenges in the induction of pain using a cold pressor distraction paradigm. In our third study, we failed to demonstrate even basic distraction effects. This highlights common difficulties in research on distraction from pain: Small methodological variations in either pain induction or distraction task can impact the effectiveness of distraction. Our findings may have been the result of a distraction task too little demanding of cognitive resources as a result of employing a visual rather than auditory random interval repetition task (Vandierendonck, De Voogt, Van der Goten, 1998; Verhoeven et al., 2010). Further, our pain stimulus, though in line with guidelines for cold pressor pain induction (Von Baeyer, Piira, Chambers, Trapanotto & Zeltzer, 2005), was less standardised across participants than that of other studies (Verhoeven et al., 2010). A large sample recruited to compensate for this between-subject variability was not sufficient to overcome this problem. This highlights the narrow range of distraction tasks as well as pain stimuli for which distraction is effective, in line with previous findings that distraction is not effective when pain is threatening, intense or novel (Crombez, Baeyens & Eelen, 1994; Crombez, Baeyens, Eccleston & Eelen, 1997; Crombez, Baeyens, Eccleston & Eelen, 1998).

We argue that current guidelines for standardising pain induction parameters do not extend far enough. Current recommendations suggest to control temperature to within ± 1°C, and our study achieved control to within ± 0.6°C. As this was insufficient, we suggest future research should aim to control temperature to ± 0.3°C or better. We further note that studies in the area of distraction from pain frequently lack power to detect small effects due to the large samples required to perform between-subject analyses. In order to investigate distraction effects reliably, future research will need to adopt much larger samples as well as more tightly

controlled pain induction parameters. When employing distraction tasks with even minor deviations from paradigms which have been previous shown to be successful (Vandierendonck, De Voogt, Van der Goten, 1998; Verhoeven et al., 2010), we recommend the use of pilot studies to establish their effectiveness as a distraction task. Given the small magnitude and volatility of the distraction effect highlighted by our research, future research must proceed with more caution and improve the robustness of their designs to between-subject differences in order to find effects reliably.

In our investigation of the relationship between self-pain enmeshment and individual differences in pain experience and self- and pain-related cognition, we were limited by a number of factors. Because participants completed these individual difference measures (chapter 5, chapter 7) in the context of other studies (chapter 4, chapter 6), it is possible that order effects impacted our findings. For example, in both chapter 5 and 7, participants experienced a pain induction prior to completing the questionnaires relating to pain-related fear and catastrophising, pain experience and the self-pain implicit associations task. This may have biased their self-reports and impacted their task performance in the self-pain IAT. Further, the inclusion criteria, specifically the recruitment of healthy, young individuals, was determined by the pain induction, which was unethical to perform on individuals with known health conditions who might suffer from complications, and by the nature of our research questions which aimed to investigate a healthy sample. In contrast, our investigation of the relationship between self-pain enmeshment and individual differences could have benefitted from a more diverse sample of individuals experiencing varying levels of pain in their everyday lives. The decision was made due to practical constraints, but was not optimal for the purpose of this research. However, pain experience reports from participants in study 4 (chapters 6, 7) indicated that participants did experience a surprising range of pain levels in their everyday lives considering they all self-identified as healthy, with some participants categorised as

notably disabled based on their pain reports. Future research investigating the relationship between self-pain enmeshment and individual differences in non-clinical populations could however benefit from specifically recruiting participants with a greater range of pain backgrounds in order to better understand differences between healthy and pre-clinical levels of pain experience and their links to self-pain enmeshment.

Our investigation of the relationship between self-pain enmeshment and inter-personal differences was further limited by our cross-sectional design. Although we drew some conclusion about the directionality of the effects found in our study, this was done based on the nature of the measures involved. For example, pain experience in our study was assessed retrospectively for the 6 months preceding the study, and was therefore considered to precede self-pain enmeshment, which was assessed during the study. Locus of control was also assessed during the study, but as this is generally considered a trait measure (Levenson, 1973), this was also assumed to precede self-pain enmeshment. However, these assumptions may not be valid. For example, participants' retrospective reports of their pain in the 6 months preceding the study may be biased by a range of factors, such as their tendency to catastrophise about pain, and locus of control may not be a stable trait difference but a state dependent on other variables such as, for example, pain experience.

The role of pain experience as well as individual differences in cognitive styles in the development of self-pain enmeshment and chronic pain would best be identified in a longitudinal design following healthy individuals through painful experiences and potentially chronic pain development. Such a study design would pose a number of challenges, as the percentage of individuals who develop chronic pain can vary greatly between populations (Latina et al., 2013) and so a large number of individuals would have to be followed for a long time to obtain a final sample in which the number of individuals with chronic pain is large enough to yield reliable results. Instead, individuals already planning to undergo medical

painful procedures which are associated with high rates of chronic pain development such as caesarean (Weibel, Neubert, Jelting, Meissner, Woeckel, Roewer & Kranke, 2016) could be targeted for such a study, and the role of pre-surgery individual differences in cognition (e.g. locus of control) as well as between-subject differences in the pain experience (e.g. medical complications, acute pain ratings immediately after the surgery) on chronic pain development could be identified. Such a design would yield crucial information about the direction and timeline of the relationship between individual differences in cognitive styles, pain experience, self-pain enmeshment and chronic pain, thereby adding a valuable missing puzzle piece to our picture of the development and maintenance of chronic pain.

Chapter 9

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Chapter 10

A

Appendix A: Bias Task Counterbalancing

Table 1. Counterbalancing of shape-label pairings across participants in Study 1 (Bias Task). Participants were randomly assigned to complete Version 1-6. The shapes and labels / symbols contained in each version were the same, but shape-label pairings differed between versions.

		Social Block		Pain Block		Reward Block	
		'You'	**'Stranger'**	**2 lightnings**	**1 lightning**	**£8**	**£0.5**
V1	**Match**	Diamond	Hexagon	Square	Circle	Triangle	Pentagon
	Mismatch	Hexagon	Diamond	Circle	Square	Pentagon	Triangle
V2	**Match**	Hexagon	Square	Circle	Triangle	Pentagon	Diamond
	Mismatch	Square	Hexagon	Triangle	Circle	Diamond	Pentagon
V3	**Match**	Square	Circle	Triangle	Pentagon	Diamond	Hexagon
	Mismatch	Circle	Square	Pentagon	Triangle	Hexagon	Diamond
V4	**Match**	Circle	Triangle	Pentagon	Diamond	Hexagon	Square
	Mismatch	Triangle	Circle	Diamond	Pentagon	Square	Hexagon
V5	**Match**	Triangle	Pentagon	Diamond	Hexagon	Square	Circle
	Mismatch	Pentagon	Triangle	Hexagon	Diamond	Circle	Square
V6	**Match**	Pentagon	Diamond	Hexagon	Square	Circle	Triangle
	Mismatch	Diamond	Pentagon	Square	Hexagon	Triangle	Circle

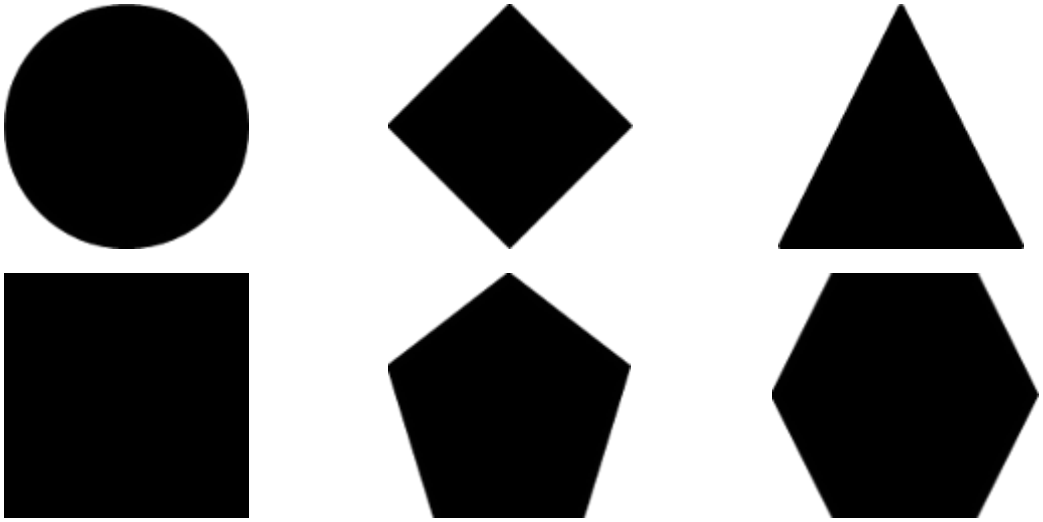
Table 2. Counterbalancing of shape-label pairings across participants in Study 2 (Bias Task). Participants were randomly assigned to complete Version 1-6. The shapes and labels / symbols contained in each version were the same, but shape-label pairings differed between versions.

		Social Block		Pain Block		Reward Block	
		'You'	**'Stranger'**	**Lightning 8**	**Lightning 0**	**£8**	**£0**
V1	**Match**	Diamond	Hexagon	Square	Circle	Triangle	Pentagon
	Mismatch	Hexagon	Diamond	Circle	Square	Pentagon	Triangle
V2	**Match**	Hexagon	Square	Circle	Triangle	Pentagon	Diamond
	Mismatch	Square	Hexagon	Triangle	Circle	Diamond	Pentagon
V3	**Match**	Square	Circle	Triangle	Pentagon	Diamond	Hexagon
	Mismatch	Circle	Square	Pentagon	Triangle	Hexagon	Diamond
V4	**Match**	Circle	Triangle	Pentagon	Diamond	Hexagon	Square
	Mismatch	Triangle	Circle	Diamond	Pentagon	Square	Hexagon
V5	**Match**	Triangle	Pentagon	Diamond	Hexagon	Square	Circle
	Mismatch	Pentagon	Triangle	Hexagon	Diamond	Circle	Square
V6	**Match**	Pentagon	Diamond	Hexagon	Square	Circle	Triangle
	Mismatch	Diamond	Pentagon	Square	Hexagon	Triangle	Circle

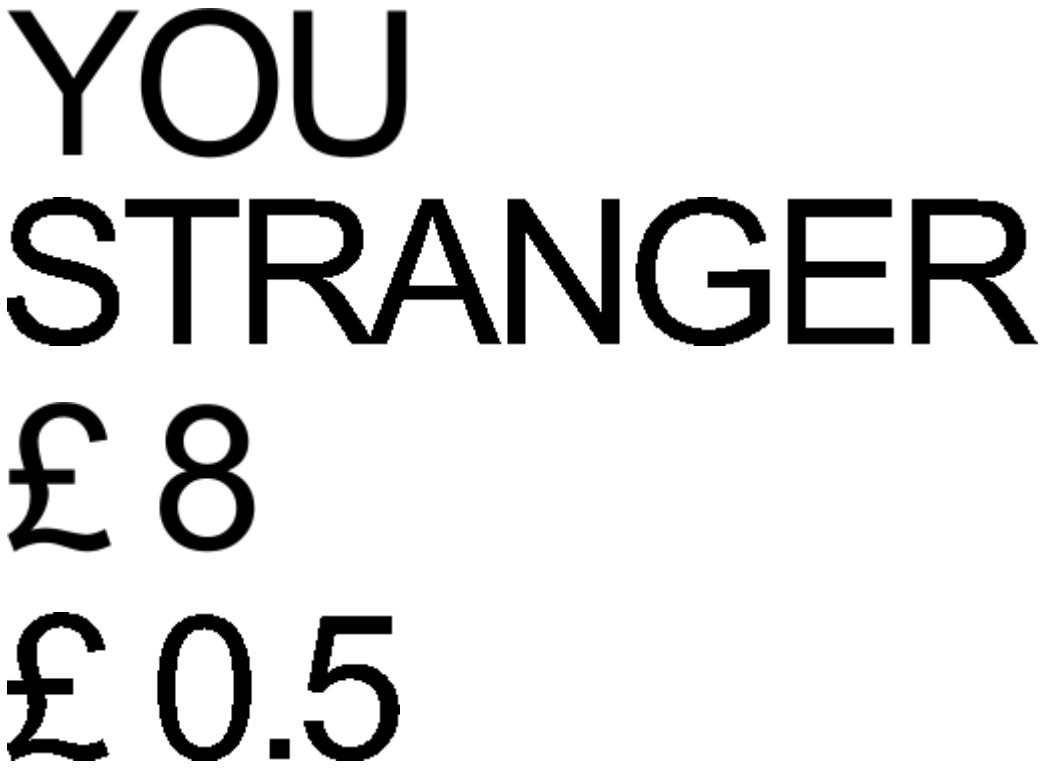
B

Appendix B: Stimulus Material (Chapters 2-4)

Neutral Shape stimuli (see below).



High and low priority labels / symbols for Pain, Social and Reward block of the Bias task (chapters 2 & 3) respectively.


YOU
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C

Appendix C: Study 3 Counterbalancing (Chapter 6)

Table 2. Sample sizes, means, standard deviations and results of independent samples t*-tests comparing attention to pain across computer task versions within each active distraction group (Neutral, Self, Neutral-Reward, Self-Reward). Values given represent the number of participants who completed each task in each group (n), the mean attention to pain score (M) and associated standard deviation (SD), the t-value (t), degrees of freedom (df), p-value, Cohen's d and lower and upper limit of the confidence interval of the difference associated with an independent samples t-test comparing computer task version 1 and 2 within each distraction group (V1, V2). Computer tasks for Neutral and Neutral-Reward groups are identical, as are computer tasks for Self- and Self-Reward distraction groups. For both computer tasks (Neutral and Self), version 1 paired the shorter stimulus word ('HEAR' in the neutral, 'MINE' in self-related task) with the response key '1' and the longer stimulus word ('BUILDING' in the neutral, 'YOURSELF' in the self-related task) with response key '2'. These stimulus-response pairings were reversed in version 2.*

									Confidence Interval	
		n	**M**	**SD**	**t**	**df**	**P**	**d**	**Lower**	**Upper**
Neutral	**V1**	16	-0.44	3.90	1.03	31	.310	0.36	-1.41	4.30
	V2	17	-1.88	4.12						
Self	**V1**	16	-2.25	3.11	0.54	31	.591	0.19	-1.90	3.29
	V2	17	-2.90	4.10						
Neutral-Reward	**V1**	16	-1.50	4.38	0.93	30	.362	0.33	-1.51	4.01
	V2	16	-2.70	3.15						
Self-Reward	**V1**	17	-2.59	4.24	-0.14	30	.892	0.05	-1.88	1.38
	V2	15	-2.40	3.46						

Table 3. Sample sizes, means, standard deviations and results of independent samples t*-tests comparing pain intensity across computer task versions within each active distraction group (Neutral, Self, Neutral-Reward, Self-Reward). Values given represent the number of participants who completed each task in each group (n), the mean pain intensity score (M) and associated standard deviation (SD), the t-value (t), degrees of freedom (df), p-value (p), Cohen's d and lower and upper limit of the confidence interval of the difference associated with an independent samples t-test comparing computer task version 1 and 2 within each distraction group (V1, V2). Computer tasks for Neutral and Neutral-Reward groups are identical, as are computer tasks for Self- and Self-Reward distraction groups. For both computer tasks (Neutral and Self), version 1 paired the shorter stimulus word ('HEAR' in the neutral, 'MINE' in self-related task) with the response key '1' and the longer stimulus word ('BUILDING' in the neutral, 'YOURSELF' in the self-related task) with response key '2'. These stimulus-response pairings were reversed in version 2.*

									Confidence Interval	
		n	**M**	**SD**	***t***	**df**	**P**	**d**	**Lower**	**Upper**
Neutral	**V1**	16	9.81	4.40	0.11	31	0.917	.040	-3.03	3.36
	V2	17	9.65	4.60						
Self	**V1**	16	9.06	4.31	0.52	31	0.608	.18	-2.08	3.50
	V2	17	8.35	3.54						
Neutral-Reward	**V1**	16	9.69	4.22	0.34	30	0.734	.12	-2.17	3.04
	V2	16	9.25	2.86						
Self-Reward	**V1**	17	8.24	4.22	-0.39	30	0.699	.14	-3.93	2.67
	V2	15	8.87	4.93						

Table 4. Sample sizes, means, standard deviations and results of independent samples t*-tests comparing pain affect across computer task versions within each active distraction group (Neutral, Self, Neutral-Reward, Self-Reward). Values given represent the number of participants who completed each task in each group (n), the mean pain affect score (M) and associated standard deviation (SD), the t-value (t), degrees of freedom (df), p-value, Cohen's d and lower and upper limit of the confidence interval of the difference associated with an independent samples t-test comparing computer task version 1 and 2 within each distraction group (V1, V2). Computer tasks for Neutral and Neutral-Reward groups are identical, as are computer tasks for Self- and Self-Reward distraction groups. For both computer tasks (Neutral and Self), version 1 paired the shorter stimulus word ('HEAR' in the neutral, 'MINE' in self-related task) with the response key '1' and the longer stimulus word ('BUILDING' in the neutral, 'YOURSELF' in the self-related task) with response key '2'. These stimulus-response pairings were reversed in version 2.*

									Confidence Interval	
		n	**M**	**SD**	**t**	**df**	**P**	**d**	**Lower**	**Upper**
Neutral	**V1**	16	10.13	5.58	-0.44	31	.663	0.14	-5.59	3.61
	V2	17	11.12	7.21						
Self	**V1**	16	11.31	4.42	0.04	31	.966	0.02	-3.59	3.75
	V2	17	11.24	5.77						
Neutral-Reward	**V1**	16	12.56	6.27	0.98	30	.334	0.35	-2.02	5.77
	V2	16	10.69	4.35						
Self-Reward	**V1**	17	12.24	5.91	0.78	30	.443	0.27	-2.88	6.42
	V2	15	10.47	6.97						

D

Appendix D: Study 3 Word Stimulus Characteristics (Chapter 6)

We considered suitable neutral matches for the self-related words 'MINE', 'YOUR', 'YOURS' and 'YOURSELF'. The characteristics associated with these words (Hyperspace Analogue to Language, Kurcera-Francis written frequency, Thorndike-Lorge written frequency, Brown verbal frequency, familiarity and concreteness ratings) are displayed in table D.1.

Table D.1. Log transformed Hyperspace Analogue to Language (HAL), Kurcera-Francis (K-F) written frequency, Thorndike-Lorge written frequency, Brown verbal frequency, familiarity and concreteness ratings for selected self-related words.

Word	***HAL written Freq.***	***K-F written Freq.***	***T-L written Freq.***	***Brown Verbal Freq.***	***Familiarity***	***Concreteness***
MINE	11.399	59	1119	30	557	452
YOUR	14.353	923	9052	424	581	256
YOURS	10.393	25	359	13	N/A	N/A
YOURSELF	11 .339	67	907	36	618	N/A

The number of words in a range of ± 5% of each self-related word's Hyperspace Analogue to Language rating and with the same number of letters, as returned by a search on the English Lexicon Project website (Balota et al., 2007), is displayed in table D.2. We also checked how many word matches were returned when the parameter was set at ± 7.5% HAL

(table D3), ± 10 % HAL (table D.4) and ± 15 % HAL (table D.5). The range of ± 5 % HAL was finally chosen for returning a sufficiently large number of matching neutral words for each self-related word that it was likely we would find a suitable match within them, while ensuring a higher degree of resemblance between the neutral and self-related words in terms of their Hyperspace Analogue to Language scores.

Table D.2. Range of HAL lower and upper bound (HAL ±5%) for match searches, number of words of same length returned by search.

	HAL written Freq.	HAL (5% lower)	HAL (5% upper)	Words returned
MINE	11.399	10.8290	11.9690	**128**
YOUR	14.353	13.6353	15.0707	**12**
YOURS	10.393	9.8734	10.9127	**255**
YOURSELF	11.339	10.7721	11.9060	**11**

Table D.3. Range of HAL lower and upper bound (HAL ±7.5%) for match searches, number of words of same length returned by search.

	HAL written Freq.	HAL (7.5% lower)	HAL (7.5% upper)	Words returned
MINE	11.399	10.5441	12.2539	**212**
YOUR	14.353	13.2765	15.4295	**25**
YOURS	10.393	9.6135	11.1725	**388**
YOURSELF	11.339	10.4886	12.1894	**100**

Table D.4. Range of HAL lower and upper bound (HAL ±10%) for match searches, number of words of same length returned by search.

	HAL written Freq.	HAL (10% lower)	HAL (10% upper)	Words returned
MINE	11.399	10.2591	12.5389	278
YOUR	14.353	12.9177	15.7883	39
YOURS	10.393	9.3537	11.4323	521
YOURSELF	11.339	10.2051	12.4729	152

Table D.5. Range of HAL lower and upper bound (HAL ±12.5%) for match searches, number of words of same length returned by search.

	HAL written Freq.	HAL (12.5% lower)	HAL (12.5% upper)	Words returned
MINE	11.399	9.9216	12.7564	364
YOUR	14.353	12.5589	16.1471	58
YOURS	10.393	9.0939	11.6921	663
YOURSELF	11.339	9.9216	12.7564	213

Table D.6. Range of HAL lower and upper bound (HAL ±15%) for match searches, number of words of same length returned by search.

	HAL written Freq.	HAL (15% lower)	HAL (15% upper)	Words returned
MINE	11.399	9.689	13.1088	440
YOUR	14.353	12.2001	16.5059	78
YOURS	10.393	8.8341	11.9520	803
YOURSELF	11.339	9.6381	13.0399	294

Of the words falling within the ± 5 % range of matching log-transformed Hyperspace Analogue to Language ratings, many were excluded on the basis that they were considered not suitable. Words were considered not suitable if they were place names, conjugations, prepositions, or potentially valenced or threatening. Words were also excluded if they deviated excessively from their matching self-related word on any one linguistic criterion (Kurcera-

Francis or Thorndike-Lorge written frequency index, Brown verbal frequency, familiarity or concreteness). This pre-selection was performed for words matching 'MINE' and 'YOURS' only, as only 11 and 12 words fell into the desired HAL range for the words 'YOUR' and 'YOURSELF'.

Suitable words falling within a range of ± 5 % HAL of self-related words are presented in tables D.7-D.10, with matches for 'YOURSELF' presented in table D.7., matches for 'YOUR' in table D.8., 'YOURS' in table D.9. and 'MINE' in table D.10..

Of these words, those which did not have ratings or Kurcera-Francis or Thorndike-Lorge written frequency indices, Brown verbal frequency, familiarity or concreteness ratings in the MRC Psycholinguistic Database were considered not suitable. For words matching 'YOURSELF' and 'YOUR', the same criteria as were applied in the pre-selection for matches for 'MINE' and 'YOURS' were now applied in choosing a suitable match. We also considered matches that might be considered as self- or reward-related unsuitable. Words that were considered potential suitable matches are highlighted in bold. We did not consider any of the matches for the word 'YOUR' particularly suitable. However, we considered the word 'BUILDING' a good match for the word 'YOURSELF'. This stimulus was therefore chosen. Due to the potential implications of using the word 'YOURSELF' as well as the word 'YOUR' given the number of letters shared between them, we decided to exclude the word 'YOUR' from consideration at this stage. This decision was guided by the fact that the word 'YOUR' did not have a familiarity or concreteness rating in the English Lexicon Project website, and therefore it would not have been possible to choose matches on the basis of those characteristics. Although no concreteness rating was available for the word 'YOURSELF' either, matches could be chosen with regard for their familiarity rating for this word. Based on these considerations, the word 'MINE' was chosen, and the word 'HEAR' identified as a good match for the word 'MINE'.

Table D.7. Log transformed Hyperspace Analogue to Language (HAL), Kurcera-Francis (K-F) written frequency, Thorndike-Lorge written frequency, Brown verbal frequency, familiarity and concreteness ratings for words matched to 'YOURSELF' by log transformed HAL scores. Suitable matches are highlighted in bold.

Word	***HAL written Freq.***	***K-F written Freq.***	***T-L written Freq.***	***Brown Verbal Freq.***	***Familiarity***	***Concreteness***
YOURSELF	11 .339	67	907	36	618	N/A
VERSIONS	10.773	-	-	2	-	-
STARTING	10.892	68	-	10	-	-
SOLUTION	**10.864**	**59**	**166**	**1**	**548**	**388**
PROVIDED	10.827	132	-	6	576	-
PRIMATES	10.878	1	-	-	-	-
MILITARY	10.776	212	178	9	576	417
MACHINES	10.798	-	-	3	-	-
FEATURES	10.888	-	-	6	-	-
CONTAINS	10.859	-	-	4	-	-
BUILDING	**10.787**	**160**	**1014**	**29**	**607**	**589**
ARGUMENT	10.807	63	255	6	-	-

Table D.8. Log transformed Hyperspace Analogue to Language (HAL), Kurcera-Francis (K-F) written frequency, Thorndike-Lorge written frequency, Brown verbal frequency, familiarity and concreteness ratings for words matched to 'YOUR' by log transformed HAL scores. Suitable matches are highlighted in bold.

Word	***HAL written Freq.***	***K-F written Freq.***	***T-L written Freq.***	***Brown Verbal Freq.***	***Familiarity***	***Concreteness***
YOUR	**14.353**	**923**	**9052**	424	**581**	**256**
WILL	**14.350**	2244	9573	197	584	275
WITH	**14.974**	7289	32903	845	608	268
WHAT	**14.098**	1908	12461	1119	608	293
WHEN	**13.758**	2331	14775	557	609	219
THIS	**14.995**	5146	14151	1582	601	240
THEY	**14.297**	3618	18010	1365	607	316
SOME	**13.857**	1617	5761	419	578	286
MORE	**13.889**	2216	8015	340	612	284
LIKE	**13.875**	1290	9499	600	610	286
JUST	**13.836**	872	6347	670	640	257
HAVE	**14.915**	3941	24456	1365	597	251
FROM	**14.455**	4369	16737	529	612	197

Table D.9. Log transformed Hyperspace Analogue to Language (HAL), Kurcera-Francis (K-F) written frequency, Thorndike-Lorge written frequency, Brown verbal frequency, familiarity and concreteness ratings for words matched to 'YOURS' by log transformed HAL scores. Suitable matches are highlighted in bold.

Word	***HAL written Freq.***	***K-F written Freq.***	***T-L written Freq.***	***Brown Verbal Freq.***	***Familiarity***	***Concreteness***
YOURS	10.393	25	359	13	-	-
TRACK	**10.727**	**38**	**309**	**5**	**515**	**547**
THROW	**10.250**	**42**	**331**	**5**	**548**	**400**
TASTE	**9.892**	**59**	**480**	**10**	**580**	**464**
STYLE	**10.674**	**26**	**301**	**10**	**555**	**344**
STICK	**10.250**	**39**	**420**	**17**	**528**	**604**
SPEAK	**10.891**	**59**	**480**	**10**	**464**	**580**
OCCUR	9.972	43	400	6	-	-
NOISE	9.943	37	269	9	-	-
GRANT	10.013	47	354	14	-	-

Table D.10. Log transformed Hyperspace Analogue to Language (HAL), Kurcera-Francis (K-F) written frequency, Thorndike-Lorge written frequency, Brown verbal frequency, familiarity and concreteness ratings for words matched to 'MINES' by log transformed HAL scores. Suitable matches are highlighted in bold.

Word	***HAL written Freq.***	***K-F written Freq.***	***T-L written Freq.***	***Brown Verbal Freq.***	***Familiarity***	***Concreteness***
MINE	11.399	59	1119	30	557	452
WISH	11.216	110	1120	19	556	270
VIEW	11.225	186	635	43	523	379
TERM	10.968	79	442	39	575	374
ROAD	11.108	197	915	34	604	583
NONE	11.414	108	601	18	569	288
NEAR	11.265	198	1338	24	582	337
HOLD	11.171	169	836	18	596	416
HEAR	**11.411**	**153**	**1052**	**34**	**602**	**394**
EASY	11.449	125	1077	21	607	288
DEAL	11.336	142	790	29	522	342
CARE	11.557	162	1622	18	563	342