THE ROLE OF PERSONALITY TYPE AND COGNITIVE BIASES IN CHRONIC BACK PAIN

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2022

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A THESIS SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS OF MANCHESTER METROPOLITAN UNIVERSITY FOR THE DEGREE OF DOCTOR OF PHILOSOPHY

DEPARTMENT OF SPORT AND EXERCISE SCIENCES
MANCHESTER METROPOLITAN UNIVERSITY

2022

"The beginning is always today."

- Mary Shelley -

‘n ons gelök is mieë waerd es ‘ne kilo verstandj

Abstract

Chronic back pain is the single biggest cause of disability among adults in the world with a significant social, economic, and personal impact. The lack of an underlying pathology in some cases of chronic back pain means that psychology may play an important role. Previous investigations considered the chronic back pain population to be a homogenous group with the same coping mechanisms and pain related behaviours. However, recent studies have suggested that there might be sub-groups with different behaviours and coping mechanisms within the chronic pain population.

This thesis used a mixed method approach to investigate the effect of personality traits on chronic back pain. Using a well-established cohort study the effects of the big five personality types on chronic back pain assessed three outcomes over an 8-year period: consistent chronic pain, recovered from chronic pain and acquired chronic pain.. Neuroticism was found to be the biggest risk factor for chronic pain in all three outcomes and physical activity and, in some cases, Extraversion and Conscientiousness were protective.

The next study investigated cognitive biases within Weinberger's personality types: defensive high anxious, high anxious, low anxious, and repressors. Results indicated that the repressors had a goal oriented gaze behaviour that is similar to that of a control group whereas in contrast the high anxious and defensive high anxious individuals appeared to have an attentional bias towards the back and face.

The final study in this thesis investigated the motor imagery profile of a chronic back pain population as well as the motor imagery profile of each of the Weinberger personality types. Overall, individuals with chronic back pain had lower imagery scores than the pain free control group. When split according to personality type the results seem to suggest that the high anxious had the lowest imagery scores, whereas the repressors' imagery scores were similar to those of the control group.

Taken together, the results from this thesis provide further support for the heterogeneity of individuals with chronic back pain and investigated a new type of imagery intervention that could address limitations in current chronic pain management.

Publications

Conference papers

Esselaar, M.W., Franklin, Z., Wright, D., Smith, D, Holmes, P. 'The effect of personality type on attentional bias and its manipulation in patients with chronic back pain' (2019) Research in Imagery and Observation Annual Research Meeting, Middlesbrough, UK, 25-26 April

Esselaar, M.W., Holmes, P., Wright, D., Marshall, B., Smith, D, Franklin, Z. (2021) 'Imagery ability in patients with chronic back pain' International Association for the Study of Pain Virtual World Congress on pain, 9-11 and 16-18 June

Esselaar, M.W., Holmes, P., Wright, D., Marshall, B., Smith, D, Franklin, Z. (2022) 'The effect of personality type on attentional bias within a chronic back pain population' Pain Science in Motion IV congress, Maastricht, The Netherlands, 19-20 May

Planned publications:

Esselaar, M.W., Holmes, P., Franklin, Z., Cukic, I. 'Big five personality traits and chronic back pain: an 8-year follow up study'

Other publications during the programme

Moreno-Verdú, M., Hamoline, G., Van Caenegem, E.E., Waltzing, B.M., Forest, S., Chembila-Valappil, A., ... Hardwick, R. (2022, September 1). Guidelines for Reporting Action Simulation Studies (GRASS): Proposals to improve reporting of research in motor imagery and action observation. PsyArXiv. https://doi.org/10.31234/osf.io/9vywr.

Acknowledgements

Firstly, I would like to thank my principal supervisor Dr. Zoe Franklin, who supported me throughout the whole project. She helped me settle into my new life in a new country. I will always be grateful for her irreplaceable guidance during the toughest time of my PhD and for her optimism when I could no longer see a way out. She always had time for a chat, and I could always trust her to point me in the right direction. I would also like to thank Prof. Paul Holmes for his extensive knowledge on everything related to this project, whilst also securing funding for me to engage within the Dutch Academic Network in the United Kingdom which has endlessly enriched my professional network.

I would like to thank the rest of my supervisory team: Dr. David Wright for helping me with the recruitment of participants and for the chance to work on his action observation and motor imagery questionnaire project. Dr. Dave Smith for always having a kind word and for his help with applying for my extension. Dr. Ben Marshall, his help with the eye-tracking design and who saw the bright side of a stolen bicycle wheel. Finally, Dr. Iva Cukic who jumped into this project at the last moment and without whom this thesis would not be as good as it is today.

My parents, Christianne and Wil, have been my rock during this entire process and for that, and the care packages filled with hagelslag and liquorice, I am forever grateful. I would also like to thank both of my sisters, Ellen and Dominique, who made sure I always had something to look forward to when I went home. The support of my whole family has been unwavering their ears must hurt from listening and their arms tiered from lifting me up, but I could not have done this without them.

I would like to thank the wonderful people in the PGR research zone you were able to make me cry with laughter and laugh after crying. I would have completed this thesis sooner without you, but it would have been a lot less fun.

I am indebted to all the clinicians at the North Manchester hospital who have embraced this project wholeheartedly, supported me during the preparation of this project and did everything within their power to help me recruit participants.

All the members of the MSSM and SES department, lecturers, tutors, technicians, support staff and postdocs, who always allowed me to distract them with random chats and coffees. They also participated in my study for which I am ever so grateful.

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1 Outline of the Thesis

The original focus of the PhD programme was to conduct an inter- and multi-disciplinary analysis of the effect of personality type on the cognitive biases of individuals with chronic back pain. Based on recent work it was thought that current research and interventions consider the chronic back pain population to be a homogenous group whereas anecdotal evidence from clinicians contradicts this. The significant constraints imposed upon the United Kingdom as a result of the global COVID-19 pandemic required a refocus and redesign of most studies as well as the design of new studies. The initial pandemic restrictions began in March 2020 at the start of the data collection of study 2 and 3 which required an immediate stop to all hospital-based recruitment and all face-to-face research taking place in the laboratories. As a result of this study 3 was redesigned to take place online and study 2 was redesigned to comply with new health and safety guidelines. Some of the studies presented within this thesis contain a smaller sample size than was originally planned based upon a-priori power analysis. This thesis now contains an inductive and deductive approach to investigate the effect of personality traits on chronic back pain. The changes to the design of the studies in this thesis, are due to the pandemic-imposed limitations. This thesis now, however, provides a more holistic view of the effect of personality traits on chronic back pain using a mixed methodological approach.

Study 1 (Chapter 3) approached the research question from a deductive manner. It presents the findings from the examination of the effect of personality traits over an 8-year period within a birth-cohort study. This chapter assesses the effect of personality traits on the development and maintenance of chronic back pain in a large population and uses statistical modelling to estimate the protective or risk factor of each personality trait. Study 2a (Chapter 4) investigated markers for visual attention during at dot-probe task within individuals with and without chronic back pain and how personality trait affected these markers. This chapter also reported on daily physical activity of chronic back pain patients. Study 2b (Chapter 5) investigate the

attentional bias of individuals with back pain using an action observation task. In the first study of its kind, it researched the differences in visual attention between individuals with and without chronic back pain as well as the differences between personality types.

Study 3 (Chapter 6) investigated the imagery ability of individuals with chronic back pain. The aim was to explore if imagery-based therapy could be a possible intervention technique based upon personality type specific deficits in the imagery ability of individuals with chronic back pain.

2 General introduction

Approximately 10 million individuals suffer with chronic musculoskeletal pain with 42% unable to work due to their condition and 19% will eventually lose their jobs (Breivik et al., 2006). There is also a significant effect on the economy, with an estimated cost of £12.3 billion per year for back pain alone (Maniadakis & Gray, 2000). Low back pain is one of the most common pain conditions in the world regardless of the geographic location of the population (Hoy et al., 2010). Although a relatively low percentage, 23% (Balague et al., 2012), of acute low back pain cases will transition into non-specific chronic low back pain which accounts for the majority of back pain related disability and economic burden (Gore et al., 2012; Maetzel & Li, 2002).

Current management of chronic pain, as recommended by the National Institute for Health and Care Excellence (NICE), includes physical exercise, manual or alternative (e.g., acupuncture) therapy, psychological therapy (e.g., acceptance and commitment therapy or cognitive behavioural therapy), and pharmacological therapy (e.g., antidepressant). It strongly advises to combine the different types of therapy to create a pain management programme. Chronic musculoskeletal pain is a subjective experience, that encompasses biological, psychological, and social facets, and thus influences individuals differently, resulting in varying levels of pain and disability. Even though there are several therapeutical options recommended for the management of chronic pain it could take a long time to find the perfect combination for a specific patient that addresses their unique biological, psychological, and social needs. Furthermore, a recent review found the psychological and social underpinnings of chronic back pain to be lacking and too often primary care clinicians still have a biomedical view of chronic pain and work from the philosophy that if they fix the injury the pain should go away (Mescouto et al., 2022). Sherwood et al. (2000) found that patient's satisfaction with pain management had less to do with a decrease in pain intensity and was more often related to the perceived

quality and effectiveness of the care they received. Over the last decade, research into the psychological factors that influence the experience of back pain suggest that the differences in pain experience can be found in the individual's attentional bias towards threat-related stimuli. Attentional bias refers to the preference of an individual's attention towards stimuli that relates to their current state. Research has found that individuals with chronic pain have an attentional bias directed towards pain-related information in comparison to non-symptomatic controls (Todd et al., 2018). Theories of attention and pain hypothesise that an intervention focusing on changing the attentional bias might be beneficial in reducing the level of pain and disability experienced by pain patients (Todd et al., 2015). The results of studies investigating the effects of manipulating attentional biases within the chronic pain population are inconclusive (Schoth et al., 2013; Todd et al., 2016).

The following chapter of this thesis provides a review of the pain literature. It highlights the differences between acute and chronic pain and the impact of chronic pain. It discusses current behavioural and developmental chronic pain models and how psychological factors influence the experience of chronic pain. The main body of research treats the chronic pain population as a homogenous group, with similar psychological characteristics that predispose these individuals to a higher chance of developing chronic pain but are thought to be absent from individuals who do not develop chronic pain. Little research, however, has looked at differences within the chronic pain population that lead to different behaviours seen within this group. Chapter 4 provides a critical and analytical review of the previous methods used to assess behaviours in chronic pain populations. It further provides a discussion of which methods were chosen for this thesis and highlight why they are best suited to explore the research questions posed in this thesis. Chapters 5 through 8 are the experimental chapters. Chapter 5 investigates chronic pain from a broad and inductive perspective using a well-established cohort birth study to investigate the effect of the big five personality types on

chronic pain over an 8-year period. Chapter 6 investigate attentional biases in the chronic back pain population compared to a pain-free control group using the dot-probe task which is the most used method for assession attentional biases in the chronic pain population. The dot-probe task is not without limitations (as will be discussed in the methodology chapter) and chapter 7 will use an action observation task to assess attentional biases, which overcome some of the limitations of the dot-probe task. The final experimental chapter, chapter 8, investigates the imagery ability of individuals with chronic pain. Assessing the imagery ability will provide an insight into the mental representation that individuals with back pain have across multiple imagery domains.

The final chapter provides a detailed discussion of the summary results of all experimental chapters and based upon these suggests next research steps as well as an overall conclusion.

Taken together, the evidence from the studies in this thesis will explore the effect of psychological variables on the experience of chronic back pain in both a large cohort study and empirical laboratory studies. This novel knowledge would inform an unmet clinical need: new chronic pain management options that address the personality specific chronic pain experience and create new management paths that would inform clinicians of the right combination of therapeutic options based on the patient's psychological profile.

3 Literature review

3.1 Definitions of pain

Pain is a noxious experience shared by most living creatures. The International Association for the Study of Pain (IASP) recently updated the definition of pain as "an unpleasant sensory and emotional experience associated with, or resembling that associated with, actual or potential tissue damage" (Raja et al., 2020). This definition is expanded upon further by the following six key notes: i) Pain is always a personal experience that is influenced to varying degrees by biological, psychological, and social factors; ii) Pain and nociception are different phenomena, pain cannot be inferred solely from activity in sensory neurons; iii) Through their life experiences, individuals learn the concept of pian; iv) A person's report of an experience as pain should be respected; v) Although pain usually serves an adaptive role, it may have adverse effects on function and social and psychological well-being; vi) Verbal description is only one of several behaviours to express pain, inability to communicate does not negate the possibility that a human or a nonhuman animal experiences pain. This definition and the additions encompass not only the sensory element but also the emotional perception of pain. It further highlights that the sensation of pain does not always mean actual tissue damage or stress and differentiates between nociception, the process by which noxious stimulation is communicated through the central and peripheral nervous system, and pain which encompasses the subjective experience of potential or actual harm.

3.2 Acute pain

Acute or nociceptive pain plays an important role in the body's defence system to prevent further injury by producing a reflexive response from a painful stimulus and creating a negative association to prevent individuals from repeating the same action (Cervero, 2012). Historically, Descartes (Melzack & Wall, 1965) explained acute pain to be a direct stimulus response

reaction, you burn your finger and experience pain immediately. This nociceptive information is transmitted along neurological pathways. The transmission of nociceptive information is no longer seen as a summation of biological processes. The perception of nociceptive pain is a combination of sensory, environmental, emotional and behavioural factors. Pain thresholds have been found to be increased in some extreme environmental situations such as combat where soldiers have been reported to have 'temporary analgesia', where they are not aware of severe injuries (Ellison, 2017). On the other hand, inflammation or injury of the nerve can lead to reduced thresholds related to a damaged area. Damage to a tissue result causes a chain reaction of four basic processes which are involved in nociception (McCaffery & Pasero, 1999; Miller, 2009): i) transduction, which involves the process of converting a noxious stimuli, which can be mechanical, thermal, or chemical in nature into a nerve impulse; ii) transmission which conducts the afferent nerve message from site of the injury to the dorsal horn of the spinal cord and from there onto the brain stem. From the brain stem finally through connections linking the thalamus, cortex, and higher levels of the brain where perception and interpretation of the stimulus happen. The third process of nociception is perception; which is when nociception is turned into pain. This stage is influenced by social, environmental, and psychological factors, which explains why the same noxious stimulus elicits different pain responses between individuals and even within one individual at different times. The final stage of nociception is modulation, the complex system involved in the modulation of pain is referred to as the descending modulatory pain pathways and can lead to either an increase in the transmission of pain impulses (excitatory) or a decrease in transmission (inhibition).

3.3 Models of acute pain

A range of theoretical accounts from numerous studies have attempted to explain the nature and cause of acute pain. These include the Specificity Theory (Cauna & Ross, 1960), Intensity theory (Dallenbach, 1939), Peripheral Pattern Theory (Weddell, 1955), and Gate Control

Theory (Melzack & Casey, 1968; Melzack & Wall, 1965). The mechanism of nociception described above explains the physiological aspect of nociceptive pain, however, it does not take into account psychological and behavioural factors. Most theories describing nociceptive pain, have a biomedical view and consider chronic pain to be an extension of acute pain where damage is still persistent. The Specificity Theory by Schiff and Woroschiloff (Rey, 1995) proposes that pain is a sensory experience signalling damage to the tissue. The theory proposes that pain is experienced when peripheral information relating to tissue trauma is transmitted to the cerebral cortex. This central notion of Specificity Theory cannot account, however, for pain that is reported in the absence of any noticeable tissue damage (e.g., migraines and phantom limb syndrome) (Ashina et al., 2012; Vase et al., 2012). Furthermore, episodic analgesia, the sensation of little or no pain despite significant damage to the tissue can also not be explained by the Specific Theory. Additionally, in individuals with chronic back pain there are few objective markers of pathology and a notoriously poor association between the underlying pathology and the experience of pain (Hart et al., 1995; Ung et al., 2014). The most recent back pain guidelines therefore no longer advise imaging to detect pathologies as part of back pain management. Studies using Magnetic Resonance Imaging (MRI) of the lumbar spine have identified 76% of asymptomatic individuals with some form of disc herniation in the complete absence of reported pain (Boos et al., 1995). Consequently, research has been increasingly directed beyond the physiological pain process and looking towards psychological factors involved in pain perception to address the weaknesses in the Specific Theory. The Gate Control Theory by Melzack and Wall (1965) attempted to overcome biomedical based limitations of Specificity Theory. This theory describes not only the mechanisms and transmission of a nociceptive stimulus from peripheral to central, but further explains how the interaction of physiology and psychology influence the experience of pain. It proposes that ‘a gate’ which sits in the dorsal horns of the spinal cord act either facilitates or inhibits transmission from the

body to the brain depending on the intensity of ascending stimulation and descending impulses from the central nervous system. Melzack and Casey (1968) proposed three psychological dimensions related to the central processing of nociceptive stimulation: (i) sensory-discriminative, which provides perceptual information relating to the location, magnitude, and spatio-temporal characteristics of the noxious stimulation; (ii) motivational-affective dimension which stimulates an individual towards either an escape or attack reaction; and (iii) cognitive-evaluative dimension which provides the individual with predictions of the outcome of different response strategies based on similar previous experiences. The Gate Control Theory was pivotal by implicating psychological factors in the experience of pain rather than adhering to a purely biomedical direct stimulus response view.

3.4 Chronic pain

Acute or nociceptive pain is the instant experience of pain that is often resolved quickly, however, sometimes the pain persists for a long time and becomes chronic. The clinical definition of chronic pain is a condition which lasts for more than three months. Chronic pain conditions include fibromyalgia, chronic fatigue syndrome, temporomandibular disorder, and chronic low back pain. Researchers investigated factors which play a role in the transition from acute to chronic pain. The purpose of acute pain is to cause a physiological reaction designed to warn individuals of an immediate danger and facilitate the healing process, however, when conditions become chronic this response may become maladaptive, as continued pain leads to fear and avoidance of physical activity (Vlaeyen et al., 1995). In chronic pain, it has been suggested that changes in long-term experience of chronic pain can lead to permanent changes in the central nervous system. Apkarian (2011) found long lasting changes in the central nervous system that are involved in the transmission and modulation of pain. Other elements such as psychological factors also seem to change because of chronic pain (Depression) as well as social factors (no work and loneliness). Waddell (1987) combined biological, psychological,

and social factors into a model, the biopsychosocial model, to guide clinicians in the management of chronic pain.

3.4.1 Biopsychosocial model

Waddell (1987) developed what is known as the biopsychosocial model, sometimes referred to as the Glasgow model, which focuses on a description of the features influencing the experience of specifically chronic lower back pain (CLBP). The seminal paper marked a change in the way researchers and clinicians thought about back pain. The model requires the integration of other factors alongside the biomechanical view. It combines biological, psychological, and social factors that are not necessarily related to the development of CLPB but, when combined, show promise for effective therapeutic changes (Pincus et al., 2013). Under the biological factor Waddell included physical damage that is traditionally associated with chronic back pain like muscles weakness, disc degeneration, and traumatic injury. However, current research has no consensus about the robustness of biomarkers that indicate back pain (Moissenet et al., 2021). A more recent biological pathway are genetic pathways that have been shown to strongly influence various spinal pain phenotypes (Hartvigsen et al., 2009). Changes in the expression of the genetics have further been found to modulate the transition from acute to chronic pain (Nachemson, 1979). Psychological factors refer to an individual's beliefs, behaviours, and perception of their pain. There is promising evidence that therapies which focus on changing psychological constructs like increasing the acceptance of inevitable pain states and psychological flexibility as well changing perceived values and beliefs reduce pain intensity (McCracken et al., 2013; Ussher et al., 2014). Social factors include potential obstacles to recovery in the form of legislation, compensation systems, and the access to health infrastructures. The review of Pincus et al. (2013) found that this element of the biopsychosocial model is most often neglected in research and treatment. The strength of the model comes from the overarching view that, for a successful treatment, all three components

should be addressed. The biological component relates to the severity, location, and type of injury. The psychological factors include the beliefs, attitudes, and illness behaviour. The social component describes the importance of returning to work as well as obstacles from legislation, and social and economic conventions when addressing CLBP.

3.4.2 Fear-avoidance model of chronic pain

The fear-avoidance (FA) model, proposed by Lethem et al. (1983) and further developed by Vlaeyen et al. (1995) describes a downward cycle of chronic disability and suffering, giving an explanation why some individuals devolve from acute to chronic pain. Fear-avoidance beliefs are a fear of pain that are exaggerated, leading to avoidance of physical activities that could or are thought to be painful. The fear-avoidance beliefs stem from beliefs of individuals with pain about the cause, severity and duration of their pain (Fordyce, 1976; Turk et al., 1983). For example, beliefs that pain can only be treated medically, and that pain is a clear signal from the body that damage is being done or increased and that this will lead to increased disability. An important factor within this model is whether pain after injury is considered temporary and non-threatening, or whether the pain is falsely considered damaging to the body and threatening. If the pain is not seen as a threat, the individual will reduce their activity level to adjust for the pain but maintain some physical activity. Thus, keeping the experienced pain at the same level and eventually fully recovering. On the other hand, an interpretation of pain that is catastrophic leads to the development of an exacerbated and irrational fear of current or expected pain and its alleged consequences, to a state where kinesiophobia, or fear of movement, leads to the avoidance of situations in which pain could be expected. This fear induced avoidance of movement, which could lead to the avoidance of work or social engagements that involve physical activity. Excluding oneself from these engagements could lead to disuse, disability and depression which enhance the vicious downward cycle. Catastrophising is defined as exaggerated, negative worry during or in anticipation of an

upcoming event (Sullivan et al., 2001). Pain catastrophising plays an important role in the fear-avoidance model of pain and is associated with negative pain related outcomes in low back pain (Wertli, Burgstaller, et al., 2014; Wertli, Rasmussen-Barr, et al., 2014). Higher levels of catastrophising are associated with a more severe pain experience due to the facilitation of negative information processing and increased attentional bias. Though catastrophising was thought to be a stable trait (Sullivan et al., 1995), studies have shown that the level of pain catastrophising can be modified and decreased. Particularly, early interventions have been linked to improvements in pain severity in later treatment (Spinhoven et al., 2004). The heightened fear of pain and re-injury will lead to the avoidance of physical activities that the individual believes will increase the pain. Pain naturally draws attention, yet some individuals become hyperaware of pain and actively scan their bodies for pain signals (Crombez et al., 2013b; Van Damme et al., 2006).

3.4.3 Schema Enmeshment Model of Pain

A later model that tries to explain the cognitive biases related to chronic pain is the Schema Enmeshment Model of Pain (SEMP) (Pincus & Morley, 2001). The model uses schemas (Segal, 1988; Williams et al., 1988), which contain information about the body, which help to interpret stimuli and are used for storing and retrieving information. The pain schema includes the sensory, spatial, and temporal information of a painful stimulus. This schema is thought to represent the initial pain sensation and is associated with the immediate relocation of attention towards the pain. Even though the pain and illness schema are related, pain is considered separate because not all illnesses are painful. The illness schema contains the long-term implications, influencing autonomous functioning goal setting and quality of life. Finally, the self-schema is an intricate structure described as “an organised cognitive structure with long-term memory, which may incorporate both general trait like information about the self, as well as specific behavioural episodes” p. 174 (Bradley & Mathews, 1983). At the core of the self is

an evaluation system which includes a reflective self-evaluation of behaviour, feelings, and thoughts that generates an evaluation of self-worth. Pincus and Morley (2001) describe three variables of the enmeshment, 1) how much the schemas overlap, 2) which schemas overlap, and 3) the setting and duration of the different schemas. Depending on these variables, the model predicts different behaviours related to pain. For individuals whose pain and illness schema significantly overlap, but where key elements of the self-schema do not, it is hypothesised that they cope actively with chronic pain. These individuals show no signs of negative mood or depression. If the pain and self-schema enmesh, but not the illness schema, the individual is probably in a more acute state of pain, but the injury relates to some central aspect of their identity (e.g., broken hand for a painter). If all three schemas significantly overlap with each other, the behaviour is dependent on what elements of each schemas become related to each other and the activation of one leads to the activation of the other. When this happens, elements of the pain schema can be activated without the bottom-up pain signal, leading to an enhanced pain sensation and further enmeshment with the other schemas.

3.4.4 Threat interpretation model

Threat Interpretation Model (Todd et al., 2015) lays an emphasis on the pain relevance and threat level of the presented stimuli (see Figure 3.1). It is the first model to outline the relationship between interpretation and attentional biases and proposes that the interpretation bias towards threat is the underlying drive of attentional biases. It is the interpretation of an ambiguous stimulus as both pain-related and threatening which results in a vigilance avoidance behaviour. Contrary to other models the threat interpretation model suggests that avoidance of threatening information is more important than the difficulty of disengaging for the development and maintenance of chronic pain. Driven by the results from a prospective study (Munafo & Stevenson, 2003), it was found that biases towards pain stimuli were associated with future pain using a masked presentation paradigm. Further support for the importance of

vigilance avoidance comes from the finding that both individuals with chronic pain (Yang et al., 2013) and healthy controls (Yang et al., 2012) with high levels of fear of pain will lead to stronger vigilance avoidance than those with low fear of pain levels. The model further attempts to explain the discrepancies between findings of prospective and cross-sectional studies. Prospective studies have found that it is avoidance of negative and threatening information or a focus on positive information that is predictive of future pain. Cross-sectional studies on the other hand place an emphasis on the difficulty of disengaging, as indicated by longer sustained attentional biases towards pain related information. The threat interpretation model suggests that this difference in results might be due to differences in threat levels. With higher levels of threat interpretation leading to avoidance behaviour, which is supported by the findings of Vervoort and colleagues (Vervoort, Trost, Prkachin, et al., 2013; Vervoort, Trost, & Van Ryckeghem, 2013) who found that as the severity of pain emotion on faces increased, thus increasing the threat level of the faces, so increased the avoidance. The model generates testable hypotheses about the impact of interpretation, attention, and threat.

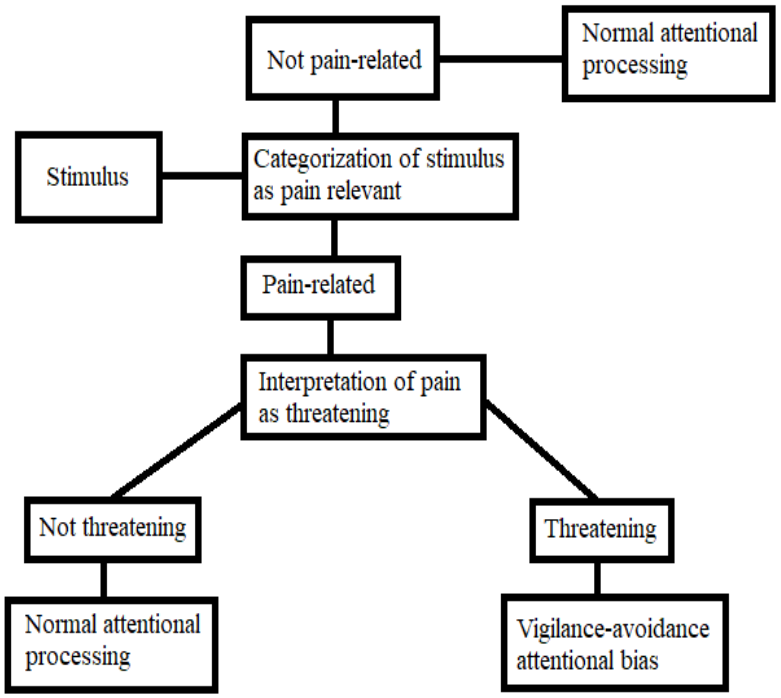


Figure 3.1 Threat interpretation model of attentional bias towards pain (Todd et al., 2015)

3.5 The impact of chronic back pain

Musculoskeletal pain is a complex condition which has significant psychological (McInnis et al., 2014), physical (Camacho-Soto et al., 2012), and social implications (Stenberg et al., 2014). Chronic musculoskeletal pain affects approximately one in five people across Europe (Breivik et al., 2006) and has a significant effect on the economy. The specific financial costs of managing chronic musculoskeletal pain are unknown, however, conditions such as osteoarthritis and low back pain are considered the most expensive to manage (Mantyselka et al., 2002; Philips et al., 2010). Within the United Kingdom (UK) specifically, back pain is estimated to cost £12.3 billion per year (Juniper et al., 2009; Maniadakis & Gray, 2000), which is the equivalent of 22% of the annual NHS budget (2014). Several studies have found that most spending in the treatment of musculoskeletal conditions is dominated by a small

percentage of individuals (Heslop et al., 2005; Rosella et al., 2014). A recent study found that 35% of the total cost for treatment of musculoskeletal pain were spend on 4% of patients. These high 4% were in the 15th percentile of highest spenders at least two-years on a row (Lentz et al., 2019). There are also personal and societal costs associated with chronic pain. Individuals with high-level intensity have been found to have higher levels of unemployment (Herman et al., 2019). Individuals with chronic back pain that are employed have been found to be more likely to miss work because of their chronic back pain and also be less productive while at work compared to those with lower intensity levels of chronic back pain (Herman et al., 2019). Besides the economic and social costs there are also several personal costs associated with chronic back pain. One of the most reported co-morbidities of chronic pain is depression, with a recent study finding that between 22.6% and 23.1% from individuals with chronic pain also reported depression (Orhurhu et al., 2019). Depression shares similar symptoms with chronic pain such as decreased quality of sleep, fatigue, and decreased physical activity. A longitudinal study showed that 63% of depression disorders appeared after the onset of pain (Knaster et al., 2012). Hadi and McHugh (2019) used a mixed methods approach, consisting of survey and interview, to assess the quality of life (QoL) of individuals living with chronic pain. They found that the QoL survey scores were significantly lower for those who had chronic pain compared to the general population across all domains. In the interview six themes emerged in which chronic pain interfered in the life of the participants: interference with physical functioning, professional life, relationships and family, social life, sleep, and mood.

3.6 Pain management

As discussed above, chronic pain is a complex condition with biological, psychological, and social factors influencing the experience of pain. Chronic pain has a significant impact on healthcare usage, economic costs, and quality of life. Current pain guidelines have moved away

from trying to treat an underlying pathology to managing life with chronic pain and instead focus on a biopsychosocial approach. However, research and treatment have still not fully embraced this (Mescouto et al., 2022). The British Pain Society last updated their chronic musculoskeletal pain conditions guidelines for Pain Management Programmes (PMP) in 2013 (British Pain Society, 2013). A PMP is a group-based intervention for people with chronic pain which remains persistent despite other treatments. It focuses on improving physical, psychological, emotional, and social factors to improve the quality of life and should last about 36 hours. The programme focuses on learning to live with the pain rather than trying to solve or fix any underlying pathology. PMPs combine an educational element with guided physical practice. The education focuses on explaining pain physiology and psychology, and the self-management of pain. The guided practice element encourages patients to improve their fitness and mobility and combines this with cognitive therapeutic methods to help patients deal with setbacks and flair-ups during exercise. PMPs that include cognitive behavioural therapy (CBT) have also been found to be effective (Burke et al., 2017). Even though studies have shown the effectiveness of PMPs in reducing pain related health care usage (Clare et al., 2013), not all individuals with chronic pain benefit the same and more research is needed to elucidate why certain subgroups do not appear to benefit from PMP (Airaksinen et al., 2006).

3.7 Psychological factors

Over the past decade and a half, it has become accepted that chronic pain is not solely a physical problem, psychological factors play an important role in both the development and maintenance of the condition as well as management (Linton, 2000; Woby, Roach, et al., 2007). The biopsychosocial model is now key in understanding and managing chronic pain conditions (Pincus et al., 2013). Anxiety related chronic pain research has overtaken depression related chronic pain research in the last 20 years. In a state-of-the-art paper, Asmundson and Katz (2009) describe the current state of research regarding the co-occurrence of anxiety disorders

and chronic pain. Their paper found that most of the research conducted in this field relates to post-traumatic stress disorder (PTSD). There are large population-wide, national and international studies showing that chronic pain often co-occurs with high anxiety and anxiety disorders (Demyttenaere et al., 2007; McWilliams et al., 2003; McWilliams et al., 2004; Von Korff et al., 2005). These studies have investigated clinically defined anxiety disorders; however, other studies have found that sub-clinical levels of anxiety plays an important role in the development chronic pain (Bair et al., 2013; Kroenke et al., 2013).

3.7.1 Anxiety

Anxiety is defined as "An emotion characterised by feelings of tension, worries, thoughts, and physical changes like increased blood pressure" (American Psychological Association, 2020). Anxiety is often used interchangeably used with fear. Anxiety, however, is considered a long-acting, future-oriented focus on a broad, and sometimes presumed, threat whereas fear is a short-lived, current-oriented response to a specific and clearly identified threat. From the definition presented previously it becomes clear that anxiety encompasses somatic and cognitive elements. Somatic anxiety refers to a persons' physical symptoms of arousal, for example, increased heart rate, blood pressure, sweating, shortness of breath, and muscular tension (Morris et al., 1981). Cognitive anxiety refers to thoughts of dread and worry about a situation and the potential consequences (Martens et al., 1990) and is closely related to catastrophising. An individual's anxiety response is dependent upon their levels of trait and state anxiety. Trait anxiety refers to a person's predisposition to perceived threats in the environment whereas state anxiety refers to situation or object specific feelings (Spielberger et al., 1983). Figure 3.2 shows the anxiety level of low trait and high trait anxious individuals in low and high state anxious situations.

Individuals with chronic pain tend to avoid daily activities because of their anxiety about the pain that is related to that activity. Pain-related anxiety has been shown to be a good predictor for how individuals adapt to chronic pain and is an important part of pain management (Kroenke et al., 2013). Individuals with Chronic pain who score high on trait anxiety have been found to also report high levels of attention to pain (Arntz et al., 1991) and tend to anticipate more pain prior to performing an action (McCracken et al., 1996) than those who score low on trait anxiety.

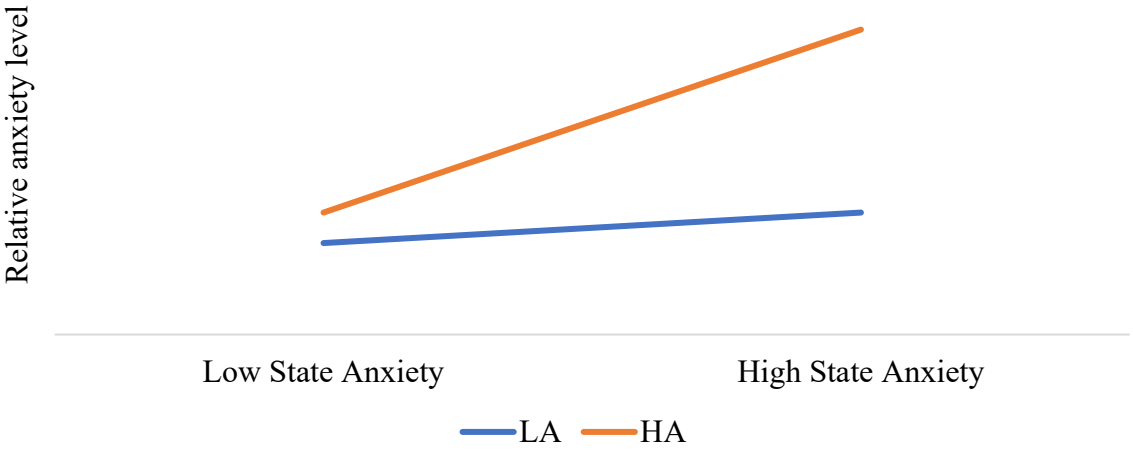


Figure 3.2 Anxiety level for trait low anxious (LA) individuals and trait high anxious (HA) individuals in a low state anxious and high state anxious situation

3.7.2 Catastrophising related to cognitive anxiety

Sullivan et al. (2001) defined catastrophising as the existence of exaggerated, negative worry during or in anticipation of an upcoming event. Pain catastrophising has been suggested to have three components: rumination, magnification, and helplessness and has been applied by Lazarus and Folkman's (1984) transactional model of stress and coping. The theory differentiates between primary and secondary and a feedback mechanism of reappraisal (Lazarus & Folkman, 1984). The primary appraisal relates to decisions whether a future threat is threatening and stressful or not. The secondary appraisal relates to the individual's beliefs about their ability to cope with the possible threat depending on the resources currently available. The reappraisal process involves the persistent monitoring of the current situation

and the success of the coping strategies, with the primary and secondary appraisals being adjusted if required. Catastrophising is closely related to the cognitive aspect of anxiety. Previous studies (Edwards et al., 2006; Sullivan et al., 2001) have found a robust relationship in asymptomatic groups and within various chronic pain groups between catastrophising and other facets of pain in trial experiments. High levels of catastrophising have further been associated with higher reports of pain intensity, more health care utilisation, and a heightened attention to physical pain responses (Graves et al., 2014; Turner, Brister, et al., 2005). Pain catastrophising has been consistently demonstrated to be associated with negative pain-related outcomes in several chronic pain conditions including, low back pain, arthritis, neck pain, and fibromyalgia as well as a mixed chronic pain sample and asymptomatic individuals participating in experimental pain procedures (Campbell et al., 2012; Edwards et al., 2011; Severeijns et al., 2002; Sullivan & Neish, 1997; Thompson et al., 2010; Wertli, Eugster, et al., 2014). This heightened negative cognitive anxiety and worry about pain are also associated with an amplification of the chronic pain experience through an exaggerated attentional bias and a negative processing of stimuli. In a study using a pain free control group, Van Damme et al. (2004) found that individuals with high levels of catastrophising had more difficulty disengaging with pain related stimuli than those with low levels of catastrophising. Vancleef and Peters (2006) who also used a pain-free control group, support these findings and found that only catastrophising, and not anxiety sensitivity or injury/illness severity, was associated with difficulty disengaging from pain. Taken together these studies show that negative cognitive anxiety or catastrophising play an important role in the way attention is allocated in the anticipation or presence of pain. Catastrophising was considered to be a stable dimension of personality (Sullivan et al., 1995). However, studies have shown that brief cognitive behavioural therapy can reduce catastrophising (Turner et al., 2005, 2006), and pre- to post-treatment decreases in catastrophising have been associated with a decreases in pain intensity

(Jensen et al., 2001). Finally, Spinhoven et al. (2004) found that within a patient group early treatment that focuses on reductions in catastrophising were associated with better later pain outcomes compared to patients whose treatment did not focus on reducing catastrophising.

3.8 Personality types

One of the major questions that drives pain research is why does anxiety about pain differ between people (Eysenck, 1997)? The pain experience is not solely a physical experience, individual differences in psychological factors play a mediating role (Linton & Shaw, 2011). Woo (2010) defined anxiety as "a psychophysiological state characterised by cognitive, somatic, emotional, and behavioural components that produce fear and worry" (p. 4). Anxiety can be divided into two components: trait anxiety refers to a person's general response to perceived threats in the environment and state anxiety refers to situation specific feelings (Spielberger et al., 1983), both of which include cognitive and somatic elements. Cognitive anxiety refers to thoughts of dread and worry about a situation and the potential consequences (Martens et al., 1990) whereas somatic anxiety refers to a persons' physical symptoms of arousal, for example, increased heart rate and sweating, shortness of breath and muscular tension (Morris et al., 1981). Individuals with chronic pain tend to avoid daily activities because of their anxiety about the pain that is related to that activity. Pain-related anxiety has been shown to be a good predictor for how individuals adapt to chronic pain and is an important part of pain management (Kroenke et al., 2013). Individuals with Chronic pain who score high on pain-related anxiety have been found to also report high levels of attention to pain (Arntz et al., 1991) and tend to anticipate more pain before performing an action (McCracken et al., 1996).

3.8.1 Weinberger's personality types

An important finding driving research into anxiety was the discrepancies found between physiological anxiety measures and self-reported anxiety levels in some participants. Studies showed that some participants showed increased physiological levels of anxiety, despite self-

reported measures of low levels of anxiety (Derakshan & Eysenck, 1997, 2001a, 2001b). To explain this behaviour, Weinberger et al. (1979) proposed four different personality types based on a combination of trait anxiety and defensiveness. Defensiveness is considered a coping mechanism to shield the individual from the negative feelings caused by physiological anxiety (Weinberger, 1990). Using these two measures created four personality types; high-anxious (HA); low-anxious (LA); defensive high-anxious (DHA); and repressors (REP). HA individuals scored high on trait anxiety but low on defensiveness; LA individuals scored low on both trait anxiety and defensiveness; REP individuals scored low on trait anxiety but high on defensiveness; and DHA individuals scored high on both trait anxiety and defensiveness. These four personality types are thought to display different coping behaviours when confronted with high anxiety situations. Weinberger (1990) found that REP types do indeed report low anxiety while their physiological measures show high anxiety, whereas the LA types showed no difference between the reported and physiological anxiety measures. Furthermore, Weinberger showed that the repressors do not lie or change their self-report to what is expected but truly believe that they are not experiencing any high levels of anxiety.

3.8.2 Eysenck's four-factor theory

The concept of the four different personality types based on anxiety and defensiveness formed the basis for Eysenck's four-factor theory of trait anxiety (Eysenck, 1997). Eysenck added the fundamental assumption that there are cognitive biases influencing four factors within the emotional system. The four factors are: the cognitive appraisal, the individual's interpretation of their physiological activity, their action tendencies and behaviour, and the individual's cognitions. Out of these four, Eysenck argued that the cognitive appraisal was the most important factor and could influence the other factors as well. The cognitive biases that influence the four factors are: the interpretation biases, memory biases, and attentional biases. The interpretation bias influences the perceived level of threat an individual attributes to a

stimulus, the memory bias refers to the preferential memory recovery of previous threatening events, and the attentional bias guides the selective attention either towards or away from the perceived threat. These biases determine to what degree the information of the four factors is used, either inhibiting or facilitating the information flow for each factor. These biases are thought to be stored in threat schemas in the long-term memory. Eysenck designed the four-factor theory to apply to the four personality types described by (Weinberger et al., 1979) and made predictions about the type of bias and the resulting behaviour that each would show based on their trait anxiety and defensiveness scores. High anxious individuals are predicted to have interpretation and attentional biases that lead to an amplification of the threat of a stimulus. They would thus interpret ambiguous stimuli as threatening and pay more attention towards threatening stimuli. Repressors are assumed to have opposite interpretation and attentional biases leading to the reduction of perceived threat of a stimulus. Repressors are thought to interpret ambiguous stimuli as not threatening and avoid threatening stimuli. It is assumed that the low anxious individuals do not show either bias. Eysenck (1997) did not make a clear prediction for the defensive high anxious group, as they are quite rare in the general population (Franklin et al., 2014; Lewis et al., 2012). He did however, state that they would adopt a defensive coping strategy, to reduce their anxiety and deal with the threat, but that this would be unsuccessful, because of their predisposed high anxiety tendencies. As for their biases, Eysenck proposed that their interpretation and attentional biases might be the same as those of the high anxious but more extreme. Due to the rareness of the defensive high-anxious group in the general population, they are often omitted from research studies or grouped with the high-anxious participants. However, within the clinical population research has found that 35-45% of the individuals belong to the defensive high-anxious group (Creswell & Chalder, 2001; Franklin et al., 2014; Lewis et al., 2012). Franklin et al. (2016) investigated the attentional bias of the four different personality types within a clinical back pain population using the reaction

times of a dot-probe task to assess selective attention. This was the first study to test Eysenck's predictions within a chronic back pain population using pain-related threat specific images. They used a set of threatening, neutral, and positive images, with the threatening images showing everyday actions that would be painful for individuals with back pain (e.g., lifting a laundry basket, reaching for a book on a high shelf). Some of their results were in line with the predictions Eysenck (1997) made about the attentional biases of the different groups, yet a difference between the attentional bias of the high-anxious and defensive high-anxious groups was found. The high-anxious group showed no attentional bias towards the threatening stimuli but had longer reaction times towards the positive images which the authors interpreted as avoidance. The defensive high-anxious group had shorter reaction time towards the threatening stimuli which was interpreted as a bias towards the threatening image but no preference for the positive stimuli. Their results suggested that defensiveness and anxiety levels can influence attentional bias.

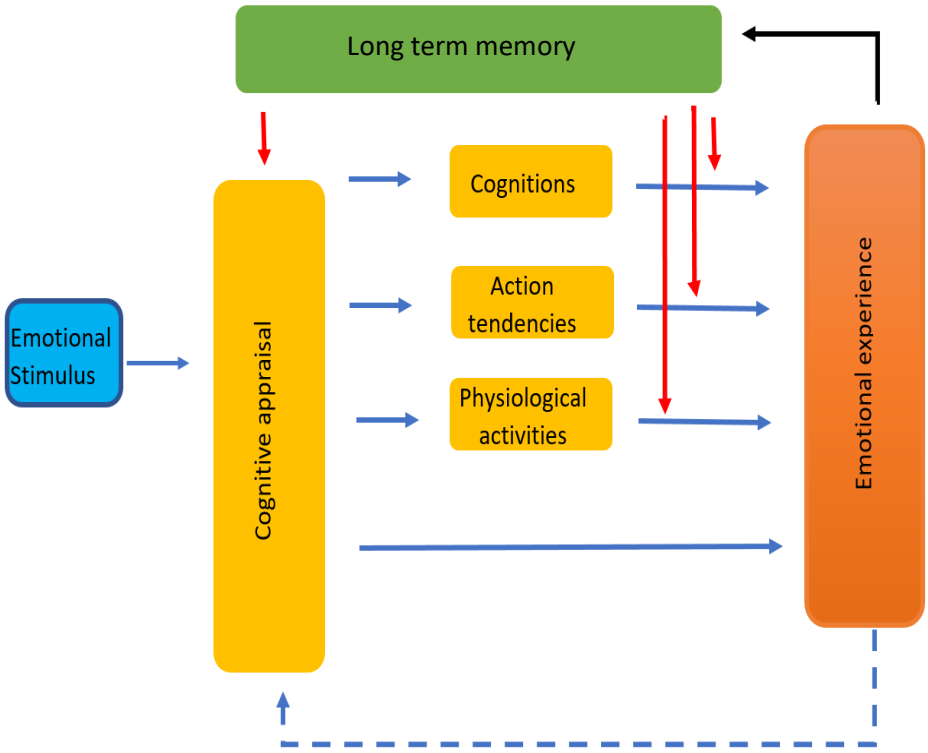


Figure 3.3 Eysenck's four factor theory of anxiety

3.8.3 Big Five personality traits

The Weinberger personality types use two traits, trait anxiety and social desirability, to create four distinct personality types. Eysenck's four factor theory explains how the cognitive biases that each of the personality types have, influence four factors within the emotional system that lead to clear predictions about how each of the personality types should behave. There are, however, more facets to personality than the two that Weinberger used. Trait anxiety has been found to closely resemble Neuroticism with typical correlations between 0.68 and 0.70 (Flett et al., 1989; Watson & Clark, 1984). Social desirability has been linked with Agreeableness with a study finding a correlation of 0.59 (Peterson et al., 2006). Both Neuroticism and Agreeableness are traits found in the Five-Factor model of personality. The Five-Factor model of personality is a hierarchical organisation of five personality traits. These traits are durable characteristics of an individual which Costa and McCrae (1985) defined as: Extraversion,

Agreeableness, Conscientiousness, Neuroticism and Openness. Extraversion is defined by positive emotions, such as gregariousness and the tendency to seek out stimulation. Agreeableness describes an individual's level of cooperativeness and compassion, Conscientiousness refers to carefulness and organizational ability whereas Neuroticism includes negative emotions, such as anxiety and depression, and is commonly defined as emotional instability. Openness captures imagination and intellectual curiosity. The personality traits identified in the Five-Factor model, or Big Five, have been related to a range of physical and mental health conditions. Stickhouser et al. (2017) found that especially Agreeableness, Conscientiousness and Neuroticism had larger effects on physical health than Openness and Extraversion. Banozic et al. (2018) found that higher Neuroticism is associated with higher pain intensity scores in experimentally induced pain, they further found that this relationship is mediated by catastrophising. The authors suggested that high Neuroticism on its own could not be enough to develop chronic pain but that catastrophising, which would heighten the perceived threat of the pain, is an important mediator in the relationship. Further research on Neuroticism and pain found that it is linked to several psychological factors that are associated with increases in pain, such as depression (Hirschfeld et al., 1989; Kadimpati et al., 2015), kinesiophobia (Goubert et al., 2004), and catastrophising (Naylor et al., 2017; Semeru & Halim, 2019). Research using the Five-Factor model in a broad exploratory manner might give a more faceted view of personality traits in chronic back pain that would lend support to Eysenck's theory because there is some overlap between trait anxiety and Neuroticism, social desirability, and Agreeableness. It would also expand upon it by finding personality traits that might have a protective function and decrease the risk of developing chronic back pain. Combining Eysenck's theory and the Five Factor will explore personality traits in chronic pain both deductively and inductively.

3.9 Cognitive biases

Most modern theories and models of pain argue that the way information is processed differs between individuals with chronic pain and non-symptomatic individuals (Fear Avoidance, Threat Interpretation, and Schema Enmeshment Model). Studies have shown that chronic pain participants process pain-related information differently than non-pain-related information (for a review see Pincus & Morely, 2001). There are three information-processing biases in three different cognitive domains: attention, memory, and interpretation (Pincus & Morely, 2001). Out of the three cognitive biases, attentional bias has been researched the most frequently using two different methods: Stroop task and Dot-probe task. The Stroop task requires participants to read the colour of a word but to ignore its meaning (Stroop, 1935). The dot-probe task requires participants to identify a probe that is located behind one of two stimuli. A recent meta-analysis assessing attentional biases within chronic pain populations has found small but consistent attentional biases towards pain related stimuli in chronic pain participants compared to controls (Todd et al., 2018). A reason for the small effect size might be that not all chronic pain participants show the same type of bias and splitting individuals with chronic pain into personality groups might increase the effect size. Eysenck (1997) predicted that the different personality groups would show different attentional biases. This was confirmed by Franklin et al. (2016), who showed that anxiety and defensiveness could influence attentional bias.

Interpretation bias has been investigated using homophone, homonym, or word stem completion tasks. In the homophone task one-syllable words that sound the same but have different meanings are used (e.g., flu vs flew). The homonym task uses words that are spelled the same but have different meanings (e.g., terminal: disease vs airport). The word stem completed tasks asks participants to complete a word after they have seen the first three letters of that word, the stems have at least two ways to complete them and one of those is pain related (e.g., hos: hospital vs hose). Experiments using these tasks (Chan et al., 2020; Khatibi et al.,

2015; Pincus et al., 1994; Pincus et al., 1996) have found that individuals with chronic pain are more likely to interpret the stimuli as threatening or pain related compared to controls. Pincus et al., (1996) used a word stem completion task to assess interpretation biases within a rheumatoid arthritis group. Their results showed that the pain participants were more likely to complete a word in a pain associated way than in a neutral way. There are few studies that have looked at the effect of anxiety and other psychological factors on interpretation bias in a pain population. There is little evidence for an association between interpretation bias and depression (Pincus et al., 1994; Pincus et al., 1996) though it should be noted that the depression score in these studies was not clinically relevant. Based on Eysenck's four-factor theory and the different personality groups it could be argued that the defensive high-anxious group, who catastrophise more, might show a more extreme interpretation bias than the other groups. Repressors, on the other hand, might show an initial interpretation bias but then avoid it once they become aware of it.

The memory bias means that individuals show a preference for remembering information that reflects their current state. For individuals with chronic pain this means that they show a preference for remembering pain-related information over other types of information. The effect of anxiety and defensiveness on memory recall has never been directly investigated in a chronic pain population, but because the effect of emotion on memory encoding is well established (Christianson & Safer, 1996), a number of predictions can be made about the type of memory bias each of the different personality types would present. Due to their general predisposition to high trait anxiety, the defensive high-anxious group would likely show a preference when recalling anxious stimuli. The repressors do not present with high trait anxiety and tend to avoid threatening stimuli and so they would likely not show any preferences for memory retrieval.

3.10 Summary and link

The models explaining pain have evolved over the years from a purely biomedical perspective to now include social and psychological factors. The addition of new psychological and emotional elements has resulted in a much more complex and holistic view of chronic pain that far exceeds the simple notion that pain is always caused by tissue damage. These models explain part of observed behavioural changes and give testable hypotheses. It is hard to say what the fundamental underlying cause of chronic pain is when the models are so scattered. By unifying the different theories, it is possible to find commonalities, contradictions, and gaps within the theories. It is still unknown why some individuals progress to chronic pain while others recover, and what is the most effective treatment for those with chronic pain or if they can predict chronic pain after injury.

Recent behavioural models propose that some chronic pain cases might be caused by an inability to cope with or regulate anxiety and stress (Asmundson & Wright, 2004; Melzack & Katz, 2004). These models state that when predisposition and social factors lead to a negative cognitive appraisal of a stimulus by an individual, their coping resources subsequently fail to deal with the threat and the anxiety heightens. The heightened anxiety releases stress hormones that feedback to the cognitive appraisal adding onto the already existing predispositions. If this feedback happens often enough, it becomes a learned behaviour and self-perpetuating negative feedback loop where the anxiety response is disconnected from the painful sensation and instead becomes linked to the cognitive appraisal of the situation. However, as discussed above dividing individuals with chronic low back pain into low and high anxious does not explain all the results that are found. The additional of different variables (both social and psychological) might be able to better explain the differences in cognitive biases.

3.10.1 Aim and objective

The aim of this project is to extend the understanding of the role of personality types in a chronic back pain population. The objectives are: i) to determine the association between personality traits and chronic back pain in a longitudinal follow-up; ii) to determine the role of personality type in attentional and interpretive bias of individuals with chronic back pain and non-symptomatic controls during a dot-probe task and action observation task; and iii) to assess the imagery ability of individuals with chronic back pain.

4 Methodology

4.1 English Longitudinal Study of Ageing

The English Longitudinal Study of Ageing (ELSA) is the first longitudinal study in England to use a multidisciplinary approach to assess economic, social, and health aspects of older adults living in England. It is argued to be the first study worldwide with an emphasis on the interplay between detailed health and economic processes. The cohort consists of individuals over the age of 50 but under the age of 100 who lived in a private household and took part in the Health Survey England (HSE) and agreed to a follow-up. In addition to this core sample, partners who were aged under 50 years and individuals who joined the household since the HSE were invited for an interview. Data was collected every 2-years since 2002 with the last accessible data collected in 2019. In the ELSA database these 2-year data sets are referred to as waves and there are nine waves in total. The sample was refreshed at wave 3, 4 and 6 to maintain the representation of individuals in the 50-55 age bracket. It assesses a range of variables including symptoms and diagnoses, subjective assessments, and biomarkers. The innovative techniques used to assess indirect measures have reinforced the ability to collect comprehensive financial and health data that is difficult to scale using standard indices. The ELSA cohort study has several pain related questions that cover the specific location or locations of the body that are in pain, the intensity of the pain and its duration that are repeated in every wave. Several previous studies have looked at the interplay between pain and health related outcomes, such as pain and frailty in older men and women (Wade et al., 2017), musculoskeletal pain related isolation and loneliness (Smith et al., 2019), and the effect of physical activity and chronic back pain (Ikeda et al., 2022) using the data of the ELSA cohort study.

The ELSA cohort study assesses the Big Five personality traits (Extraversion, Neuroticism, Openness, Agreeableness, and Conscientiousness) in wave 5 using the Midlife Development Inventory (MIDI) personality scale (Lachman & Weaver, 1997), a shortened

version of the NEO-Five Factor Inventory (NEO-FFI) (McCrae & Costa, 1989). It used the items with the highest item to total correlation and factor loading of the NEO-FFI and has previously been used in the National Study of Midlife in the United Stated (MIDUS) and with 200 resulting publications. Lachman (2005) reported correlations between 0.42 and 0.81 between the MIDI subscales and those of the 60-item NEO-FFI. Doing longitudinal studies with a large sample is both time and cost intensive. The existence of pre-existing cohort studies makes it easier to access a large group of individuals and follow them over a long period. However, the ELSA cohort data is not without weaknesses. The broad nature of the study means that few health-related variables are as specific or in depth as hypothesis driven research. In addition, there are very few ethnic minority participants within the dataset. Attrition is also an issue, it is socio-economically graded and steeper at the less affluent end of the sample and since the data collection starts when participants turn 50 years old data about their life before that was collected retrospectively. However, these limitations are common across all large cohort studies and the other factors make the ELSA cohort study suited for investigating the interaction between personality traits and chronic back pain.

4.2 Laboratory study

Within the current literature there are various methods used for assessing an individual's cognitive biases. This methodology chapter provides a detailed discussion of the considerations that have been taken into account when designing the studies. This methodology chapter is split into four sections: 1) dot-probe task; 2) imagery; 3) action observation (AO) and 4) activity tracker.

4.2.1 Dot-probe task

The dot-probe task, originally called the visual-probe task and developed by Macleod (1986) and current version by Mogg and Bradley (1999), is one of the most widely used tasks for assessing, and more recently altering, emotional attentional biases (Thigpen et al., 2018). In

the dot-probe task, participants are asked to first attend to a central fixation cross presented on a screen, followed by two stimuli (either words or images). A probe then replaces one of the stimuli and the participant must respond either to the type of probe or its location. During the last decade, the dot-probe task has been used to assess attentional biases in chronic pain populations (Schoth et al., 2012). It replaces the previously used emotional Stroop task during which emotional words are presented in different colours and the participant had to name the colour without reading the word. The emotional Stroop task has several shortcomings as shown by the experiments of Algom et al. (2004) who concluded that reading, lexical decision, and colour naming all are slower with emotional words and that this interruption is immune to task-irrelevant variation and to changes in the relative salience of the used words and the colours. A threat-driven slowdown of the reaction time is thought to be caused by lexical processes which happen during the processing of words, not because of a selective attention mechanism associated with the classic Stroop effect. The design of the dot-probe task for the studies within this thesis considered the use of eye-tracking, the stimulus location, Simon effect, stimulus type, stimulus combinations, stimulus presentation length and image rating scales. Each of these factors are discussed below to inform a conclusion regarding the method to be used in the series of studies.

4.2.1.1 Eye tracking

The reliability of the dot probe task has been discussed and found to be lacking (Chapman et al., 2019). Dear et al. (2011) investigated the reliability of the dot-probe task for pain-related attentional biases. They found poor internal-consistency (α range: .56 to .17; split-half r range: .20 to .25). The poor internal-consistency could be explained by a weakness of the dot-probe task, which is that the attention is only assessed at the moment of the probe presentation. As the dot-probe task does not allow for tracking attention continuously over time, eye-tracking methods that trace visual attention by constantly recording the gaze behaviour have been

introduced (Franklin et al., 2019; Vervoort, Trost, Prkachin, et al., 2013; Yang et al., 2013; Yang et al., 2012). Researchers in other fields (e.g., addiction and obesity) have used eye tracking to investigate attention during stimulus presentation. Eye tracking can assess attention orientation (first fixation) and further attention towards the stimuli (maintenance). The different personality types are hypothesised to locate their attention differently at different times. Repressors are hypothesised to show vigilance towards the threat followed by avoidance, whereas the defensive high-anxious could be expected to focus on the threat and either not disengage or disengage later. Eye tracking will also allow the investigation of exactly what participants pay visual attention to within the threatening images.

4.2.1.2 Stimulus location

Stimuli in the dot-probe task can be presented either horizontally or vertically. Of the 12 studies used in a recent meta-analysis (Todd et al., 2018) two used a horizontal layout of the stimuli and 10 used a vertical orientation. It is important to consider how an individual's inherent bias may influence their attentional process when viewing information presented on a screen (Yang et al., 2012). Chokron and Imbert (1993) found that western readers (left to right) showed an attentional bias towards the left of the centre whereas Hebrew readers (right to left) show an attentional bias towards the right of the centre. Rinaldi et al. (2014) found that this horizontal bias was modified by reading habits, but the generation of this bias was caused by hemispheric specialisation and visuospatial processing. The right over left bias is thought to be driven by hemispheric asymmetry in the dorsal visual processing network. Both hemispheres are thought to generate a contralateral bias of attention, whereas the right front eye field is involved in attention to both hemispheric spaces, the left frontal eye field is only involved in attention to the right hemisphere space (Duecker & Sack, 2015). Written texts in western society are usually read from top to bottom which might lead to a preference of the top picture over the bottom one (Nicholls et al., 2004). This bias is linked to an asymmetry in the relative activation

of the dorsal and ventral systems which are connected to the upper and lower visual fields respectively (Drain & Reuter-Lorenz, 1996). Both these eye-scanning strategies may lead to a bias towards the upper or left stimulus because of their spatial location instead of the visual attentional bias towards a stimulus because of the participants cognitive biases. Though neither of these biases can be avoided, they do warrant caution when analysing and interpreting attentional bias in both reaction times and gaze behaviour. For this study, the vertical layout was chosen as this is the most frequently used for pain-related dot-probe studies and most participants are primarily English speakers and readers (Lautenbacher et al., 2010).

4.2.1.3 Simon effect

The design of the dot-probe task carries inherent risk due to its spatial component of being confounded by a Simon effect, regardless of the design of the task. The Simon effect describes a faster reaction time (RT) when the stimulus location and response location correspond (See Figure 4.1 part A and B). The Simon effect shows that spatial information cannot be ignored and will affect response selection (both in time and accuracy), even if the participant knows that the spatial information is irrelevant (Hommel, 1993). There are two main dot-probe designs, Dot-Probe One where participants must respond to the probe location and Dot-Probe Two where participants have to respond to the type of probe. With a Dot-Probe One design, it can be argued that participants will adopt a less even observation of the screen (Schoth et al., 2012; Todd et al., 2018). If the participant only focuses on one side and a probe does not follow the stimulus on that side, it must be on the other side. Thus, the participant can react without shifting their visual attention, adding a validity error into the design.

It could be argued that this design leads to participants focusing solely on one stimulus (e.g., the left side stimulus) and ignoring the other stimulus due to a strategy to respond as quickly as possible, rather than a function of their attentional bias. When this happens, the task might be better described as one that only presents a single stimulus at a time. In this case, if a

probe shares the same location as the emotional stimulus, the Simon effect would facilitate a faster RT. Similarly, if a probe does not share the same location as the emotional stimulus, RT would be slower adding to the time it takes for participants to shift their visual attention, resulting in inaccurate findings and conclusions.

A Dot-Probe Two design encourages the participant to switch their visual attention to the probe, if it is not behind the stimulus they are attending to, in order for the participant to identify the correct probe type. A classic Simon effect can be found in this method, as the probe location becomes irrelevant information, and the type of probe becomes relevant. A faster RT can be found when the location of the probe and the response location match. A slower RT should be found if the probe location and response location do not match.

The Dot-Probe Two design is used more commonly within chronic pain research. One way of minimising the Simon effect would be to decouple stimulus and response location (e.g., using the arrow key left and right to respond to vertical stimulus lay out; see Figure 4.1 part C and D). A limitation of decoupling the stimulus and response location is that participants may find it more difficult to learn the task, which may lead to an increased error rate and a learning effect because there is no stimulus response mapping (Schoth et al., 2012). To overcome this, instead of only having one practice block, studies have multiple practice blocks and start the experiment block after the participant responds correctly in at least 90% of the trials. Multiple practice blocks would allow participants to become familiar with the task and reduce the number of wrong responses and the learning effect.

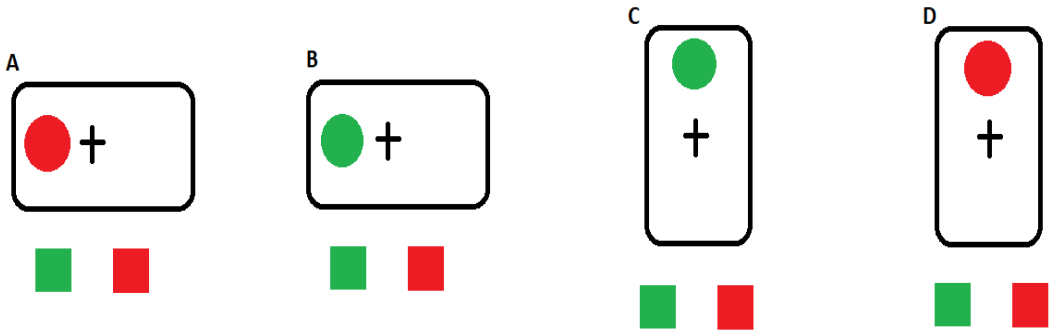


Figure 4.1 Part A and B describe a normal stimulus-response task. In this task, participants have to react to the colour of the stimulus and ignore the spatial location. Part A represents an incongruent trial where the red stimulus is presented on the left side, but the red response button is on the right, which leads to a longer reaction time. Part B represents a congruent trial where the stimulus location and response location are the same, which leads to a shorter reaction time. Part C and D describe a stimulus-response task where the stimulus and response location are decoupled. The stimuli have a vertical layout, but the response buttons have a horizontal layout.

4.2.1.4 Stimulus type

The use of the correct type of stimuli is important. The stimulus should elicit an emotion-based response of interpreting the stimuli as threatening for the chronic pain group but non-threatening for the control group. There has been some debate as to which type of stimulus is the best to use (e.g., sensory pain words, affective pain words, general threat words, images of pain faces or images of pain-related actions) to elicit this response. In the most recent meta-analysis, Todd et al. (2018) discussed the visual attentional biases to pain-related information in dot-probe studies. They found that individuals with chronic pain have a visual attentional bias towards both pain words (d=0.136, p=0.002) and pain images (d=0.110, p=0.045). Word stimuli were further divided into sensory pain, affective pain, general threat and positive. Individuals with chronic pain showed an attentional bias towards sensory pain information (d=0.198, p<0.001). Concerns have been raised about the ecological validity of words as stimuli as they are not always ambiguous, (e.g., stab or sting) (Asmundson et al., 2005; Crombez et al., 2013b; Roelofs, 2003; Roelofs & Hagoort, 2002; Schoth et al., 2012; Todd et al., 2018). Van Ryckeghem and Crombez (2018) argued that symbolic stimuli might not be able to activate relevant pain schemas automatically and the memories linked to the schema, which underpins the occurrence of attentional bias in specific populations. Images could

therefore be more ecologically valid. However, if the images are considered generally threatening (e.g., perceived pain faces or limbs in perceived painful positions) the control group may also show an attentional bias towards the image because their memory schemas may relate the facial expressions to a previous acute pain event that they have experienced (e.g., stepping on a piece of Lego). Eye-tracking studies have found that pain words, and pain related faces lead to vigilance even in healthy populations (Priebe et al., 2015; Yang et al., 2013). However, the Photo Series of Daily Activity (PHODA) (Kugler et al., 1999) contains a back pain specific stimuli set of images of men and women performing everyday actions (e.g., working in the garden or walking up the stairs). These images may be perceived more threatening for a chronic lower back pain population, whereas a control group should have no negative or threatening association with the actions in the images. Another advantage is that these images have implied movement (Kourtzi & Kanwisher, 2000) with a consequential stronger activation of the memory schema as more elements of the stimulus contribute to it. This is supported by theories of pain (Pincus & Morely, 2001) which place an important role on memory when interpreting different stimuli and is supported by Jeannerod's Simulation Theory (Jeannerod, 1994).

4.2.1.5 Image rating

Todd et al. (2018) meta-analysis found that more than half of the reviewed studies did not ask their participants to rate the stimuli presented to them. They recommended that it is important to check if the stimuli that are used during the dot-probe task are relevant and fall into the correct category (i.e., positive, neutral or threat).

Many dot probe studies use images from the International Affective Picture System (IAPS) (Lang et al., 1997) for their neutral and positive images. The IAPS was designed for, and scored by, a healthy population, using the Self-Assessment Mannequin (SAM) (Bradley & Lang, 1994) scale to rate the valence and arousal of the images. However, high anxious and defensive high anxious back pain populations are hypothesised to misinterpret the neutral

stimuli as threatening, because of their cognitive biases, thus they might score certain neutral images as threatening thereby confounding attentional bias scores during the dot-probe task (Eysenck, 1997).

As discussed above, the PHODA (Kugler et al., 1999) database was used to select the threatening back pain specific images. These images have been previously used in dot-probe studies with chronic back pain participants (Roelofs et al., 2005). In their study the participants were asked to rate the images according to how threatening the shown action would be for their back pain. No further rating of the images was performed.

To rate the images of the IAPS and PHODA during this study the SAM scale was used. The SAM scale assesses the valence and arousal of all the images in the dot-probe task. The scale contains five images for each dimension and the scale runs from 1 to 9 with higher scores representing higher arousal and valence scores. Since the IAPS has already been scored using the SAM scale, using it for the PHODA images as well makes it possible to compare arousal and valence scores between the two databases. It also serves as a useful check to make sure the images are in their correct category (e.g., positive, neutral or threat). The internal consistency of the SAM scale has been found to be very good α=0.89 (Naziri et al., 2012).

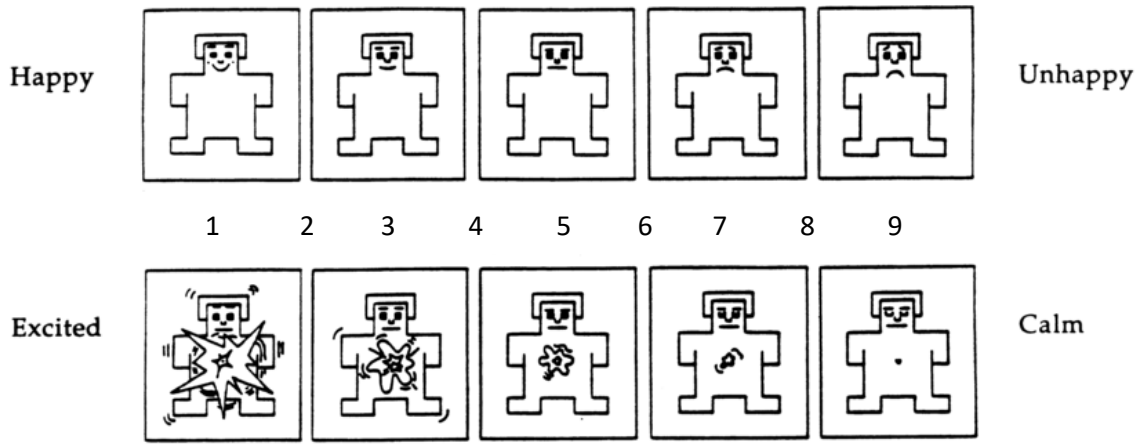


Figure 4.2 The Self-Assessment Manikin (SAM) (Bradley & Lang, 1994) for valence (top row) and arousal (bottom row). The graphic figures and the spaces in between each figure each define a nine-point scale, with 1 in the centre of the left-most image and 9 in the centre of the right-most image.

To further assess the relevance of the threatening images, all participants (including non-symptomatic control) rate the images on an eleven-point Likert-type scale; for how much pain they expect to be in when performing the action seen in the image (0: no pain and 10: pain as bad as could be) and for how fearful they would be of doing the action shown in the image (0: not fearful and 10: extremely fearful).

4.2.1.6 Stimulus combination

Most studies use neutral-threat and neutral-positive stimulus pairs and compare them to neutral-neutral pairs to investigate the direction and size of the attentional bias (Todd et al., 2015).

The neutral images are selected based on their score which is in the middle of the valence and arousal scales (4.5-5.5 ±1 out of 1-9). It is possible that because of the arousal and valence scores, neutral images would not alter visual attention when they are paired with an emotional picture that might moderate the attention bias. To prevent this, when calculating the attentional bias, the neutral-neutral trials are averaged and subtracted from the emotional stimulus reaction times (Franklin et al., 2019). The threat images should score on the other extremes of the valence and arousal scales compared to the positive images. Comparing visual attention between a threat-positive pair should give a more valid attentional bias score.

4.2.1.7 Stimulus presentation length

The stimulus presentation time for dot probe studies varies from 100ms-2500ms (Liossi et al., 2011; Schoth & Liossi, 2010). Most theories of attention and pain have hypervigilance as a central tenant, such as the Schema Enmeshment Model of Pain (SEMP; Pincus & Morely, 2001) and Threat Interpretation Model (Todd et al., 2015). Schoth et al.'s (2012) meta-analysis found a mean between-group effect size ($d = 0.29$, $p<0.0001$) for visual attentional bias to threatening stimuli (both words and images) in the initial orientation phase (<500ms) between

healthy participants and chronic pain participants. The initial orientation phase is associated with hypervigilance (Beck et al., 1985). The same meta-analysis also found a mean between-group effect size (d = 0.42, p = 0.006) for maintained attention (>1250ms) between controls and individuals with chronic pain, which has been linked with sustained attention as a result of continuous cognitive engagement with the stimulus (Donaldson et al., 2007). The different attentional mechanisms of the different personality types could explain the relatively small effect sizes in the initial orientation phase. The maintained attention could be explained by the catastrophising behaviour of defensive high anxious individuals, whereas the repressors' initial vigilance would be seen in an initial visual attention orientation towards the threatening stimulus followed by avoidance (Derakshan & Eysenck, 1997). By using eye tracking and a longer stimulus presentation time it is possible to investigate the differences in initial and subsequent maintained attention of the different personality types that are yet to be investigated within these groups.

4.2.2 Questionnaires to be used in the study

4.2.2.1 Personality type

Personality types will be assessed using two validated questionnaires which assess an individual's levels of social desirability and the trait anxiety.

The 10-item Marlowe-Crowne Social Desirability Scale (MC-SDS; (Strahan & Gerbasi, 1972)) is used to assess defensiveness and to discriminate defensive high-anxious from high-anxious individuals. The scale consists of items that are culturally approved but rarely occur. The internal consistency for the 10-item MC-SDS scale is α=0.66 (Reynolds, 1982).

The trait part of the State-Trait Anxiety Inventory (STAI; (Spielberger et al., 1983)) is used to assess trait-anxiety. The scale consists of 20 items that the participant has to rate on a scale

from 1 (not at all) to 4 (very much so) with a test-retest reliability of between α=0.73 and 0.86 (Spielberger et al., 1983).

4.2.2.2 Pain catastrophising

The Pain Catastrophizing Scale (PCS; (Sullivan et al., 1995)) has 13 items that are used to assess self-reported measure of catastrophic thinking associated with pain. The internal consistency is high with α=0.87 (Sullivan et al., 1995).

4.2.2.3 Disability

The Roland Morris Disability Questionnaire (RDQ; (Roland & Morris, 1983)) contains 24 items that are rated true or false. The higher the score, the more severe the disability. The internal consistency is α=0.90 (Roland & Fairbank, 2000).

4.2.2.4 Self-efficacy

A modified version of the Arthritis Self-efficacy Scale, the Chronic Pain Self-efficacy Scale (CPSS; (Anderson et al., 1995)) specifically made for measuring self-efficacy within people with chronic pain with an internal consistency of α=0.88 (Woby, Urmston, et al., 2007). It assesses the individual's self confidence in their ability to complete a daily task successfully.

4.2.2.5 Kinesiophobia

The Tampa Scale of Kinesiophobia (TSK) assesses the fear of performing a movement. The 17-item assessment has an internal consistency of α=0.79 (Woby et al., 2005). Using the shortened 11-item (Miller et al., 1991) version also helps to keep the amount of questionnaire completion manageable for the participants.

4.2.3 Action observation (AO) task

There is no database for validated threat or neutral videos for individual with chronic back pain. It was therefore necessary to create a new dataset of videos with both threatening and non-threatening videos. Actions from the Back Pain Performance Scale (Strand et al., 2002) were

used as guidance for the design of the new database. There are several variables that should be considered and controlled when matching AO tasks including observation perspective, task nature, object interaction, and instruction (Holmes & Calmels, 2008). A recent study showed that the context of an action (meaningful vs non-meaningful) modulated corticospinal excitability (Riach et al., 2018). Several studies have also found that the type of instruction, "watch passively or with the intention to copy the action later", given prior to the AO task influences the neural profile e.g., (Decety et al., 1997). Roosink and Zijdewind (2010) found a larger increase in corticospinal excitability when participants were instructed to "watch with the intent to imitate the action" compared to when they observed passively with no specific attentional instructions. Two other studies (Clark et al., 2004; Wright et al., 2016) did not find any differences in corticospinal excitability between viewing with the intent to imitate compared to viewing with no specific attentional instructions. Watching with intent to copy would therefore keep the participants engaged and should be closest to a realistic therapy session where an individual with back pain receives the same instruction. It would also be interesting to investigate this specific setting and use it as a steppingstone for the development of video-based rehabilitation applications. This is different from study one but would be more appropriate for this type of stimulus.

Threat:	Neutral:
Pick up paper from floor	Pick up paper from table
Lift box from floor	Lift box from table
Put on sock	Put on glove
Bent over touch toes (MIQ-BP)	Raise arms in front of body (MIQ-BP)
Sit-to-stand (MIQ-BP)	Step forward (MIQ-BP)

4.3 Imagery and self-report measures

An easy and comprehensive method to assess a person's visual and kinaesthetic imagery ability characteristics is the use of self-reported measures. There are several questionnaire type assessments that can be used to assess imagery abilities: the Vividness of Visual Imagery Questionnaire-2 (VVIQ-2) (Marks, 1995) the Motor Imagery Questionnaire (MIQ) (Hall & Pongrac, 1983) and the Movement Imagery Questionnaire-Revised (MIQ-R) (Hall & Martin, 1997) and the most recent MIQ-3 (Williams et al., 2012) as well as the Vividness of Movement Imagery Questionnaire-2 (VMIQ-2) (Roberts et al., 2008). The VVIQ consists of 16 items which assess general visual imagery by asking participants to create and image in their head (e.g., relative or friend, rising sun, front of a shop or a landscape). Participants are then asked to zoom into a specific part of the image they created (e.g., the exact contour of face, head or shoulders of a relative or friend) and score the vividness of it from 1 (perfectly clear and vivid as normal vison) to 5 (no image at all, you "know" that you are thinking of an object). Both the MIQ, MIQ-3, and VMIQ-2 questionnaires specifically assess the generation and vividness of motor imagery. An important reason to select the MIQ-3 is the clear instruction provided for executing the action which differs from the instructions of the VMIQ-2. In the VMIQ-2 participants are asked to imagine kicking a ball but it is not stated what kind of ball or what technique to use and the questionnaire also includes some items that a participant might not have done at all (e.g., swinging from a rope or riding a bike). The many ways the instructions could be interpreted may lead to considerable variation in the mental image produced (Caliari, 2008). Both MIQ and MIQ-3 versions have clear instructions about how to execute the actions and participants are asked to first perform the actions before imagining them. Another advantage of executing an action before imagining it is that differences in imagery ability due to recency effects are prevented as it further primes the images and primes a first-person

perspective. An important improvement of the MIQ-3 upon the older MIQ versions is that the MIQ-3 splits the visual imagery into first- and third-person perspective whereas the MIQ-R only discriminates between kinaesthetic and visual imagery without specifying what type of visual imagery to use. The popularity of the MIQ versions has led to the development of a version adapted for children (MIQ-C; (Martini et al., 2016) and a version developed for upper limb rehabilitation (MIQ-RS; (Gregg et al., 2010). The MIQ-3 assesses the individual's ability to image four movements using first-person visual imagery, third-person visual imagery, and kinaesthetic imagery (Williams et al., 2012). The MIQ-3 has good psychometric properties, internal reliability, and predictive validity (composite reliability 0.7 and above for all subscales) (Williams et al., 2012).

4.3.1 Movement Imagery Questionnaire – Back Pain

The four actions used in the MIQ-3 are: 1) raising the right knee as high as possible; 2) jump in the air as high as possible with both arms extended above the head; 3) move arm forward until it is directly in front of you still parallel to the floor and 4) bend forward at the waist and try to touch your toes. These actions might work well in a healthy population, however, individuals with chronic back pain may not be able or willing to perform some of these actions because of fear and/or pain associated with these movements (e.g., raising the knee and jumping). Forgoing the movement execution before imagery would lose the advantage of mitigating recency effects. After consultation with a physiotherapist, it was decided that two of the actions (jumping in the air and lifting the right thigh) were deemed too demanding and threatening for the back pain group and should be replaced with two different actions. In consultation with a physiotherapist, it was suggested that three replacement actions for the jump; 1) sit to stand without using arms, 2) stepping up onto a larger step, and 3) squatting down. Sit-to-stand was suggested to be the most relevant action because it is often used within back pain assessments and the timed up and go test is also a regular assessment in

physiotherapy. The lifting the right thigh action was replaced with taking a step forward. Both of these actions have a standing position, and because the participant will imagine while standing, it will increase the kinematic and kinetic functional equivalence between the image and the execution of the movement, incorporating the physical element of the PETTLEP motor imagery model (Holmes & Collins, 2001).

A further consideration when changing the MIQ-3 actions is the influence of fear/pain on imagery ability characteristics. By dividing the four actions of the MIQ-3 into two threatening and two non-threatening actions. The effect of pain/fear on the different modalities of imagery can be investigated.

The modified questionnaire, known as MIQ-BP (Movement Imagery Questionnaire - Back Pain), contains the following actions:

1. Raise your stretched arms forward with your palms facing down until they are parallel to the ground (neutral action)
2. Take a single step forward (neutral action)
3. Slowly bend forward at the waist letting your arms hang down (threat action)
4. Stand up with your arms crossed in front of you and your hands are placed at your shoulder (threat action)

The validity of the MIQ-BP was before the main data collection.

4.4 Summary

This chapter discussed different methods used in this thesis. The ELSA cohort study is a well-established database that has previously been used. The large sample size, back pain specific questions, and assessment of personality traits over several timepoints, make it ideal to determine the role that personality traits play in chronic back pain. The methods used to assess attentional biases in chronic back pain patients have been discussed in the light of new

techniques and evolving theory. The dot-probe task in this thesis is enhanced by adding eye-tracking and carefully selecting the stimuli. It further discusses the effect of the layout of the stimuli. The action observation task enabled further assessment of visual attention biases using dynamic stimuli which is more ecologically valid than static images. Finally, this chapter discussed self-report measures to assess motor imagery. Previous motor imagery methods that have been used within the chronic pain population, both to assess imagery ability and as a therapeutic option, have used imagery tasks, left right judgement tasks, and lateral judgement tasks which do not necessarily require motor imagery. Other self-report imagery measures which require an individual to imagine a movement are not always suited for chronic back pain individuals so an update on the measures is required.

5 Study 1: English Longitudinal Study of Ageing - Personality traits

5.1 Introduction

The experience of chronic pain is highly individual and depends on the subjective evaluation of information rather than on objective measures (Wettstein et al., 2019). Pain-related beliefs and coping strategies have shown to be highly valuable in predicting which individual will make the transition from acute to chronic pain. Catastrophising thoughts and avoidance based coping styles have been shown to increase the risk of transitioning from acute to chronic pain (Luque-Suarez et al., 2020; Luque-Suarez et al., 2019; Thompson et al., 2016; Westman et al., 2008). The fear-avoidance (FA) model (Lethem et al., 1983; Vlaeyen et al., 1995) describes a downward spiral of chronic disability caused by pain. The model predicts that those individuals who have catastrophising thoughts and beliefs towards pain (Fordyce, 1976; Turk et al., 1983) will be fearful of situations that might cause them pain and ultimately avoid them. Dersh et al., (2002) proposes that pre-existing personality traits can be predispositions that heighten the negative thoughts and emotions related to pain and can be the foundation for the downward spiral of catastrophising, fear, and avoidance.

Previous studies investigating personality traits and chronic pain have focused on extreme cases of maladaptive behaviour and mainly assessed individuals with a psychiatric diagnosis (Kadimpati et al., 2015; Poppe et al., 2011). Other studies have focused on a heterogenous group with a wide variety of chronic pain conditions including musculoskeletal, fibromyalgia, and neuropathy (Asghari & Nicholas, 2006; Naylor et al., 2017; Poppe et al., 2011). Since 1.71 billion people have a recognised musculoskeletal condition and low back pain is the most prevalent at an estimate of 568 million people worldwide (Cieza et al., 2021), it is important to determine which personality trait profile puts individuals at the highest risk of developing chronic pain. With this knowledge, it might be possible to design personalised

and personality trait focussed interventions to not only help those with chronic pain but also prevent those with a high-risk profile from developing it.

The basic dimensions of personality are known as personality traits and they are the most important ways in which individuals are different in their interpersonal, experiential, attitudinal, emotional, and motivational styles. Historically, there has been disagreement among personality theorists about both the number and importance of personality traits (Cattell argued that there were 16 personality factors whereas H. J. Eysenck identified only three traits). Since the early 1980s the consensus has been that there are five major personality traits which Costa and McCrae (1985) defined as: Extraversion, Agreeableness, Conscientiousness, Neuroticism, and Openness. These five factors are often described as the Five Factor Model (FFM) or the Big Five. For many centuries the idea that personality can influence physical health has existed in medical and philosophical writing (McMahon, 1976). Alexander (1950) and Dunbar (1943) further developed the hypothesis that personality is casually related to health outcomes. Several studies have demonstrated links between personality traits and health. Lahey (2009) reviewed the relationship between Neuroticism, and mental and physical health. Lahey highlighted the direct and indirect evidence linking Neuroticism with health outcomes. Indirect evidence comes from studies that show the strong links between physical health and mental condition, in turn mental conditions such as depression and anxiety disorders are strongly linked with Neuroticism. Direct evidence can be found for a range of conditions including cardiovascular disease (Cukic & Bates, 2015; Suls & Bunde, 2005; Zhang et al., 2021), irritable bowel syndrome (Midenfjord et al., 2021; Spiller, 2007), asthma (Huovinen et al., 2001; Najjab et al., 2020), diabetes (Cukic & Weiss, 2014) and atopic eczema (Buske-Kirschbaum et al., 2001). Bouhuys et al., (2004) found that Neuroticism predicted poor health when other risk factors, depression, and lack of social support, were controlled for. Kern and Howard's (2008) meta-analysis suggested the industriousness and orderliness facets of

Conscientiousness are strongly related to mortality risk. Martin et al. (2007) found that health behaviours partially explain the relationship between Conscientiousness and mortality risk. Hampson et al. (2007), repeated a 40-year longitudinal study which suggests that high childhood levels of Openness, Agreeableness and Conscientiousness were associated with good health in adult life. They proposed that the process works through eating habits, smoking, and educational attainment. These studies show that personality traits can influence health and health outcomes.

Studies that investigated the big five personality traits in relation to chronic pain have focused on Neuroticism. Several studies have found strong links between high Neuroticism and psychological factors that are associated with increases in pain related disability and pain intensity like risk of depression (Hirschfeld et al., 1989; Kadimpati et al., 2015), pain related anxiety (Paulus et al., 2016), increased kinesiophobia (Goubert et al., 2004) and heightened pain catastrophising (Naylor et al., 2017; Semeru & Halim, 2019) within pain populations. The strong association between Neuroticism and these factors has resulted in the neglect of the other four factors and their possible beneficial roles. For example, low Conscientiousness scores are associated with difficulties defining goals and problems with adaptive coping which might impede individuals with chronic pain from coping with their pain (Naylor et al., 2017). Whereas individuals with high Agreeableness rely on their social support systems to relieve stress and the lack of this system might increase pain related stress in those with a high Agreeableness score.

Ibrahim et al. (2020) assessed how the five dimensions of the Five Factor Model (Costa & McCrae, 1997) were associated with anxious mood and beliefs of fear and avoidance within a chronic back pain population in a cross-sectional study. They recruited 102 individuals with debilitating chronic low back pain without psychiatric diagnosis. The individuals with back pain had an average pain score of 5.7 out of 10 and a disability score that indicated severe

disability. The findings revealed that both men and women had significantly lower scores for Openness to experience compared to the general population of France. The average Conscientiousness score for both sexes was significantly higher than the general population. High Neuroticism was associated with higher scores of fear avoidance, clinical depression, and clinical anxiety. All the results remained significant after adjusting for age, gender, duration of chronic pain, and pain intensity level. Women with chronic pain had a higher level of Agreeableness compared to the general female population of France. The cross-sectional nature of this study means that it is not possible to assess temporal differences or causal relationships between back pain and personality traits.

The aim of this study was to investigate the effect of personality traits on three chronic pain outcomes: i) consistent pain group (pain reported in both time points), ii) attained pain (pain reported at follow-up only) and iii) recovered pain group (reported pain at baseline only).

5.2 Method

5.2.1 Participants

The English Longitudinal Study of Ageing (ELSA) was used, which interviews participants every two years, and includes adults over the age of 50 who are living independently. These participants were drawn from the annually collected Health Survey for England (HSE) which collects health data of the general population in England. The ELSA was first collected in 2002-2003 and has since completed nine waves (Chapter 3). Participants were selected from wave five and wave nine. Wave five was collected between 2010 and 2011 and chosen as the baseline because this wave contains personality trait questionnaire and wave nine was collected between 2018 and 2019 and was the most recent wave that could be accessed. Wave five had 10,274 participants in total of which 7,252 were included because they had complete personality trait data, their age range was 50-84 years and 45% were male. Wave nine had a total of 8,736 participants, of which 3,528 had complete personality data and the age range was 52-81 years

and 48% was male. The final sample size of participants in the current study was $N = 10780$ (mean age = 66 years ± 2.67; 46% male).

5.2.2 Measures

5.2.2.1 Back pain

The ELSA cohort study has questions on pain location, intensity, and duration. Pain location was attained by asking participants "in which part of the body do you feel pain?", participants could select from seven different options including back. For pain intensity participants were asked "How would you rate your pain if you were walking on a flat surface?" with zero being no pain and 10 is severe or excruciating pain as bad as you can imagine. For pain duration participants were asked "How long has the pain been bothering you?" here participants could choose from four options; 1) less than three months, 2) more than three months but less than six, 3) more than six months but less than 12 months and 4) more than 12 months. Participants who reported pain in the back that had an intensity score of at least one and lasted more than three months (option two and above) were classified as individuals with chronic back pain. Participants who reported no pain at all were classified as control group. The consistent pain outcome was defined as individuals reporting chronic back pain both at baseline and follow-up. The recovered from pain chronic back pain outcome was defined as individuals who reported chronic back pain at baseline but reported no pain at follow up. The attained chronic back pain outcome was where individuals reported no pain at baseline but reported chronic back pain at follow up.

5.2.2.2 Personality traits

Levels of the five major personality traits, Neuroticism, Extraversion, Agreeableness, Conscientiousness, and Openness, were assessed during wave five (2010-2011) using a shortened version of the Midlife Development Inventory (MIDI) previously used in the US Health and Retirement Survey (Lachman & Weaver, 1997). The dimensions were assessed

using 26 self-ratings of adjectives. Participants were asked to rate the degree to which each adjective described them, on a four-point Likert scale (ranging from 1: all the time to 4: not at all). The adjectives making up each dimension: Neuroticism (4): moody, worrying, nervous, and calm; Extraversion (5): outgoing, friendly, active, talkative, and lively; Agreeableness (5): warm, helpful, soft-hearted, sympathetic, and caring; Conscientiousness (5): organised, responsible, thorough, hardworking, and careless; Openness (7): creative, imaginative, intelligent, curious, sophisticated, broadminded, and adventurous. Each score was calculated by inverting the scoring, leading to higher scores indicating stronger traits and then obtaining the average of the ratings for each dimension. The scales are shown to be reliable and valid measures of the FFM: Cronbach alpha values for these data were 0.78 (Extraversion), 0.80 (Agreeableness), 0.74 (Neuroticism), 0.57 (Conscientiousness) and 0.77 (Openness to experience).

5.2.2.3 Covariates

The following covariates were used: age was treated as a continuous variable, sex was coded as one for male and two for female, pain intensity was treated as a continuous variable where zero was coded as no pain and 10 was the worst pain possible, and physical activity was a categorical variable between zero and three (Ikeda et al., 2022).

5.2.3 Data analysis

T-tests and chi-square tests were used to compare individuals who were classified as having chronic pain with those that were classified as not having chronic pain. Two logistic regression models were used to predict back pain from the big five personality traits. Two models were created for each of the three outcomes. The outcome was the pain status in the baseline and follow up. The consistent pain outcome was defined as individuals reported chronic back pain at both time point, the recovered from pain outcome was defined as individual reported chronic back pain at baseline but reported no pain at follow up, and the attained pain outcome was

where individuals reported no pain at baseline but reported chronic back pain at follow up. Model 1 used the five personality traits, age, and sex to predict chronic pain and Model 2 contained the same predictors as Model 1 and added different levels of physical activity. All models were fit using R 4.1.0 (R Core Team, 2022; RStudio, 2021).

5.3 Results

Table 5.1 contains the baseline characteristics of the participants in total and stratified by group, the pain group includes all those who reported chronic pain at baseline, the non-pain group included all those who did not report any pain. There were 1,391 individuals classified as having chronic back pain and the control group consisted of 5,861 individuals who did not report pain at baseline. At baseline the chronic pain group had significant higher scores for Neuroticism ($t= -13.14$, $p<0.001$), Agreeableness ($t=-7.67$, $p<0.001$), and were significantly older ($t=-6.11$, $p<0.001$) than the control group. The scores of the pain group for Conscientiousness ($t=10.13$, $p<0.001$), Extraversion ($t=12.76$, $p<0.001$) and Openness ($t=7.26$, $p<0.001$) were all significantly lower at baseline compared to the control group. Of the personality traits, Neuroticism and Agreeableness were significantly positively correlated with having back pain ($r=0.165$, $p<0.001$, and $r=0.097$ $p<0.001$ respectively). Conscientiousness, Extraversion, and Openness were all negatively correlated with having back pain at base line ($r= -0.142$, $p<0.001$; $r= -0.167$, $p<0.001$ and $r= -0.1$, $p<0.001$ respectively).

Table 5.1 Descriptive statistics at baseline and comparison between pain and non-pain group

	Total	Pain group		Comparisons
	n=7252	Pain (n=1391)	No Pain (n=5861)	Pain vs. No Pain

	M (SD)	M (SD)	M (SD)	t	p
Neuroticism	2.08 (0.60)	2.29 (0.62)	2.03 (0.58)	-13.14	<.001
Agreeableness	3.15 (0.40)	3.23 (0.41)	3.13 (0.40)	-7.67	<.001
Conscientiousness	3.30 (0.49)	3.16 (0.54)	3.34 (0.47)	10.13	<.001
Extraversion	3.16 (0.56)	2.97 (0.58)	3.21 (0.54)	12.76	<.001
Openness	2.89 (0.55)	2.78 (0.58)	2.92 (0.54)	7.26	<.001

In the follow-up, there were 754 individuals who reported chronic back pain and 2,774 individuals who did not report pain. Of the 754 individuals who reported pain at follow up 445 had consistent pain as their outcome (59%) and 309 did not report pain at baseline and had acquired chronic back pain as their outcome (41%). Of the 2,774 individuals who did not report chronic back pain, 113 (4%) had chronic back pain at baseline and are the recover group. The remaining 2,661 individuals (96%) did not report pain in the follow up nor at baseline and are the no pain group. Table 5.2 displays mean (± SD) for each group. Neuroticism was significantly lower for the no pain group compared to the pain groups, consistent pain ($p<0.001$), recover from pain ($p=0.005$), acquired pain ($P<0.001$). Agreeableness was significantly higher for the consistent pain group compared to the acquired pain group ($p=0.02$) and the no pain group ($p<0.001$). Conscientiousness was significantly lower for the consistent pain group compared to the acquired pain ($p=0.041$) and no pain group ($p<0.001$). The recovered from pain group had significantly lower conscientiousness scores compared to the no pain group ($p=0.024$). Extraversion was significantly lower for the consistent pain group compared to the acquired pain group ($p<0.001$) and the no pain group ($p<0.001$). The recovered from pain group had significantly lower Extraversion compared to the no pain group ($p=0.004$). Openness was significantly lower for the consistent pain group compared to the no pain group ($p<0.001$). The consistent pain group and recover from pain group were both significantly older

than the no pain group (p<0.001, p=0.05). The consistent pain group had the highest pain intensity compared to all the other pain groups at both baseline and follow-up, recover from pain at baseline (p<0.001) and acquired pain at follow-up (p<0.001). At baseline the consistent pain group had a lower physical activity level compared to the no pain group (p<0.001). At follow-up physical activity was the highest for the no pain group compared to the pain groups, consistent pain (p<0.001), recovered from pain (p<0.001), and acquired pain (p<0.001).

Table 5.2 average and standard deviation personality traits and covariates per outcome. Differences between outcomes were tested using an ANOVA and a Tukey post hoc pair wise comparison was used and adjusted p values are displayed.

	Consistent pain	Recover from pain	Acquired pain	No pain	Between groups	
	M (SD)	M (SD)	M (SD)	M (SD)	f	p
n	445	113	309	2661		
Neuroticism	2.28 (2.28)	2.19 (0.62)	2.16 (0.57)	2.00 (0.57)	33.12	<.001
Agreeableness	3.25 (0.39)	3.14 (0.41)	3.17 (0.40)	3.11 (0.40)	15.83	<.001
Conscientiousness	3.24 (0.52)	3.23 (0.53)	3.34 (0.48)	3.37 (0.45)	10.48	<.001
Extraversion	3.02 (0.57)	3.06 (0.54)	3.20 (0.54)	3.24 (0.53)	21.62	<.001
Openness	2.83 (0.56)	2.88 (0.55)	2.91 (0.57)	2.95 (0.53)	5.81	<.001
Age	65.68 (8.75)	66.02 (9.79)	65.09 (8.23)	64.01 (8.05)	7.726	<.001
Pain intensity baseline	6.01 (2.09)	5.16 (2.14)	0.00	0.00	7722	<.001
Pain intensity follow-up	6.03 (2.22)	0.00	4.47 (2.34)	0.00	5353	<.001
	Median	Median	Median	Median	X^2	p
Physical active baseline	1	1	2	2	345	<.001

Logistic regression models tested whether personality traits predicted three possible outcomes, consistent chronic back pain, recovered from chronic back pain, and acquired chronic back pain. Model 1 (Table 5.3) include all personality traits whilst controlling for age and sex. Model 2 (Table 5.3) further controlled for physical activity. For the consistent pain outcome Model 1 showed that the increase of one standard deviation of Neuroticism increased

the change of having back pain at follow-up by 40%. The addition of physical activity level in Model 2 did not mediate the risk of Neuroticism on the risk of getting chronic back pain. Agreeableness also was a risk factor in Model 1 for consistent chronic back pain with one increase in standard deviation leading to 82% change in consistent chronic back pain. Physical activity attenuated the risk to 66%. Conscientiousness had a protective association with one increase in score leading to 18% lesser chance of being in the consistent pain group. This protective factor disappeared when physical activity was controlled for in Model 2. Extraversion had a protective association with a 38% decrease in the odds of being in the consistent pain group in Model 1. Model 2 showed that physical activity did not influence the protective effect of a one standard deviation increase in Extraversion. A one standard deviation increase in age heightened the risk of being in the consisted chronic pain group by 3% in Model 1. Adding physical activity in Model 2 did slightly decrease the risk to 2%.

For the recovery outcome a one standard deviation increase in Neuroticism was associated with a 38% increase in belonging to the recovery group in Model 1. Adding physical activity as a predictor in Model 2 increased the odds of being in the recovery group to 192%. A one standard deviation increased in Agreeableness also increased the odds of belonging to the recovery group by 28%. This increase was no longer significant when physical activity was controlled for in Model 2. Extraversion decreased the odds of belonging to the recovery group by 30% in Model 1. The protecting effect of Extraversion was increased to 81% when physical activity was controlled for in Model 2. A one standard deviation increase in age heightened the risk of belonging to the recovery group by 4%, controlling for age in Model 2 slightly decreased this to 3%.

For the acquired pain outcome neuroticism was a risk factor in Model 1 increasing the odds of acquiring chronic back pain by 36% per standard deviation. Controlling for physical activity in Model 2 resulted in an 181% increase in the odds of acquiring chronic back pain. A

standard deviation increase in Agreeableness increased the odds of acquiring chronic back pain with 18% in Model 1. When controlling for physical activity in Model 2 this increase in risk disappeared. An increase in one standard deviation in age increased the odds of acquiring chronic back pain with 2% in Model 1. When controlling for physical activity the increased odds remained 2%.

Table 5.3 Odds ratios and 95% confidence intervals of back pain incidence associated with demographics, personality traits, and physical activity.

		Consistent pain		Recovery from pain		Acquired pain	
	Predictors	OR (95% CIs)	p	OR (95% CIs)	p	OR (95% CIs)	p
Model 1	Neuroticism	1.41 (1.24-1.61)	<.001	1.38 (1.09-1.75)	.008	1.36 (1.18-1.58)	<.001
	Agreeableness	1.82 (1.59-2.10)	<.001	1.28 (1.02-1.62)	.037	1.18 (1.03-1.37)	.021
	Conscientiousness	0.82 (0.72-0.93)	<.001	0.83 (0.67-1.06)	.122	0.98 (0.84-1.15)	.838
	Extraversion	0.62 (0.54-0.71)	<.001	0.7 (0.55-0.90)	.004	0.96 (0.81-1.14)	.602
	Openness	1.02 (0.88-1.17)	.815	1.12 (0.87-1.46)	.394	0.95 (0.81-1.11)	.495
	Sex F	1.13 (0.90-1.42)	.292	1.01 (0.67-1.52)	.973	0.8 (0.80-1.62)	.08
	Age	1.03 (1.02-1.05)	<.001	1.04 (1.01-1.06)	.004	1.02 (1.01-1.04)	.003
Model 2	Neuroticism	1.42 (1.24-1.63)	<.001	2.92 (1.35-6.52)	.012	2.81 (1.75-4.56)	<.001
	Agreeableness	1.66 (1.43-1.92)	<.001	4.69 (0.83-28.22)	.096	2.76 (0.93-8.36)	.072
	Conscientiousness	0.88 (0.77-1.00)	.051	0.37 (0.09-1.61)	.181	0.96 (0.37-2.58)	.944
	Extraversion	0.68 (0.59-0.79)	<.001	0.19 (0.05-0.74)	.011	0.89 (0.36-2.22)	.796
	Openness	1.03 (0.88-1.19)	.729	2.01 (0.57-7.48)	.294	0.82 (0.38-1.82)	.633
	Sex F	1.21 (0.95-1.54)	.123	1.02 (0.68-1.55)	.912	0.83 (0.64-1.07)	.156
	Age	1.02 (1.00-1.03)	.012	1.03 (1.00-1.06)	.023	1.02 (1.01-1.04)	.017
	low phys active	0.5 (0.29-0.87)	.014	1.59 (0.43-10.83)	.551	0.8 (0.35-2.09)	.621
	med phys active	0.15 (0.09-0.26)	<.001	0.85 (0.24-5.49)	.831	0.65 (0.29-1.65)	.325
	high phys active	0.07 (0.04-0.13)	<.001	0.59 (0.59-3.93)	.512	0.49 (0.21-1.26)	.118

5.4 Discussion

The aim of this study was to investigate the effect of personality traits on three chronic pain outcomes: i) consistent pain group (pain reported in both time points), ii) attained pain (pain reported at follow-up only) and iii) recovered pain group (reported pain at baseline only). An increase in both Neuroticism and Agreeableness was associated with a higher risk of back pain in all three outcomes. Higher Conscientiousness and Extraversion were associated with a lower risk in the consistent pain outcome and higher Extraversion was associated with a lower risk in the recovery outcome. After controlling for physical activity, Neuroticism was still associated with an increased risk across all three outcomes. Moreover, Agreeableness as a risk factor disappeared in the recovery and attained back pain outcomes and Conscientiousness was no longer protective for the consistent pain outcome. Extraversion was still protective for the consistent pain and recovery outcome. All forms of physical activity were protective but only for the consistent pain outcome.

The consistent pain group had the highest pain scores at the baseline and follow-up compared to all the other groups. They were also older than the no pain control group. Controlling for physical activity attenuated the risk of Agreeableness from 82% to 66%, it further negated the protective function of Conscientiousness. Every level of physical activity, low, medium, and high, was protective against the consistent back pain outcome. Two facets of Neuroticism anxiety and depression have previously been shown to be related to the development and maintenance of chronic pain (Castro et al., 2009; Woo, 2010) including results from previous chapters in this thesis. Agreeableness has previously been found to be a predictor for pain anxiety within individuals with fibromyalgia (Martinez et al., 2011; Sanchez et al., 2011). High Agreeableness is further associated with risk avoidance behaviour. This might be protective when people are not in pain but when they are in pain the avoidance of risk (e.g., activities that would cause pain) could lead to a maladaptive behaviour (such as avoiding

physical rehabilitation and increased inactivity) and the downward spiral of fear-avoidance especially when combined with high Neuroticism.

The recovery from pain group had a similar risk profile to the consistent pain group with the exception of a lower pain intensity at baseline than the consistent pain group, and independently Conscientiousness and physical activity had no protective effects. Even though they recovered from back pain at the follow up, their Neuroticism score was the same as that of the consistent pain group and the acquired pain group. Controlling for physical activity increased the risk of Neuroticism, enhanced the protective function of Extraversion, and removed the risk of Agreeableness. It is interesting that controlling for physical activity would increase the risk of Neuroticism, given that findings within the general population show that there is a negative correlation between physical activity and Neuroticism (Wilson & Dishman, 2015). It should be noted that the confidence interval in the second model is much larger than those in the first model leading to a loss of certainty which could be because of missing values in the physical activity variable.

The acquired pain group had higher Neuroticism at baseline that the non-pain control group and reported no pain at baseline and their pain intensity score was lower at follow up than the consistent pain group. Similarly, to the other two pain groups, Neuroticism and Agreeableness were associated with the increased risk of pain. The risk of Agreeableness disappeared when the second model controlled for physical activity. Unlike the consistent pain and recovered group Extraversion had no effect on the outcome. Wong et al. (2015) found that Neuroticism was a significant predictor for the development of chronic pain and negative affect after surgery which they based in the fear-avoidance model. Banozic et al. (2018) found that Neuroticism and pain catastrophising enhance the pain intensity in healthy population. Even though pain intensity is not related to pain chronification, a higher pain intensity has been

related to higher fear-avoidance (Kroska, 2016), and in turn fear-avoidance has been shown to be a model for the transition from acute pain to chronic pain.

This study is not without limitations. First, even though two time points were used to assess the effect of personality traits on chronic back pain, it is not possible to determine causality from this observational study. Also, the design of this study was limited by the measures that were used in the ELSA cohort study. Personality traits were only assessed at one timepoint, which was used as the baseline time point in the current study. However, the personality trait questionnaire was rich enough to be used and there was enough data on chronic pain, location, duration, and intensity of pain to include the most important controls. Furthermore, the personality traits were assessed using a validated and reliable personality measure. There are further strengths to this study that mitigate these limitations. The sample size is large enough to have enough power to create three distinct pain outcomes (consistent pain, recovery and acquired pain) over two time points. This appears to be the first study to use these three classifications.

5.5 Conclusion

This study used a well-established cohort study to investigate the effect of personality traits on three chronic pain outcomes and found that Neuroticism was a risk for both the maintenance and the development of chronic pain. It further found that both Extraversion and Conscientiousness are protective personality traits that decrease the risk of chronic back pain. It further found that physical activity was only protective for the maintenance of chronic back pain outcomes. The personality traits used in this study are broad dimensions and each single trait is made up of multiple sub-traits (e.g., Neuroticism has anxiety, depression, and anger as main sub traits (John and Srivastava, 1999)). Using these broad traits has value because they have some clinical relevance and are often used in big cohort studies like the ELSA, allowing

the assessment of large populations over longer time periods. They give an indication of risk and protective factors for the development and maintenance of chronic back pain.

It is now important to look at personality type more specifically and understand their attentional biases to threatening situations. Neuroticism and Conscientiousness, which the results presented above showed were important risk factors for the development and maintenance of chronic pain, are closely related to trait anxiety and defensiveness respectively. These two traits (trait anxiety and defensiveness), which are explored in more depth in the next chapter, are two key traits in Eysenck's four factor theory. This makes it possible to investigate personality type specific attentional biases using a dot-probe task.

6 Study 2a: Attentional Bias – Dot-Probe

6.1 Introduction

Attentional bias towards pain related information has become an important area of focus for pain research, not only as a possible cause for the development of chronic pain but also as a possible intervention point for new forms of therapy. Attentional bias was first assessed using an emotional Stroop task, but is now more commonly assessed using the dot-probe task (for a full explanation of the dot-probe task see chapter 4.2.1, page 46). The first dot-probe tasks associated with pain used sensory or affective pain words. A meta-analysis to summarise this work was completed by Schoth et al. (2012) and analysed ten studies with a total of 215 different types of individuals with chronic pain and 314 control participants. They found that individuals with chronic pain showed a significantly greater attentional bias towards pain related information than control participants with a Hedges' adjusted effect size of G = 0.36. The attentional bias in the later stages of attention (over 500ms) (d = 0.42) were larger than in the initial stages of attention (up to 500ms) (d = 0.29), suggesting that the attentional bias might be driven more by conscious cognitive processing than subconscious vigilance processing. Another meta-analysis utilised 50 studies with a total of 515 individuals with different types of chronic pain and 1398 controls (Crombez et al., 2013a). They found that the effect size of the attentional bias of individuals with chronic pain was small (d = 0.13) and that it did not significantly differ from that of individuals in control groups (d = 0.08). They also performed a moderator analysis and found that type of stimulus (picture or image) and exposure time affected the presence and magnitude of attentional biases. Todd et al. (2018) meta-analysis found a similar small but significant attentional bias towards sensory pain words (d = 0.14) within individuals with chronic pain but no attentional bias for those in acute pain, anticipating pain, or pain free. Further analysis revealed an attentional bias towards sensory pain words for individuals with chronic pain (d = 0.20) but no bias for affective pain words. One of the main

recuring discussion points in these three meta-analyses using words in the dot-probe task was the lack of ecological validity and thus dot-probe tasks with images became more popular see (Chapter 4 for the full discussion about stimulus validity).

The newest addition to the dot-probe task methodology is the use of eye tracking which allows researchers to assess visual attention in a more direct way to provide markers for attention continuously instead of a button press snapshot attention assessment of the original dot-probe task. A recent systematic review compiled the results of 24 eye-tracking studies investigating the effects of chronic pain, individual differences in pain related concepts (pain catastrophising and fear of pain), stimulus valence, and experimentally induced pain or pain related threat on the attentional bias of individual with and without chronic pain (Chan et al., 2020). Chan et al. (2020) found that pain attracted attention in all populations and gaze behaviour did not differ between pain free and chronic pain individuals. Eye tracking has become more popular as a marker for assessing attentional biases in the chronic back pain population because it is a marker of visual attention compared continuously to the more indirect and snap-shot nature of attention assessment in the dot-probe task. A recent eye-tracking meta-analysis (Jones et al., 2021), investigated if individuals (children or adults) have a greater attentional bias in the initial orientation of attention (during the first 500ms of stimulus presentation) which would show support for the vigilance avoidance theory and/or during the following deployment of attention (after the first 500ms until the stimuli disappears) which would support the maintenance or avoidance theory. Their secondary aim was to investigate the role of task parameters and other moderating variables. Their meta-analysis of 24 studies and with a total sample of 1,425 participants revealed that there are significant attentional biases towards pain related pictures and words for first fixation. It further showed that total dwell time was longer when looking at pain related pictures in both the initial attention orientation phase as well as in the following maintenance phase. There was no effect of group

on these findings, meaning that the attentional bias for individuals with and without chronic pain was the same. The analysis of moderators found significant effects of task parameters and some effect of threat status and study quality.

The ubiquitous attentional bias towards pain found by Jones et al. (2021) could be explained by evolutionary cognitive processes that focus on threat for survival purposes (Priebe et al., 2015; Yang et al., 2013). Pain faces are not enough to identify abnormal cognitive processes within a chronic back pain population because they do not have enough context to differentiate between normal threat related attentional biases and abnormal biases. To better investigate abnormal attentional bias, the stimuli need to have no threat connotations for a control group but need to elicit a threat response in a specific pain group. Other research fields have used stimuli tailored to a specific patient group or even a specific individual (e.g., images of smoking for smokers, (Mogg & Bradley, 2002); alcohol for alcoholics (Field et al., 2013); and specific types of food for anorexics (Shafran et al., 2007). Todd et al. (2018), review advocates that researchers check whether their stimuli elicit a general attentional bias, out of general evolutionary developed threat detection, or if it is an abnormal attentional bias specific to a specific group. There are, however, few studies that have checked, either before or after, for these responses. By having participants rate their fear of a stimulus and whether the stimuli have specific painful associations for them it is possible to check the arousal and valence levels (Childs et al., 2005; Leeuw et al., 2007).

Chan et al. (2020) suggested that the chronic pain group is not as homogenous as previously presumed and that there might be sub-groups with specific cognitive processes which might lead to either avoidance behaviour or difficulty disengaging. Todd et al. (2018) Threat Interpretation Model not only categorises stimuli as pain related or not, but further splits the pain related stimuli as threatening or not. These two categorisations, which lead to different behaviours (normal attentional processing or vigilance avoidance), give a testable hypothesis

for attentional biases. However, the strongest attention bias is found during later conscious attention processes which are related to difficulty disengaging and not vigilance followed by avoidance (Schoth et al., 2012). Vigilance-avoidance has been proposed to fit with the Repressor personality type (Derakshan et al., 2007), whereas the Defensive High Anxious have been found to have difficulty disengaging (Franklin et al., 2016). These opposite behaviours within the same pain population might also explain why effect sizes in recent meta-analyses are small.

It has been advised for individuals with chronic back pain to remain physically active, because long periods of inactivity have been shown to affect recovery negatively (NHS NICE guidelines 2016). There is, however, evidence for a U-shaped relationship between physical activity and low back pain where both ends of the continuum, a total inactivity and continuous strenuous activity are both considered risk factors (Heneweer et al., 2009). Thus, when advising individuals with back pain to move more it is important to get an effective intensity and duration. The fear-avoidance model further states that short term pain due to activity can enhance the fear leading to further avoidance of activity (Vlaeyen et al., 1995). An important element in the fear avoidance model is whether individuals with chronic pain catastrophise their painful experience, as catastrophising leads to the negative spiral of fear of movement, avoidance, and disuse/disability/depression. Changes in beliefs about pain have been found to be associated with a decrease in pain catastrophising and disability (Jensen et al., 2001, 2007). The defensive high anxious individuals would most likely be the group that would develop fear of movement because of their tendency to catastrophise. Whereas the low anxious would confront their fear and overcome it because their low anxiety makes them less likely to catastrophise.

The current study aimed to: i) investigate the different attentional biases within a chronic back pain population depending on their personality type using a dot-probe design and

eye-tracking to assess visual attention continuously; ii) investigate daily physical activity using both self-reported measures and an activity tracker; iii) investigate pain beliefs and the effect of covid on care using a short interview.

6.2 Method

6.2.1 Participants

In total, 38 participants were recruited for this study, nine chronic back pain participants (BPP) and 29 controls. An overview of their demographics can be found in Table 2. Ethical approval for the study was granted by the NHS Research Ethics Committee. Due to the low number of participants, a median split was used to define the cut-offs for the four personality types for both the 10-item MC-SDs (social desirability scale) and the STAI (trait anxiety sub scale) to include all participants who took part in this study (Jensen, 1987; Shaw et al., 1986). See 5.3 for details of the median split.

6.2.2 Measurements

6.2.2.1 Eye tracking

Eye-tracking data was collected using a static eye-tracker (RED 250, SensoMotoric Instruments Tellow, Germany) with a sample frequency of 250Hz and a gaze position accuracy of 0.5°. The eye tracker was calibrated prior to the start of each block using the recommended 3-point calibration. Duration of the first fixation, fixation count, mean fixation duration and mean dwell time during the first 500ms were used as a marker of visual attention during the initial orientation phase (Franklin et al., 2019; Yang et al., 2012). Fixation count, mean fixation duration, and mean dwell time after 500ms were used as markers for maintained attention. As per previous studies, fixations were defined as maintaining the gaze in a radius of less than 1º for a minimum of 100ms (Sharpe et al., 2017; Yang et al., 2012).

6.2.2.2 Dot-Probe Paradigm

Participants were asked to complete a dot-probe task. During this task, participants were presented with a fixation cross in the centre of the screen followed by two images, one on the upper half and one on the lower half of the screen. The images were a combination of threatening (showing an action that mainly involves the back and could be painful for someone with back pain), positive (evoking a positive emotion), or neutral (not evoking any strong positive or negative emotions). The participants started with a practice block containing 20 trials. There were 350 trials in the testing blocks, 100 threatening/neutral images, 100 positive/neutral images, 100 positive/threat images and 50 neutral/neutral images. The image pairs were shown for 2000ms, after this time the images disappeared and in the location of one of the images, a probe appeared, which were two dots either vertically (:) or horizontally (..) orientated. The probe remained in place until it had been displayed for 750ms. The participant had to press as quickly and accurately as possible, one of two keys identifying the probe presented. The fixation cross was presented for between 1,000 and 1,500ms (see Figure 6.1 for an example trial). The trials were divided into five blocks of each 70 trials. The stimuli combination and presentation were fully randomised. The threatening images were taken from the lower back pain specific section of the Photo Series of Daily Activity (PHODA) (Kugler et al., 1999) image bank and the positive and neutral images from the from International Affective Picture System (IAPS) (Lang et al., 1997) based on arousal and valence measures. The size of each image was 15 x 10cm. This dot-probe task was delivered to keep participants engaged during the task.

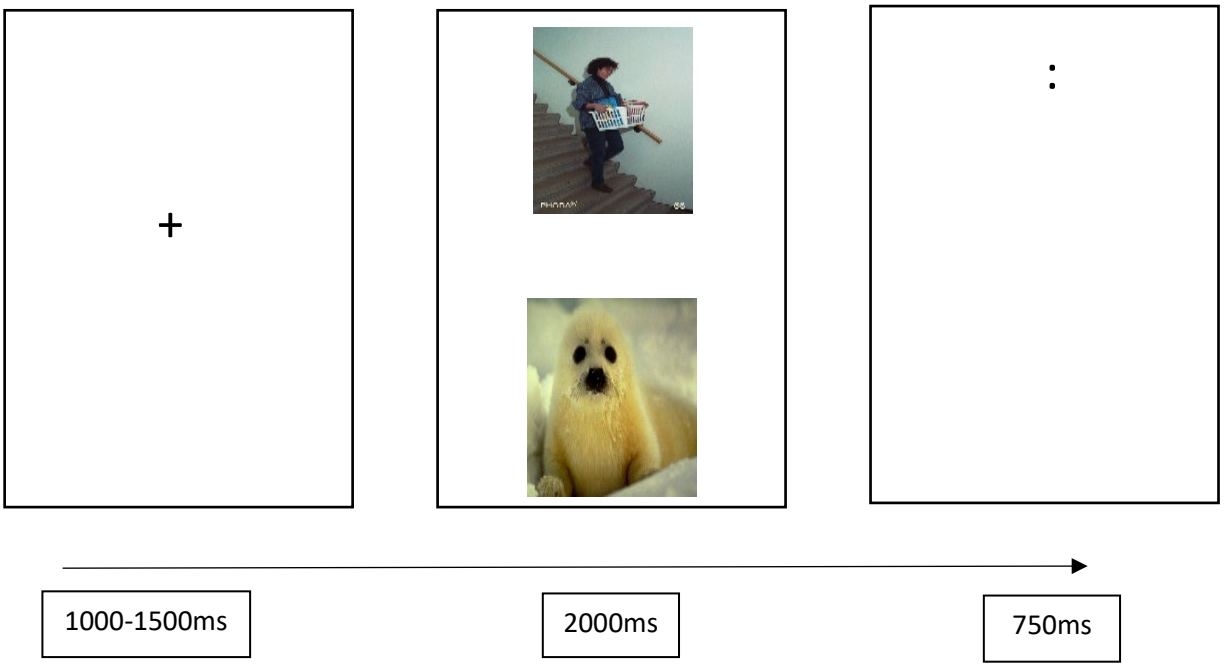


Figure 6.1 Example of the three stages of the dot-probe task in the positive threat condition. First is the initial presentation of fixation cross for 1,000 to 1,500ms. Images are presented for 2,000ms. A pair of dots appear behind one of the images for 750ms

6.2.2.3 Questionnaires

Participants were asked to fill out a range of validated questionnaires. The 10-item Marlowe Crowne Social Desirability Questionnaire (MC-SDS) (Strahan & Gerbasi, 1972) and trait part of the STAI (Spielberger et al., 1983) were used to form the base of the personality type classification. Participants further completed the Pain Catastrophising Scale (PCS) (Sullivan et al., 1995), the Roland-Morris Disability Questionnaire (RDQ) (Roland & Morris, 1983), the Chronic Pain Self-efficacy Scale (CPSS) (Anderson et al., 1995), and the 11-item Tampa Scale for Kinesiophobia TSK (Miller et al., 1991) using the JISC® software. For full details of questionnaire see Chapter 3.

Pain intensity on the day of testing over the previous 24-hours was assessed via a scale from (0) no pain to (10) pain as bad as could be. Age, sex, current employment situation, and medication use was also recorded.

6.2.2.4 Stimuli rating

The self-assessment mannequin scale (Figure 6.2) (Bradley & Lang, 1994) assessed valence and arousal. For the threat images fear and pain were assessed along a visual scale from (0) not fearful/no pain to (10) very afraid/pain as bad as could be as well as familiarity. For positive and neutral images only, fear was additionally assessed. The stimulus rating was performed using custom built PsychoPy software (Peirce et al., 2019; Peirce, 2007).

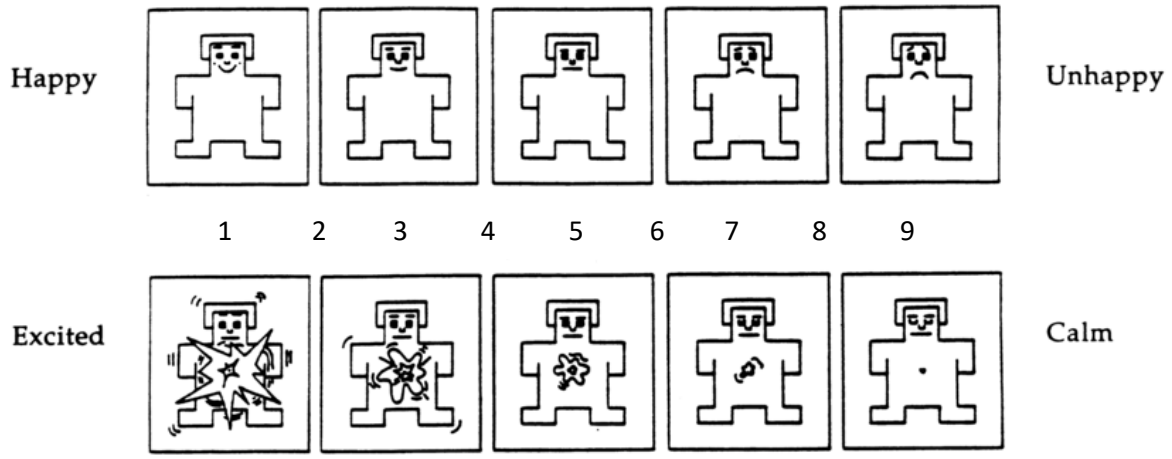


Figure 6.2 The Self-Assessment Manikin (SAM) (Bradley & Lang, 1994) for valence (top row) and arousal (bottom row). The graphic figures and the spaces in between each figure each define a nine-point scale, with 1 in the centre of the left-most image and 9 in the centre of the right-most image.

6.2.2.5 Daily physical activity

At the end of the first laboratory session, the participants were fitted with a triaxial accelerometer of 4x4x1 cm (GENEA, Activinsights Ltd, Kimbolton, UK) to assess habitual physical activity over a 7-day period. The accelerometer was worn like a wristwatch on the left or right wrist depending on the participants preference. The device was worn continuously for 7 days and placed no restrictions on the activity of the participants. If participants experienced any adverse reaction to the strap, they were advised to take it off immediately. The device was set-up with: i) a sample frequency of 100Hz; ii) the wrist that the participant wore it on and; iii) was validated for this type of measurement.

Participants completed a daily activity diary, where they were asked to record the amount of low, moderate, high and inactivity per day, when they went to bed and woke up, and in case they took the tracker off, when it was reattached.

6.2.3 Procedure

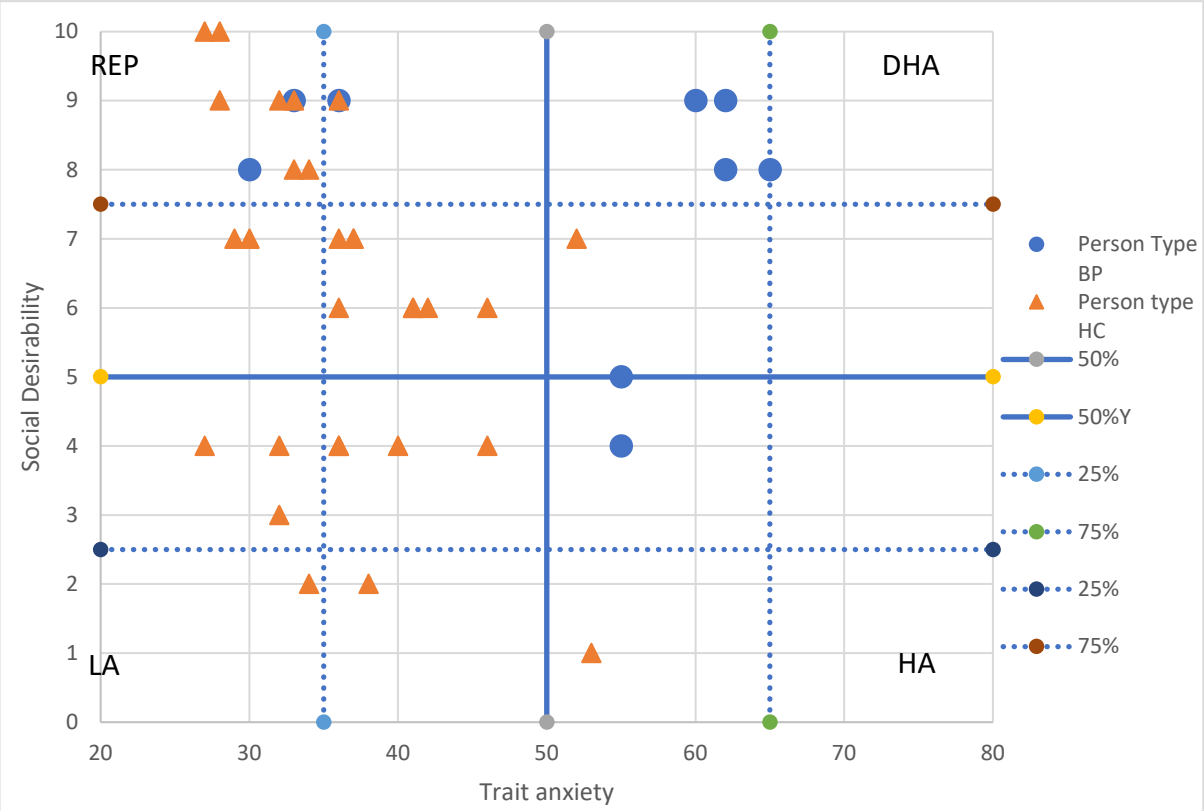
At the beginning of the session participants were asked to fill in a series of validated questionnaires assessing, disability, kinesiophobia, personality type, self-efficacy, and catastrophizing. Participants were then asked to sit at a table at approximately 40cm from 22-inch screen which has a RED 250 (SensoMotoric Instruments Tellow, Germany) static eye-tracker integrated under the screen. After the dot-probe task, participants were asked to rate their expected pain and fear ratings for the images. For both fear and pain, participants were asked to indicate on an eleven-point Likert-scale i) how much pain they would expect to experience when they perform the action shown in the image (0: no pain and 10: pain as bad as could be) and ii) how fearful they would be of completing the action (0: not fearful and 10: extremely fearful). They were also asked whether they have performed this action in the last three months (yes/no/don't know). As well as ratings on the emotions the images evoke, participants rated the images on arousal and valence of the images using the SAM scale. These questions were presented to them using bespoke PsychoPy software. A short interview was conducted asking participants about their pain beliefs, their experience during covid and their care during covid. At the end of the session, the participant was fitted with the accelerometer.

6.2.4 Data analysis

All data was analysed in SPSS (IBM Corp. Released 2020. IBM SPSS Statistics for Windows, Version 27.0. Armonk, NY: IBM Corp) after being exported from the original software. Due to the small sample size of back pain participants (n= 9) and control group (n= 29) a Shapiro Wilk's test was used to test for normality. If a variable had a normal distribution average and

SD were reported and appropriate parametric tests were selected. If a variable had a non-normal distribution the median was reported, and appropriate non-parametric tests were selected.

Figure 6.3 Diagram showing the trait anxiety on the x-as and social desirability on the y-as. Back pain participants



are represented as blue circles and the controls as orange triangles. The dotted lines are 25% and 75% the solid line is 50%.

6.2.4.1 Eye-tracking

For the dot-probe task Areas of Interest (AOI) were drawn around each image, the fixation cross, and the probes. Each AOI coded the type and location (Threat_Top, Threat_Bottom, Neutral_Top, Neutral_Bottom, Positive_Top, Positive_Bottom) of each image (see Figure 6.4 for an example). To account for the inherent natural bias of individuals to look at the top image first, the neutral-neutral trials were used as a baseline condition. To assess the time course of attention data was split into early attention (< 500ms) and maintenance (501-2000ms).

6.2.4.2 Stimuli rating

The PsychoPy programme (Peirce et al., 2019; Peirce, 2007) saved the response values for all participants in an Excel spreadsheet in a dedicated data folder. Valence and arousal were coded on a 0 (centre of the leftmost image) to 9 (centre of the rightmost image) on the SAM scale. Meaning that a score of 0 on arousal or valence represents excitement or happiness respectively and a score of 9 represents calmness or unhappiness. A score of 5 is neutral on both. For pain and fear a higher score meant higher pain or fear expectation. The familiarity was coded as 0 (have not done this movement in the last 3 months), 1 (have done this movement in the last 3 months) or 2 (don't know). For the images used in the dot-probe task scores were averaged per participant per stimulus type (threat, neutral and positive).

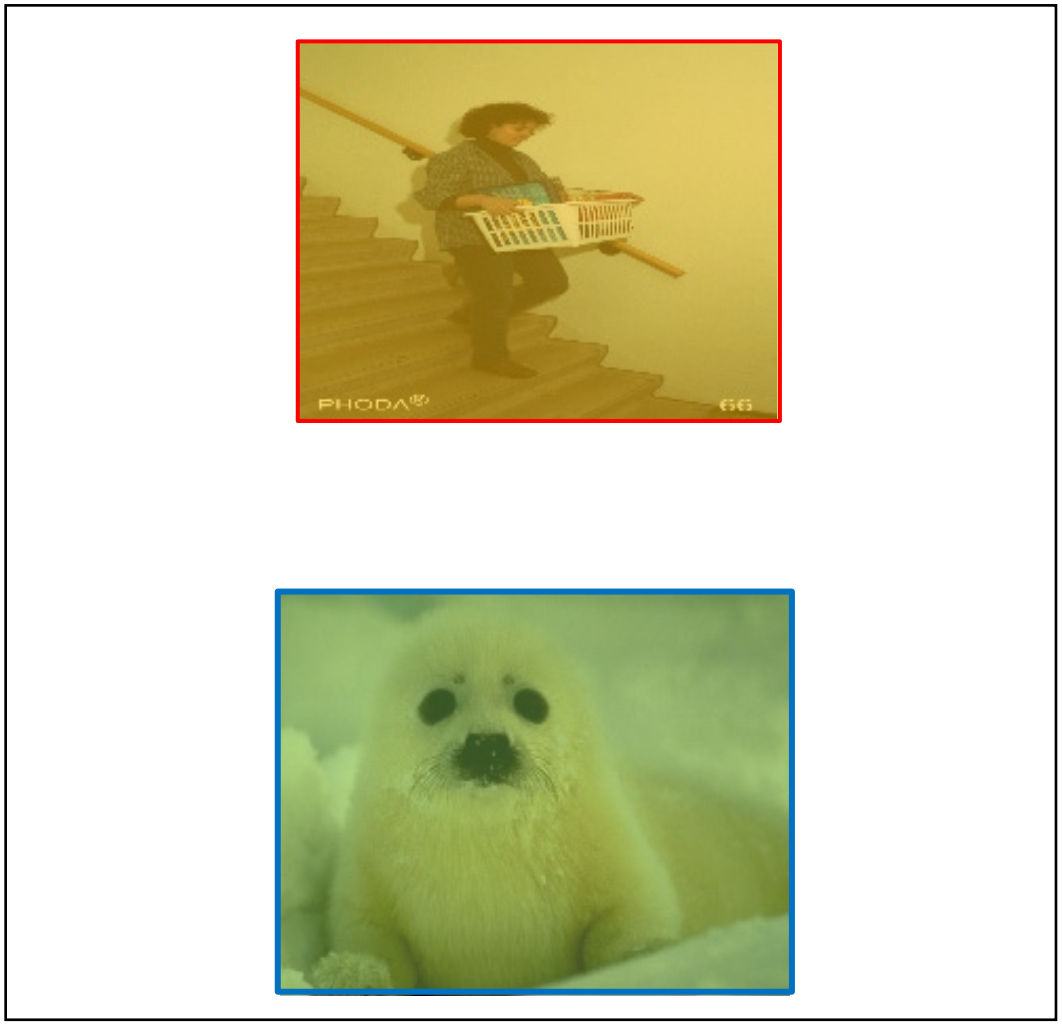


Figure 6.4 Example of AOI drawn on a threat positive trial. The yellow overlay with red border would be the Threat_Top AOI and the green overlay with the blue border would be Positive_Bottom AOI.

6.2.4.3 Daily activity

Data of the activity tracker was analysed if there was seven days of data. The activity tracker data was analysed with an R script provided by the manufacturer (GENEactive, Kimbolton, UK). The activity tracker data software classified activities as either low, medium, or high, and further measured sitting and sleeping time. The output was the total seconds per day spent in each of the activity levels, sedentary and sleep. It also counted total daily steps. The data of the activity diary was analysed if it was filled out completely. To make the two data sets comparable activity, sedentary and sleep times from the activity tracker were converted into minutes.

6.2.4.4 Participant interview

The data from the short interview were analysed using six-step thematic analysis, as described by Braun and Clarke (Braun & Clarke, 2006). The first step in the analysis involved initial familiarisation with the interview by reading the whole transcript, followed by the second step of annotating the interviews. Step three was identification of initial codes. Step four was the identification of themes and step five was the naming, reorganising, and completion of themes. Step six was theme comparison and write-up.

6.3 Results

6.3.1 Participants

Participants were classified along a median split to create four different personality groups, i) defensive high anxious defensiveness score above 5 and trait anxiety score over 50, ii) repressors defensiveness score above 5 and trait anxiety score under 50, iii) high anxious defensiveness score under 5 and trait anxiety over 50 and, iv) low anxious defensiveness score below 5 and trait anxiety score under 50 (see Figure 5.3). Using the median split the back pain group had five defensive high anxious, three repressors, one high anxious and zero low anxious individuals. The control group had one defensive high anxious, 18 repressors, one high anxious

and nine low anxious individuals. Table 6.1 has an overview of the number, age, sex, defensiveness scores, and trait anxiety scores for each participant group and per personality group.

Table 6.1 Median values of age in years, sex, defensiveness score and trait anxiety score per personality type (DHA: defensive high anxious, REP: repressors, HA: high anxious, LA: low anxious) and participant group (back pain or control). As well as the number of participants in each group.

	Back pain participants (BPP)				Controls				
	DHA	REP	HA	Total	DHA	REP	HA	LA	Total
N	5	3	1	9	1	18	1	9	29
Age (years)	32	28	36	31	34	26	26	28	26
Sex male	3	1	1	5	1	7	1	3	12
Defensiveness	8	9	4	8	6	7	1	4	6
Trait Anxiety	62	33	55	55	42	35	53	36	36

6.3.2 Demographics

6.3.2.1 Control vs back pain

The Shapiro Wilk's test showed all the variables violated the assumptions of a normal distribution. Based on this, and after visual inspection of the QQ-plots, the non-parametric Mann-Whitney U test was chosen to test for differences between the control and back pain group. All participants reported that they were either in full employment or that they were fulltime students. The chronic back pain participants (BPP) reported median pain duration of seven years and with a median pain score on the test day of four out of ten. The median age for the BPP was 31 years old and 26 for the control group. A Mann-Whitney U test indicated that the difference in age was non-significant U ($N_{back\ pain}$= 9, $N_{Controls}$= 29) = 77.00, z= -1.86 , p= 0.063. There was also no significant difference between the median defensiveness score of the BPP (Mdn = 8) and control group (Mdn = 6) U ($N_{back\ pain}$= 9, $N_{Controls}$= 29) = 82.00, z= -1.68 , p= 0.092. The median trait anxiety score of the BPP (Mdn= 55) was significantly higher than the median trait score of the controls (Mdn= 36) U ($N_{back\ pain}$= 9, $N_{Controls}$= 29) = 56.00, z= -2.57, p= 0.010. The BPP had higher median scores for disability ($Mdn_{back\ pain}$= 34, $Mdn_{controls}$=

24) U ($N_{back\ pain}$= 9, $N_{Controls}$= 29) = 0.00, z= -5.00, p< 0.001, pain catastrophising (Mdn= 34, $Mdn_{controls}$= 15) U ($N_{back\ pain}$= 9, $N_{Controls}$= 29) = 10.50, z= -4.19, p< 0.001 and kinesophobia (Mdn= 32 $Mdn_{controls}$= 14) U ($N_{back\ pain}$= 9, $N_{Controls}$= 29) = 7.00, z= -4.29, p< 0.001. The control had a significant higher self-efficacy median score (Mdn= 81) compared to the BPP (Mdn= 58) U ($N_{back\ pain}$ = 9, $N_{Controls}$= 29) = 258.00, z= 5.47, p< 0.001. Figure 6.5 has an overview of the questionnaire scores per participant group.

6.3.2.2 Back pain personality types

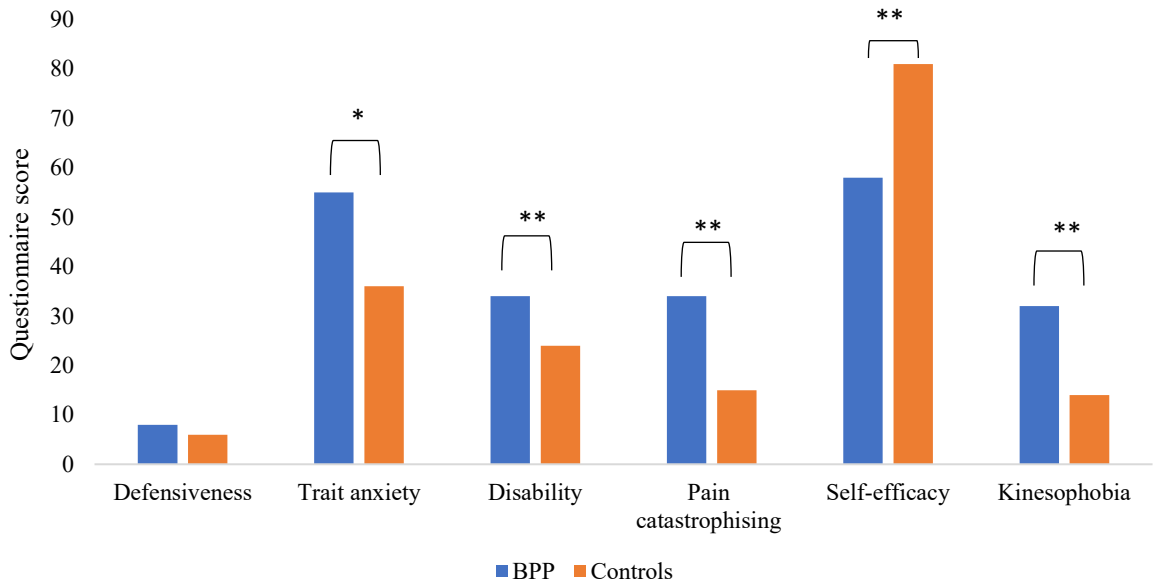


Figure 6.5 Median defensiveness, trait anxiety, disability, pain catastrophising, self-efficacy and kinesophobia scores for back pain participants (BPP) and control group. *p=0.05, **p<0.001

Due to the low number of individuals in each personality type of the back pain group, repressors (n= 3), defensive high anxious (n= 5), and high anxious (n= 1) only descriptive values are presented. Figure 6.6 shows the median score per personality type for disability, pain catastrophising, self-efficacy, and kinesophobia.

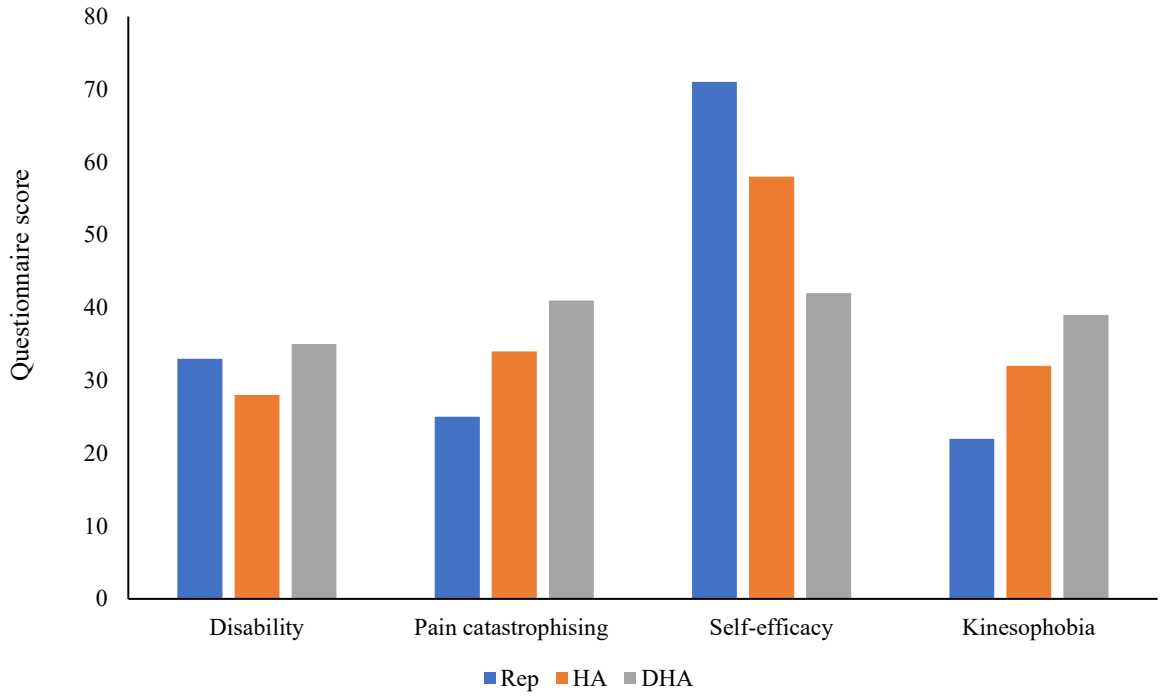


Figure 6.6 Disability, pain catastrophising, self-efficacy and kinesophobia score for REP: repressors, HA: high anxious, DHA: defensive high anxious and controls.

6.3.3 Dot-probe task

6.3.3.1 Image rating

The Shapiro Wilk's test showed all the variables violated the assumptions of a normal distribution. Based on this and after visual inspection of the QQ-plots the non-parametric Chi^2 test was used to assess whether there was a difference in fear, valence, and arousal scores of the different type of images (neutral, positive and fear). Post hoc analysis with Wilcoxon Signed Ranked Test was conducted with a Bonferroni correction applied, with a new significance level set at $p<0.017$. For the control participants there were no significant differences between the fear $X^2(2) = 4.845$, $p= 0.089$ and arousal $X^2(2) = 3.373$, $p= 0.185$ scores. There was a significant difference in the valence scores $X^2(2) = 39.622$, $p< 0.001$, post hoc analysis revealed higher valence scores for the neutral images compared to the positive image ($Z= -4.51$, $p<0.001$), higher valence score for the threatening image compared to positive

(Z= -4.51, p<0.001), and a higher score for the neutral images compared to the threatening images (Z= -2.547, p<0.011). See Figure 6.7.

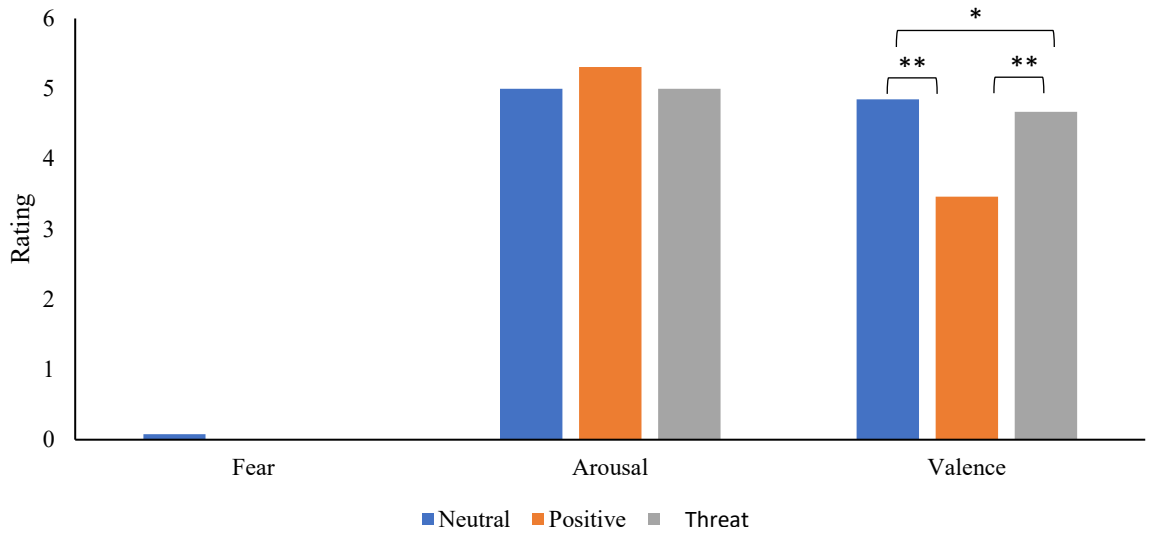


Figure 6.7 Median fear, arousal, and valance scores for the neutral, positive and threat type images for the control group.

For the BPP the Chi^2 test revealed significant differences in fear $X^2(2) = 14.970$, p<0.001 and valence $X^2(2) = 16.222$, p<0.001 scores depending on the type of image. Post hoc analysis for the fear scores showed that there was no significant difference between positive and neutral images (Z= -0.738, p=0.461), there were significant differences between threat and positive images (Z= -2.67, p= 0.008) and between neutral and threatening images (Z= -2.67, p= 0.008). Post hoc analysis for the valence scores showed that there were significant differences between positive and neutral (Z= -2.67, p= 0.008), positive and threat (Z= -2.67, p= 0.008) but no significant difference between neutral and threat (Z= -2.19, p= 0.028). See Figure 6.7 for the median scores.

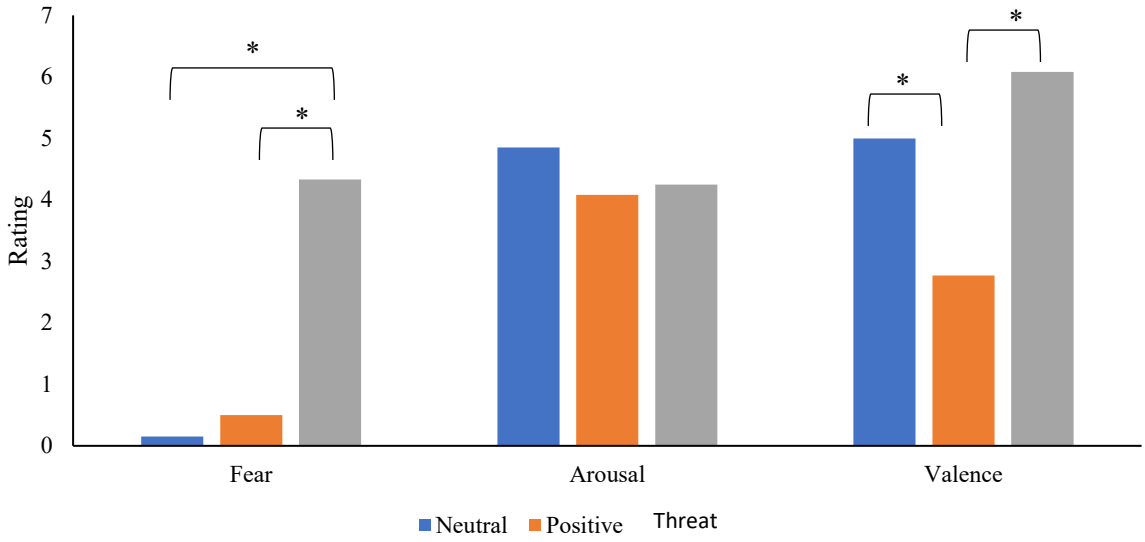


Figure 6.8 Median fear, arousal, and valence score for the chronic back pain group per image type. *p=0.05

Median fear, pain, familiarity, arousal, and fear of the images used in the dot-probe task score are represented in Figure 6.9. Differences in image rating scores between groups (back pain and controls) were assessed using a Mann-Whitney U test. There were no differences in any of the rating for the neutral images for the threat or familiarity score. For the positive images there was no difference for fear scores, but the BPP scored significantly lower for both arousal U ($N_{back\ pain}$= 9, $N_{Controls}$= 29) = 206,00, z= 2.59, p< 0.009 and valence score U ($N_{back\ pain}$= 9, $N_{Controls}$= 29) = 192.5, z= 2.13, p< 0.033. For the threatening images BPP scored higher on pain U ($N_{back\ pain}$= 9, $N_{Controls}$= 29) = 0.00, z= -4.60, p< 0.001, fear U ($N_{back\ pain}$= 9, $N_{Controls}$= 29) = 4.00, z= -4.84, p< 0.001 and valence U ($N_{back\ pain}$= 9, $N_{Controls}$= 29) = 23.00, z= -3.70, p< 0.001. Controls scored higher in the threat arousal score U ($N_{back\ pain}$= 9, $N_{Controls}$= 29) = 234.00, z= 3.57, p< 0.001.

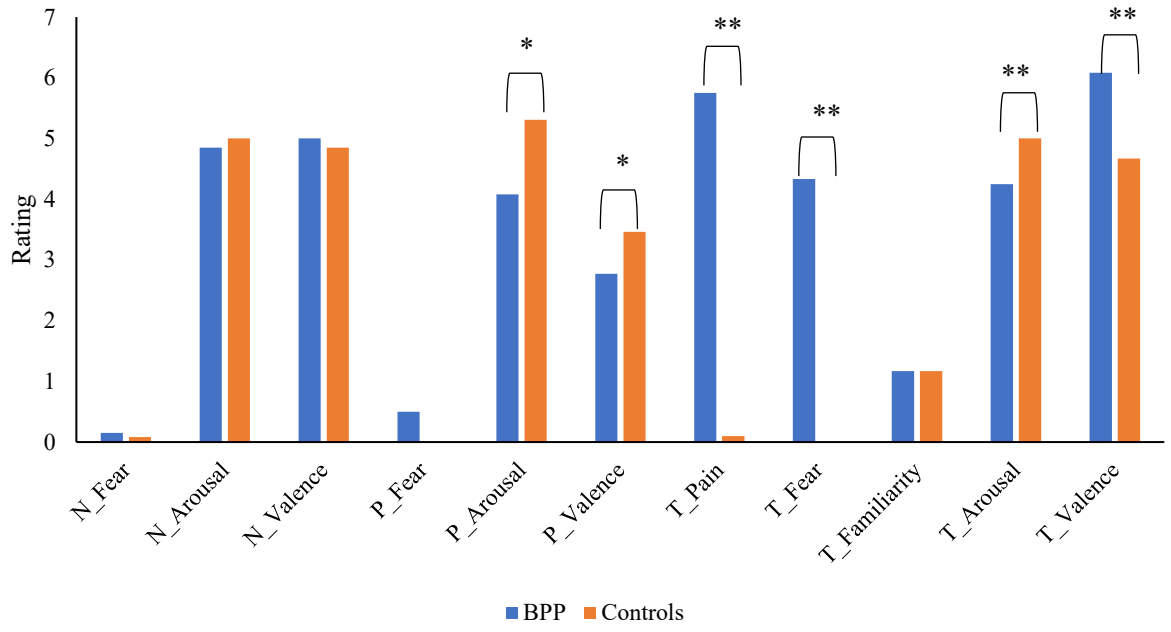


Figure 6.9 Median fear, pain, arousal, and valence score for the back pain and control group per image type, N: neutral, P: positive and T: threat. *p<0.05, **p<0.001

Figure 6.10 shows the median values split per personality type of the back pain group. Because the high anxious group only has one person it is not possible to apply any statistical analysis. The DHA group had median fear scores of 0.08, 0 and 6.25 for the neutral, positive, and threat images respectively. The high anxious group had median fear scores of 0.15, 1.3 and 3.41 for neutral, positive and threat images respectively. The repressor group had median fear scores of 0.46, 0.50 and 1.25 for neutral, positive and threat images respectively. The median neutral arousal scores were 4.92 for repressors and 4.85 for both high anxious and defensive high anxious. Median valence scores for the neutral image were 4.85 for the repressors and 5.08 for both high anxious and defensive high anxious groups. For the positive image median arousal scores were 4.38, 3.77 and 4.08 for repressors, high anxious and defensive high anxious respectively. Arousal scores for the positive image were 2.77 for repressors, 2.23 for high anxious and 2.85 for defensive high anxious. The median pain score for the threatening image was 3.00 for repressors, 3.75 for high anxious, and 6.42 for defensive high anxious. The median arousal score for the threatening image was 5.00 for repressors, 4.25 for high anxious and 4.00

for the defensive high anxious. The valence score for the threatening image was 5.33 for repressors, 6.08 for the high anxious and 6.03 for the defensive high anxious.

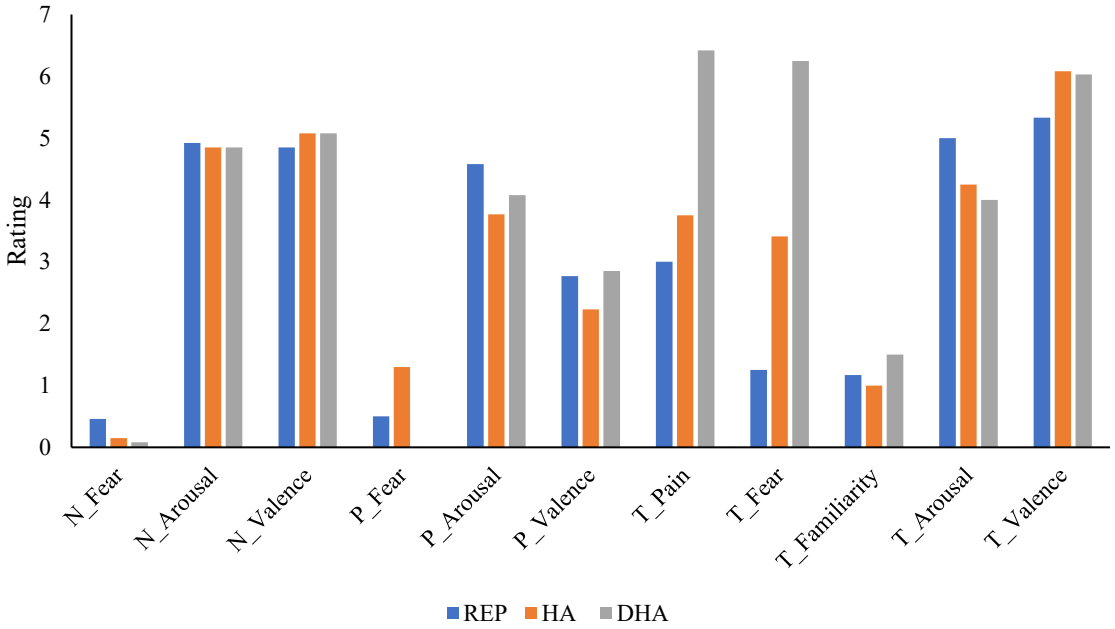


Figure 6.10 Median fear, arousal, valance, and pain scores for the neutral, positive and threat type images for the back pain group split into personality type. REP: repressors, HA: high anxious, DHA: defensive high anxious, N_ neutral images, P_ positive images, T_ threatening images.

6.3.4 Eye-tracking

The Shapiro Wilk's test showed all the variables violated the assumptions of a normal distribution. Based on this, and after visual inspection of the QQ-plots, the non-parametric Mann-Whitney U test was chosen to test for differences between the control and back pain group. The data is split into two epochs, the first is 0 to 500ms assessing initial attention and the second is 501 to 2,000ms assessing maintained attention. During the first 500ms first fixation duration, dwell time as a percentage of total, average fixation duration, and fixation counts were measured. During the second time frame, 501 to 2,000ms, dwell time as a percentage of total time, average fixation location, and fixation counts were measured. Because of the low number of participants in the chronic back pain group only descriptive results are presented.

6.3.4.1 Initial attention

6.3.4.1.1 First fixation

For the first fixation duration the overall trend was that the control group had a longer first fixation for the top image than the back pain group and the back pain group had longer first fixations on the bottom image (See Figure 6.11). The Mann-Whitney U test showed that this difference was only significant for the threat-positive image combination where the back pain group had a significant longer fixation median on the threatening image when it was on the lower half of the screen U ($N_{back\ pain}$= 9, $N_{Controls}$= 29) = 68.50, z= -2.193, p= 0.032 compared to the control group. In the same threat-positive image combination BPP also had a longer median first fixation when it was a positive image at the lower half U ($N_{back\ pain}$= 9, $N_{Controls}$= 29) = 54.50, z= -2.635, p= 0.008 compared to the control group.

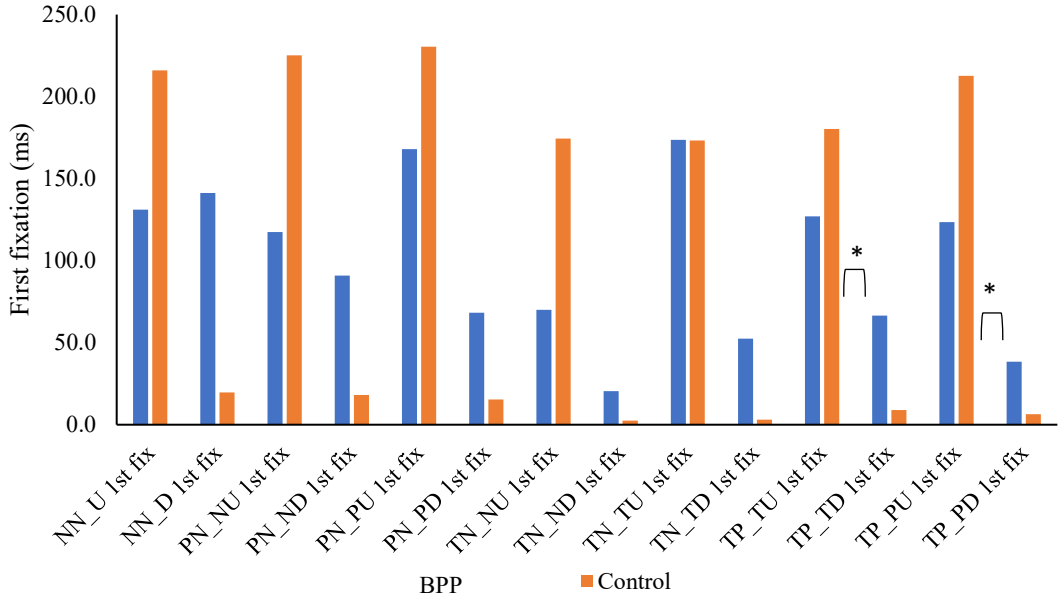


Figure 6.11 Median first fixation duration in ms per image pair, NN: neutral-neutral images, PN: positive-neutral, TN: threat-neutral, TP: threat-positive, PU: positive image upper, PD: positive lower image, TP: threatening upper image, TD: threatening lower image per patient and group for back pain and control participants *p<0.05

The median first fixation durations per back pain personality types are presented in Figure 6.12. The overall trend for the repressors seems that they had longer median first fixations on the top image then at the bottom image for all image combinations (neutral-neutral, positive-neutral, threat-neutral and positive-threat). The median first fixation duration of the high anxious and defensive high anxious appear to be similar and more evenly distributed between the top and bottom images.

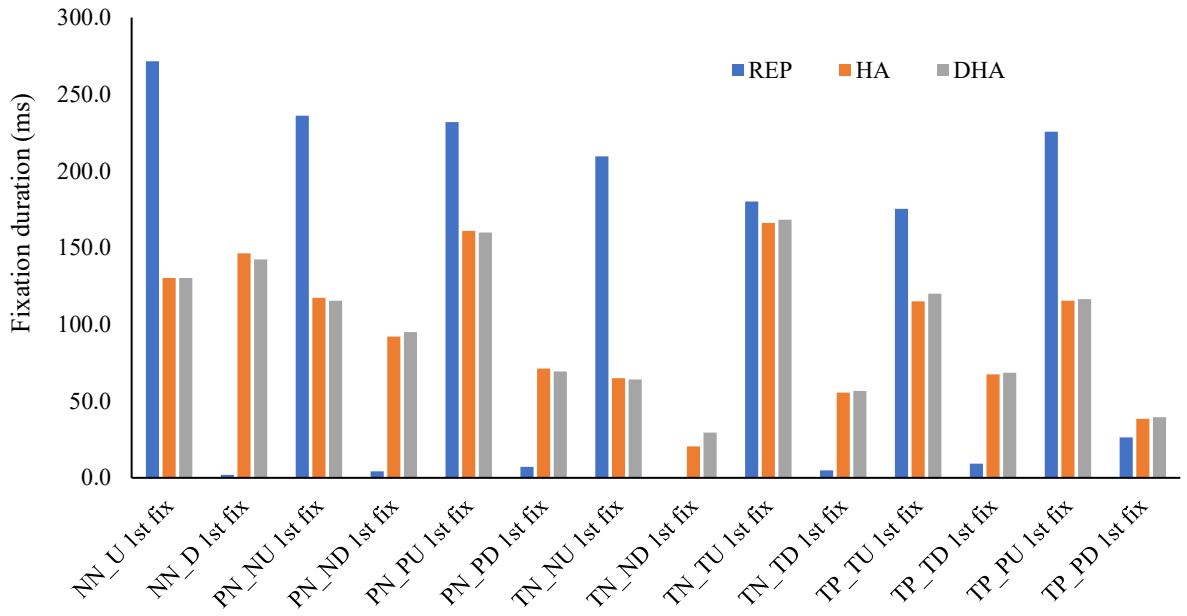


Figure 6.12 Median first fixation duration NN: neutral-neutral images, PN: positive-neutral, TN: threat-neutral, TP: threat-positive, PU: positive image upper, PD: positive lower image, TP: threatening upper image, TD: threatening lower image per back pain personality type

6.3.4.1.2 Dwell time

For the median average dwell time a similar trend of longer median dwell time for the control group on the top image compared to the back pain group and a longer median dwell time for the BPP on the bottom image compared to the controls (See Figure 6.13). The Mann-Whitney U test showed that this difference was only significant for the threat-positive image combination where the back pain group had a significant longer median fixation on the positive image when it was on the lower half of the screen U ($N_{back\ pain}$= 9, $N_{Controls}$= 29) = 55.00, z= -2.600, p= 0.009 compared to the control group.

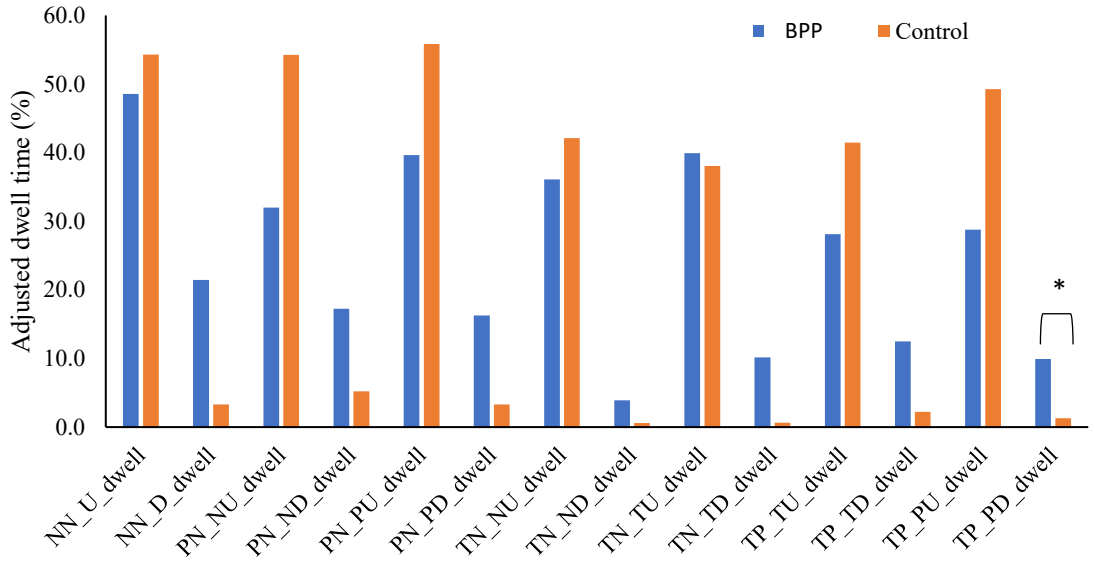


Figure 6.13 Median dwell time as a percentage of total per image pair, NN: neutral-neutral images, PN: positive-neutral, TN: threat-neutral, TP: threat-positive, PU: positive image upper, PD: positive lower image, TP: threatening upper image, TD: threatening lower image per back pain and group *p<0.05

Figure 6.14 contains the normalised dwell time as a percentage of total dwell time per back pain personality type. The repressors seem to have a longer dwell time on the top image than on the bottom image whereas this distribution is more equal across the images for the high anxious and defensive high anxious individuals.

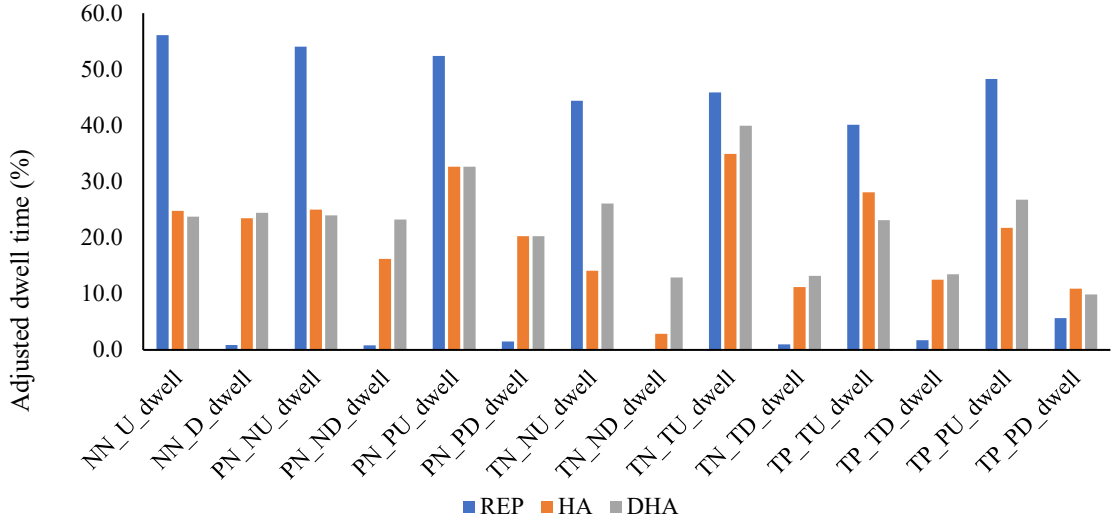


Figure 6.14 Median normalised dwell time as a percentage of normal NN: neutral-neutral images, PN: positive-neutral, TN: threat-neutral, TP: threat-positive, PU: positive image upper, PD: positive lower image, TP: threatening upper image, TD: threatening lower image per back pain personality type

6.3.4.1.3 Average fixation duration

Average fixation duration (See Figure 6.15) also showed a trend of longer average median fixation for the control group on the top image compared to the back pain group and a longer average median fixation on the bottom image for the back pain compared to the controls. The Mann-Whitney U test showed that this difference was significant for positive-neutral and positive-threat image combination. For the positive-neutral combination, BPP had a significant longer average fixation on the positive image when it was at the bottom U ($N_{back\ pain}$ = 9, $N_{Controls}$= 29) = 72.00, z= -2.011, p= 0.044. For the positive-threat combination BPP had a significant longer fixation time on the threatening image on the bottom U ($N_{back\ pain}$ = 9, $N_{Controls}$= 29) = 68.50, z= -2.139, p= 0.032 and when the positive image was at the bottom U ($N_{back\ pain}$ = 9, $N_{Controls}$= 29) = 50.00, z= -2.773, p= 0.006 compared to the control group.

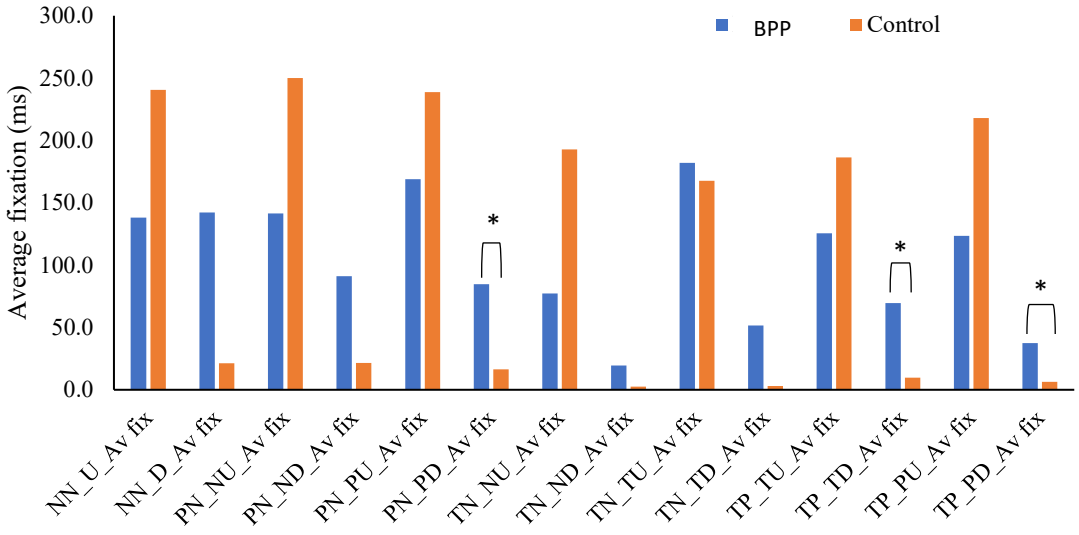


Figure 6.15 Median average fixation duration in ms per image pair, NN: neutral-neutral images, PN: positive-neutral, TN: threat-neutral, TP: threat-positive, PU: positive image upper, PD: positive lower image, TP: threatening upper image, TD: threatening lower image per back pain and control group *p<0.05

Figure 6.16 represents the median average fixation duration per back pain personality type. The repressors seem to have a fixation duration on the top image compared to the bottom image regardless of the type of image. The high anxious and defensive high anxious seem to have a similar gaze behaviour and had a similar average fixation duration on the top and bottom images.

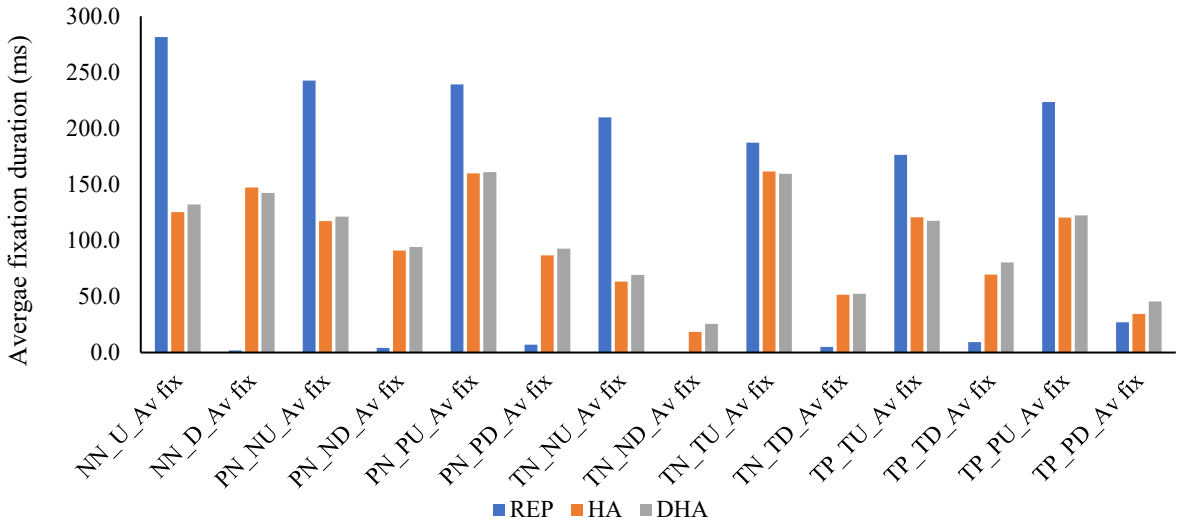


Figure 6.16 Median average fixation duration NN: neutral-neutral images, PN: positive-neutral, TN: threat-neutral, TP: threat-positive, PU: positive image upper, PD: positive lower image, TP: threatening upper image, TD: threatening lower image per back pain personality type

6.3.4.1.4 Fixation count

Fixation count (See Figure 6.17) was significantly different in the control condition, where two neutral images were shown, where BPP had a significant higher median fixation count on the bottom neutral image U ($N_{back\ pain}$= 9, $N_{Controls}$= 29) = 72.00, z= -2.015, p= 0.044 compared to the control group. It also was significantly different in the threat-positive image combination where BPP had a significantly higher fixation count on the positive bottom image compared to the control group U ($N_{back\ pain}$= 9, $N_{Controls}$= 29) = 43.00, z= -3.037, p= 0.002.

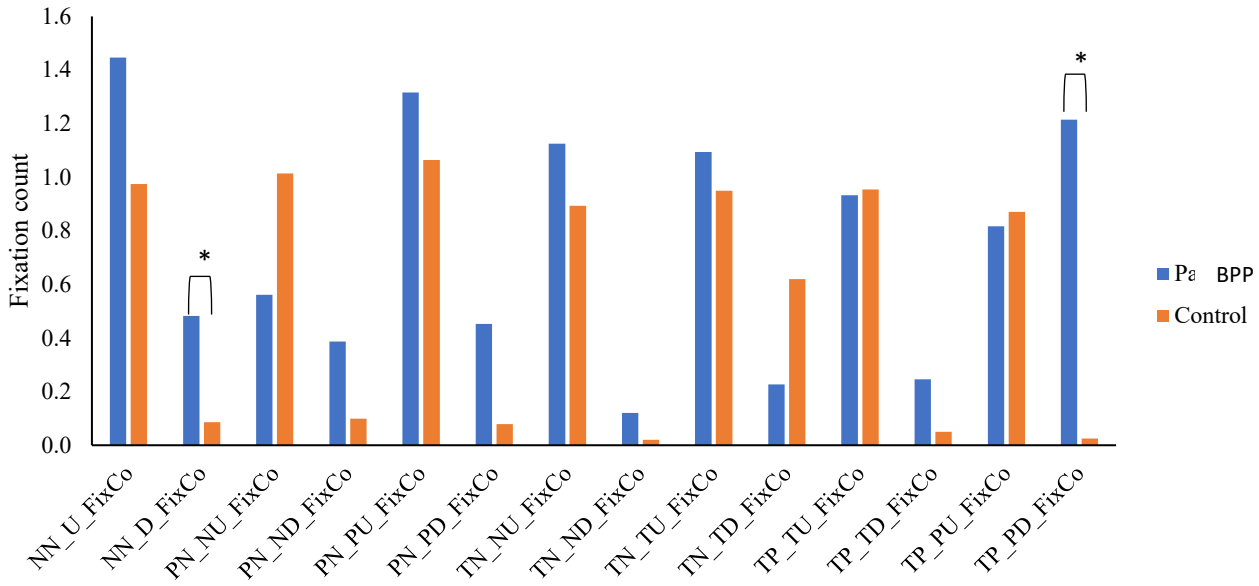


Figure 6.17 Median fixation count image pair NN: neutral-neutral images, PN: positive-neutral, TN: threat-neutral, TP: threat-positive, PU: positive image upper, PD: positive lower image, TP: threatening upper image, TD: threatening lower image per patient and group *p<0.05 for patients and controls.

The median fixation counts per back pain personality type can be found in Figure 6.18. The repressors seem to have more fixations on the top image than the bottom image. The fixation count of the high anxious and defensive high anxious individuals did not seem to follow this pattern of more fixations on the top image compared to the bottom image.

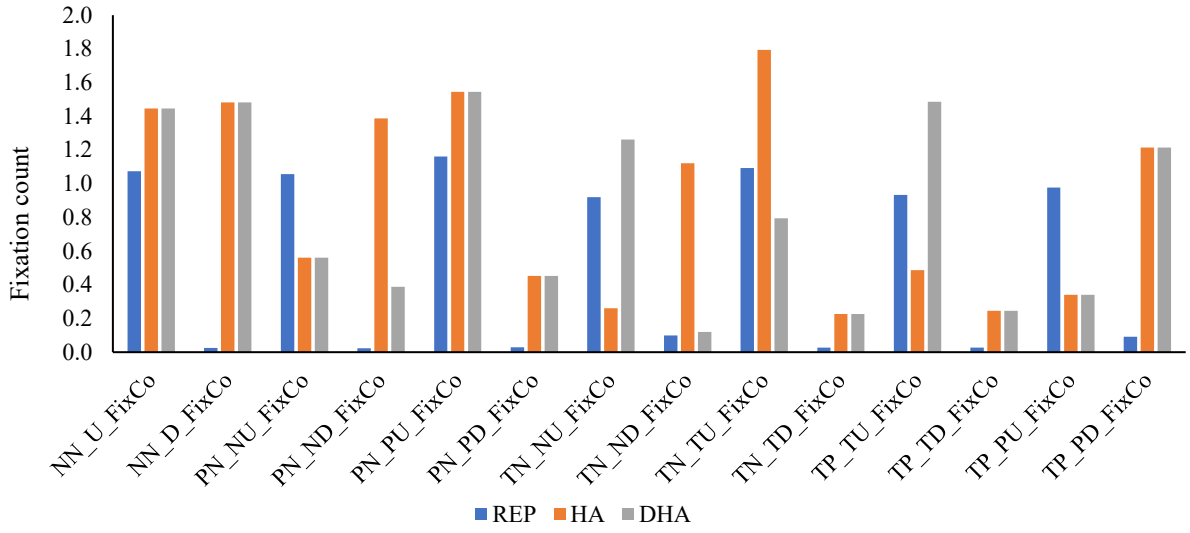


Figure 6.18 Median fixation count NN: neutral-neutral images, PN: positive-neutral, TN: threat-neutral, TP: threat-positive, PU: positive image upper, PD: positive lower image, TP: threatening upper image, TD: threatening lower image per back pain personality type

6.3.4.2 Initial attention compared with neutral-neutral control condition

To assess whether variables differed depending on the type of image, all variables were compared to the control condition, where two neutral images were shown. To assess differences between the control condition, neutral-neutral image combination, the Wilcoxon Signed Ranked Test with a Bonferroni adjusted significance level of $p= 0.0024$ was used.

The back pain group had significant differences for the threat-neutral image combination compared to the control condition. For first fixation this was for the neutral image when located at the top ($Z=-3.723$, $p= 0.001$), as well as for when the neutral image was located at the bottom ($Z= 4.037$, $p< 0.001$). For average fixation this was for the neutral image at the top ($Z=3.382$, $p< 0.001$) and neutral image at the bottom ($Z=4.146$, $p< 0.001$). For average fixation duration there was a significant difference with the control condition when the neutral image was at the bottom ($Z= 4.146$, $p< 0.001$) and at the top ($Z= 3.382$, $p< 0.001$). For fixation count there was a significant difference when the neutral image was at the bottom ($Z= 3.164$, $p= 0.002$). The dwell time did not differ from the control condition. BPP had no difference in any of the other variables. The natural bias to look at the top image first and longer was not found in the neutral-neutral control condition.

For the control group there were no significant differences for any of the variables of the neutral-positive stimulus combination compared to the control condition. For the first fixation duration in the threat-neutral image combination, both image types (neutral and threat) in each location (top and bottom) were significantly different from the control condition ($p< 0.001$, for all conditions). In the threat-positive image combination each condition ($p< 0.001$ for each significant condition) was different from control except when the positive image was at the top. For dwell time all conditions were different from the control one in the threat-neutral condition (a max $p= 0.002$). In the threat-positive image combination there was a significant difference with the control condition when the positive image was at the bottom ($Z= 3.465$, $p<$

0.001) and threatening image at the top (Z= 3.708, p<0.001). For average fixation duration all the conditions in the threat-neutral image combination were significantly different from the control condition (Z= 3.718, p< 0.001). Threat-positive image combinations were significantly different from the control condition when the threatening image was at the top (Z= 4.194, p< 0.001), the threatening image was at the bottom (Z= 3.070, p= 0.002), and when the positive image was at the bottom (Z= 4.194, p< 0.001). For the fixation count, threat-positive image combinations were significantly different when the threatening image was at the top (Z=3.915, p< 0.001), the positive image was at the bottom (Z= 4.285, p<0.001), for the threat-neutral image when the neutral image was at the top (Z= 3.799, p< 0.001) and when the neutral image was at the bottom (Z= 3.164, p= 0.002). The control group did have longer first fixation durations (Z= -4.206, p< 0.001), dwell time (Z= -4.227, p< 0.001), average fixation duration (Z= -4.292, p< 0.001) and a higher fixation count (Z= -4.314, p< 0.001) on the top image in the neutral-neutral control condition.

6.3.4.3 Maintained attention

The Mann-Whitney U test showed no significant differences in any of the variables for the positive-neutral image combination, the neutral-neutral control condition, or the positive-threat image combination. For the threat-neutral image combination there were significant differences. The control group had a significantly longer dwell time than then back pain group U ($N_{back\ pain}$= 9, $N_{Controls}$= 29) = 213.00, z= 2.844, p= 0.004 on the neutral top image, the control group also had significantly longer average fixation duration on the neutral top image U ($N_{back\ pain}$ = 9, $N_{Controls}$= 29) = 201.00, z= 2.422, p= 0.014. The back pain group had a significant longer dwell time on threat image at the bottom U ($N_{back\ pain}$= 9, $N_{Controls}$= 29) = 63.00, z= -2.323, p= 0.019.

6.3.4.4 Maintained attention compared to the neutral-neutral control condition

To assess whether variables differed depending on the type of image all variables were compared to the control condition, where two neutral images were shown. To assess differences between the control condition, neutral-neutral image combination, the Wilcoxon Signed Ranked Test with a Bonferroni adjusted significance level of $p= 0.0024$ was used.

The back pain group had only one significant different variable that differed from the control condition. The fixation count in the threat-neutral condition when the threat image was at the bottom ($Z= -3.272$, $p= 0.001$).

The control group had no significant differences for average fixation duration between any of the image combinations and the control combination. The dwell time for the threat-positive image combination was significantly shorter for the top threat image ($Z= -3.465$, $p< 0.001$) than in the control condition as well as for the positive-neutral image combination for when the positive is at the bottom ($Z= -3.647$, $p< 0.001$). The fixation count was significantly lower for the threat-positive image combination for the top threat image ($Z= -4.346$, $p< 0.001$) and when the threatening image is at the bottom ($Z= -3.495$, $p< 0.001$), for the threat-neutral image combination on the top threat image ($Z= -4.285$, $p< 0.001$), and the positive-neutral image combination for when the positive image is at the bottom ($Z= -3.677$, $p< 0.001$).

6.3.5 Physical activity

There were seven out of nine BPP who had a complete data set of seven days of activity tracker data and a filled-out activity diary. One back pain participant did not return their activity diary and one back pain participant did not wear the activity tracker for seven days. Twenty-four of the 29 control participants had complete data sets. Two participants did not take part in this part of the study, two did not return their activity diary, and one did not wear the activity tracker for seven days. A Shapiro-Wilk test was used to test for normality of the data. All variables of

the back pain group were not normally distributed. Two variables were normally distributed in the control group (the median activity level in minutes measured by the tracker and the sitting time in minutes measured by the tracker). It was decided, therefore that median values should be presented, The Mann-Whitney U test was used to assess differences between the back pain and control group, and the Wilcoxon Signed Ranked Test was used to assess differences between the self-reported activity and the tracker within groups. Figure 6.19 shows the median number of minutes for low, medium, and high intensity activities and Figure 6.20 shows the median number of sitting and sleeping.

6.3.5.1 Activity tracker data between groups

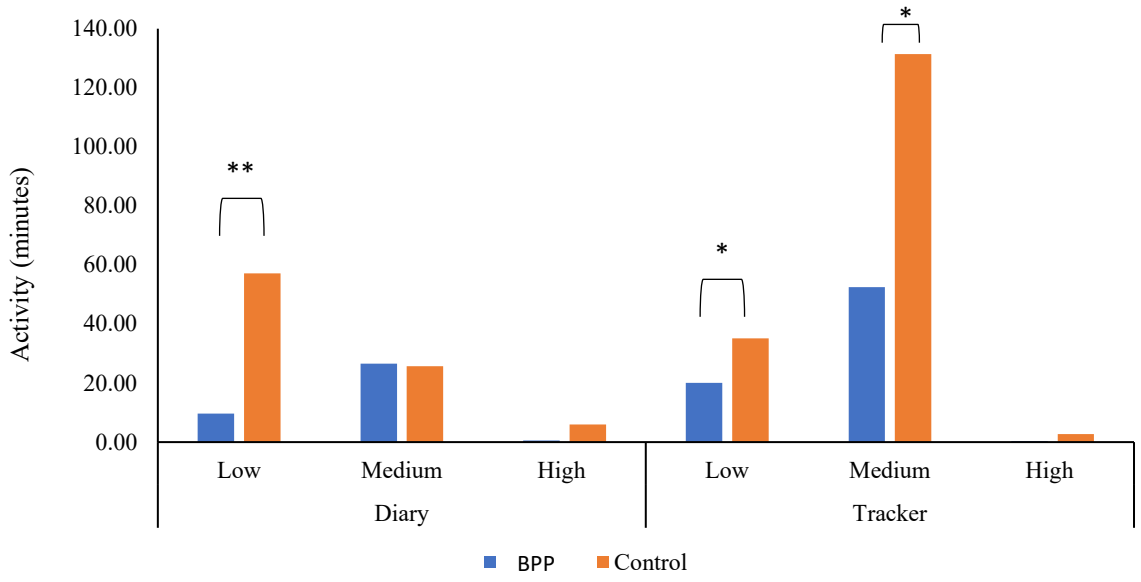


Figure 6.19 Median minutes of low, medium, and high intensity activities per day for back pain and control group for self-reported activity diary and activity tracker. *p<0.05, **p<0.001

The Shapiro-Wilk test showed significant differences between the number of minutes of low intensity activity U ($N_{back\ pain}$ = 8, $N_{Controls}$= 27) = 48.00, z= -2.357, p= 0.018. BPP had a significant lower number of minutes spent in low intensity than the control group did. The number of minutes of medium intensity activity between BPP and the control group was also significantly different U ($N_{back\ pain}$= 8, $N_{Controls}$= 27) = 35.00, z= -2.872, p= 0.004. The control group had significantly more daily minutes medium intensity activity. There was also a

significant difference between the amount of sleep each of the groups had U ($N_{back\ pain}$= 8, $N_{Controls}$= 27) = 186.00, z= 3.064, p= 0.002, where BPP got less sleep per day than the control group. The difference in steps was significant U ($N_{back\ pain}$= 7, $N_{Controls}$= 27) = 51.00, z= -2.152, p= 0.031 and the control group made significantly more steps than the BPP. There were no significant differences for high intensity and sedentary times.

6.3.5.2 Activity diary data between groups

The Shapiro-Wilk test showed a significant difference between the reported number of minutes of low intensity between the back pain and control group U ($N_{back\ pain}$= 8, $N_{Controls}$= 26) = 12.50, z= -3.715, p< 0.001. The back pain group reported significantly less time spent doing low intensity activities. There were no significant differences in reported time spent doing medium and high intensity activities and no differences in sedentary or sleep time.

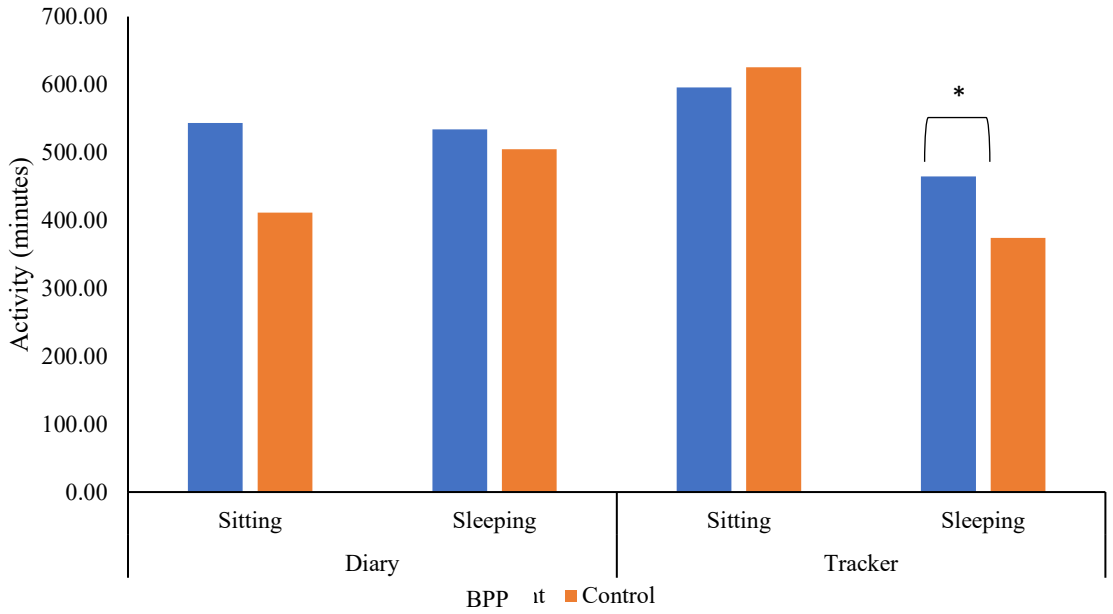


Figure 6.20 Median minutes of sitting and sleeping per day for back pain and control group for self-reported activity diary and activity tracker. *p<0.05

6.3.5.3 Differences between activity tracker and activity diary

The Bonferroni adjusted significance level is 0.001 for both the back pain and control group. For the back pain group, the Wilcoxon Signed Ranked Test revealed no significant differences

between the self-reported number of minutes doing low, medium, and high intensity activities and the number of minutes measured by the activity tracker.

The control group had a significant difference between the self-report measures and the activity tracker. A pair-wise comparison found the medium intensity activities as self-reported and as measured by the activity tracker where significantly higher than the self-report measure ($Z= 4.381$, $p< 0.001$). The difference between self-reported time and measured time of sedentary ($Z= 4.211$, $p< 0.001$) and amount of sleep ($Z= -4.330$, $p< 0.001$) were also significant, where the control group underestimated how sedentary they were and overestimated the amount of sleep they got.

6.3.6 Participant interview

The analysis of the question about causes for chronic back pain showed that the answers of the back pain and control group were similar. The three topics they mentioned were not moving enough ("not moving enough will make my back stiff so when I then start moving it hurt" back pain participant 8), an unhealed injury ("pain is when there is something wrong in your back so when it hurts that injury hasn't healed yet" control 12), and old age or general wear and tear ("I did a lot of sports during uni and also do a manual job all of this just wore my back out" back pain participant 9). When individuals with back pain were asked what would make their pain worse, they echoed similar themes as what they said would cause pain. Specifically, staying in one position for too long either standing or sitting ("not moving will definitely make my back pain worse, when I then start to move it will hurt a bit more but will soon feel better" back pain participant 1) as well as doing strenuous exercises ("if I push myself too far by lifting something heavy, I can always tell straight away it will hurt for a while" back pain participant 4). When individuals with back pain were asked what they did to alleviate their pain they mentioned rest, stretch, or move and taking pain killers ("stretching really helps me" back pain

participant 3, “if the pain is too bad the only thing that helps is bedrest, hot-water bottle, and my pain medications” back pain participant 7).

The analysis of the questions related to their experience during the pandemic revealed that some had more pain and the reasons they gave for this were an increase in anxiety and a decrease in the amount of time they spent moving (“the overall idea of the pandemic made me worried for my own health but also for the health of my older relatives” back pain participant 2, “Working from home and being in lockdown I rarely left home so I never moved much” back pain participant3). Two themes were given for the increase in anxiety, a general fear of catching the COVID virus and a fear of not being able to access healthcare because of the lockdowns (“I was told I could no longer visit my physiotherapist and his help is essential for managing my pain” back pain participant 4, “I took special back pain classes at the gym and they were all cancelled and not knowing when they would start again made me worry” back pain participant 9).

The analysis of the questions about care during the pandemic revealed that about half of the individuals with back pain did not seek the attention of a health care professional for their back during the pandemic. All BPP gave the same reason for it which was that they did not need it (“I can manage my pain on my own” back pain participant 1). The half that did seek the attention of a health care professional for their back said that it was the continuation of their normal care. Half the back pain group who used video care during the pandemic, preferred this from of care over face-to-face appointments. The reason was that the appointments took less time, they didn’t have to travel to the hospital or clinic and could schedule appointments that would work for them (“I liked the video conference, I could take the meetings at work in my office to talk through how I was doing and if I had any problems” back pain participant 9). Those that used video care but did not prefer the video appointment over the face-to-face appointments gave two reasons. The first was that they felt that the therapist could not properly

assess their back over video ("When I tried to explain where my pain was, I pointed at my back, but the physio didn't seem to understand or couldn't touch my back to assess my tight muscles" back pain participant 4). The second reason was that they experienced technical problems with the video care ("I tried it a couple times but there was always a lag or sound distortion. One time the video just cut out and I couldn't reconnect" back pain participant 6).

6.4 Discussion

This study assessed visual attentional bias within a chronic back pain population following the predictions of Eysenck's theory (1997) and previous research (Franklin et al., 2016). The study investigated the visual attentional bias using a classic dot-probe task with the addition of eye-tracking to assess visual attention. This study further addressed weaknesses in previous studies by having the back pain and control participants rate the images of the dot-probe task and the videos of the action observation task on pain, fear, arousal, and valence as well as on familiarity for the PHODA images to control for familiarity of the actions seen.

The rating of the images used in the dot-probe task showed that the control participants did not rate the threatening images as painful or fearful. The back pain group scored significantly higher on pain and fear for the threatening images compared to the control group. The back pain participants (BPP) had no significant differences in their fear or arousal score between the neutral and positive images of the dot-probe task. Even though no statistical tests could be performed, once the data was split into personality type there seemed to be little differences in the fear, arousal, and valence score in the neutral images. There appear to be small but not significant differences in arousal and valence score between the different back pain personality types in the positive images. The biggest differences, which were unable to be tested for significance, were found in the pain, fear, arousal, and valence scores of the threatening images. The defensive high anxious group had the highest score, and the repressors had the lowest score for fear and pain. Familiarity scores appear similar amongst the three

groups. The high anxious and defensive high anxious scored arousal for the threatening pictures under the neutral five score meaning they scored the image as more exciting; they also had a higher valence score meaning the felt more unhappy looking at the threatening pictures than the repressors or controls. The repressors had valence and arousal scores on the threatening images that were closer to neutral feelings. Taken together, these findings support the predictions made by Eysenck. The higher pain and fear scores of defensive high anxious individuals could be due to their tendency to catastrophise, seeing an image of an individual performing an action that could be painful for them and could make them think about the related negative experiences. This is supported by the lower valence score which shows that they experienced negative emotions when seeing the image. Similar to Eysenck's prediction, the high anxious group still scored high on fear and pain but because of their low defensiveness they catastrophise less which could explain why they scored lower than the defensive high anxious group. The repressors scored the lowest on pain and fear in accordance with their low trait anxiety and avoidance traits.

The eye-tracking data from the dot-probe were split into two epochs. The first was from 0-500ms long and the second was 501-2,000ms to assess differences in early and late attentional processes. For the initial attention (0-500ms) the only significant differences between the back pain and control group were for the threat-neutral or threat-positive stimulus combination and only for the stimuli located at the bottom half of the screen. The back pain group had longer first fixations, longer dwell time, and longer average fixations on a threatening image on the bottom half of the screen when it was paired with a positive image at the top compared to the control group. Previous studies assessing natural attentional bias found that individuals have a tendency to look at the top image first followed by the image at the bottom (Chokron & Imbert, 1993). It might be that this bias is smaller in the back pain group, because they are actively looking for a threatening image and might thus look down as often

as up. The control group had a visual attentional bias towards the top image whereas the individuals with back pain did not have this bias. This could be argued that they have an overall different gaze behaviour compared to the controls. This explanation could support the attentional bias theory that individuals with back pain are actively looking for threat images (Jones et al., 2021). The natural bias to look at the top picture is so strong though that only five variables in the back pain group and only eight variables in the control group out of a total of 56 eye-tracking variables significantly differed from the neutral-neutral control condition.

In the 501-2,000ms maintained attention epoch there were no significant differences for any of the variables in the positive-neutral, neutral-neutral, and positive-threat image combinations. For the threat-neutral stimulus combination the control had a significant longer dwell time and average fixation duration on the top neutral image compared to the back pain group. When the threatening image was displayed at the bottom, the back pain group had a longer dwell time. The significantly longer dwell time and average fixation duration at the top neutral image for the control group fits with the significantly longer dwell time of the back pain group on the threatening image that would be located under the neutral image. This is tentative support for a maintained attentional bias in the back pain group as they pay more attention on the threatening image over the neutral image whereas the controls look longer at the top image. Similar to the first epoch, only one variable for the back pain group and five variables for the control group, out of a total of 42 eye-tracking variables, significantly differed from the neutral-neutral control condition.

Recent literature reviews (Chan et al., 2020) and meta-analysis (Jones et al., 2021) suggested that attentional biases towards pain might be present in both back pain and control participants. When combining results of the rating data with those of the eye-tracking this study shows initial evidence for an abnormal attentional bias of the back pain group towards a stimulus that does not draw attention of the control group. Because the threatening images were

not classed as such by the controls but only by the BPP, it could be argued that these stimuli are ambiguous enough to assess a true attentional bias. Chan et al. (2020) further argue that the chronic pain population is not homogenous and that there could be sub-groups that have distinct attentional biases. It was an aim of this study to investigate the attention bias of the different personality types but due to the low number of participants it was not possible. If the sample size had been bigger, the defensive high anxious group would most likely show an attentional bias towards the threatening image in both the early stages and in the later stages of the stimulus presentation. They orientated their attention to the perceived threat and would not show avoidance because their catastrophising would keep them engaged with the threatening image. The repressors on the other hand would show an attentional bias towards the threatening image in the initial phase but then avoid that image in the later phase. This would be vigilance avoidance behaviour. The high anxious group may show the same bias as the defensive high anxious in the initial phase however because their catastrophising is lower they would not stay engaged with the threatening image in the later phase.

This study has found that, in both the self-report and in the activity tracker measures, BPP had a significantly lower amount of low intensity activity per day. It further found a difference between the number of minutes in high intensity measured by the activity tracker. It has been advised for individuals with chronic back pain to remain physically active, because long periods of inactivity have been shown to negatively affect recovery (NHS NICE guidelines 2016). Inactivity has been associated with reduced muscle mass in the lumbar extensor muscles (Smeets et al., 2008). However, physical activity with a high workload is associated with an increased risk of back pain (Andersen et al., 2007; Burdorf & Jansen, 2006). There is evidence for a U-shaped relationship between physical activity and low back pain where both ends of the spectrum, a total inactivity and continuous strenuous activity were both considered risk factors (Heneweer et al., 2009). Thus, when advising individuals with back

pain on how much to move it is important to get the correct intensity and duration which is effective, fluid, and variable depending on what the back pain patients need. A systematic review (Heneweer et al., 2011) found that heavy occupational workloads and frequency of lifts were moderate to strong risk factors. The results were inconsistent for leisure activities and sport but found that studies investigating habitual daily activities were non-existent. Habitual activity, e.g., domestic activities and commuting, are physical activities that are generally in low intensity and are often part of a daily routine. Daily activity might thus be an effective form of physical activity for individuals with back pain.

Heneweer et al. (2011) discussed the lack in validity of studies assessing the effect of physical activity on back pain as they often use self-report measures and no objective measures to assess physical activity. This study used both a self-report measures in the form of an activity diary and a more objective wrist worn activity tracker. Comparison between the two measures found no difference in the activity intensity levels, sedentary and sleeping time for the back pain group. Within another clinical population of breast cancer survivors, Wagoner et al. (2019) found agreement between the self-report measure and activity trackers supporting the current results. The result of this study could be interpreted cautiously as a sign that the self-report questionnaire is a valid measure of assessing physical activity, sedentary and sleep time in a chronic back pain population, however further validation with a larger population is necessary. There were differences between the self-report questionnaire and the tracker in the control group. Controls overestimated the amount of sleep they got but underestimated their medium intensity activity and time sitting. The differences in medium intensity activity, sleep and sedentary behaviour are in line with a systematic review assessing links between sedentary behaviour and physical activity (Mansoubi et al., 2014) where healthy adults were found to underestimate their sedentary time and overestimate their sleep and medium activity. The authors reasoned that since sedentary behaviour is often combined with another activity (doing

desk work, watching TV, or eating), which are not always counted, people underestimate their total time seated. Medium intensity activities such as walking climbing stairs, and commuting are often done in short burst (going to grab a coffee, visiting a college in another part of the building) and as such might go unnoticed and uncounted in the self-report measure. Other studies have found that chronic pain has a negative impact on both the amount (Menefee, Cohen, et al., 2000; Menefee, Frank, et al., 2000) and the quality of sleep (Marty et al., 2008; Sayar et al., 2002).

Both back pain and control participants, regardless of personality type, gave a biomedical reason for what would cause back pain. In Edwards' Pain Beliefs Questionnaire (PBQ) (Edwards et al., 1992) answers were themed as organic personal causes, which are associated with a more distressing attitude towards pain than when they are attributed to external causes (Storms & Nisbett, 1970). Previous studies have reported that organic pain beliefs are associated with a higher reliance on different forms of health care as individuals with chronic pain will "shop around for" a clinician who can tell them what their exact injury is and are more likely to consider surgical intervention for their pain (Main et al., 2010) and with feelings of loss of control of their pain which are further associated with low self-efficacy scores (Anderson et al., 1995) (Miles et al., 2011). This universal attribution of pain towards a physical injury was expected for the defensive high anxious BPP and high anxious groups. It was not expected within pain-free control groups or with repressors (Eysenck, 1997). A meta-analysis of pain beliefs in the general population found that despite public awareness campaigns about back pain, most pain-free individuals do associate pain with a physical injury and rest as the best treatment (Morton et al., 2019).

The question about experience during the pandemic revealed that individuals who experienced more pain associated this with less physical activity and more anxiety. The increase in anxiety was not only attributed to fear of catching COVID but also uncertainty or

in some cases lockdown related shutdown of back pain related health care. The worry about access to health care is supported by Sabatello et al., (2020) who found that those with a disability that depended upon health care had both more trouble accessing care and finding a replacement as it is often highly specialised.

6.5 Conclusion

This study provided evidence for an attentional bias in individuals with chronic pain towards images they rated as painful and fearful in a dot-probe task, however the lay-out of the dot-probe task means that there is also the natural bias to look at the top image before the bottom image to consider. Differences between personality types could not be assessed because of the low number of individuals with back pain. These findings of attentional bias on different types of threatening stimuli provides support for a general attentional bias towards pain information within a chronic back pain population. The use of the activity tracker measure showed that back pain participants have less high level of activity, less sleep, and more sedentary behaviour. Individuals with chronic back pain were able to estimate their physical activity accurately. The interview revealed that both the pain and healthy population hold pain beliefs that are associated with an outdated biomedical model. Questions about their pain experience during the pandemic revealed that catching COVID and access to health care were stressors for the pain participants. About half the back pain participants who used tele-health care said they preferred it over face-to-face appointments whereas the other half preferred face-to-face appointment.

As discussed in chapter 4 Methodology, the dot-probe task is not without limitations: 1) it uses static images of actions which might cause problems with the ecological validity and 2) as two images are presented simultaneously it is not possible to ascertain exactly what participants are looking at. The next chapter uses a new method to further probe attentional biases that mediates some of the limitations of the dot-probe task. This method uses

videos as stimuli in combination with eye tracking, which allows for continuous tracking and is a more direct measure of attention. These videos could be argued to be more ecologically valid than static images and with the preference of some back pain participants to use tele-health videos might also reflect attention during a realistic physical therapy setting.

7 Study 2b: Attentional Bias – Action Observation Task

7.1 Introduction

Action observation evokes an internal motor simulation of the actions that an observer sees (Buccino, 2014). During action observation, mental processes trigger neurocognitive mechanisms that underlie the planning of voluntary movement in a manner that is similar but not equal to when an action is actually performed (Hardwick et al., 2018; Lotze et al., 1999; Stephan et al., 1995). Several studies have found that attention during action observation modulates the corticospinal excitability and the activation of the motor system (Fadiga et al., 1995; Schuch et al., 2010; Wright et al., 2018). Wright et al. (2018) investigated the effect of visual attention during an action observation task. They found that when visual attention was directed towards the task-relevant objects during action observation, motor evoked potential amplitudes were significantly higher than when visual attention was directed somewhere else. These findings show that attention is a mediator for the delivery of action observation interventions especially in the chronic back pain population who are thought to process pain related information differently and have been shown to direct their attention differently when observing images that they perceive to be threatening.

The most recent meta-analysis revealed that an attentional bias towards pain might be ubiquitous (Jones et al., 2021). However, if videos are used that are only interpreted to be painful by the chronic back pain population (e.g., lifting a heavy box or picking up something from the floor) there might be a specific attentional bias in the chronic back pain population that is absent within the pain-free population. Chan et al. (2020) further argue that the chronic pain population might consist of subgroups with different cognitive processes that could lead to different attentional processes. Franklin et al. (2016) found that in a dot-probe task, the four Weinberger personality types, based on trait anxiety and social desirability, have distinct attentional biases. The defensive high anxious, high in both social desirability and trait anxiety,

were found to have an attentional bias towards pain related information. High anxious individuals did not have an attentional bias towards painful information but had an avoidance of positive information. Repressor individuals had a bias towards positive information but an avoidance of pain related information.

Previous studies assessing attentional biases within chronic pain populations used images, faces and words and found differences in attentional biases (Todd et al., 2018). The back pain threat images used showed snapshots of actions or facial expressions that could be interpreted as being related to back pain. However, the exact nature of how the threat and back pain relate is open to the debate. Videos that show a complete action have more context and leave less room for ambiguous interpretation than using images which show part of the action. Videos also allow assessment of specific elements of the movement individuals attend towards.

The aims of this study are to i) investigate the attentional bias of individuals with chronic back pain during an action observation task and to ii) investigate the effect of personality type on the attentional bias of individuals with chronic back pain.

7.2 Method

7.2.1 Participants

In total 38 participants were recruited for this study, nine chronic back pain participants (BPP) and 29 controls an overview of their demographics can be found in table 2 chapter 6. Ethical approval for this study was granted by the NHS Research Ethics Committee. Because of the low number of participants, a median split was used to define the four personality types for both the 10-item MC-SDS (social disability scale) and the STAI (trait anxiety sub scale) to include all participants who took part in this study (Jensen, 1987; Shaw et al., 1986). See Figure 6.3 and Table 6.1 in Chapter 6 for a demonstration of the median split cut-off.

7.2.2 Measurements

7.2.2.1 Eye-tracking

Eye-tracking data was collected from all participants using a static eye-tracker with a sample frequency of 250Hz (RED 250, SensoMotoric Instruments, Teltow, Germany) and a gaze position accuracy of 0.5°. The eye tracker was calibrated prior to the start of the of each block using the recommended 3-point calibration. Duration of the first fixation, fixation count, mean fixation duration and mean dwell time were extracted from the raw eye-tracking data (Yang et al., 2012). As per previous studies, fixations were defined as maintaining the gaze in a radius of less than 1º for a minimum of 100ms (Sharpe et al., 2017; Yang et al., 2012).

7.2.2.2 Action Observation Task

There were 10 videos. The videos showed either a threatening or a neutral action. The threatening actions were taken from the Back Pain Performance Scale (Strand et al., 2002); putting on a sock, lifting a box from the ground, picking up a piece of paper from the ground, touching their toes with stretched legs and standing up from a seated position in a chair without using their hands. The neutral videos showed actions that include putting on a glove, picking up a piece of paper from a table, picking up a box from a table, raising their arms in front of them, and taking a step forward. When there was an object involved the pain and non-actions were matched as closely as possible, e.g., pain-action: lifting a box from the floor, non-pain action: lifting a box from a table and pain action: putting on a sock, non-pain action: putting on a glove. Participants were instructed to watch the videos with the intent to copy the movement later.

7.2.2.3 Stimulus Rating

The PsychoPy programme saved the response values per participants in an Excel spreadsheet in a dedicated data folder. Valence and arousal were coded on a zero (centre of the most left image) to nine (centre of the right most image) on the SAM scale. Meaning that a score of zero

on arousal or valence represents excited or happy respectively and a score of nine calm or unhappy. A score of five is neutral on both. For pain and fear a higher score meant higher pain or fear score. The familiarity was coded as zero (have not done this movement in the last three months), one (have done this movement in the last three months) or three (don't know). The videos of the action observation task video scores were averaged per movement and per movement type (threatening or neutral movements).

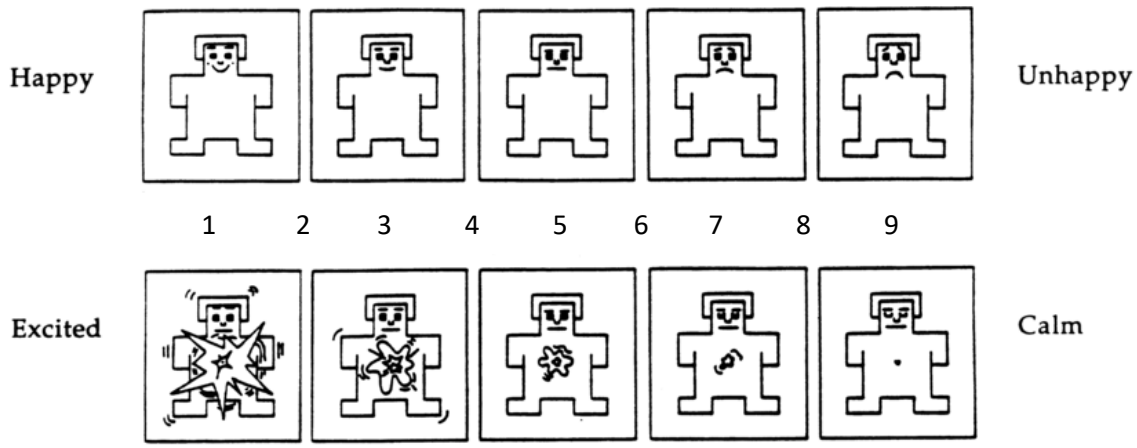


Figure 7.1 The Self-Assessment Manikin (SAM) (Bradley & Lang, 1994) for valence (top row) and arousal (bottom row). The graphic figures and the spaces in between each figure each define a nine-point scale, with 1 in the centre of the left-most image and 9 in the centre of the right-most image.

7.2.3 Procedure

All participants were asked to stand in front of a 22-inch static eye-tracker at approximately 0.8m from the screen. Participants were asked to complete an action observation task. They were presented with a video (approximately 8-12s long) of a person performing an action and were asked to look at the video with the intention to imitate the movement later (although participants were not asked to complete this movement later). There were 60 trials divided into three blocks of 20 videos each. After the action observation task participants rated on an 11-point Likert-scale; 1) how much pain they would expect to experience when they perform the action shown in the video (0: no pain and 10: pain as bad as could be) and 2) how fearful they would be of completing the action (0: not fearful and 10: extremely fearful). They were also

asked whether they have performed this action in the last 3 months (yes/no). As well, rating the arousal and valence of the videos using the same SAM scale as in session one. This rating was completed with a PsychoPy script similar to the one used in study 2a.

7.2.4 Data Analysis

7.2.4.1 Action Observation task

For the action observation task, the location of the areas of interest (AOI) depended on the task that was shown in the video. Each video had an AOI drawn around the head and the back of the actor in the video. For actions where the actor engaged with an object (lifting the box, picking up a piece of paper, putting on a sock or a glove), additional AOIs were drawn around those objects. For the arm movement an additional AOI was drawn around the arms and for the touch the toes movement additional AOIs were drawn around the hands and feet. The sit to stand and step forward action have no additional AOIs added besides the head and back AOI. See Table 7.1 for an overview.

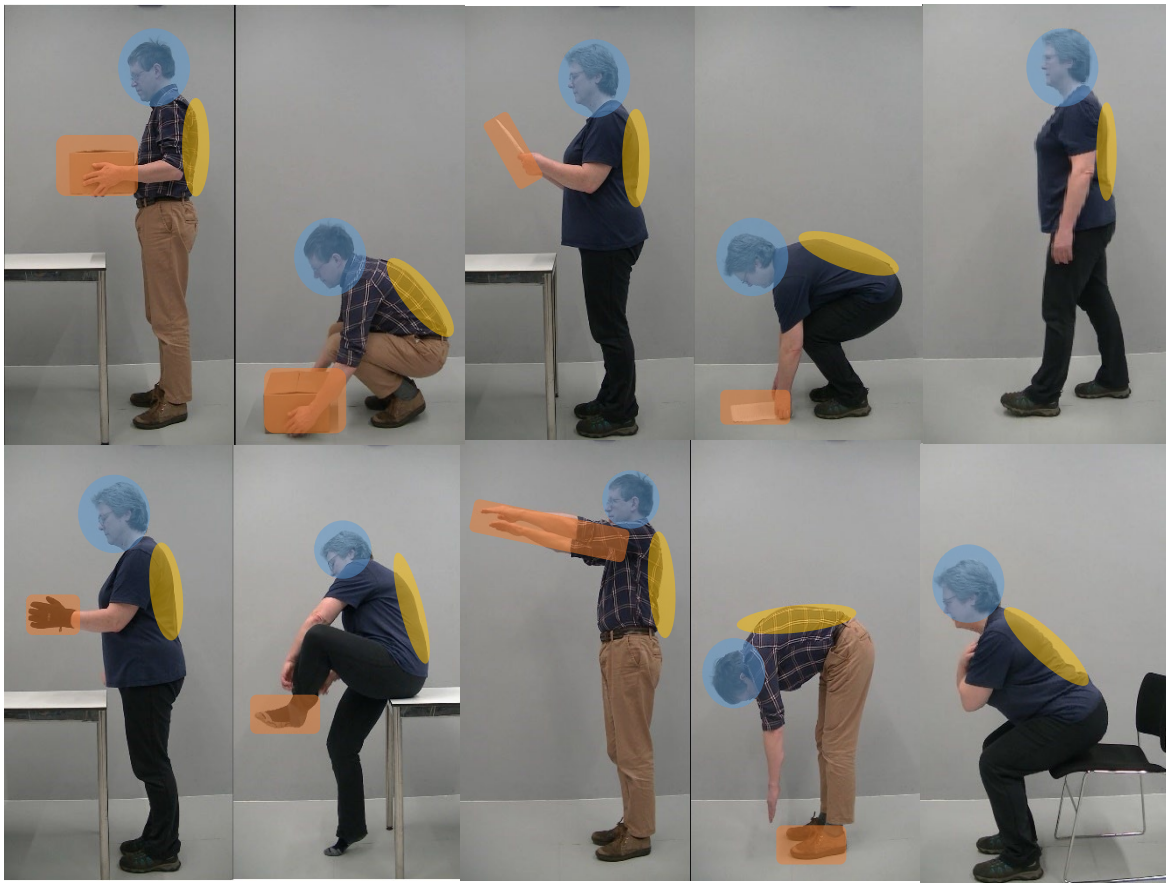
Action	Threat or neutral	AOIs
Pick up box from floor	Threat	Head, back, box
Pick up box from table	Neutral	Head, back, box
Pick up piece of paper from floor	Threat	Head, back, piece of paper
Pick up piece of paper from table	Neutral	Head, back, piece of paper
Put on a sock	Threat	Head, back, sock
Put on a glove	Neutral	Head, back, glove
Sit-to-stand	Threat	Head, back
Take a step forward	Neutral	Head, back
Try and touch toes	Threat	Head, back, toes
Move arm forward	Neutral	Head, back, arms

Table 7.1 Overview of actions, what type they are and the AOIs for each action

7.3 Results

7.3.1 Participants

Participants were split in the same way as for study 2a, a median split, to create four different personality groups, i) defensive high anxious individuals, defensiveness score above five and trait anxiety score over 50, ii) repressors, defensiveness score above five and trait anxiety score under 50, iii) high anxious individuals, defensiveness score under five and trait anxiety over 50 and, iv) low anxious individuals, defensiveness score below five and trait anxiety score under 50. Using the median split the back pain group had five defensive high anxious, three repressors, one high anxious and zero low anxious individuals. The control group had one



defensive high anxious, 18 repressors, one high anxious and nine low anxious individuals. Table 6.1 has an overview of the number, age, sex, defensiveness scores, and trait anxiety scores for each participant group and per personality group.

7.3.2 Video Rating

A Mann-Whitney U test was used to assess differences in video ratings between the back pain and the control group. Figure 7.3 shows the median pain, fear, familiarity, arousal, and valence scores. There were no significant differences between the familiarity of the threatening and

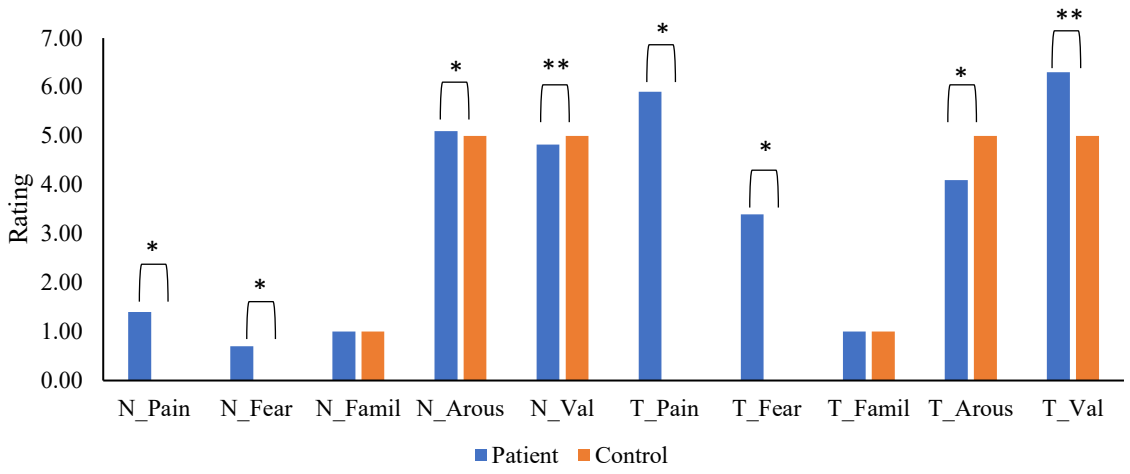


Figure 7.3 Median fear, pain, arousal, and vale BPP re for the AO videos per patient and control group per video type, N: neutral and T: threat. *p<0.05, **p<0.001

neutral videos (p= 0.446 and p= 0.098 respectively). The median pain score was significantly higher in the back pain group for both the neutral U ($N_{back\ pain}$= 9, $N_{Controls}$= 29) = 0.00, z= -5.081, p< 0.001 and threatening videos U ($N_{back\ pain}$= 9, $N_{Controls}$= 29) = 0.00, z= -4.665, p< 0.001. The fear scores were also significantly higher for the back pain group in both the neutral U ($N_{back\ pain}$= 9, $N_{Controls}$= 29) = 45.00, z= -3.474, p< 0.001 and threat U ($N_{back\ pain}$= 9, $N_{Controls}$= 29) = 0.00, z= -5.299, p< 0.001 videos compared to the control group. The arousal score was significantly higher for the back pain group when rating the neutral images U ($N_{back\ pain}$= 9, $N_{Controls}$= 29) = 69.50, z= -2.707, p= 0.007 but was significantly lower for the threatening images U ($N_{back\ pain}$= 9, $N_{Controls}$= 29) = 249.50, z= 4.833, p< 0.001 compared to the control group. The valence score of the BPP was significantly lower for the neutral videos U ($N_{back\ pain}$= 9, $N_{Controls}$= 29) = 200.00, z= 2.617, p= 0.009 and was significantly higher for the threatening videos U ($N_{back\ pain}$= 9, $N_{Controls}$= 29) = 48.00, z= -3.029, p= 0.002 than the control participants.

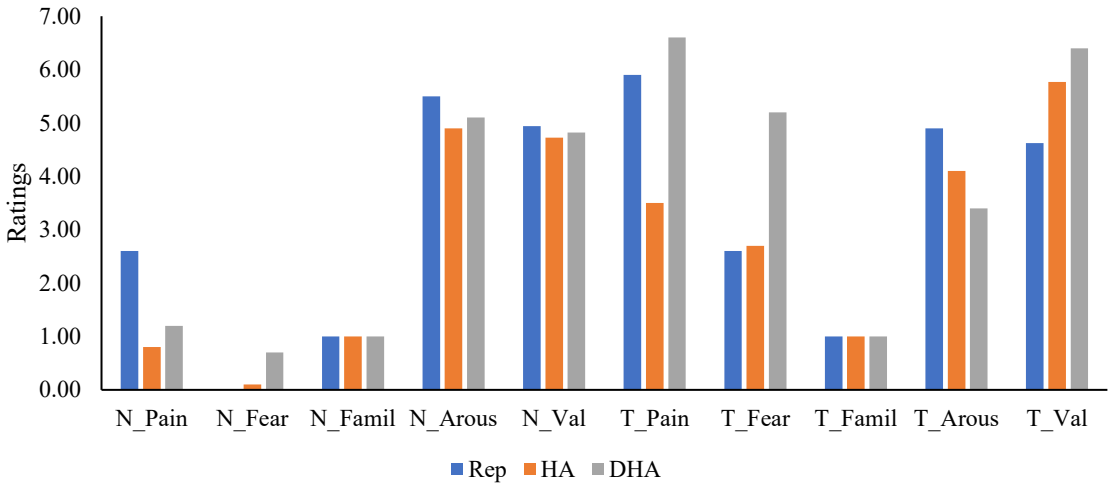


Figure 7.4 Median fear, pain, familiarity, arousal, and valence score for AO videos per back pain personality type

Figure 7.4 shows the median rating values split per personality type of the back pain group. The high anxious group only has one person therefore, it is not possible to perform any statistical analysis. Repressors had a median pain score of 2.6 for the neutral video and 5.9 for the threatening video. The high anxious group had a median pain score of 0.8 for the neutral video and 3.5 for the threatening video. The defensive high anxious group had a median pain score of 1.2 for the neutral video and 6.6 for the threatening video. The fear scores for the neutral image were 0, 0.1 and 0.7 for repressors, high anxious and defensive high anxious respectively. The median familiarity score was 1 for both neutral and threat videos and for all back pain groups. The median arousal score for the neutral video was 5.5 for repressors, 4.9 for high anxious, and 5.1 for defensive high anxious. Median arousal scores for the threatening video were 4.9 for repressors, 4.1 for high anxious and 3.4 for the defensive high anxious. The median valence scores were for the neutral video were 4.94, 4.73, and 4.82 for repressors, high anxious and defensive high anxious groups, for the threatening video median scores were 4.63, 5.77, and 6.40 for the repressors, high anxious and defensive high anxious respectively.

7.3.3 Eye-tracking

The eye-tracking variables (1st fixation duration, dwell time as a percentage of total, average fixation duration and fixation count) were averaged per AOI (head, back and object). A Mann-Whitney U test was used to assess differences in video ratings between the back pain and the control group.

7.3.3.1 Back pain vs control

7.3.3.1.1 First fixation duration

First fixation median values for control and back pain group per AOI are shown in Figure 7.5. Significant differences between the control and back pain group were found for both the neutral and threat video for the back AOI. Back pain participants (BPP) had a significantly longer median first fixation duration on the back (Mdn= 283.51ms) than the control group (Mdn= 17.95ms) U ($N_{back\ pain}$= 9, $N_{Controls}$= 29) = 28.50, z= -3.469, p< 0.001 in the control videos. BPP also had a significantly longer median first fixation on the back (Mdn= 473.54ms) than the control group (Mdn= 473.54ms) U ($N_{back\ pain}$= 9, $N_{Controls}$= 29) = 29.00, z= -3.453, p< 0.001 in the threat videos. None of the other AOIs had a significant difference for first fixation duration. In the neutral videos participants had a significant longer first fixation duration on the object (Z=-1.33, p=0.014), and head (Z=1.667, p=0.001) compared to the first fixation duration on the back. In the threatening videos BPP had a longer first fixation duration on the head compared to the back (Z=1.33, p=0.014) and compared to the object (Z=1.33, p=0.014). The control group had significantly shorter first fixation duration for the back compared to both the

head, threat (Z=1.61, p=0.001) and neutral (Z=1.61, p=0.001) and object, threat (Z=-1.29, p=0.001) and neutral (Z=-1.39, p=0.001).

7.3.3.1.2 Dwell time

Median dwell times as a percentage of total per AOI and group are represented in Figure 7.6. There were no significant differences between the control and back pain group for the dwell time on the object in neither the neutral nor threatening video. The back pain group had a significantly higher median dwell times when looking at both the neutral video for the head U ($N_{back\ pain}$= 9, $N_{Controls}$= 29) = 25.00, z= -3.575, p< 0.001 and the back U ($N_{back\ pain}$= 9, $N_{Controls}$= 29) = 25.50, z= -3.576, p< 0.001 than the control group. For the threatening videos the back pain group had longer dwell times looking at the head U ($N_{back\ pain}$= 9, $N_{Controls}$= 29) = 40.00, z= -3.044, p= 0.002 and back U ($N_{back\ pain}$= 9, $N_{Controls}$= 29) = 8.00, z= -3.364, p< 0.001 than the control group. The back pain group had longer dwell time on the head in the threatening condition compared to their dwell time on the back (Z=1.44, p=0.00) and object (Z=1.22, p=0.029), but no differences in the neutral condition. The control group had significantly shorter dwell time on the back compared to the object (Z=-1.39, p=0.001), and head (Z=0.61, p=0.001) for the threatening videos. For the neutral videos the control group had shorter dwell times on the back compared to the head (Z=1.14, p=0.001) and object (Z=1.86, p=0.001).

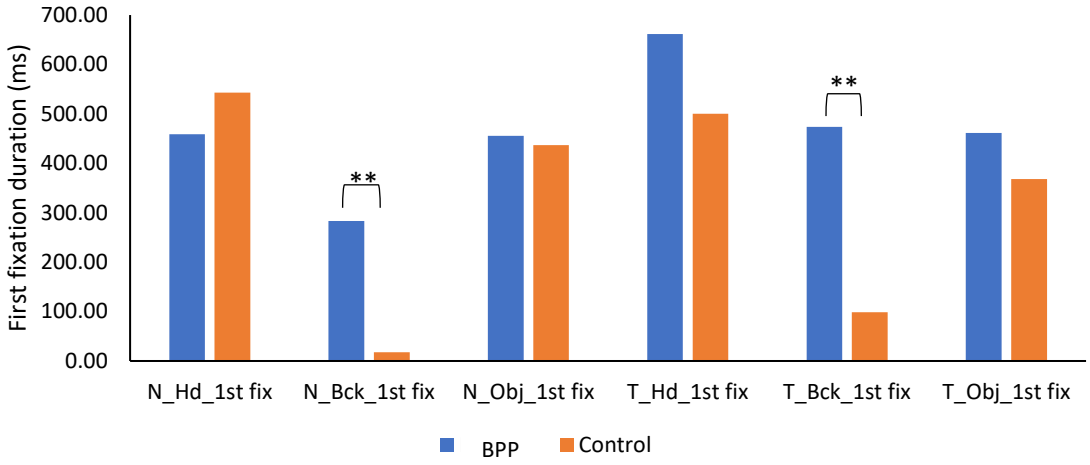


Figure 7.5 Median first fixation duration per video type N: neutral, T: threat and area of interest Hd: head, Bck: back, Obj: Object for back pain and control group. **p<0.001

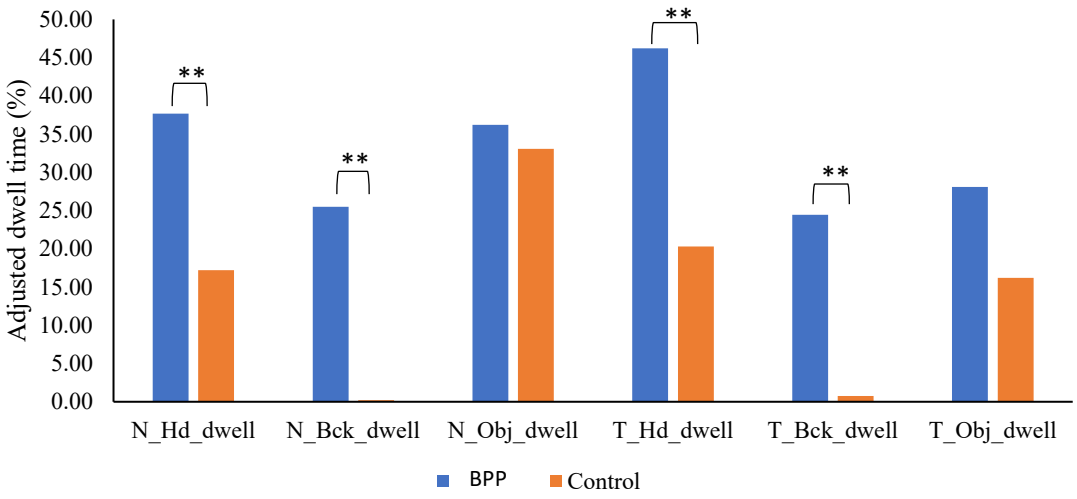


Figure 7.6 Median dwell times as a percentage of total per video type N: neutral, T: threat and area of interest Hd: head, Bck: back, Obj: Object for back pain and control group. **p<0.001

7.3.3.1.3 Average fixation duration

The median values of the average fixation duration per AOI and group are represented in Figure 7.7. There were no significant differences in average fixation duration for the object or the head in either the neutral or threatening videos. The back pain group had a significant longer median average fixation time on the back for the neutral videos than the control group U ($N_{back\ pain}$= 9, $N_{Controls}$= 29) = 29.50, z= -3.433, p< 0.001. The back pain group also had longer average fixation duration on the back for the threatening videos than the control group U ($N_{back\ pain}$= 9, $N_{Controls}$= 29) = 31.50, z= -3.364, p< 0.001. The back pain group had shorter fixation duration on the back compared to the head (Z=1.22, p=0.029) and object (Z=-1.78, p=0.001) for the neutral videos. For the threatening videos the back pain group had longer fixation durations on the head compared to the back (Z=1.56, p=0.003). The control group had significantly shorter fixation durations on the back compared to the head (Z=1.45, p=0.001), and object (Z=-1.54,

p=0.001) in the neutral videos and in the threat videos head (Z=1.71, p=0.001) and object (Z=-1.18, p=0.001).

7.3.3.1.4 Fixation count

Median fixation count per AOI and group are shown in Figure 7.8. There were no differences in the fixation count for the object AOI in the neutral or threatening videos. The back pain

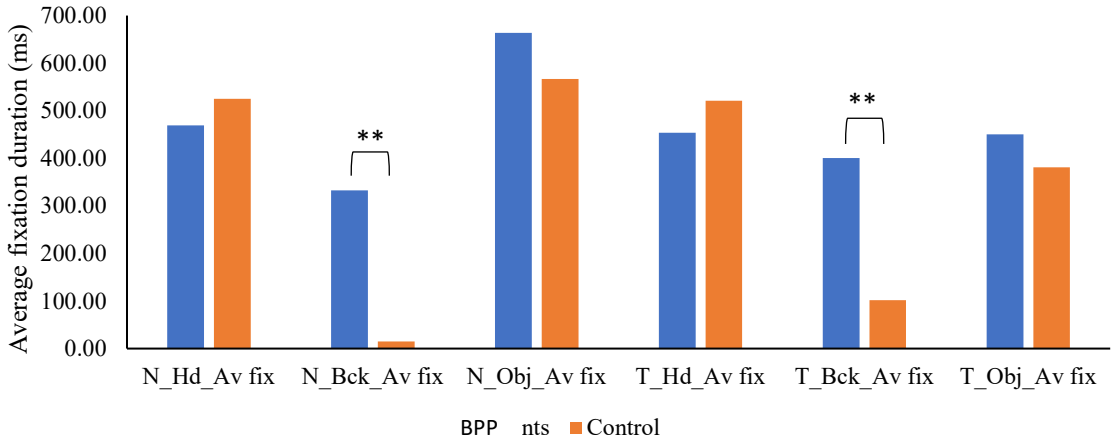


Figure 7.7 Median average fixation duration in ms per video type N: neutral, T: threat and area of interest Hd: head, Bck: back, Obj: Object for back pain and control groups. **p<0.001

group had a higher fixation count on the head in the neutral video compared to the control group U ($N_{back\ pain}$= 9, $N_{Controls}$= 29) = 63.00, z= -2.231, p= 0.026. The back pain group also had a higher fixation count on the back in the neutral video compared to the control group U ($N_{back\ pain}$= 9, $N_{Controls}$= 29) = 27.50, z= -3.510, p< 0.001. For the threatening videos BPP had a longer fixation duration on the head U ($N_{back\ pain}$= 9, $N_{Controls}$= 29) = 48.50, z= -2.744, p= 0.006 and on the back U ($N_{back\ pain}$= 9, $N_{Controls}$= 29) = 20.50, z= -3.739, p< 0.001 compared to the control group. The back pain participants had more fixations on the object for the neutral videos (Z=-2.00, p=0.001), and for the threatening videos the back pain participants had more counts on the head compared to the back (Z=1.33, p=0.014), and object (Z=1.33, p=0.014). The control group had less fixations on the back compared to the head (Z=-1.36, p=0.001) and the object

(Z=1.64, p=0.001) for the threatening videos and for the head (Z=1.11, p=0.001) and the object (Z=-1.89, p=0.001) for the neutral videos.

7.3.3.2 Back pain personality types

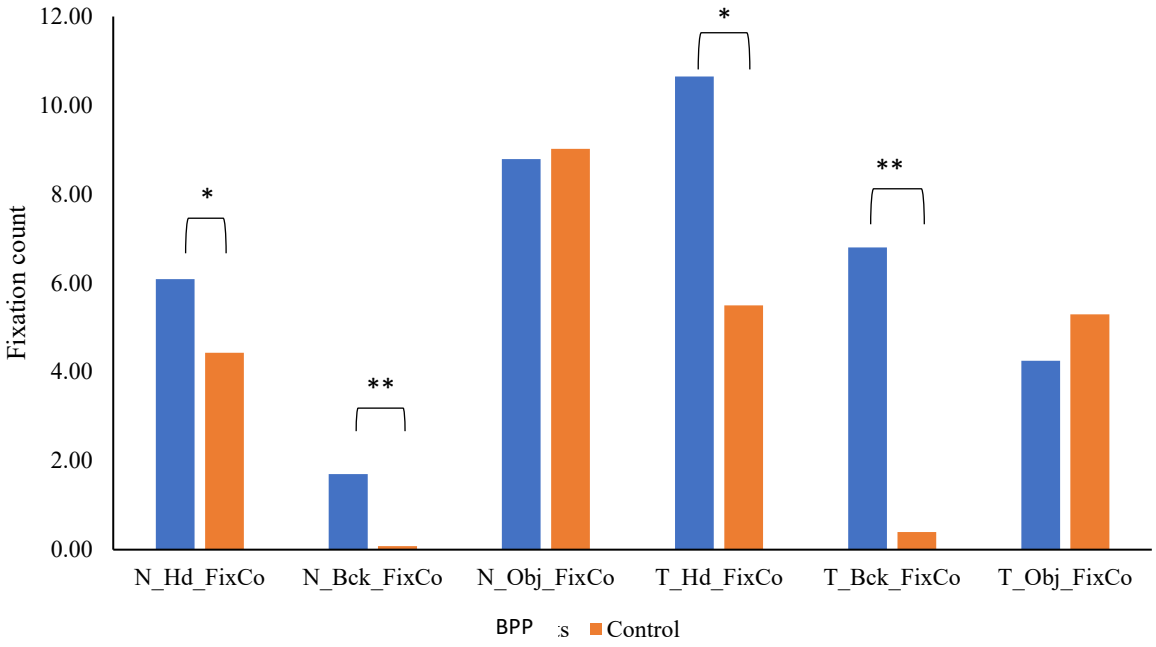


Figure 7.8 Median average fixation count per video type N: neutral, T: threat and area of interest Hd: head, Bck: back, Obj: Object for back pain and control groups *p=0.05, **p<0.001.

7.3.3.2.1 First fixation duration

Figure 7.9 shows the median first fixation duration split per back pain personality type. For the neutral videos the median first fixation time was 548.39ms, 458.68ms and 454.84ms for repressors, high anxious and defensive high anxious respectively when looking at the head. For the back it was 99.03ms, 3123.78ms, and 283.51ms for repressors, high anxious and defensive high anxious groups. The first fixation durations on the object were 454.25ms, 459.66ms and 455.86ms for repressors, high anxious and defensive high anxious groups. For the threatening videos median first fixation duration on the head was 661.49ms, 661.33ms and 650.95ms for the repressors, high anxious and defensive high anxious respectively. On the back the median average fixation duration was 170.76ms for repressors, 493.09ms for high anxious, and

481.00ms for defensive high anxious. Median first fixations on the object were 447.64ms for the repressors, 468.63ms high anxious, and 461.34ms for the defensive high anxious.

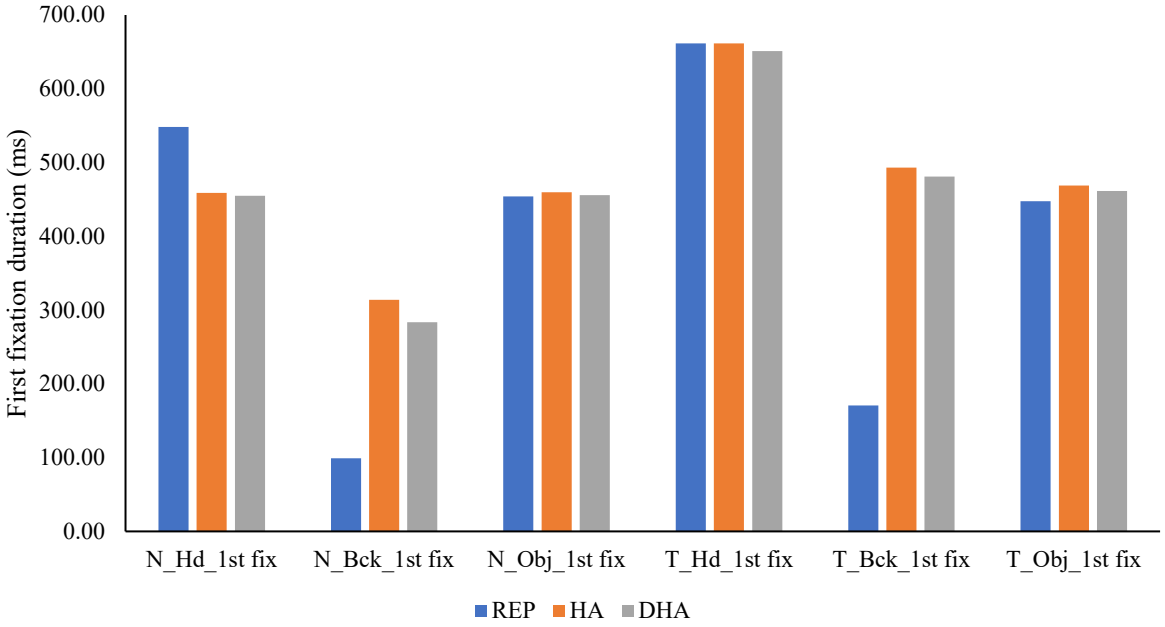


Figure 7.9 First fix duration in ms per video type N: neutral, T: threat and area of interest Hd: head, Bck: back, Obj: Object per back pain personality type.

7.3.3.2.2 Dwell time

Figure 7.10 shows the median dwell time as a percentage of total split per back pain personality type. For the neutral video the median dwell time at the head was 23.22% for repressors, 53.65% for the high anxious and 38.97%. Dwell time on the back was 1.34% for the repressors, 46.34% for the high anxious and 25.61% for the defensive high anxious. Dwell time on the object was 27.7% for the repressors, 36.23% for the high anxious and 44.83% for the defensive high anxious. For the threatening video dwell time on the head was 22.56% for the repressors, 46.2% for the high anxious, 54.49% for the defensive high anxious. Median dwell time on the back was 22.56% for the repressors, 46.20% for the high anxious, and 54.49% for the defensive high anxious. Median dwell time on the object was 8.62% for the repressors, 39.09% for the high anxious and 28.40% for the defensive high anxious.

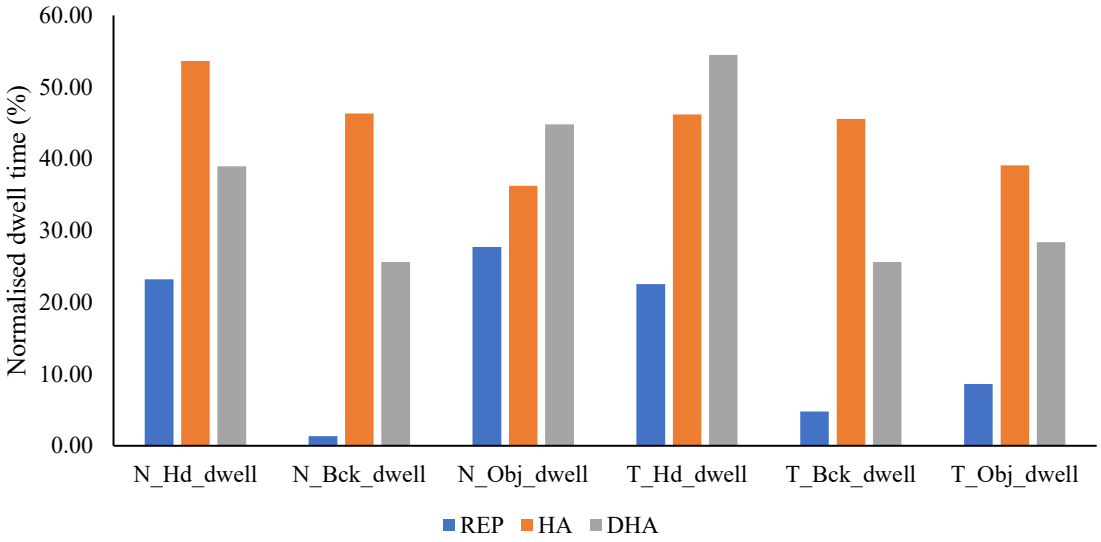


Figure 7.10 Median dwell time as a percentage of total per video type N: neutral, T: threat and area of interest Hd: head, Bck: back, Obj: Object per back pain personality type

7.3.3.2.3 Average fixation duration

Figure 7.11 shows the median average fixation duration split per back pain personality type. For the neutral video the median average fixation duration on the head was 584.74ms for repressors, 425.91ms for high anxious and 469.25ms for the defensive high anxious. On the back it was 108.83ms for the repressors, 354.15ms for the high anxious, 332.39ms for the defensive high anxious. Average fixation duration on the object was 652.90ms for the repressors, 666.86ms for the high anxious and 663.84ms for the defensive high anxious. For the threatening video the average fixation duration on the head was 450.26ms for the repressors, 443.60ms for the high anxious and 462.69ms for the defensive high anxious. For the back it was 181.20ms for the repressors, 426.08ms for the high anxious and 400.56ms for the defensive high anxious. Average fixation duration on the object was 445.26ms for the repressors, 473.28ms for the high anxious and 450.46ms for the defensive high anxious.

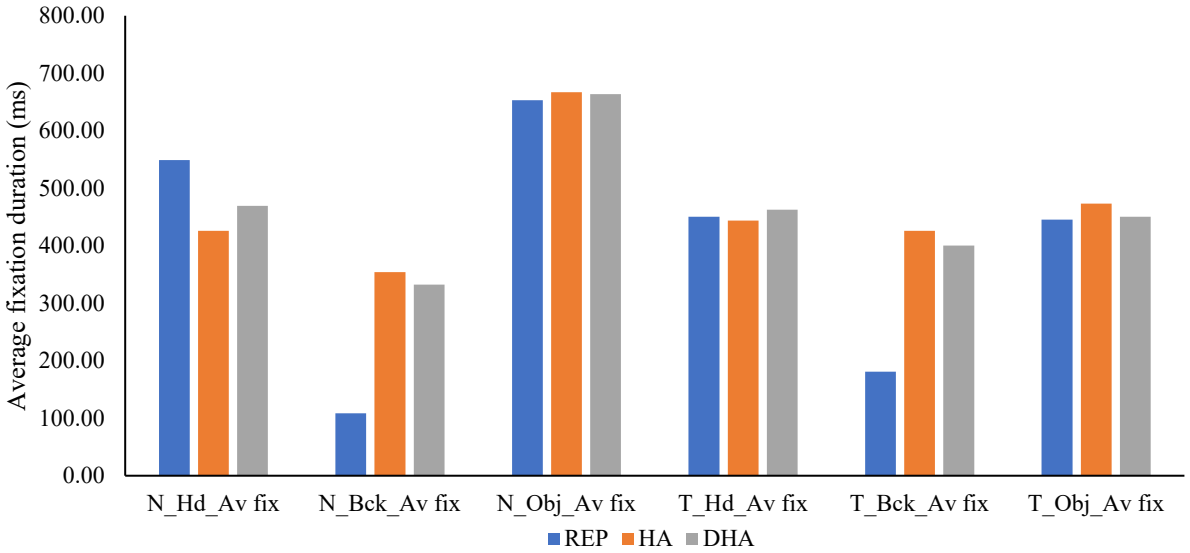


Figure 7.11 Median average fixation duration in ms per video type N: neutral, T: threat and area of interest Hd: head, Bck: back, Obj: Object per back pain personality type

7.3.3.2.4 Fixation count

Figure 7.12 shows the median fixation count split per back pain personality type. For the neutral video the median fixation count on the head was 7.27 for the repressors, 5.94 for the high anxious and 5.97 for the defensive high anxious. Fixation count on the back was 0.57 for the repressors, 2.15 for the high anxious, and 1.69 for the defensive high anxious. Fixation count on the object was 8.33 for the repressors, 8.79 for the high anxious and 8.82 for the defensive high anxious. For the threatening video the fixation count on the head was 10.17 for the repressors, 10.65 for the high anxious and the defensive high anxious. Fixation count on the back was 3.80 for the repressors, 7.60 for the high anxious and 7.29 for the defensive high anxious. Fixation count on the object was 4.93 for the repressors, 4.11 for the defensive high anxious and 4.24 for the defensive high anxious.

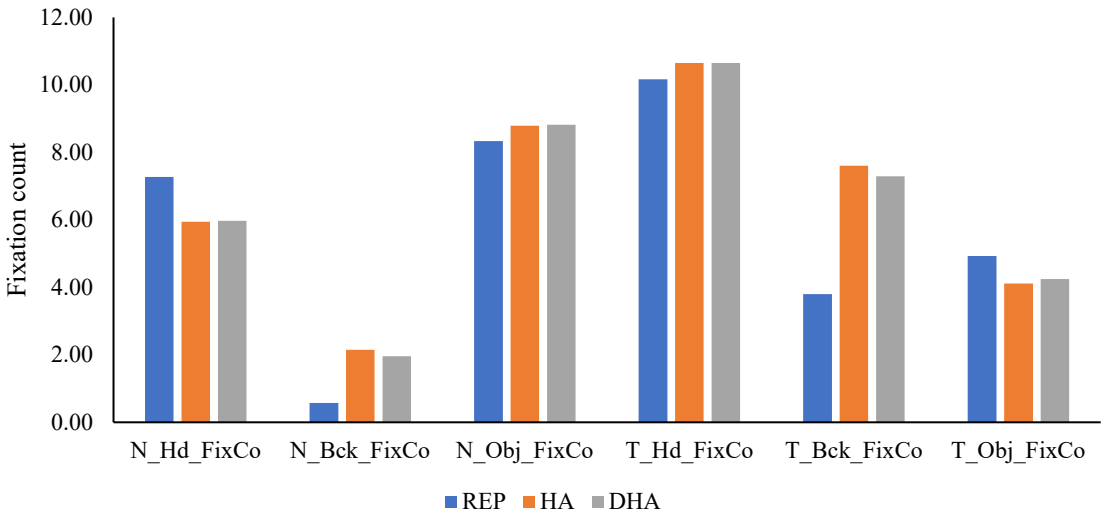


Figure 7.12 Median average fixation count per video type N: neutral, T: threat and area of interest Hd: head, Bck: back, Obj: Object per back pain personality type

7.3.3.3 Threat vs neutral videos

A Wilcoxon-signed rank test was used to assess the differences between the neutral and threatening variables within the back pain and control group separately. A Bonferroni adjusted significance level of 0.0042 was used.

7.3.3.3.1 Back pain group

The median fixation count was significantly lower on the head in the neutral video condition than in the threatening video condition (Z= -2.668, p=0.004). The median first fixation on the back was significantly lower for the neutral video than the first fixation duration on the back for the threatening video (Z= -2.667, p= 0.004). Average fixation duration on the back was significantly shorter than the average fixation duration on the back during threatening videos (Z= -2.687, p= 0.004) see Figure 7.13.

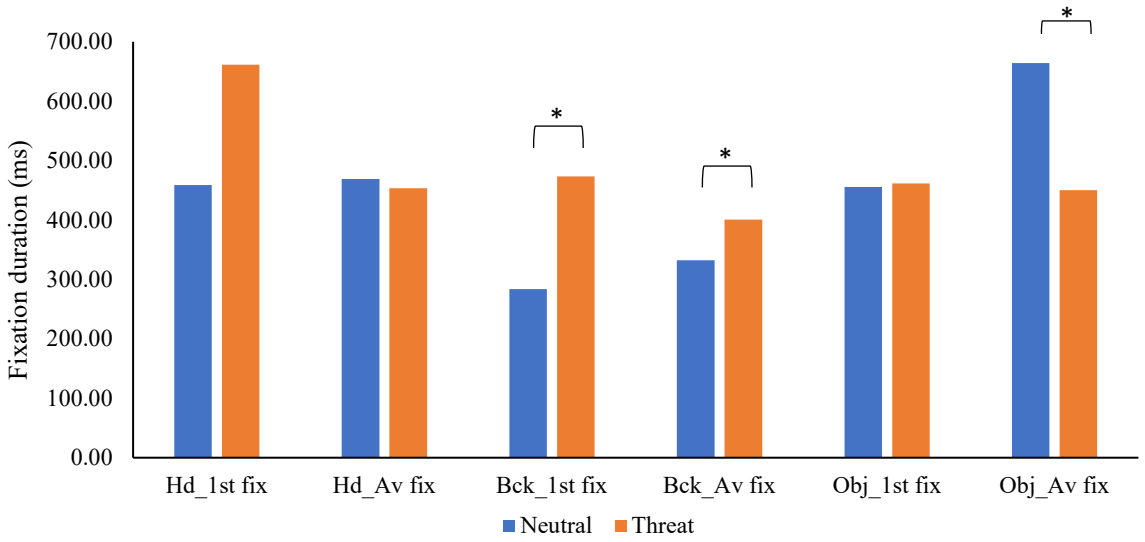


Figure 7.13 Median 1st and average fixation duration of threatening and neutral videos per area of interest Hd: head, Bck: back, Obj: Object. *p<0.05 for the back pain group

The number of fixations on the back for the neutral videos was significantly lower than the number of fixations for the threatening videos (Z= -2.666, p= 0.004). The average fixation duration on the object was significantly longer for the neutral video than for the threatening video (Z= -2.668, p= 0.004). The number of fixations was also significantly larger for the neutral video than for the threatening video (Z= -2.667, p= 0.004) see Figure 7.14.

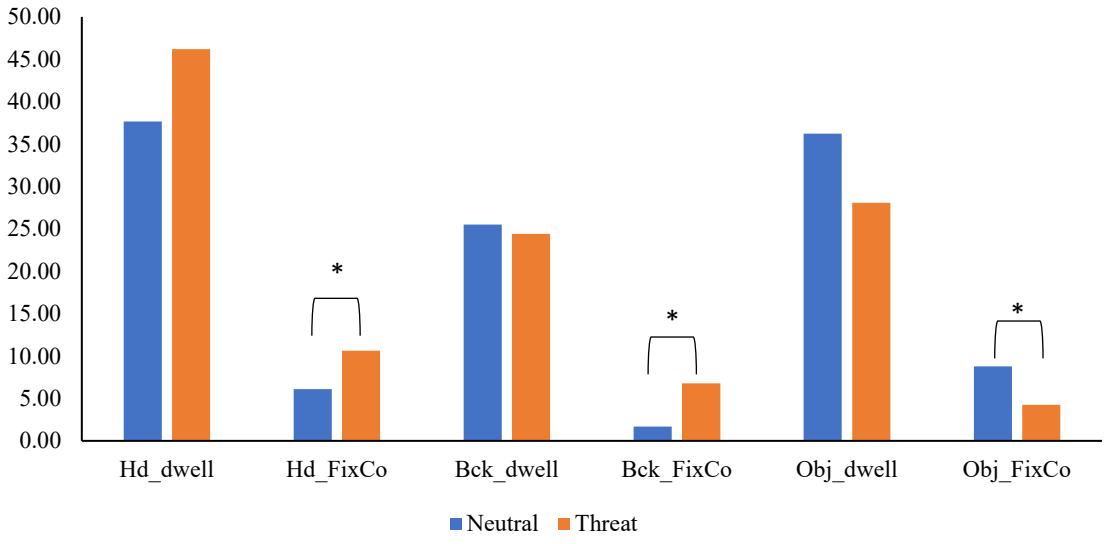


Figure 7.14 Median normalized dwell time (%) and median fixation count (FixCo) threat and neutral videos. The area of interest Hd: head, Bck: back, Obj: Object. *p<0.05 for the back pain group.

7.3.3.3.2 Controls

The median values for normalised dwell time and fixation count are displayed in Figure 7.15. The control group had a significantly higher fixation count (Z= -4.361, p< 0.001) and significantly longer normalised dwell (Z= -4.554, p< 0.001) on the object in the control condition compared to the threat condition. Control participants further had a longer normalised dwell time on the head in the threat condition compared to the control condition (Z= -3.532, p< 0.001).

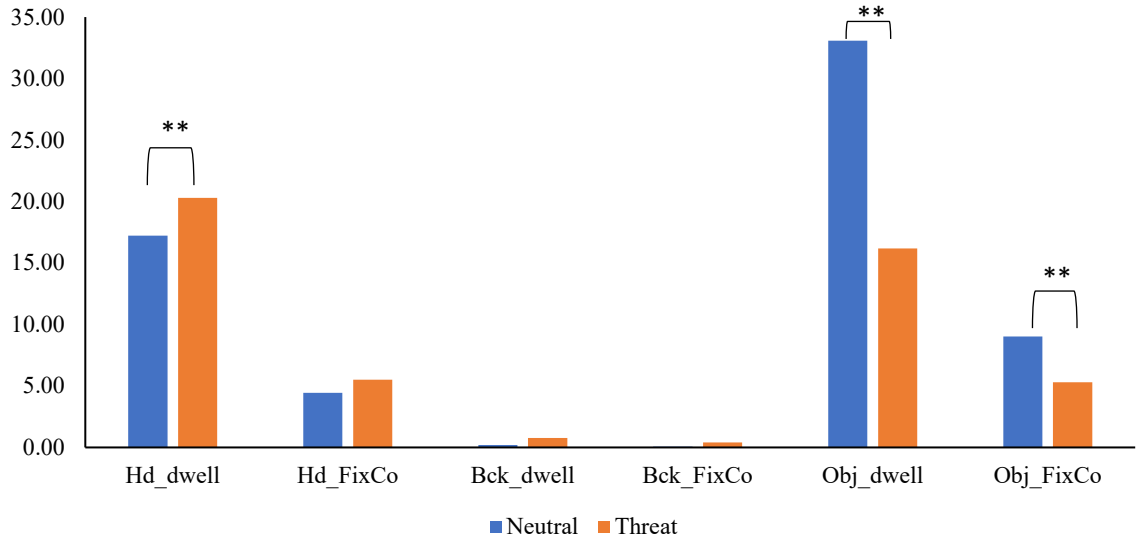


Figure 7.15 Median normalized dwell time (%) and median fixation count (FixCo) threat and neutral videos. The area of interest Hd: head, Bck: back, Obj: Object. *p<0.05 for the back pain group.

Median 1st fixation duration and median average fixation duration are represented in Figure 7.16. The control group has a significant longer first fixation (Z= -2.532, p= 0.003) and average fixation duration (Z= -2.645, p= 0.003) on the back in the threatening videos compared to the control videos. The average fixation duration on the object was significantly longer in the neutral condition compared to the threat condition (Z= -4.235, p< 0.001).

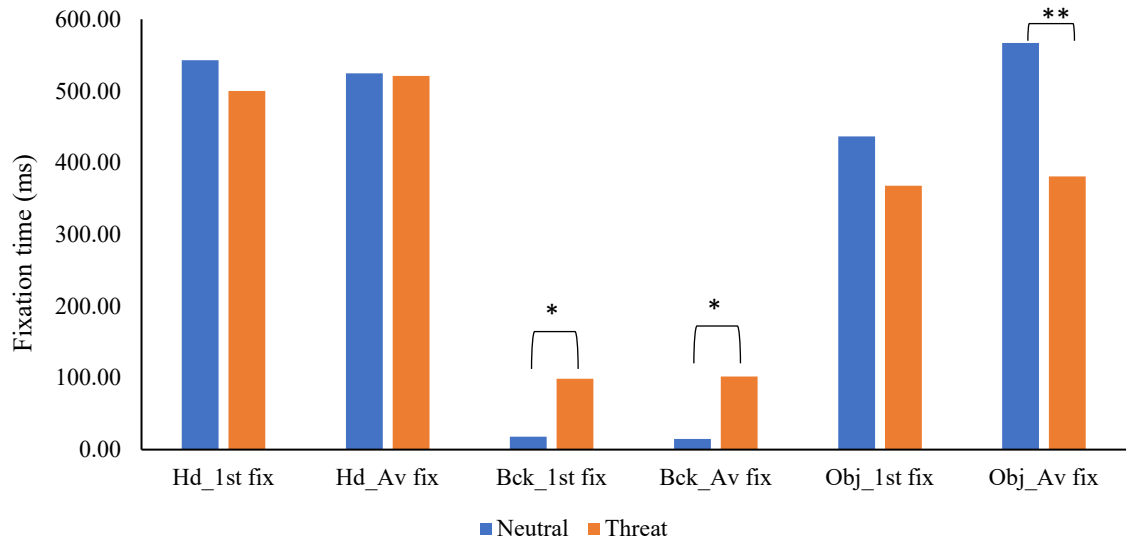


Figure 7.16 Median 1st fixation duration and average fixation duration for threat and neutral videos. The area of interest Hd: head, Bck: back, Obj: Object for the control group *p<0.05

7.4 Discussion

To the author's knowledge this is the first study to use an action observation task to assess attention in a chronic back pain population. This study had two aims: i) to assess the attentional bias during an action observation task, and ii) to assess the effect of personality type on the attentional bias during an action observation task.

The videos were split into two groups: threatening videos which showed actions that involved movements which involved the movement of the back, and neutral videos which were matched to the threatening videos but involved less or no movement of the back. To test if the grouping was correct participants rated the videos on pain and threat. The rating of the videos used in the action observation task showed that the control participants did not rate the threatening images or videos as painful or fearful. The back pain participants (BPP) scored significantly higher on pain and fear for the neutral and threatening videos compared to the controls. The threatening videos were rated as more painful and more fearful compared to the neutral videos. BPP also rated the threatening videos higher in valence meaning they evoked more negative feelings and lower in arousal making them feel more excited. Taken together these results indicate that the assumption that neither the threatening nor the neutral videos

were threatening for the control group holds true. It is, however, interesting that the BPP considered the neutral videos, which have no or minimal movement of the spine, painful and fearful. The scores were lower than those of the threatening videos which contained actions that involve major movement of the spine but were still significantly higher than the pain and fear scores of the control group. This could mean that individuals with chronic back pain experience, and are afraid of, pain even when they are not moving their back. For future research it is thus highly recommended to have participants rate the stimuli and to consider that pain can be consistent and unrelated to movement.

Even though no statistical analysis could be performed once the back pain participant data was split into personality type, certain trends were observed. Both pain and fear appear to be higher for the threatening videos compared to the neutral videos for all personality types. For the threatening videos defensive high anxious (DHGA) individuals had what appears to be the highest pain and fear scores. Repressors (REP) appeared to have a similar pain score as the DHA but their fear score was lower than the DHA and the high anxious (HA). This difference in fear score is in line with the predictions made by Eysenck (1997) whichstated that REP will experience threat physiologically but that they either do not interpret these signals or report that it is not anxiety but excitement that they feel. On the other hand, DHA and HA interpret the anxiety they experience as threatening because of their high trait anxiety and the DHA have the highest score because their high defensiveness makes them more likely to catastrophise the anxiety they experience. Arousal and valence scores for the neutral videos appear similar and around the neutral score for all personality types. The threatening videos appear to have the largest effect on the valence and arousal scores of the DHA group making them feel unhappy and more excited when looking at them. The HA group appear to feel slightly less happy and slightly less excited compared the DHA. The arousal and valence scores of the REP group seem to cluster around the neutral score thus not changing how they feel when they look at the

videos in a positive or negative way. These findings seem to support the prediction made by Eysenck (1997) whereby the cognitive biases of DHA enhance their interpretation of the perceived threat of the videos in a negative way. The REP reported that the actions in the videos would be painful in a similar way to the DHA group but said that they were not afraid of doing the action. Contrary to the predictions of Eysenck (1997) the REP seemed to have the highest pain score for the neutral videos. Prasertsri et al. (2011) found no differences in current pain assessed using the Visual Analogue Scale (VAS), nor in the current pain quality assessed with the McGill Pain Questionnaire (MPQ) between REP and DHA. Though the results of this study are supported by similar findings the low number of participants in the current study means that the results should be interpreted cautiously.

The action observation task is the first of its kind conducted with a chronic back pain population according to the author's knowledge. The BPP had significantly longer first fixation, average fixation duration, dwell time, and more fixations on the back and a higher fixation count and dwell time on the head during neutral and threatening videos compared to the control group. Previous studies that used other stimuli (images, words, or faces) found a visual attentional bias towards presumed threatening stimuli in general, the findings of this study show that the areas that individuals with chronic back pain find threatening are the back and the face. Both these areas could hold clues that would indicate to the back pain group whether the action might be threatening for them. The face could show expressions of pain, which have been found to draw attention in both control and pain groups (Yang et al., 2013). Not only was the attention of the back pain group towards the back significantly larger than the control group, but the time that the control group spent looking at the back was close to zero in both the neutral and threatening videos. Studies in action observation have found that eye-gaze is directed towards task relevant elements in those videos, because the control group did not

attend to the back much this part may not have been relevant for them to understand the task. For the back pain group looking at the back might a task relevant cue.

This study found differences in the gaze behaviour of the BPP and control group depending on the video condition. The back pain group had significantly longer first fixations and average fixation durations and a higher fixation count on the back and a higher fixation count on the head during the threatening videos than during the neutral videos. They also decreased the fixation count and average fixation duration on the object. This could mean that when the perceived pain and fear level of a video increases, the BPP shift from a goal oriented to a stimulus oriented attentional system. In accordance with Attentional Control theory (ACT) studies have found that under a higher situational stress condition individuals with high trait anxiety shift their attention to stimulus driven cues. The BPP had a significantly higher trait anxiety score than the control group, which could support an attentional shift from goal to stimulus related elements. The different back pain personality types showed some trends in different gaze behaviour that would lend further support to a change in attentional control. Most notably was that REP, who are low in trait anxiety, appeared to spend less time looking at the back than the HA and DHA, who are both high in trait anxiety, in both the neutral and threating conditions. The gaze behaviour of the REP is in line with how they scored the videos, similar in pain but less fearful than the HA and DHA which also supports Eysenck's four factor theory. This could mean that it is not necessarily the pain associated with the video but the fear of that pain which drives the attention to different elements of the action. In a different clinical population, Lazarov et al. (2016) found that stimuli with a higher perceived threat level had longer dwell times for individuals with social anxiety compared to stimuli with a lower perceived threat level, which further supports the findings in this study.

7.5 Conclusion

This study provides evidence for an attentional bias in individuals with chronic pain specifically towards the back and face during an action observation task. Differences between personality types could not be assessed because of the low number of back pain participants. There are however trends observed that support Eysenck's theory. Taken together these findings add a nuance to the conclusion presented in the meta-analysis by Jones et al. (2020). This meta-analysis concluded that pain related stimuli always draw attention. The results from the comparison between BPP and controls show that it is the interpretation or assumption of a stimulus as painful that would seem to draw attention. Diving deeper into the differences within the BPP group, it appears that even when a stimulus is rated as painful, as done by all personality type groups, it is the difference in whether that pain is considered a threat that changes the attention as well. REP did not rate the pain as fearful and had what appears to be a deferent gaze behaviour compared to the DHA and HA who did rate the pain as fearful. It also hints at the heterogeneity of the chronic back pain population and how their personality traits drive their coping mechanisms when confronted with perceived threatening information.

The action observation task showed what participants pay attention to when they observe another person move. It does not however, probe what sensations and visual ques a person with back pain pays attention to when they themselves have to perform the movement. Motor imagery does probe the mental representation of a movement and it has been shown to rely on similar neural pathways as an action observation task. The next experimental chapter investigates the imagery ability of individuals with chronic pain using the Movement Imagery Ability Questionnaire 3. This will provide a novel insight into the motor imagery ability that individuals with back pain have across multiple imagery domains.

8 Study 3: Motor Imagery Questionnaire – Back Pain

8.1 Introduction

Chronic back pain is one of the most common causes of disability in adults and illness-related work absences (Hartvigsen et al., 2018; Hoy et al., 2010). Graded Motor Imagery (GMI), which involves a left/right judgement task, motor imagery, and mirror therapy, has been used as a tool to assist in treatment of chronic pain (Bowering et al., 2013; Breckenridge et al., 2019) and has shown some promise in decreasing pain intensity. However, few of these studies investigate the ability of individuals with chronic pain to create imagery and whether it has sufficient vividness. Disruptions in the mental representation of the body as measured by a motor imagery task are thought to contribute to the maintenance of some chronic pain conditions (Moseley et al., 2008) and restoring the working body schema shows promising effects on pain and disability (Bowering et al., 2013; Bray & Moseley, 2011). Previous research has demonstrated that imagery has the potential to reduce anxiety associated with the imagined scenario e.g., (Hale & Whitehouse, 1998; Hanton et al., 2004) as well as improving self-efficacy e.g., (Feltz & Riessinger, 1990). Data from the previous studies in this thesis have shown that the chronic back pain patients have significantly higher trait anxiety and significantly lower self-efficacy compared to the control group, and trends were observed for differences in these psychological elements and the different personality types.

A recent meta-analysis investigated whether individuals with chronic musculoskeletal pain have impaired motor imagery as assessed by the left/right judgement task (LRJT) (Breckenridge et al., 2019). The authors analysed 25 studies with 2,266 participants which included a range of chronic pain conditions. LRJT, a mental rotation task, in which a body part is shown in different rotations and participants are asked to determine as quickly and accurately as possible whether an image of a body part is of the left or right side. Abnormally long response times are thought to reflect delayed processing of the body's spatial representation,

whereas lower accuracy is thought to reflect disrupted cortical proprioceptive representation of the body's schema (Parsons, 2001). The results of the meta-analysis show that imagery ability assessed by the LRJT was only impaired in individuals who had chronic limb or face pain, but that chronic neck and lower back pain did not interfere with the LRJT. Mibu et al. (2020) used two mental rotation tasks: the lateral judgement task (LJT) which requires participants to judge whether they are shown a right or left hand and the same-different judgement task (SDJT), in which participants are shown two hands and they have to judge whether they are both right or left hands, to assess whether a mental rotation task requires motor imagery to be solved. They assessed the presence of the biomechanical constraints effect and the linear relationship between rotation angles and response times (RT) in participants and between the two tasks. The biomechanical constraints effect refers to more errors and longer response time when the observed hand is rotated in a more difficult way, laterally. The linear relationship between RT and rotation angle is thought to be a result of performing the mental rotation of one's own hand, the larger the angle the longer it takes to mentally rotate the hand and thus the longer the RT. According to their results, however, the biomechanical constraints effect, longer reaction times or less accurate answers for limbs in biomechanically impossible rotations, was not observed in up to 37% of the participants in the palmar view condition of the LJT. Moreover, up to 60% of the participants did not show simultaneously the linear angle-RT relationship and the biomechanical constraints effect. This finding indicates that individuals do not necessarily require the use of motor imagery–based strategies to solve the mental rotation tasks. The use of these judgement tasks to assess imagery abilities in clinical populations should thus be reconsidered and previous results should be interpreted cautiously. A recent review by Kim et al. (2021) which reviewed 17 studies that used a LRJT in cohorts of pain suggested that peripheral pain might not alter sensory or motor cortical representations. Taken together the

review and Mibu studies suggest that the LRJT might not be ideal for assessing motor imagery in chronic back pain patients.

Another simple yet comprehensive method to assess aspects of a person's visual and kinaesthetic imagery abilities is the use of self-report measures. There are several questionnaire assessments that can be used to assess aspects of imagery ability; the most common of which assess image generation ability (e.g., the Movement Imagery Questionnaire-3 (MIQ-3) (Williams et al., 2012)) and the vividness of a person's imagery (e.g., the Vividness of Movement Imagery Questionnaire-2 (VMIQ-2) (Roberts et al., 2008)). The VMIQ-2 and MIQ-3 assess motor imagery specifically. The VMIQ-2 describes 12 actions that the participant imagines in an external visual perspective, internal visual perspective and kinaesthetically. They are then asked to rate the vividness of that image on a scale 1-5 where 1 is "Perfectly clear and vivid as normal vision" and 5 represent "No image at all, you only know that you are thinking of the skill". The MIQ-3 assesses the individual's ability to image four movements using 1st person (internal) visual imagery, 3rd person (external) visual imagery, and kinaesthetic imagery (Williams et al., 2012). The four actions used in the MIQ-3 are 1) raising the right knee as high as possible then lowering it, 2) crouching down and then jumping in the air as high as possible with both arms extended above the head, 3) moving the non-dominant an arm forward until it is directly in front of you whilst still parallel to the floor, and 4) bending forward at the waist to try touch and touch toes. Both the VMIQ-2 and MIQ-3 have good psychometric properties, internal reliability, and predictive validity (Roberts et al., 2008; Williams et al., 2012). The VMIQ-2 and MIQ-3 both rely on self-reported responses on a Likert scale on similar imagery domains. The VMIQ-2 assesses the vividness of the image created whereas the MIQ-3 the ability to generate the images. Although different components of imagery ability, vividness, and ease of imagining have been found to be correlated highly (Anuar et al., 2016). The MIQ-3 requires that participants first execute the movement before they imagine it.

The MIQ-3 provides clear and explicit instructions for executing the action compared to the instructions of the VMIQ-2. For example, in the VMIQ-2, participants are asked to imagine kicking a ball in the air, but it is not stated what kind of ball or what technique to use (e.g., kicking a ball from the floor or from the hands). The many ways this could be interpreted may lead to considerable variation in what mental image is produced (Caliari, 2008). The MIQ-3's instructions about how to execute the actions and because participants are asked to first perform the actions before imagining them makes the images more consistent across participants. Another advantage of executing an action before imagining it is that differences in imagery ability due to recency effects are prevented, whereas the VMIQ-2 uses actions that are fairly obscure or that participants may have never done (e.g., swinging on a rope, kicking a stone, riding a bike). An important improvement of the MIQ-3 over the earlier versions of the MIQ is that the MIQ-3 splits the visual imagery into 1st and 3rd-person visual perspective, whereas the MIQ-R only discriminates between kinaesthetic and visual imagery without specifying what visual perspective to use. The popularity of the MIQ versions has led to the development of a version adapted for children (Martini et al., 2016) and a version developed for the rehabilitation setting (MIQ-RS) (Gregg et al., 2010). These actions are suitable for a healthy population; however, individuals with chronic back pain may not be able or willing to perform some of these actions because of fear and/or pain associated with these movements (e.g., crouching and jumping in the air). The MIQ-RS is further focused on the upper extremities and does not involve actions that would be relevant for back pain rehabilitation. Whilst it would be possible to omit the movement execution element before the imagery task, this would lose the advantage of mitigating recency and experience effects.

La Touche et al. (2019) investigated the ability for individuals with chronic pain to generate motor imagery compared to individuals without chronic low back pain, using an adapted version of the MIQ-R. The MIQ-R asks participants to execute an action and then

create an image of the action they just performed either visually or kinaesthetically. When the individual has performed the mental task required, they are then asked to rate the vividness of the image on a scale of 1-7, with 1 being "very difficult to see or feel" and 7 being "very easy to see or feel". They also timed how long it took participants to create the imagery. La Touche et al. (2019) made one adaptation to the MIQ-R; for safety reasons they replaced the crouch then jump action with the action of standing on tip toes. Their results showed that the chronic back-pain group not only had more difficulty generating visual and kinaesthetic imagery but also took longer to create them than asymptomatic controls.

As mentioned above, the MIQ-R does not differentiate between 1st and 3rd person visual perspectives. Ruby and Decety (2001) found that visual imagery from a 1st person perspective elicited different neural activity to that of the 3rd person. During the 1st person perspective, the left inferior parietal and somatosensory cortex were activated which are cortical areas associated with functional equivalence between simulation and execution. Visual imagery in the 3rd person perspective activated the right inferior parietal, praecuneus, posterior cingulate and frontopolar cortex which are thought to be related to mapping the actions of others onto the self and thus possibly transforming the copied motor plan into execution. The results of these studies suggest that each visual perspective has distinct cognitive processes. The imagery questionnaire that La Touche et al. (2019) used does not differentiate between 1st and 3rd person visual imagery. The studies above show that 1st and 3rd visual imagery have different cognitive processes and this study will use a questionnaire that differentiates between 1st and 3rd person visual imagery.

This study consists of two parts. The first part was conducted online during the COVID lockdown and had two aims; i) investigate differences in self-reported imagery ability between individuals with chronic back pain and healthy controls, ii) to test a new version of the MIQ-3 designed for individuals with chronic back pain. Part two of the study was conducted in a

laboratory setting and had two aims: i) to further investigate differences in imagery ability, and ii) to see if personality type influences imagery ability.

8.2 Method

8.2.1 Participants

For part one, 50 volunteers (17 female) were recruited via social media posts. Fifteen of the participants had current back pain for over three months or had an episode of back pain in the past six months that lasted longer than three months. Ethical approval for this study was granted by the university ethics board. For part two 38 volunteers (21 female) were recruited via the NHS. Nine participants had chronic back pain. Ethical approval for part two was granted by the NHS Research Ethics Committee. Age and gender split for parts one and two are represented in Table 8.1.

Table 8.1 Participant age and gender demographics for part one age as average (standard deviation) and for part two as median

Part	Group	Age (years)	Gender
1	Chronic Back Pain (n=15)	37.7 (11.78)	5 female
	Control Group (n=35)	36.1 (13.15)	12 female
2	Chronic Back Pain (n=9)	31	4 female
	Control Group (n=29)	26	17 female

8.2.2 Motor Imagery Questionnaire

This study used the validated MIQ-3 (Williams et al., 2012) and a newly adapted Movement Imagery Questionnaire – Back Pain (MIQ-BP) to assess self-reported imagery generation ability. The MIQ-3 consists of four actions: lifting the right knee, bending forward trying to touch your toes, jumping in the air, and moving the non-dominant arm forward. After consultation with a physiotherapist, it was decided that two of the actions (jumping in the air and lifting the right knee) would likely be too demanding and threatening for the back pain

group and should be replaced with two different actions. Using this advice, the jumping and lifting the right knee were replaced by a sit-to-stand and a step forward action in the MIQ-BP. Both the MIQ-3 and MIQ-BP assess imagery generation ability in two different modalities: visual and kinaesthetic. The visual modality is further split into a 1st person perspective (internal visual imagery) and a 3rd person perspective (external visual imagery).

8.2.3 Procedure

8.2.3.1 Part one

The study was conducted online via video conferencing and an online questionnaire due to Covid lockdowns. Participants received two Microsoft Teams links that gave them access to an individual virtual room to which only they and the researcher had access. At the start of the first online session participants were asked if they had any questions after reading the participant information sheet. After any questions were answered to the satisfaction of the participant, the researcher shared a link to an online questionnaire designed with the JISC© software (online surveys JISC, Bristol, UK). The first page of the questionnaire consisted of a consent form, the second page had demographic questions (age and sex) as well as questions about their knowledge of imagery and their back pain history. The last page included an explanation of both the MIQ-3 and MIQ-BP questionnaire, which participants were then asked to fill out. After participants completed the demographics questionnaire, the researcher verbally repeated part of the MIQ explanation to make sure participants understood the different imagery modalities, procedure, and the rating scale, and answered any remaining questions. Participants then completed either the MIQ-3 or the MIQ-BP. For both the MIQ-3 and MIQ-BP, participants listened to the description of an action read aloud by the researcher, then executed that action and the researcher corrected them if needed. After participants executed the action there was a short pause before they were asked to imagine the action. Participants were asked to imagine it from either a 1st person visual perspective, a 3rd person visual

perspective, or kinaesthetically. Participants could take as long as they needed to imagine seeing or feeling the action. After they indicated they had completed their imagery, the researcher asked them how hard/easy it was to create the image and participants provided a verbal rating (on a scale of 1: very hard to 7 very easy). The scale was visible on the participants' screen throughout the experiment for them to reference. The order of the actions was randomised. After the imagery task there was a short interview with four open questions. 1) Was there an action that was very painful? 2) Did you have trouble imagining a specific movement, if so which one? 3) Did you have trouble with the execution of a specific movement? 4) What did you think of using imagery? The researcher wrote down the answers using shorthand. At the end of the first session the date for the second session was confirmed. At the start of the second session, one week after the first, the experimenter asked whether the participants had had any episodes of back pain in the past week, then repeated the explanation that the participants received in session one. The same procedure from the first session was repeated for the other questionnaire, and the same short interview as in session one was also conducted. At the end of the second session participants were able to ask questions about the purpose of the study.

8.2.3.2 Part two

This study was conducted in a laboratory setting. After participants completed the dot-probe task they were asked to complete the MIQ-BP (see Chapter 4). Participants only completed the adapted MIQ-BP version in this part. There were four actions (try and touch your toes, an arm movement, sit-to-stand, and a step forward) that the participants first performed and then imagined. Participants were asked to imagine it from either a 1st person visual perspective, a 3rd person visual perspective, or kinaesthetically. Participants could take as long as they needed to imagine seeing or feeling the action. After they indicated they had completed their imagery, the researcher asked them how hard/easy it was to create the image and participants provided

a verbal rating (on a scale of 1: very hard to see or feel to 7 very easy to see or feel). The researcher then recorded their score and moved on to the next action.

8.2.4 Data analysis

The scores of each imagery modality were averaged across all actions and all participants for each version of the MIQ. The Shapiro Wilk's test was used to assess normal distribution. Based on this and after visual inspection of the QQ-plots a decision was made about whether the assumption of normal distribution was maintained. For normally distributed data parametric paired t-tests were used to compare the modalities scores between the MIQ-3 and MIQ-BP. Follow-up paired t-tests were used to compare the imagery modalities scores within each group. A 2x3 (group x imagery modality) between-groups Analysis of Variance (ANOVA) was used to identify differences between the modalities scores of the MIQ-3 and the MIQ-BP between the backpain and control group. Where necessary, additional post-hoc tests were done. For non-parametric data the Mann-Whitney U test was chosen to test for differences between the control and back pain group.

The data from the short interview were analysed using six-step thematic analysis, as described by Braun and Clarke (2006). The first step in the analysis involved initial familiarisation with the information by reading the whole transcript, followed by the second step of transcribing the interviews. Step three was identification of initial codes. Step four was the identification of themes and step five was the naming reorganising and completion of themes. Step six was theme comparison and write-up.

8.3 Results

8.3.1 Part one

8.3.1.1 MIQ-3 vs MIQ-BP imagery domain scores

The average imagery modality scores of the MIQ-3 were 5.7 (± 1.0) for kinaesthetic, 5.6 (± 1.2) for 1st person visual and 6.2 (± 0.9) for 3rd person visual. The average MIQ-BP modality scores were 5.5 (± 1.1) for kinaesthetic, 5.8 (± 1.2) for 1st person visual and 6.2 (± 0.9) for 3rd person visual. The t-tests revealed no significant differences between the kinaesthetic, $t(49) = 1.198$ $p = 0.237$, 1st person visual, $t(49) = -1.190$ $p = 0.240$, or 3rd person, $t(49) = -.275$ $p = 0.798$, modality scores between the questionnaires. The participants were split into a chronic back pain and control group. For the control group there were no significant differences between the MIQ-3 and MIQ-BP modality scores, kinaesthetic $t(34) = 1.176$ $p = 0.248$, 1st person visual, $t(34) = -0.823$ $p = 0.416$, or 3rd person, $t(34) = 0.867$ $p = 0.392$. For the back pain group there were no significant differences between the MIQ-3 and MIQ-BP domain scores kinaesthetic $t(14) = 0.382$ $p = 0.710$, 1st person visual, $t(14) = -0.886$ $p = 0.394$, or 3rd person, $t(14) = -1.567$ $p = 0.145$.

8.3.1.2 Backpain vs control group domain scores

The average imagery ability for the control group was 5.7 (± 0.97) for kinaesthetic, 5.9 (± 1.16) for 1st person and 6.2 (± 0.97) for 3rd person. The average imagery ability for the chronic back pain group was 4.9 (± 1.21) for kinaesthetic, 5.1 (± 1.35) for 1st person and 6.2 (± 0.78) for 3rd person (see Figure 8.1) of the MIQ-3. The average modality scores per questionnaire per group were compared using a 2 (group) x 6 (imagery modalities) ANOVA. The back pain group scored significantly lower in the kinaesthetic modality of both the MIQ-3 $F(2, 6) = 6.451$, $p=.015$, $d = 0.7$ and MIQ-BP $F(2, 6) = 5.403$, $p=.025$, $d = 0.6$ and in the 1st person visual modality of the MIQ-3 $F(2, 6) = 5.099$, $p=.029$, $d = 0.6$.

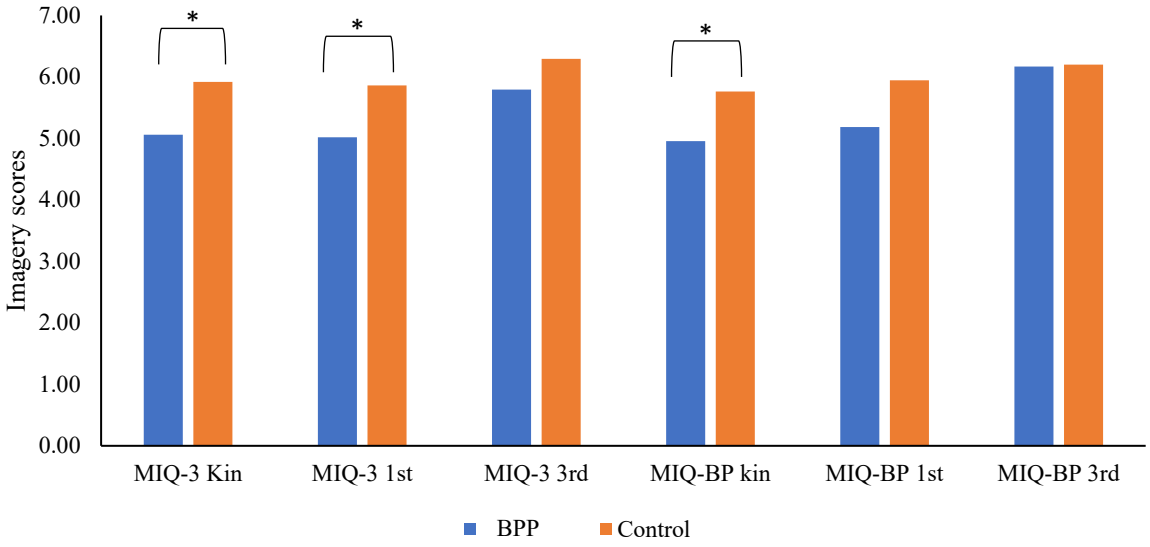


Figure 8.1 Average imagery scores per questionnaire and per domain. *p<0.05

8.3.1.3 Interview

Thematic analysis of the interview data revealed that each person in the back pain group reported experiencing pain or unpleasant feelings when they had to physically touch their toes or jump in the air. A smaller proportion reported pain or an unpleasant feeling when raising their right knee (e.g., "it feels like a stabbing pain in my lower back, more on the side of the leg I am lifting" back pain participant 4). The pain or unpleasant feeling was always felt in the back. Most of the back pain group also reported that they would imagine pain during kinaesthetic imagery as part of a painful action. Participants reported two reasons for this; most common was that the pain belonged/was part of the movement ("When I imagine the feeling of the action pain just belongs to the move as it is always there when I do it" back pain participant 7), whilst others said that pain was the strongest kinaesthetic feeling they had when doing the movement ("It is hard to actually focus on another sensation as the pain in my back is the only thing I feel" back pain participant 1). 80% further reported that they would feel pain when imagining the 1st person visual perspective and said that they knew at what point it was going to hurt and could not block that feeling ("When viewing from my own perspective I

know when the pain would set in so it told me when I should stop imagining the bending" back pain participant). Some of the back pain group felt pain in the 3rd person visual perspective ("When I look at myself while jumping in the air the landing would make me cringe a bit because this would be very painful for me to do" back pain participant 12). Most back pain participants (BPP) reported that they felt like they were looking at someone else when doing 3rd person visual imagery ("The third person perspective I imagine like someone who looks like me but since I am imagining it from a distance it cannot be me" back pain participant 6).

In the control group some reported a stretching feeling when they had to try and touch their toes but did not report this as painful or unpleasant ("It feels like the hamstring stretch I do before football practice, and I really like the feeling" control 4). All those who reported the stretch feeling in the control group, also imagined the stretch feeling during kinaesthetic imagery. Participants reported that the stretch was either the strongest kinaesthetic sensation ("I know I am a bit stiff so for me there is nothing else to feel when I bend forward" control 16) or it was the goal of the action ("The reason I do this movement normally is to stretch my hamstring, so the feeling is what I am supposed to feel" control 14). Only a few of the control group felt the stretch during 1st person visual imagery ("The amount of stretch I feel when I see my feet coming closer tells me when to stop moving, I also never saw myself move further" control 1) and during 3rd person imagery ("since I try to see myself I know how far I can bend and it is the feeling that tells me how far I can go" control 8).

In both groups half of the participants reported that simple one limb actions were easier to imagine than complex whole-body actions ("It is easier to focus on a single feeling like my arm compared to everything that is going on when I jump" back pain participant 9), whereas the other half reported that whole body actions were easier to imagine than one limb actions ("There isn't much to feel when I step forward it is all so automatic, when I jump I can actually feel myself engaging muscles to push-off and also when I absorb my landing" control 22).

8.3.2 Part two

The Shapiro Wilk's test showed all the variables violated the assumptions of a normal distribution. Based on this and after visual inspection of the QQ-plots the non-parametric Mann-Whitney U test was chosen to test for differences between the control and back pain group. The median imagery scores for the chronic back pain group were 4, 4 and 5 for the kinaesthetic, 1st person visual and 3rd person visual domains respectively. The median imagery scores for the control group were 5, 6 and 6 for the kinaesthetic, 1st person visual and 3rd person visual domains respectively. There was a significant difference between median kinaesthetic imagery score of the BPP and the median kinaesthetic score of control group, the back pain group scored significantly lower than the control group $U(N_{back\ pain}= 9, N_{Controls}= 29)= 7.00$, $z= -4.86$, $p= 0.03$. There was also a significant difference between the median 1st person visual perspective of the BPP and that of the controls, where the BPP scored lower than the controls $U(N_{back\ pain}= 9, N_{Controls}= 29)= 10.50$, $z= -4.19$, $p< 0.001$. The difference between the 3rd person visual domain scores were non-significant.

When the BPP were spit into personality groups, using a median split (Jensen, 1987; Shaw et al., 1986), there were three individuals who qualified as repressors, five defensive high anxious and one high anxious. Because of these low numbers only descriptive values are presented in Figure 8.2. The repressor group had a median score of six for kinaesthetic, 1st person visual and 3rd person visual. The high anxious had a median score of four for the kinaesthetic imagery domain and a median score of five for 1st and 3rd visual domains. The defensive high anxious had median scores of 4 four all imagery domains.

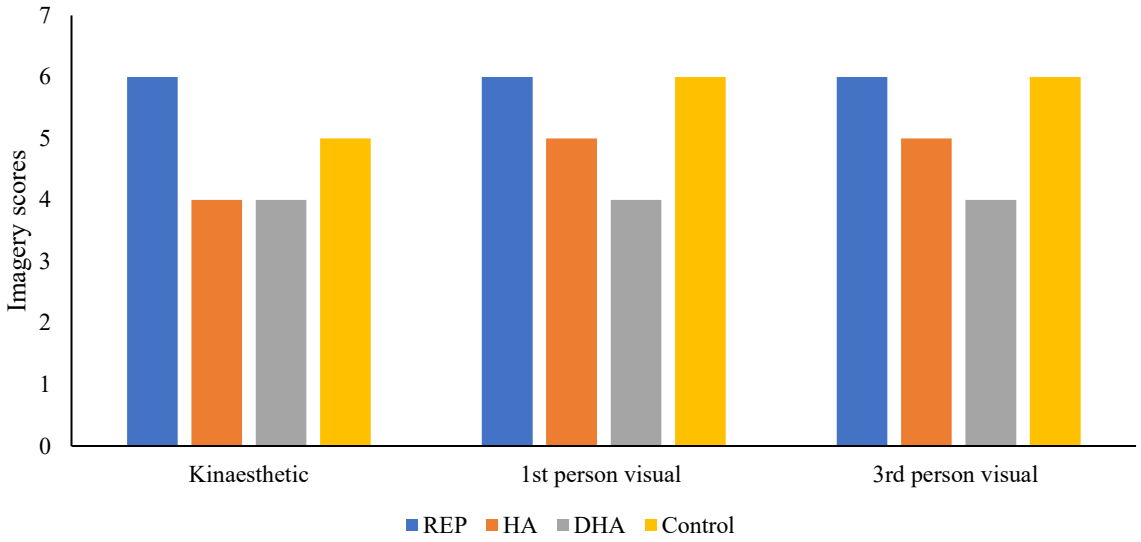


Figure 8.2 Median scores per imagery domain, Kinaesthetic, 1st person visual and 3rd person visual for REP: repressors, HA: high anxious, DHA: defensive high anxious and control group.

8.4 Discussion

This study consisted of two parts, part one was conducted online and had two aims: i) investigate differences in self-reported imagery ability between individuals with chronic back pain and pain-free controls, ii) to test a new version of the MIQ-3 designed for chronic back pain participants (BPP). Part two of the study was conducted in a laboratory setting and had two aims: i) to investigate differences in imagery ability between individuals with back pain and pain-free controls, and ii) to see if personality type influences imagery abilities.

One of the aims of this study was to assess the use of a new version of the MIQ-3. La Touche et al. (2019) replacement of the crouch to jump action with the standing on tip toes action was considered to be problematic as the crouch to jump action is a more complex whole-body action whereas the standing on tip toes is more focused on keeping your balance. In this study, a sit-to-stand action was used as a replacement for the crouch to jump action as they are both complex full body movements. Furthermore, the sit-to-stand action is often used within back pain assessments and is a regular assessment in physiotherapy. The lifting the right thigh action was replaced with taking a step forward. Both of these actions have a standing position, and because the participant will imagine while standing, it will increase the functional

equivalence between the image and the execution of the movement thus incorporating the physical element of the PETTLEP model (Holmes & Collins, 2001) (see Chapter 3 for more information about the design of the MIQ-BP). There were no differences between the MIQ-3 and MIQ-BP scores in any of the imagery modalities. This could mean that the MIQ-BP assesses imagery ability in a similar way as the MIQ-3 and that the MIQ-BP could potentially be used to assess the imagery ability in a chronic back pain population. It should be noted that further validation and reliability studies are needed with a larger population. However, these initial results do show potential that the MIQ-BP might be a suitable equivalent of the MIQ-3 when used in a chronic back pain population. To further investigate equivalence of the two questionnaires other measures of agreement should be investigated in a larger sample such as Pearson correlations.

Another aim was to assess differences in the imagery ability between individuals with back pain compared to healthy controls. Part one which was conducted online revealed that when comparing the imagery scores of the chronic back pain population with those of the control population, the control group had significantly higher scores in the kinaesthetic modality of the MIQ-3. BPP further had lower scores in the first-person visual domain of the MIQ-3 but not in the first-person visual domain of the MIQ-BP than the control group and there were no differences in the 3rd person visual domain. In the laboratory-based part two which only used the MIQ-BP, BPP had lower scores for the kinaesthetic and 1st person imagery compared to the control group and no differences in the 3rd person visual domain. The lower scores in the kinaesthetic domain have been consistent between the two parts of this study and between the two different imagery questionnaires they are further supported by similar findings by La Touche et al. (2019). La Touche et al. (2019) further found lower scores for BPP when they used visual imagery but did not differentiate between 1st and 3rd person perspectives. This study found that when BPP used 3rd person visual imagery, they scored the same as the control

participants. Differences in imagery ability were only found when they used 1st person visual imagery where the BPP scored significantly lower than the controls. These novel findings could support previous findings of the effect of perspective on neural activity (Ruby and Decety, 2001) and the height of motor evoked potentials which are indicator of corticospinal excitability (Fourkas et al., 2006).

The differences between 1st and 3rd person imagery scores could further be explained by the findings from the interview. The overall finding was that both BPP and controls had kinaesthetic sensations when using visual imagery but that the number of individuals who reported kinaesthetic sensations was higher in the 1st person than in 3rd person. The percentage of BPP who had a kinaesthetic sensation during 1st and 3rd person visual imagery was higher than the control participants. During 1st person visual imagery most of the BPP reported feeling pain, while in 3rd person visual imagery one out of three participants felt pain when they used visual imagery. This may be explained by another finding from the interviews in which several BPP felt that they were looking at someone else during 3rd person visual imagery. Researchers have anecdotal evidence that 1st person imagery has higher embodiment than 3rd person imagery, but this study is the first to ask participants what they felt. These findings also align with results from action observation and transcranial magnetic stimulation studies (Jackson et al., 2006; Maeda et al., 2002) which rely on similar neurological pathways as motor imagery (Hardwick et al., 2018) that show a facilitation of the 1st person perspective compared to the 3rd person perspective.

Part two examined the influence of personality type on imagery abilities. The low number of participants in each group made it impossible to do any statistical comparisons between the different personality types. This part of the discussion will discuss speculatively how anxiety might explain the observed differences in motor imagery. Kosslyn et al. (1995) proposed that mental imagery plays “a special role in representing emotionally charged

material" (p. 405) and reframed imagery from a single process into several modules including image generation and image maintenance (Kosslyn et al., 1984) which rely on memorial processes. Imagery generation relies on long-term memory processes to retrieve the information necessary to re-create the image (Ishai & Sagi, 1997) whereas imagery maintenance relies on working memory capacity to keep the image clear in one's mind (Keogh & Pearson, 2011). The memorial bias of individuals with chronic pain predicts that they have a preference for recalling pain-related information over other types of information. When a back pain participant tries to generate an image, their memorial bias could lead to them remembering only the painful associations of an action. Due to their high trait anxiety, the defensive high-anxious group might show a preference for painful memories when retrieving information from their long-term memory to generate an image of an action. This might explain why the defensive high anxious seemed to have the lowest scores of the personality types. The repressors are thought not to have a memorial bias for painful information which might explain why their imagery scores seemed higher than the other personality types. The high anxious individuals might also have a memorial bias towards pain which could explain why their imagery scores appeared to be lower than those of the repressors but because they are low in defensiveness, they might catastrophise less which could explain why their scores appeared to be higher than the defensive high anxious. Chronic pain has been shown to restrict the capacity working memory by diverting attention from the task and towards the stressor and related cognitions like fear, worry, and negative thoughts about the future (for a review see (Berryman et al., 2013). The four Weinberger personality types (Weinberger et al., 1979) are thought to deploy behaviours when dealing with anxious information. If the predictions made by Eysenck, based on the cognitive biases of each group, hold true the defensive high anxious and high anxious group should have the lowest imagery scores as their cognitive biases would amplify their anxiety which would further restrict their working memory and thus decrease their ability

to hold a created image in their mind's eye. Repressors, who's cognitive biases are thought to reduce their anxiety, and thus would not inhibit their working memory capacity could then perform imagery in a similar way as low anxious. Further research with more participants would be able to test these hypotheses.

8.5 Conclusion

This study shows that individuals with chronic back pain have specific deficits in kinaesthetic and 1st person visual motor imagery modalities but perform the same as controls in the 3rd person visual modality as shown in both part one and part two. Part one further shows that the MIQ-BP could possibly be used to assess imagery ability in a similar way as the MIQ-3 but that further analysis of the agreement between the measures in a larger sample is necessary. The interview also highlights differences between controls and BPP and that back pain participants imagine pain as part of the imagery. These findings could have future implications on applying imagery therapies.

9 Epilogue

This thesis investigated the effects of personality types on imagery and attentional bias of individuals with chronic back pain as well as the effect of personality traits on chronic back pain over an eight-year follow-up. The main conclusions of this thesis are discussed in relation to the objectives stated in Chapter 3.

Objective 1: To determine the association between personality traits and chronic back pain in a longitudinal follow-up.

The results of Chapter 5 showed for the first time that Neuroticism was a significant risk factor for the development and maintenance of chronic back pain across all three groups (consistent pain group, acquired pain group and the recovery group). For individuals who had chronic back pain an increase in Neuroticism was related to a 40% higher change of still having chronic back pain after an 8-year follow-up. Those that did not report chronic pain at baseline had a 36% higher change of developing chronic back pain in 8 years with each standard deviation increase in their Neuroticism score, even when controlling for physical activity. Accounting for physical activity did not change the risk of Neuroticism. This study further investigated for the first time, protective personality traits and found that and increase in Extraversion was associated with a decrease in developing chronic pain for those in the recovery group. Physical activity was protective at any intensity (low, medium and high) for the group that had chronic pain at both the baseline and follow-up. These results show a partial risk profile for the development and maintenance and the novel finding that certain also highlight traits that could be protective.

Objective 2: To determine if the role of personality type in attentional and interpretive bias chronic back pain patients and non-symptomatic controls during a dot-probe task and action observation task.

In Chapter 6 and 7 the well-established dot-probe task and for the first time a novel action observation task were used to assess attentional biases within the chronic back pain population as a whole and when split into personality types. The stimuli rating of the images and videos showed that individuals with chronic back pain interpreted the stimuli as painful and that they were afraid of performing the actions presented in the stimuli. In contrast, the controls did not interpret them as painful and were not anxious about performing. The threatening stimuli also made individuals with chronic back pain feel less happy and caused more excitement than the controls. This is one of the few studies that asked all participants to rate the stimuli as recommended by the Todd et al review. The eye-tracking data of the dot-probe revealed indirect evidence for an attentional bias towards painful images by the back pain participants but not the controls. The action observation task showed that the individuals with back pain had a specific attentional bias towards the back and the head of the actor in both the neutral and the threatening videos. Evidence from the interview about pain beliefs revealed that both patients and controls believed that pain is always the cause of a physical injury that has not healed. This pain belief is related to the belief that an external intervention helps with pain which further supports the finding that the lack of excess to care during the COVID pandemic was a cause of stress for the individuals with chronic back pain during the pandemic.

Objective 3: To assess the imagery ability characteristics of individuals with chronic back pain.

The motor imagery study gave a more complete insight into the mental representation for the first time across all three imagery domains of individuals with chronic back pain as assessed by the Motor Imagery Questionnaire – 3 and the Motor Imagery Questionnaire – Back Pain during an online and laboratory study. Individuals with chronic back pain had lower kinaesthetic and 1st person visual imagery ease scores compared to the controls. The ease of imagery scores in the 3rd person visual domain of the chronic back pain patients were the same

as those of the controls. The interview revealed pain was integrated into the kinaesthetic imagery for all chronic back pain patients and pain also intruded in the visual imagery of some chronic back pain patients. It was further found that both chronic back pain patients and controls both felt more like they more looking at someone similar to themselves but also someone else while they were using 3rd person visual imagery. There seemed to be an effect of personality type but due to the low number of participants the effects are speculative. The defensive high anxious individuals appeared to have the lowest imagery scores whereas the repressors seemed to have similar score to the control group. These results indicate that chronic back pain might influence the mental representation of the body as measured by motor imagery task. When looking at the personality types it appears that the defensive high anxious individuals might have the most disturbed body schema representation. The use of motor imagery as a therapy tool might restore the body schema and might reduce movement related anxiety by going from 3rd person visual to kinaesthetic imagery.

9.1 Limitations

The studies within this thesis are not without limitations. First, were low participant numbers in the second part of the imagery study and in study two. The number of chronic back pain patients was low resulting in personality groups with only a few or a single participant in each group. *A priori* power analysis ($\alpha=0.5$, $1-\beta=0.95$, $d=0.8$ (taken from Franklin et al., 2019)) revealed that at least 20 participants were needed in each personality type group, the nine chronic back pain patients that were recruited for this study fell short of that number. This means that the study is underpowered meaning that the results should be interpreted cautiously as significant finding might be the result of a chance finding and null findings might hide true effects. Every effort was made to recruit as many individuals as possible, including recruitment via the university physiotherapy clinic, contacting local physios and repeated emails from the hospital clinicians to potential patients. However, the delays due to COVID lockdowns and the

recruitment ban from the NHS severely shortened the time in which data gathering was possible. Another cause for the low number of back pain patients could be that patients were afraid to catch COVID when travelling to the university to take part in the study. Especially since the defensive high anxious individuals' high trait anxiety and high defensiveness might make them more fearful to catch the virus. The low number of participants also influenced the decision to use a median split to select the personality types. The median split has the benefit of including the entire recruited population, however disadvantages of using this method are that the differences between groups could be relatively small and that the median cut-off points could be skewed by the spread of the general population. Using any of these methods would exclude several participants, further dropping the small number of participants in these studies. Future studies with larger sample sizes would be able to assess the differences between personality types using a different split method. Another consideration is that some data in study two, the personality type classification and the data from the ELSA cohort study were based on self-reported measures. The cognitive factors that were assessed can only be measured by self-reported questionnaires and the scale of the ELSA sample sizes makes it impractical to collect data using objective measures. The self-report assessments used in these studies were all validated and well established thus maximising the validity and reliability. The layout of the dot-probe task suggested that there would be a natural bias to the top image over the bottom image, however the bias appears to be so strong that the effect of the type of image was lost. In the methodology chapter it is discussed why a top-bottom layout was chosen over the left-right one. Future studies should consider using both layouts and possibly even add a diagonal stimuli orientation to prevent the natural attentional bias.

9.2 Clinical implications

There are several clinical implications that follow from the findings in this thesis. The first study investigated a broader spectrum of personality traits in a longitudinal study. Data

was collected at two time points and showed that traits can be used to build a risk profile using very broad personality traits but also highlights the protective function of specific traits.

The main finding is that the chronic back pain population is not a homogenous group but that there are distinct sub-groups which appear to show distinct cognitions and behaviours when confronted with painful stimuli. Grouping all the chronic back pain patients together might mask these differences or skew the results if one of the subgroups is overrepresented. Study one found that DHA and HA appear to have impaired motor imagery skills which could reflect an impaired motor representation, whereas the repressors seemed to have similar imagery scores to the control group. This impairment was different for the different imagery domains (visual 1st person, visual 3rd person and kinaesthetic). Study 2a found that the attentional biases of each personality type were different and as similar to Franklin et al. (2016). Study 2b showed that gaze behaviour during action observation was different between the personality types. The repressors had similar object orientated gaze behaviour to the controls, in contrast to the DHA and HA who seemed to be more focus on the back. This study also found that the threat level influenced where individuals with chronic back pain looked. Finally, the third study found that individuals with chronic back pain have a disrupted mental representation of movements as assessed by the movement imagery questionnaire – 3. Graded Motor Imagery has shown promise in decreasing pain intensity within a chronic pain population. However, part of this therapy might not be suited for chronic back pain patients, especially the left/right judgement task might not be as effective, and the mirror illusion task is not practical for the movements involving the back. Integrating movement imagery therapy based on the MIQ-BP could be beneficial for chronic back pain patients. Taken together the evidence from these studies lends not only support for differences in attentional bias between the personality types but further demonstrates that the differences between the personality types could play an important role in the development of chronic pain and the mental representation

of movements. Clinicians and researchers should consider using personality types and traits both as a screening tool to assess which individuals are at risk for developing chronic back pain and to classify patients presenting with chronic back pain in order tailor treatments which aim to address the personality specific behaviours and cognitions. This study further found that traits could also function as a protective factor in the development and clinicians might focus on developing these traits alongside managing the traits that increase the risk of developing chronic back pain.

9.3 Directions for future research

There are several directions for future research that arise from this study that would help inform a deeper understanding of the differences between the different personality types. Future studies should adapt the dot-probe task to account for natural biases that occur because of the spatial lay-out of the stimuli and not because of their emotional loading. By changing the lay-out and combining the top-bottom used in this study with the left-right lay-out used in other studies the stimulus locations are spread out more. Future studies could also move to other paradigms, like an action observation task, which in combination with eye-tracking could be argued to be more ecologically valid stimuli and allows for continuous tracking of visual attention. The action observation task could also be used in combination with measures that look for neurological markers such as electroencephalogram (EEG) or Functional Magnetic Resonance Imaging (fMRI).

Analysis of the ELSA cohort study revealed that personality traits, can both increase and decrease the risk of developing chronic back pain. The personality traits were only assessed at baseline in one wave in the ELSA study and although they are considered stable it might be interesting to see if there is a two-way interaction where chronic pain increases or decreases the traits associated with the development of chronic back pain. Follow-up studies are needed to further understand the interaction between personality traits and the development of chronic

back pain. This would increase the understanding of the underlying mechanism that govern the interaction between personality traits and chronic back pain. It would also help with identifying key timepoints of changes in the development of chronic back pain and help develop interventions that targeting these changes at the right timepoints.

The eye-tracking data of the dot-probe task and the action observation task showed some evidence for an attentional bias within the chronic back pain population and there are some signs that these biases might be different for the different personality types. Future studies will need to recruit a larger patient population to be able to recruit enough individuals in each personality type group to identify any differences. To achieve this, future studies should be run as close to the patients as possible (e.g., at the hospital or physiotherapy clinic). To participate in the current study participants had to travel to the university which might have been a barrier for participating, especially since some of them might have travelled with public transport towards the end of the COVID pandemic.

Based on the findings from this thesis it can be concluded that chronic back pain influences the cognitive biases that effect how pain related information is processed. Furthermore, it provides tentative evidence that the chronic back pain population is a heterogenous group whose cognitive biases are influenced by the personality type and trait. This thesis has provided new methods to further probe the effects of personality type and trait have on their cognitive biases. It has also showed, for the first time, that individuals with chronic back pain show an altered imagery profile, which might also be personality type specific. Since imagery can be used as a valid therapeutic tool, there are exciting new possibilities for future research and interventions with multimodal imagery.

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Appendix 1: ELSA R script

```
rm(list = ls(all.names = TRUE)) #will clear all objects includes hidden objects.
gc() #free up memrory and report the memory usage.

install.packages("tableone")
install.packages("psych")
install.packages("bestNormalize")
install.packages("Hmisc")


#load libraries
library(readr)
library(tableone)
library(dplyr)
library(Hmisc)
library(tidyverse)
library(Hmisc)


#read data
data <- read_csv("wave_5_elsa_data_v4csv.csv")
data2 <- read_csv("wave_9_elsa_data_eul_v1.csv")

# n/a all incomplete data
is.na(data) = data < 0
is.na(data2) = data2 < 0
summary(data$hebck) #check data
summary(data2$hebck) #check data

# recode inverse big 5 values
data$scdemo <- recode(data$scdemo, 4, 3, 2, 1)
data$scdewo <- recode(data$scdewo, 4, 3, 2, 1)
data$scdene <- recode(data$scdene, 4, 3, 2, 1)
data$scdehe <- recode(data$scdehe, 4, 3, 2, 1)
data$scdewa <- recode(data$scdewa, 4, 3, 2, 1)
data$scdeca <- recode(data$scdeca, 4, 3, 2, 1)
data$scdesof <- recode(data$scdesof, 4, 3, 2, 1)
data$scdesy <- recode(data$scdesy, 4, 3, 2, 1)
data$scdeor <- recode(data$scdeor, 4, 3, 2, 1)
data$scdere <- recode(data$scdere, 4, 3, 2, 1)
data$scdeha <- recode(data$scdeha, 4, 3, 2, 1)
data$scdeth <- recode(data$scdeth, 4, 3, 2, 1)
data$scdefr <- recode(data$scdefr, 4, 3, 2, 1)
data$scdeli <- recode(data$scdeli, 4, 3, 2, 1)
data$scdeac <- recode(data$scdeac, 4, 3, 2, 1)
data$scdeta <- recode(data$scdeta, 4, 3, 2, 1)
data$scdeou <- recode(data$scdeou, 4, 3, 2, 1)
data$scdecr <- recode(data$scdecr, 4, 3, 2, 1)
data$scdeim <- recode(data$scdeim, 4, 3, 2, 1)
data$scdead <- recode(data$scdead, 4, 3, 2, 1)
```

```
data$scdein <- recode(data$scdein, 4, 3, 2, 1)
data$scdecu <- recode(data$scdecu, 4, 3, 2, 1)
data$scdebr <- recode(data$scdebr, 4, 3, 2, 1)
data$scdeso <- recode(data$scdeso, 4, 3, 2, 1)


# select individuals who are have pain pain, longer than 3 months
data$pain_BP <- NA
data$Qhebck <- NA
data2$pain_BP <- NA
data2$Qhebck <- NA
data$pain_BP[(data$hepain==1 & data$hepag>1 & data$hebck>0)] <- 1 #1: chronic pain
data2$pain_BP[(data2$hepain==1 & data2$hebck>0)] <- 1 #1: chronic pain
data$Qhebck <- data$hebck
data$Qhebck[(is.na(data$hebck))] <- 0 #0: no pain
summary(data$Qhebck)
table(data$Qhebck)
data2$Qhebck <- data2$hebck
data2$Qhebck[(is.na(data2$hebck))] <- 0 #0: no pain
summary(data2$Qhebck)
table(data2$Qhebck)
data$pain_BP[(data$hepain==2)] <- 0 #0: no pain
data2$pain_BP[(data2$hepain==2)] <- 0 #0: no
table(data2$pain_BP)
newdata <- subset(data, !is.na(data$pain_BP)) #& !is.na(data$Qhebck))
newdata2 <- subset(data2, !is.na(data2$pain_BP))
summary(newdata$pain_BP)
summary(newdata2$pain_BP)


#Chronic pain
newdata$neurot <- NA
newdata$agree <- NA
newdata$consien <- NA
newdata$extra <- NA
newdata$open <- NA

#calculate sum scores for big 5 pain all participants
newdata$neurot <- (newdata$scdemo + newdata$scdewo + newdata$scdene + newdata$scdecal)/4
#SCDECAL (inverse)
newdata$agree <- (newdata$scdehe + newdata$scdewa + newdata$scdca + newdata$scdesof +
newdata$scdesy)/5
newdata$consien <- (newdata$scdeor + newdata$scdere + newdata$scdeha + newdata$scdecar +
newdata$scdeth)/5 #SCDECAR (inver)
newdata$extra <- (newdata$scdefr + newdata$scdeli + newdata$scdeac + newdata$scdeta +
newdata$scdeou)/5
newdata$open <- (newdata$scdecr + newdata$scdeim +  newdata$scdein + newdata$scdecu +
newdata$scdebr + newdata$scdeso + newdata$scdead)/7

#tableOne
tablevars <- c("neurot", "agree", "consien", "extra", "open", "Qhebck", "diagr")
```

```
tableOne <- CreateTableOne(vars=tablevars, strata=c("pain_BP"), data=newdata) #strat back pain
0:no, 1:pain
tableOne
tableOne <- CreateTableOne(vars=tablevars, strata=c("disex"), data=newdata) #strat by sex
tableOne
tableOne <- CreateTableOne(vars=tablevars, data=newdata) #overall
tableOne

# ANOVA pain vs no pain at baseline
neurot_aov <- aov(neurot ~ pain_BP, data = newdata)
summary(neurot_aov)
agree_aov <- aov(agree ~ pain_BP, data = newdata)
summary(agree_aov)
consien_aov <- aov(consien ~ pain_BP, data = newdata)
summary(consien_aov)
extra_aov <- aov(extra ~ pain_BP, data = newdata)
summary(extra_aov)
open_aov <- aov(open ~ pain_BP, data = newdata)
summary(open_aov)
age_aov <- aov(diagr ~ pain_BP, data = newdata)
summary(age_aov)
chisq.test(newdata$palevel, newdata$pain_BP, correct=FALSE)
#correlation matrix
datavars <- newdata[,c("neurot", "agree", "consien", "extra", "open", "pain_BP", "Qhebck", "diagr")]

newwdata <- na.omit(datavars)
#newwdata$pain_BP <- is.factor(newdata$pain_BP)
head(newwdata)
cor_neww <- rcorr(as.matrix(newwdata))
cor_neww
cor_neww$P


#Histrograms of person traits
hist(newdata$neurot)
hist(newdata$agree)
hist(newdata$consien)
hist(newdata$extra)
hist(newdata$open)
hist(newdata$hebck)

#log transformation
newdata$neurot_LT <- NA
newdata$agree_LT <- NA
newdata$consien_LT <- NA
newdata$extra_LT <- NA
newdata$open_LT <- NA

newdata$neurot_LT <- log(newdata$neurot)
newdata$agree_LT <- log(newdata$agree)
newdata$consien_LT <- log(newdata$consien)
```

```
newdata$extra_LT <- log(newdata$extra)
newdata$open_LT <- log(newdata$open)

newdata$disex <- as.factor(newdata$disex)
newdata$pain_BP <- as.factor(newdata$pain_BP)


#covariates (age, sex, physical activity summary, pain intensity)
neurot.regress <- glm(as.factor(newdata$pain_BP) ~ newdata$neurot_LT +
                 newdata$diagr + as.factor(newdata$palevel) #+ newdata$Qhebck
                +  as.factor(newdata$disex), family='binomial')
summary(neurot.regress)
agree.regress <- glm(as.factor(newdata$pain_BP) ~ newdata$agree_LT +
                 newdata$diagr + as.factor(newdata$palevel) #+ newdata$Qhebck
                +  as.factor(newdata$disex), family='binomial')
summary(agree.regress)
consien.regress <- glm(as.factor(newdata$pain_BP) ~ newdata$consien_LT +
                   newdata$diagr + as.factor(newdata$palevel) #+ newdata$Qhebck
                 +  as.factor(newdata$disex), family='binomial')
summary(consien.regress)
extra.regress <- glm(as.factor(newdata$pain_BP) ~ newdata$extra_LT +
                 newdata$diagr + as.factor(newdata$palevel) #+ newdata$Qhebck
                +  as.factor(newdata$disex), family='binomial')
summary(extra.regress)
open.regress <- glm(as.factor(newdata$pain_BP) ~ newdata$open_LT +
                 newdata$diagr + as.factor(newdata$palevel) #+ newdata$Qhebck
                +  as.factor(newdata$disex), family='binomial')
summary(open.regress)

newdata$pain_BP_W5 <- newdata$pain_BP
newdata2$pain_BP_W9 <- newdata2$pain_BP

# Tabulate data W9 + W5
table(newdata2$pain_BP)
table(newdata2$Qhebck)
table(newdata$pain_BP)
table(newdata$Qhebck)

# Merge W5 and W9
newdata3 <- merge(newdata, newdata2, by="idauniq", all.x = TRUE)

table(newdata3$pain_BP_W5, newdata3$pain_BP_W9)
table(newdata3$pain_BP.x,newdata3$pain_BP.y)
newdata3$PainVar <- NA
newdata3$PainVar[(newdata3$pain_BP.x == 1 & newdata3$pain_BP.y == 1)] <- 1 # 1: Pain in both
newdata3$PainVar[(newdata3$pain_BP.x == 1 & newdata3$pain_BP.y == 0)] <- 2 # 2: pain in 5 not in
9
newdata3$PainVar[(newdata3$pain_BP.x == 0 & newdata3$pain_BP.y == 1)] <- 3 # 3: pain in 9 not in
5
newdata3$PainVar[(newdata3$pain_BP.x == 0 & newdata3$pain_BP.y == 0)] <- 4 # 4: pain in 5 not in
9
```

```
summary(newdata3$PainVar)
table(newdata3$PainVar)

# Comparisions between participant groups PainVar
tablevars_2 <- c("neurot", "agree", "consien", "extra", "open", "Qhebck.x", "Qhebck.y", "palevel",
"hepag", "diagr")
tableOne <- CreateTableOne(vars = tablevars_2, strata = c("PainVar"), data = newdata3)
tableOne

newdata3$both_pain <- NA
newdata3$W5_pain <- NA
newdata3$W9_pain <- NA
newdata3$recover <- NA

# Binary for regression 1 pain 0 is no pain
newdata3$both_pain[(newdata3$PainVar == 1)] <- 1 # 1 pain
newdata3$both_pain[(newdata3$PainVar == 4)] <- 0 # 0 no pain
newdata3$w5_pain[(newdata3$PainVar == 2)] <- 1 # 1 pain
newdata3$w5_pain[(newdata3$PainVar == 4)] <- 0 # 0 no pain
newdata3$w9_pain[(newdata3$PainVar == 3)] <- 1 # 1 pain
newdata3$w9_pain[(newdata3$PainVar == 4)] <- 0 # 0 no pain
newdata3$recover[(newdata3$PainVar == 1)] <- 1
newdata3$recover[(newdata3$PainVar == 2)] <- 0 # 0 no pain
newdata3$gotp[(newdata3$PainVar == 1)] <- 1
newdata3$gotp[(newdata3$PainVar == 3)] <- 0 # 0 no pain

summary(newdata3$Qhebck.x)

# Both pain m1 and m2
bothm1 <- glm(newdata3$both_pain ~ scale(newdata3$neurot_LT) + scale(newdata3$agree_LT) +
              scale(newdata3$consien_LT) + scale(newdata3$extra_LT) + scale(newdata3$open_LT)
              + as.factor(newdata3$disex) +
                newdata3$diagr, family='binomial')
summary(bothm1)
exp(cbind(OR = coef(bothm1), confint(bothm1)))

bothm2 <- glm(newdata3$both_pain ~ scale(newdata3$neurot_LT) + scale(newdata3$agree_LT) +
                 scale(newdata3$consien_LT) + scale(newdata3$extra_LT) + scale(newdata3$open_LT)
               + as.factor(newdata3$disex) + newdata3$diagr +
                as.factor(newdata3$palevel) , family='binomial')
summary(bothm2)
exp(cbind(OR = coef(bothm2), confint(bothm2)))

# w5 only pain m1 and m2
w5m1 <- glm(newdata3$w5_pain ~ scale(newdata3$neurot_LT) + scale(newdata3$agree_LT) +
            scale(newdata3$consien_LT) + scale(newdata3$extra_LT) + scale(newdata3$open_LT)
          + as.factor(newdata3$disex) +
            newdata3$diagr, family='binomial')
summary(w5m1)
exp(cbind(OR = coef(w5m1), confint(w5m1)))
```

```
w5m2 <- glm(newdata3$w5_pain ~ newdata3$neurot_LT + newdata3$agree_LT +
              newdata3$consien_LT + newdata3$extra_LT + newdata3$open_LT
            + as.factor(newdata3$disex) + newdata3$diagr +
              as.factor(newdata3$palevel) , family='binomial')
summary(w5m2)
exp(cbind(OR = coef(w5m2), confint(w5m2)))

# got pain only pain m1 and m2
w9m1 <- glm(newdata3$w9_pain ~ scale(newdata3$neurot_LT) + scale(newdata3$agree_LT) +
          scale(newdata3$consien_LT) + scale(newdata3$extra_LT) + scale(newdata3$open_LT)
        + as.factor(newdata3$disex) +
          newdata3$diagr, family='binomial')
summary(w9m1)
exp(cbind(OR = coef(w9m1), confint(w9m1)))

w9m2 <- glm(newdata3$w9_pain ~ newdata3$neurot_LT + newdata3$agree_LT +
              newdata3$consien_LT + newdata3$extra_LT + newdata3$open_LT
            + as.factor(newdata3$disex) + newdata3$diagr +
              as.factor(newdata3$palevel) , family='binomial')
summary(w9m2)
exp(cbind(OR = coef(w9m2), confint(w9m2)))

# recovery m1 and m2 predicts who recovers
recoverm1 <- glm(newdata3$recover ~ scale(newdata3$neurot_LT) + scale(newdata3$agree_LT) +
          scale(newdata3$consien_LT) + scale(newdata3$extra_LT) + scale(newdata3$open_LT)
        + as.factor(newdata3$disex) +
          newdata3$diagr, family='binomial')
summary(recoverm1)
exp(cbind(OR = coef(recoverm1), confint(recoverm1)))

recover2 <- glm(newdata3$recover ~ scale(newdata3$neurot_LT) + scale(newdata3$agree_LT) +
          scale(newdata3$consien_LT) + scale(newdata3$extra_LT) + scale(newdata3$open_LT)
        + as.factor(newdata3$disex) + newdata3$diagr + newdata3$Qhebck.x +
          as.factor(newdata3$palevel) , family='binomial')
summary(recover2)
exp(cbind(OR = coef(recover2), confint(recover2)))

# predicts who gets pain?
recoverm1 <- glm(newdata3$gotp ~ scale(newdata3$neurot_LT) + scale(newdata3$agree_LT) +
            scale(newdata3$consien_LT) + scale(newdata3$extra_LT) + scale(newdata3$open_LT)
          + as.factor(newdata3$disex) +
            newdata3$diagr, family='binomial')
summary(recoverm1)
exp(cbind(OR = coef(recoverm1), confint(recoverm1)))

recover2 <- glm(newdata3$gotp ~ scale(newdata3$neurot_LT) + scale(newdata3$agree_LT) +
            scale(newdata3$consien_LT) + scale(newdata3$extra_LT) + scale(newdata3$open_LT)
          + as.factor(newdata3$disex) + newdata3$diagr + newdata3$Qhebck.y +
            as.factor(newdata3$palevel) , family='binomial')
summary(recover2)
exp(cbind(OR = coef(recover2), confint(recover2)))
```

```
#descriptive
tapply(newdata3$neurot, newdata3$PainVar, summary)
tapply(newdata3$agree, newdata3$PainVar, summary)
tapply(newdata3$consien, newdata3$PainVar, summary)
tapply(newdata3$extra, newdata3$PainVar, summary)
tapply(newdata3$open, newdata3$PainVar, summary)
tapply(newdata3$diagr, newdata3$PainVar, summary)
tapply(newdata3$Qhebck.x, newdata3$PainVar, summary)
tapply(newdata3$Qhebck.y, newdata3$PainVar, summary)
tapply(newdata3$palevel, newdata3$PainVar, summary)

# Anovas between pain groups
age_aov2 <- aov(diagr ~ as.factor(PainVar), data = newdata3)
summary(age_aov2)
TukeyHSD(age_aov2)

neurot_aov2 <- aov(neurot ~ as.factor(PainVar), data = newdata3)
summary(neurot_aov2)
TukeyHSD(neurot_aov2)

agree_aov2 <- aov(agree ~ as.factor(PainVar), data = newdata3)
summary(agree_aov2)
TukeyHSD(agree_aov2)

open_aov2 <- aov(open ~ as.factor(PainVar), data = newdata3)
summary(open_aov2)
TukeyHSD(open_aov2)

consien_aov2 <- aov(consien ~ as.factor(PainVar), data = newdata3)
summary(consien_aov2)
TukeyHSD(consien_aov2)

extra_aov2 <- aov(extra ~ as.factor(PainVar), data = newdata3)
summary(extra_aov2)
TukeyHSD(extra_aov2)

painintx_aov2 <- aov(Qhebck.x ~ as.factor(PainVar), data = newdata3)
summary(painintx_aov2)
TukeyHSD(painintx_aov2)

paininty_aov2 <- aov(Qhebck.y ~ as.factor(PainVar), data = newdata3)
summary(paininty_aov2)
TukeyHSD(paininty_aov2)

chisq.test(newdata3$palevel, newdata3$PainVar, simulate.p.value = TRUE)
chisq.test(newdata3$disex, newdata3$PainVar)
summary(newdata3$palevel)
```

Appendix 2: Participant information sheet study 2
Participant Information Sheet

Attention and Pain during action observation

Dear participant,

I would like to invite you to take part in a research study being conducted by myself, Maaike Esselaar at Manchester Metropolitan University. The aim of the study is to investigate some of the factors that may affect the way you respond to pain and its treatment. The results of this study might help me in the development of new therapies for the treatment of chronic pain. This study is part of my educational qualification for a PhD and is supervised by Dr Zoe Franklin. The contact details of all the team members can be found on the last page.

1. This is an invitation to take part in a piece of research

You are being invited to take part in a research study. Before you decide whether or not to take part, it is important for you to understand why the research is being done and what it will involve. Please take time to read the following information carefully and discuss it with others if you wish. Ask me if there is anything that is not clear or if you would like more information. Please take time to decide whether or not you wish to take part.

2. Who is invited to take part?

You are able to take part in the study if you are between 18 – 80 years of age and have had chronic low back pain for more than 3 months.

3. Do I have to take part?

You are under no obligation to take part in this study. If, after reading this information sheet and asking any additional questions, you do not feel comfortable taking part in the study you do not have to. If you do decide to take part, you are free to withdraw from the study at any point, without having to give a reason. If you do withdraw from the study, you are free to take any personal data with you, and this will not be included when the research is reported. If you decide not to take part or withdraw from the study, this will not affect your medical care or relationship with any of the staff at the Manchester Metropolitan University.

4. What will I be asked to do?

You will be asked to attend two testing sessions which will last 90 minutes, at Manchester Metropolitan University. The sessions are one week apart, and during the week in between session one and two you will be asked to wear an activity tracker and keep an activity diary.

Session one (90 minutes)

In session one, if you agree to take part, you will be asked to sign an informed consent form. At the beginning of the testing phase, you will be asked to sit at a desk whilst looking at a screen that monitor your eye movements. The screen will not restrict the movement of your eyes or head and there will be no contact with your eyes. The glasses can be worn like you normally do. The eye tracking will be calibrated before the start of the first trial and in between trials as well. You will then be asked to view 350 pair of photos, of people doing various everyday actions. After you have seen all the pictures, you will be asked some questions about

them. You will also be asked to fill out a set of questionnaires to assess your pain duration, intensity and medication, physical activity levels, disability, fear of movement and movement confidence, and employment status. As well as a short test where you will be asked to first perform four actions followed by questions about your ability to imagine the action. The actions you will be asked to perform are all taken from physiotherapy sessions and have been selected in cooperation with physiotherapists. If you feel like you cannot do them or uncomfortable you don't have to do them.

At the end of this session, you will be given an activity tracker that looks like a wristwatch. The activity tracker will identify how active you are, number of steps, time active, time spent sitting and sleeping but not where you are. You will be asked to wear the tracker throughout the day and night until your next lab session one week later. You will be able to do all the activities that you would normally do. If you have an adverse reaction to the strap, you can remove the tracker and bring it to your next lab appointment. You will also be asked to keep a paper or electronic activity diary where I would like you to keep track of the type and amount of activity that you do during the day and the times that you wore the tracker.

Session two (90 minutes)

Session two will be one week later and consists of one part. You will be ask to stand and watch 60 short videos of an individual doing a variety of different actions. Whilst you watch these videos you will be using the same eye tracker as you did in session one. After you have watched all the videos, you will be asked some questions about your interpretation of the videos. You will be able to have breaks throughout this session if the session becomes too strenuous or you are uncomfortable in any other way the task will be stopped immediately.

All the procedure will be explained to you again verbally when you arrive at the lab. You will also be given the opportunity to ask any questions about the testing procedure. If you are interested in the results of this study please do indicate this on your consent form and once the study is published you will be sent a copy of the article and a short summary in less technical language. If you have given consent to me to contact your GP about your participation in this study, they will receive a short explanation of the tests you have done. You will also be offered a five-pound high street voucher.

5. Are there any risks if I participate?

None of the methods used during this study are harmful or unsafe. Even though it is very unlikely that you will experience any negative effects during or after the study, there are protocols in place if anything were to happen while you are in the lab. The university has first aiders on site at all times during the testing and psychological support (Healthy Minds service) is also available. If you feel any physical discomfort after you have left the lab, please contact your GP or physiotherapist. If you feel anxious or in distress after you have left the lab please contact one of the following helplines:

Anxiety UK: charity providing support if you have been diagnosed with an anxiety condition. Phone: 03444 775 774 (Monday to Friday, 9.30am to 10pm; Saturday to Sunday, 10am to 8pm)

Samaritans: confidential support for people experiencing feelings of distress or despair. Phone: 116 123 (free 24-hour helpline)

The address for Healthy Minds is: Humphrey House, 4 Angouleme Way, Bury BL9 0EQ. Further details about the service can be found at https://www.penninecare.nhs.uk/healthymindsbury and patients can self-refer at https://www.iaptportal.co.uk/ServiceUser/SelfReferralForm.aspx?sd=222b5d28-4580-49be-9a08-c394e080bff1 or by calling 0161 253 5258.

6. Are there any advantages if I participate?

I cannot promise the study will help you directly but the information I get from the study will help to improve our knowledge of the brain processes involved in observing an activity. This might help to inform rehabilitation techniques for individuals with chronic back pain. By taking part in this project, it will give you the opportunity to gain insight into the newest research in the area of pain research.

7. What will happen with the data I provide?

We (the data controller: Manchester Metropolitan University) will need to use information from you for this research project. We collect personal data as part of this research (such as name, contact details and age). People will use this information to do the research or to check your records to make sure that the research is being done properly. People who do not need to know who you are will not be able to see your name or contact details. Your data will have a code number instead. We will keep all information about you safe and secure. We will only retain your personal data for as long as is necessary to achieve the research purpose. Your data will be encrypted and stored on a password secured laptop secured in a lockable room. You will be given a randomized participant number at the start of the experiment and all your data will be stored under this number. Once we have finished the study, we will keep some of the data so we can check the results. We will write our reports in a way that no-one can work out that you took part in the study. Your data will be stored no longer than 5 years and will then be disposed of. The paper forms will be shredded and all the digital data will be deleted.

What are my choices about how my information is used?

You can stop being part of the study at any time, without giving a reason, but we will keep information about you that we already have.

We need to manage your records in specific ways for the research to be reliable. This means that we won't be able to let you see or change the data we hold about you.

If you agree to take part in this study, you will have the option to take part in future research using your data saved from this study.

Where can I find out more about how my information is used?

You can find out more about how we use your information

at www.hra.nhs.uk/information-about-patients/

at www2.mmu.ac.uk/data-protection/

by asking one of the research team by sending an email to maaike.w.esselaar@stu.mmu.ac.uk

Who has reviewed this research project?

The study was designed together with the research team. The other team members are Dr Zoe Franklin (z.franklin@mmu.ac.uk), Prof Paul Holmes (p.s.holmes@mmu.ac.uk), Dr David Wright (d.j.wright@mmu.ac.uk) and Dr Dave Smith (d.d.smith@mmu.ac.uk) from Manchester Metropolitan University. Two members of this faculty but outside of the research team have provided internal approval. This research project has been subjected to review from the relevant NHS REC (research ethics commissions)

Who do I contact if I have concerns about this study or I wish to complain?

If you have a concern about any aspect of this study you should contact the Chief Investigator (email: z.franklin@mmu.ac.uk) or the Principal Investigator (email: maaike.w.esselaar@stu.mmu.ac.uk) who will do their best to answer any questions. If you remain unhappy and wish to complain formally, then please contact the researcher's university through the address provided below:

The University's Research Ethics and Governance Manager

The Research and Knowledge Exchange Directorate

Manchester Metropolitan University

Ormond Building

Tel: 0161 247 2853

ethics@mmu.ac.uk

Secretary of the Faculty Research Ethics and Governance Committee

0161 2473652 or 0161 2475410

ethics-scieng@mmu.ac.uk

If you have any concerns regarding the personal data collected from you, our Data Protection Officer can be contacted using the legal@mmu.ac.uk e-mail address, by calling 0161 247 3331 or in writing to: Data Protection Officer, Legal Services, All Saints Building, Manchester Metropolitan University, Manchester, M15 6BH. You also have a right to lodge a complaint in respect of the processing of your personal data with the Information Commissioner's Office as the supervisory authority. Please see: https://ico.org.uk/global/contact-us/

THANK YOU FOR CONSIDERING PARTICIPATING IN THIS PROJECT

I hope that the information I have provided is in enough detail for you. If you have any questions before you agree to participate, please do not hesitate to ask.