An examination of the role of self-regulatory fatigue in adaption to chronic pain

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Table of Contents

List of tables

List of figures

Abstract

Objectives: The prevalence of chronic pain and disability will continue to increase due to an aging population and lifestyle factors. Identifying factors which facilitate self-management is essential. Managing chronic pain requires the self-regulation of many factors that affect self-management, for example, to manage activity levels, mood, motivation, self-discipline, self-efficacy and inner conflicts. It has been proposed that difficulties in self-management in people with chronic pain arise from deficits in self-regulation, or a reduced capacity for self-regulation. It would be useful, therefore, to understand the factors that impact on self-regulatory processes in chronic pain as a possible means by which self-management might be optimised. This thesis applied the Strength Model to understand self-regulation in people with chronic pain.

Methods: Six studies were conducted. In the first study, people with chronic pain and controls participated in tasks of self-regulation to examine the role of self-regulatory fatigue and self-efficacy on performance. In the second study, a cross-sectional design was employed where participants completed questionnaires to assess the relationship between self-regulatory fatigue, pain self-efficacy and mood. In the third study, two short forms of the Self-regulatory Fatigue Scale (SRFS) were developed and an initial validation was conducted. A discriminant content validity study of the SRFS was conducted in study 4. A series of N-of-1 studies formed studies 5 and 6, which employed diary methods to examine the role of pain, self-regulatory fatigue, self-efficacy, motivation, goal striving and demands on goal pursuit.

Results: The findings did not support Strength Model assumptions due to conceptual and methodological limitations of the Strength Model. At between-person and within-person levels, self-regulatory fatigue did not reliably predict self-regulation performance or goal pursuit. The findings suggest that self-regulatory fatigue and self-efficacy influence allocation of resources during self-regulation. Higher self-efficacy may be adaptive at the group level, but not at the within-person level when self-regulatory capacity is reduced.

Discussion: The evidence did not support the Strength Model but pointed to a motivated resource allocation explanation of self-regulation in people with chronic pain. The findings have implications from both a theoretical and clinical perspective.

1 General Introduction

1.1 Background

Pain has been defined as an unpleasant experience comprising of sensory, emotional and cognitive components which occurs in the presence of actual or anticipated tissue damage (Merskey, 1965; Merskey & Spear, 1967). Chronic pain is characterised as pain experienced on most days lasting longer than the usual healing period for acute injury of 12-16 weeks (Bonica & Hoffman, 1954; Merskey, 1986). The experience of chronic pain encompasses a complex relationship between sensory, cognitive and emotional aspects of pain (Gatchel, Peng, Peters, Fuchs, & Turk, 2007; IASP, 2019; Melzack & Wall, 1965). It is estimated that between 35% and 51% of people experience chronic pain (Breivik, Collett, Ventafridda, Cohen, & Gallacher, 2006; Fayaz, Croft, Langford, Donaldson, & Jones, 2016; Kuehn, 2018; Simon, 2012). This includes experiencing chronic pain as a primary condition or secondary to another health condition.

Chronic pain is a leading cause of disability worldwide (Palazzo, Nguyen, Lefevre-Cou, Rannou, & Poiraudeau, 2016; VosFlaxmanNaghaviLozanoMichaudEzzati et al., 2012). As such, it accounts for significant disease burden including poor mobility, limitations in activities of daily living and ability to carry out labour, lack of participation in daily life and high rates of comorbidity due to sedentary lifestyles (Fayaz et al., 2016; Ford & Caspersen, 2012; González, Fuentes, & Márquez, 2017; Palazzo et al., 2016; Turner, Franklin, Fulton-Kehoe, Egan, Wickizer, Lymp et al., 2004). Additional burden is generated by emotional incapacity in the form of pain-related distress and cognitions (Campbell & Edwards, 2009; Vlaeyen & Linton, 2000). Prevalence of chronic pain and rates of disability are likely to continue to increase due to an aging population and lifestyle factors. Guidelines for the treatment of chronic pain recommend introducing supported self-management early in the process to aid long-term management (SIGN, 2013). Identifying factors which facilitate and impede ability to self-manage in people with chronic pain are crucial to implementing these guidelines, particularly as there is a need to develop an understanding of mechanisms which underpin treatment and build evidence for these (Colvin, Stein, & Smith, 2014).

1.1.1 Psychological factors in managing chronic pain

Anxiety and depression are factors which contribute to disability in people with chronic pain and may impede self-management (Vlaeyen & Linton, 2000; Vos et al., 2012). The prevalence of depression in people with chronic pain is estimated at between 5% and 22% in community samples and between 6 and 46% in patients (Atkinson, Slater, Patterson, Grant, & Garfin, 1991; Bair, Robinson, Katon, & Kroenke, 2003; Gureje, Simon, & Von Korff, 2001; McWilliams, Cox, & Enns, 2003; Munce & Stewart, 2007; Tsang, Von Korff, Lee, Alonso, Karam, Angermeyer et al., 2008). The prevalence of anxiety varies between 15% and 31% in people with chronic pain (Atkinson et al., 1991; Gerrits, van Oppen, van Marwijk, Penninx, & van der Horst, 2014; Von Korff, Crane, Lane, Miglioretti, Simon, Saunders et al., 2005). Pain has an interruptive effect on activities making the management of pain taxing (Bushnell, Ceko, & Low, 2013; Eccleston & Crombez, 1999; Gatzounis, Schrooten, Crombez, & Vlaeyen, 2014). Given cognitive (e.g. catastrophic thinking styles and ruminative worry), emotional (e.g. distress related to change in social roles), behavioural (e.g. demands of employment) and physiological (e.g. pain, fatigue) demands that arise with chronic pain, the link to mood disorder is not surprising.

Pain avoidance behaviour, defined as a decrease in activities of daily living and physical activity, is also a contributing factor to disability in chronic pain (Crombez, Vlaeyen, Heuts, & Lysens, 1999; Vlaeyen & Crombez, 1999; Vlaeyen, Kole-Snijders, Boeren, & van Eek, 1995). Sedentary behaviour is related to higher back and lower limb pain (Hanna, Daas, El-

Shareif, Al-Marridi, Al-Rojoub, & Adegboye, 2019; Santos, de Andrade, González, Dias, & Mesas, 2018). Importantly, physical activity is a key behaviour for self-management of chronic pain, improving outcomes such as pain, physical function, fatigue, sleep and mood (Ambrose & Golightly, 2015; Geneen, Moore, Clarke, Martin, Colvin, & Smith, 2017; Polaski, Phelps, Kostek, Szucs, & Kolber, 2019), but is not well adhered to (Friedrich, Gittler, Halberstadt, Cermak, & Heiller, 1998; Peek, Carey, Mackenzie, & Sanson-Fisher, 2018). On the other hand, both underactivity and overactivity can be problematic and maladaptive (Hasenbring, Hallner, Klasen, Streitlein-Bohme, Willburger, & Rusche, 2012; Hasenbring & Verbunt, 2010). Overactivity, also known as persistence or endurance behaviour, has been less frequently investigated and there is still ambiguity as to when it can be detrimental or advantageous (Andrews, Strong, & Meredith, 2012; Hasenbring et al., 2012; Kindermans, Roelofs, Goossens, Huijnen, Verbunt, & Vlaeyen, 2011). Self-management of activity levels can be challenging in people with chronic pain.

The experience of chronic pain is frequently associated with pain-related cognitions which may hinder adaption to chronic pain. For example, pain catastrophising is a negative thinking style where there is a tendency to amplify the threat value of pain (Quartana, Campbell, & Edwards, 2009). Pain catastrophising is associated with fear-related pain avoidance behaviours and lower levels of physical exertion (Vlaeyen et al., 1995; Vlaeyen & Linton, 2000). There is a relationship between pain catastrophising and ineffective emotion regulation strategies, such as thought suppression, which may lead to greater pain (Gilliam, Burns, Quartana, Matsuura, Nappi, & Wolff, 2010; Linton & Bergbom, 2011; Wong & Fielding, 2013). Pain catastrophising is also related to bias toward pain-relief goals and these are likely to be prioritised compared to non-pain goals when pain catastrophising is high (Crombez, Eccleston, Van Hamme, & De Vlieger, 2008; Crombez, Lauwerier, Goubert, & Van Damme, 2016; Flink, Boersma, MacDonald, & Linton, 2012). Goals which prioritise the relief of pain, or solving the pain problem, are not adaptive when pain is chronic and cannot be eradicated (Aldrich, Eccleston, & Crombez, 2000; Flink et al., 2012). Therefore, pain catastrophising is linked to poorer self-management of emotions, behaviour and goals in people with chronic pain.

Pain self-efficacy may also play a role in the management of chronic pain. Self-efficacy beliefs are defined as confidence in one's ability to complete a task and they determine how much effort will be exerted in the face of challenges, how long to persist on a task, and whether coping efforts are required (Bandura, 1977). Pain self-efficacy are beliefs relating specifically to confidence in ability to manage pain (Nicholas, 1989). Pain self-efficacy is related to active coping, such as task persistence (Turner, Ersek, & Kemp, 2005). In patients with rheumatoid arthritis, pain self-efficacy was related to adaption, such as physical, affective and social functioning (Somers, Shelby, Keefe, Godiwala, Lumley, Mosley-Williams et al., 2010). Pain self-efficacy is also related to self-regulation of goal processes in chronic pain (Arends, Bode, Taal, & Van de Laar, 2013). Changes in pain self-efficacy during treatment are significantly associated with improvements in outcomes (Altmaier, Lehmann, Russell, Weinstein, & Kao, 1992; Turner, Holtzman, & Mancl, 2007). Thus, pain self-efficacy appears to facilitate better self-management of chronic pain.

1.1.2 The role of self-regulation in self-managing chronic pain

Self-regulation predicts positive life outcomes such as educational attainment, psychosocial adjustment and employment (Converse, Beverage, Vaghef, & Moore, 2018; Duckworth, 2011; Fergusson, Boden, & Horwood, 2013; Tangney, Baumeister, & Boone, 2004). Moreover, poor self-regulation has also been linked to negative outcomes such as criminal offending, harmful health behaviours such as substance use, poor mental health (Fergusson et al., 2013; Hagger, Wood, Stiff, & Chatzisarantis, 2009) and has been implicated in poorer adjustment to chronic health conditions (De Ridder, Geenen, Kuijer, & van Middendorp, 2008; Leventhal, Halm, Horowitz, Leventhal, & Ozakinci, 2005). Self-regulatory process are required to manage factors which affect self-management, such as mood, motivation, self-discipline, self-efficacy and inner conflicts related to the contradictory needs that arise in chronic illness (Schulman-Green, Jaser, Park, & Whittemore, 2016). Deficits in self-regulation have been implicated in difficulties in the self-management of chronic pain conditions (Solberg Nes, Ehlers, Whipple, & Vincent, 2017; Solberg Nes, Roach, & Segerstrom, 2009).

Recently, there has been a shift towards investigating self-management of chronic pain within the affective-motivational context of pursuing valued goals and activities (Crombez, Eccleston, Van Damme, Vlaeyen, & Karoly, 2012; Van Damme & Kindermans, 2015). From this self-regulation perspective, when costs outweigh benefits during goal pursuit (e.g. increasing pain), the induction of fatigue leads to decreases in motivation. The onset of fatigue during activity serves to ensure the optimal allocation of resources in the face of increasing demands (Van Damme, Becker, & Van der Linden, 2018). When fatigue arises during goal pursuit, cognitive control is employed to supress pain and goal-discrepant cognitions. This delays the onset of fatigue and goal disruption (Van Damme et al., 2018). However, recruiting cognitive control is effortful and cannot be continually sustained, even in people without a chronic health condition (Baumeister, Bratslavsky, Muraven, & Tice, 1998). In people with chronic pain there may be a reduced capacity for engaging in self-regulation (Solberg Nes, Carlson, Crofford, de Leeuw, & Segerstrom, 2010; Solberg Nes et al., 2009).

One mechanism by which a reduction in capacity for self-regulation occurs may be deficits in executive functioning in people with chronic pain (Solberg Nes et al., 2009). Executive function is important for focusing on tasks despite pain (Katrien, Van Damme, Eccleston, Van Ryckeghem Dimitri, Legrain, & Crombez, 2011). Physiological, cognitive, emotional and social demands that occur in chronic pain may limit the availability of cognitive resources for engaging in self-regulation. Demands such as organising activities, problem solving, regulating emotions and managing healthcare appointments may be more taxing in those with chronic pain than those without a health condition. Evidence suggests that people with chronic pain have deficits in working memory, emotional control, attentional deployment, inhibition, mental flexibility and deliberative decision making and that high pain intensity, pain catastrophising, mood and medications contribute to poorer performance (Abeare, Cohen, Axelrod, Leisen, Mosley-Williams, & Lumley, 2010; Baker, Gibson, Georgiou-Karistianis, Roth, & Giummarra, 2016; Baker, Gibson, Georgiou-Karistianis, & Giummarra, 2018; Berryman, Stanton, Bowering, Tabor, McFarlane, & Moseley, 2014; Karp, Reynolds, Butters, Dew, Mazumdar, Begley et al., 2006). Although, some studies have found no differences in tests of executive function between people with chronic health conditions and healthy controls (Masiliūnas, Vitkutė, Stankevičius, Matijošaitis, & Petrikonis, 2017; Oosterman, Derksen, van Wijck, Kessels, & Veldhuijzen, 2012). That said, it has been suggested that areas of the brain required for pain processing overlap with areas of the brain recruited for effortful inhibition (J. M. Glass, Williams, Fernandez-Sanchez, Kairys, Barjola, Heitzeg et al., 2011). This shared neural circuitry may account for the deficits in executive function encountered by people with chronic pain, impeding the ability to engage in cognitive control and resulting in reduced capacity for self-regulation.

1.2 The Strength Model

1.2.1 Theoretical assumptions

One of the most prevailing theories within the self-regulation field, the Strength Model, hypothesises that capacity for self-regulation is determined by the availability of limited domain-general self-regulatory resources (Baumeister et al., 1998; Baumeister & Vohs, 2016b). Acts of cognitive, emotional and behavioural self-regulation all draw from the limited pool of resources (Baumeister et al., 1998). Effortful self-regulation is akin to volition or willpower and includes acts of volitional control, inhibiting impulses, desires, temptations and automatic responses, controlling thoughts and emotions and making decisions. Examples include attempting to suppress laughter during work-related meetings, overcoming the desire to eat a piece of cake while on a diet, breaking a habit or making many decisions or choices while shopping. Engaging in effortful self-regulation uses the finite resources and they become temporarily depleted with continued use (Muraven, Tice, & Baumeister, 1998). This means that continued engagement in self-regulation becomes increasingly difficult and, as the resource is exhausted, there is the increased likelihood of self-regulation failure (Baumeister et al., 1998; Baumeister, Heatherton, & Tice, 1994; Muraven et al., 1998). The term 'ego-depletion' was applied to refer to a state of reduced self-regulatory capacity, caused by the reduction of limited self-regulatory resources after previous self-regulatory exertion.

The analogy of self-regulatory exertion as being similar to that of a muscle was quickly adopted as a heuristic (Muraven & Baumeister, 2000). When engaging in exercise which targets a particular muscle, initial energy or strength is required to achieve the desired movement. As continued effort is employed over time, the muscle starts to become fatigued and weaker. To sustain performance, more strength and effort needs to be recruited. The initial level of exertion cannot be sustained unceasingly and so performance decreases until failure occurs. Similarly, self-regulatory exertion becomes increasingly difficult as the self-regulatory strength weakens and self-regulation failure occurs when resources become depleted (Baumeister, 2016; Muraven & Baumeister, 2000). Aiding the muscle metaphor was evidence that resting (Tyler & Burns, 2008) and positive affect (Tice, Baumeister, Shmueli, & Muraven, 2007) allowed self-regulatory capacity to replenish. Additionally, one can "build" the self-control muscle with regular self-control practice and even physical exercise (Muraven, 2010; Oaten & Cheng, 2006a, 2006b).

Going beyond the metaphor, it was also suggested that glucose was a physiological mechanism underlying ego-depletion. It appeared that there was reduction of blood glucose during an ego-depleted state and that consumption of glucose or even a mouth rinse with a sweetened drink could facilitate recovery from ego-depletion (Dvorak & Simons, 2009; Gailliot, Baumeister, DeWall, Maner, Plant, Tice et al., 2007; Hagger & Chatzisarantis, 2013). However, follow-up studies with higher power have cast doubt on the effect of ego-depletion on glucose levels as earlier findings could not be replicated (Boyle, Lawton, Allen, Croden, Smith, & Dye, 2016; Lange & Eggert, 2014; Lange, Seer, Rapior, Rose, & Eggert, 2014; Schimmack, 2012). Despite the poor evidence of glucose as an underlying physiological mechanism, the Strength Model held intuitive appeal and so has been widely studied (Baumeister, 2016). As a result, research examining the ego-depletion effect on self-regulation performance proliferated. Prior to evaluating the evidence for the Strength Model, it is necessary to clarify definitions, terms and related concepts and describe methods used to assess the model.

1.2.2 Defining executive function, self-regulation, self-control and willpower

Executive function is comprised of three cognitive processes, namely updating, inhibition and shifting (Miyake, Friedman, Emerson, Witzki, Howerter, & Wager, 2000). Updating is related to continually having relevant information available within working memory through consistent updating (Kane, Bleckley, Conway, & Engle, 2001). Inhibition refers to the deliberative inhibition of prepotent responses as required (Miyake et al., 2000). Shifting, or task switching, is the act of interchanging between multiple cognitive tasks and mental sets (Monsell, 2003). Executive functions are proposed to underlie and support self-regulatory operations and are implicated in self-regulation failure (Hofmann, Schmeichel, & Baddeley, 2012). For example, working memory is necessary for emotion regulation and task switching allows for flexible goal pursuit with temporary goal disengagement. Inhibition, which is most closely aligned to traditional definitions of self-control, relates to overriding impulses. Limits in executive function capacity can occur due to "bottlenecks" in processing (Marois & Ivanoff, 2005). It has been argued that situational impairments in self-regulation are a result of state reductions in executive functions due to high cognitive load or accumulative effects of prior engagement in executive functions (Hofmann, Schmeichel, et al., 2012). Therefore, successful self-regulation relies on executive functions, although these are separate cognitive processes.

The distinction between self-regulation and self-control must be discussed. One conceptual problem within the literature is the propensity of researchers to use the terms self-control and self-regulation interchangeably. This problematic confounding of terms may have originated from Baumeister and colleagues themselves, who despite clearly defining self-regulation and self-control as distinct but related concepts, have frequently stated that they use the terms interchangeably (Baumeister & Vohs, 2016b; Baumeister, Vohs, & Tice, 2007). Self-regulation is defined as the process of modulating thoughts, emotions and behaviours to expedite the pursuit of short and long-term goals (Carver & Scheier, 1998). The purpose of self-regulation is to ensure psychological homeostasis such that occurs with physiological homeostasis, for example, the regulation of optimal body temperature (Carver, 2006). Self-regulation includes processes such as goal-setting, planning and goal engagement and disengagement. Therefore, when there is a discrepancy between current and desired psychological states, self-regulation is the process of taking action to correct this discrepancy (Carver & Scheier, 1998; Gollwitzer, 1999).

Baumeister and Heatherton (1996) described self-regulation as having three processes: standards, monitoring, and operation. Standards are personal values and goals which provide direction for action. Monitoring is the process of comparing current states with desired states, also referred to by Carver and Scheier (1998) as the feedback loop. Operation refers to *what* action takes place for the discrepancy to be resolved. Self-control is the ‘operate’ part of self-regulation to reduce discrepancies in goal pursuit (Baumeister & Heatherton, 1996; Gillebaart, 2018). Self-regulation is integrative of cognitive, motivational and behavioural aspects of goal pursuit (Baumeister & Heatherton, 1996; Fujita, 2011). However, self-regulation has many mechanisms to produce desired states, as described above. Thus, self-control is always a self-regulatory endeavour but self-regulation does not always involve self-control.

Self-control has traditionally been defined as the act of forgoing immediate, smaller rewards in favour of delayed, larger rewards, or delay of gratification (Metcalfe & Mischel, 1999; Mischel, Shoda, & Rodriguez, 1989). Early studies assessed self-control by the degree of temporal discounting which took place (Kirby & Herrnstein, 1995; Kirby & Maraković, 1995). That is, the extent to which the subjective value of an objectively more valuable reward was discounted because it was delayed. This view of self-control is also consistent with a conceptualisation of self-control as conflict resolution between two competing motivations (Fujita, 2011). One motivation which is smaller, but proximate and more concrete, and another which is larger, but more abstract and distal (Carnevale & Fujita, 2016; Fujita, 2011). The foregoing of smaller, immediate rewards in favour of distal goals is what is understood in lay-terms as willpower (Baumeister et al., 1994; Baumeister & Tierney, 2011).

Within the Strength Model framework, self-control has almost exclusively been defined as the inhibition of impulses (Baumeister et al., 1994; De Ridder, Lensvelt-Mulders, Finkenauer, Stok, & Baumeister, 2011). Self-control is most frequently understood as being one aspect of self-regulation including a range of mental processes which enables the inhibition of urges, impulses and temptations which threaten goal pursuit (Inzlicht & Berkman, 2015). Authors have also used terms such as effortful control, effortful inhibition and inhibitory control to refer to self-control (Duckworth & Kern, 2011). In their work, Baumeister and colleagues have stated that their focus is on effortful self-control (e.g. Baumeister & Vohs, 2016). That is, self-control which involves the effortful, ‘in-the-moment’ inhibition of temptations, desires and distractions from a long-term goal. As a result of this focus in their work, many subsequent studies have narrowly defined self-control exclusively as effortful inhibition, and tested only this aspect in the pursuit of understanding the ego-depletion effect. It has even been argued that defining self-control to include acts which go beyond inhibition, such as monitoring or moderating thoughts, emotions and behaviour, is too broad in scope (Lurquin & Miyake, 2017).

Despite this, more recent work has applied a further-reaching definition to self-control which goes beyond effortful inhibition (Duckworth, Gendler, & Gross, 2016; Fujita, 2011; Milyavskaya & Inzlicht, 2017). For example, it has been suggested that there are reactive and proactive strategies to promote goal pursuit. An example of a reactive strategy would be attempting to constrain the desire to buy an expensive item while saving money for a holiday. Whereas a proactive strategy would be to avoid going to a place where one might be tempted to purchase an expensive item (Carnevale & Fujita, 2016; Fujita, 2011). Whereas the Process Model of self-control has hypothesised that there are a range of situational and cognitive self-control strategies such as distraction, cognitive reappraisal and situation selection (Duckworth et al., 2016). Situation selection, reappraisal and distraction are aligned to proactive strategies described by Fujita (2011), when they are employed with forethought. For example, planning a fun activity in advance as a distraction from waiting for important test results is a proactive strategy. These additional self-control strategies, beyond effortful inhibition, bypass the need to engage in effortful control. This is an advantage as effortful control is cognitively demanding and leads to ego-depletion (Hagger, Wood, Stiff, & Chatzisarantis, 2010). Other strategies negate the need to use effortful inhibition as they prevent the occurrence of temptations, making them cognitively conservative (Fujita, 2011).

Therefore, conflating self-control with effortful inhibition is unhelpful and has limited what was known about self-control until recently.

Of additional significance is the distinction between trait and state self-control. Trait self-control describes a stable, innate self-control ability (Tangney et al., 2004). Trait self-control is related to the ability to manage potential self-control conflicts by prioritising the long-term goal (De Ridder, Kroese, & Gillebaart, 2018). State self-control refers to the momentary, transient ability to engage in self-control. The Strength Model makes hypotheses about, and studies, state self-control or the level of momentary possible self-control, based on available self-regulatory resources (Muraven et al., 1998). Questions have arisen regarding the relationship between trait and state self-control as this is not well understood. Prior suggestions as to the link between trait and state self-control have argued that people with high trait self-control are more capable of resisting temptations (Tangney et al., 2004), that high trait self-control acts as a buffer to ego-depletion (DeWall, Baumeister, Stillman, & Gailliot, 2007), or that high trait self-control relates to more efficient use of resources (Baumeister et al., 2007). For example, it was demonstrated that people with high trait self-control were better able to resist blinking and had higher pain tolerance (Schmeichel & Zell, 2007). Additionally, trait self-control was found to moderate the effect of ego-depletion (DeWall et al., 2007). Compared with participants who self-reported high trait self-control, those with low trait self-control were more likely to express an aggressive response to an imagined scenario after completing a task requiring inhibition of a previously-learned response (DeWall et al., 2007).

While the notion that there is a relationship between trait and state self-control seems reasonable, more recent evidence has demonstrated seemingly counter-intuitive findings which question whether trait and state self-control are related. Evidence from a meta-analysis demonstrated that self-report trait self-control is only weakly correlated with tasks of delay-of gratification (Duckworth & Kern, 2011). Also, tests of inhibition-related executive function have been found to be unrelated to self-report measures of trait self-control (Saunders, Milyavskaya, Etz, Randles, & Inzlicht, 2018). Experimental research has also shown that trait self-control was predictive of motivation for performance on a cognitive control task, but participants with high trait self-control had poorer self-control performance when ego-depleted than those with low trait self-control (Imhoff, Schmidt, & Gerstenberg, 2014; Lindner, Nagy, Ramos Arhuis, & Retelsdorf, 2017).

One explanation for this is that people who are high in trait self-control are not better at resisting temptation, but are better at avoiding situations where they may need to resist temptation. That is, people with high trait self-control may structure their lives to experience less conflict. For example, within-person diary studies have demonstrated that people with high trait self-control were less likely to experience temptation in daily life but that experiencing temptations was perceived as more depleting, leading to less self-control success (Hofmann, Baumeister, Forster, & Vohs, 2012; Imhoff et al., 2014; Milyavskaya & Inzlicht, 2017). Research has demonstrated that people with high trait self-control are better at identifying potential conflict and resolving it (Duckworth et al., 2016; Gillebaart, Schneider, & De Ridder, 2016). Further, people with high trait self-control are more likely to develop habits and strategies which prevent the need to use effortful self-control (De Ridder et al., 2018; De Ridder, Lensvelt-Mulders, Finkenauer, Stok, & Baumeister, 2012). This includes preferring to work in less distracting environments (Ent, Baumeister, & Tice, 2015), eating fewer unhealthy snacks (Adriaanse, Kroese, Gillebaart, & De Ridder, 2014) and exercising more (Gillebaart & Adriaanse, 2017). The disparity in the observed direction of the relationship between trait and state self-control may be accounted for by more robust methods and larger samples sizes in recent research. Additionally, the methods used in more recent work has frequently investigated within-person relationships between trait and state self-control.

It seems that defining and measuring self-control in narrow terms of effortful inhibition may account for the weak relationship between trait and state self-control. Those with high trait self-control are much less likely to employ effortful inhibition as a strategy. Taken together, the evidence in this section suggests that self-control should be defined as actions which promote the pursuit of distal rather than proximal goals. Defining self-control this way may reconcile the relationship between state and trait self-control. That is, trait self-control is an individual difference of the general propensity to utilise strategies which advance distal goals successfully. State self-control is the momentary ability to engage in strategies which promote the distal goal based on phasic changes in psychological and environmental demands.

1.2.3 Defining self-control strength, self-regulatory capacity and self-regulatory resources

Self-control strength, on which the Strength Model is based, is the power that one has to overcome strong impulses, desires, temptations and emotions (Baumeister & Heatherton, 1996). Self-control strength is determined by capacity for self-regulation. In turn, self-regulatory capacity is assumed by the Strength Model to be determined by the amount of limited self-regulatory resources available (Baumeister et al., 1998; Baumeister & Heatherton, 1996). Self-regulatory resources have been described as psychological energy available to the self (Ryan & Deci, 2008; Tice et al., 2007). As with the discussion above, the terms self-control capacity and self-control resources are used interchangeably with self-regulatory resources and self-regulatory capacity. It could be argued that the terms self-control capacity and self-control resources are misleading as it suggests that there is a capacity specifically for instances of self-control, but not self-regulation more generally. It may be more accurate to describe acts of self-control as one way in which self-regulatory capacity and resources are depleted. Alternatively, it is perhaps reasoned that use of the terms self-control capacity or self-control resources are justified as it is the effortful nature of self-control (when defined as the inhibition of prepotent responses) that uses limited resources and causes ego-depletion. However, this does not hold as cognitive resources are required for mental processes which support self-regulation, such as attention deployment, working memory and executive planning (Franconeri, Alvarez, & Cavanagh, 2013; Schmeichel, 2007).

Early work conceptualised ego-depletion from a broad self-regulatory perspective, as a lack of capacity to engage in volitional acts caused by prior exercise of volitional control (Baumeister et al., 1998). There is no definitive evidence that engaging in self-control is the only way to induce a state of ego-depletion or reduce resources. Despite this broader definition of ego-depletion, tests of the ego-depletion effect have almost exclusively operationalised self-control through tasks of effortful inhibition. The ego-depletion effect has been observed after engaging in other volitional acts such as decision making (Vohs, Baumeister, Schmeichel, Twenge, Nelson, & Tice, 2008) and there is evidence that the ego-depletion effect is moderated by whether motivation is intrinsic or extrinsic (Muraven, 2008) and whether individuals believe that self-regulation capacity is limited (Job, Walton, Bernecker, & Dweck, 2015). Therefore, acts of self-control, conceptualised as effortful inhibition, are not the sole source of ego-depletion (Carnevale & Fujita, 2016).

It has been argued that general self-regulatory capacity is determined by both trait and state components (Solberg Nes et al., 2009). Again, trait self-regulatory ability is an individual difference while state self-regulatory capacity is the momentary capability to engage in self-regulation, which is affected by environmental and psychological demands. Self-regulatory capacity relies on resources for executive function processes (Clarkson, Otto, Hassey, & Hirt, 2016; Schmeichel, 2007; Wilkowski & Robinson, 2016). This general self-regulatory capacity is susceptible to fatigue when there are increasing demands. Therefore, acts of self-control draw resources from a general self-regulatory capacity which maintains all aspects of self-regulation. Within this thesis, the terms self-regulatory capacity and self-regulatory resources will be used as opposed to self-control capacity and self-control resources.

1.2.4 Defining ego-depletion, mental fatigue and self-regulatory fatigue

Ego-depletion is said to be the converse of self-regulatory capacity. Where self-regulatory capacity has been described as having energy available to the self (Ryan & Deci, 2008), ego-depletion is the state of reduced capacity for self-regulation resultant from expended energy. Ego-depletion is the temporary reduction of the ability to enact volitional control as a result of prior exercise of volition (Baumeister et al., 1998). This definition of ego-depletion refers to the behavioural outcome of a previous exercise of volition, but not the mechanisms by which it occurs. Ego-depletion is a condition under which self-regulation failure is proposed to occur (Baumeister & Heatherton, 1996). The separation of ego-depletion from limited-resource accounts of self-regulation is important as some scholars believe that there is a measurable reduction in self-regulation performance after previous self-regulation, but have suggested different mechanisms for its occurrence (e.g. Inzlicht, Schmeichel & Macrae, 2014; Saunders & Inzlicht, 2015; see section 1.4.2, p33).

Ego-depletion is accompanied by feelings of subjective or mental fatigue (Z. L. Francis & Inzlicht, 2016; Hagger et al., 2010). Mental fatigue has been defined as feelings of low arousal, negative mood and a lack of focus or concentration (Hockey, 2013). This includes tiredness, weariness and boredom. Although subjective fatigue and physical fatigue are related (Thayer, 1996, 2001; Van Cutsem, Marcora, De Pauw, Bailey, Meeusen, & Roelands, 2017), they are distinct constructs. It was demonstrated that sleep deprivation had no effect on aggressive responses between non-depleted participants who were either sleep deprived or not, or between depleted participants who were either sleep-deprived or rested (Vohs, Glass, Maddox, & Markman, 2011). Although, the participants in this study were sleep deprived for 24 hours and so conclusions cannot be drawn about the cumulative effects of chronic sleep deprivation on self-regulatory capacity. Nevertheless, ego-depletion is not simply a state of physical fatigue.

As argued above, ego-depletion has almost entirely been empirically tested by using tasks of effortful inhibition, which is only one self-control strategy. The language used within the literature also frequently refers to ego-depletion in self-control terms. However, the term self-regulatory fatigue has been used to describe a decrease in general self-regulatory capacity (Solberg Nes, Ehlers, Whipple, & Vincent, 2013). Self-regulatory fatigue may be a more suitable term to describe a decrease in self-regulatory capacity. It provides a wider scope and allows for reduced capacity for self-regulation processes, such as lack of monitoring, planning and task-switching, to be encompassed as well as self-control failure (Solberg Nes et al., 2009; Wilkowski & Robinson, 2016). Therefore, the term self-regulatory fatigue will be used in this thesis to refer to a reduction in self-regulatory capacity.

1.2.5 Methods for investigating the Strength Model

The method for assessing the Strength Model presented in the seminal paper was an experimental method called the dual-task paradigm (Baumeister et al., 1998). The dual-task paradigm is the most commonly used method for testing the ego-depletion effect. The paradigm involves the administration of two sequential tasks. In the ego-depletion condition, both tasks require self-regulation and the purpose of the first task is to deplete self-regulatory resources. The purpose of the second task is to measure self-regulation performance. In the control condition, two sequential tasks are also administered. Unlike the ego-depletion condition, the first task in the control condition does not require self-regulation. The ego-depletion and control conditions complete the same measurement task. Performance on the measurement task is directly compared between the ego-depletion and control conditions. Support for the ego-depletion hypothesis is said to be provided when those who were administered the prior self-regulation task perform more poorly than the control condition in the measurement task.

In initial papers by Baumeister and colleagues (e.g. Baumesiter et al., 1998; Muraven et al., 1998; Muraven & Baumeister, 2000), a manipulation check was administered to determine whether changes in performance occurred as a result of the proposed mechanisms. These manipulation checks are self-report and there is no standard for what should be measured (Friese, Loschelder, Gieseler, Frankenbach, & Inzlicht, 2019). They are to be administered after the depletion task but not all ego-depletion studies do so (Friese et al., 2019). Common examples are self-report measures of fatigue, frustration and perception of task difficulty. Manipulation checks are also used to confirm that other factors could not have accounted for the results incurred by the manipulation, such as differences in positive or negative mood between the control and ego-depletion conditions. However, the utility of these manipulation checks have been questioned (Fayant, Sigall, Lemmonier, Restin, & Alexopoulos, 2017; Friese et al., 2019). For example, the validity of such items has not been determined and there is an assumption that the items chosen indicate that ego-depletion has taken place. It is also unclear how much weight should be given to such items in a case of reduced performance in ego-depleted participants but no significant differences in the manipulation check items. It has been suggested that it may be more valid to use objective measures such as physiological measures of expended effort (Friese et al., 2019).

Another feature of the dual-task paradigm, which was argued to be necessary in early papers, was the administration of depletion and measurement tasks which tap different domains

(Muraven et al., 1998). For example, the depletion task may involve suppressing emotions while the measurement task may involve persistence on a frustrating puzzle. The purpose of using tasks from two different domains is twofold. First, as self-regulatory resources are domain-general, then acts of self-regulation across domains should draw from the same limited resource. Therefore, using tasks from different domains provides evidence for the hypothesised domain general resource. Second, using the same or similar tasks may be susceptible to practice effects and facilitate subsequent self-regulation performance. A multitude of different combinations of cognitive, affective and behavioural tasks have been used including thought suppression, suppressing emotion while watching a sad video clip, breaking a formed habit, making choices, arithmetic task with auditory interference and persistence on a cold pressor task (Hagger et al., 2010). While the dual-task paradigm is the most accepted means to test the Strength Model, the adequacy of this method in providing evidence for the theoretical predictions has been questioned (Lee, Chatzisarantis, & Hagger, 2016). The limitations of the dual-task paradigm will be discussed further in section 1.3 (p26).

More recently, a striving to assess the ecological validity of the Strength Model and develop more rigorous, standardised and replicable methods have led to alternative designs and tests being used. For example, diary methods have been used to examine the effect of self-regulatory demands and cumulative depletion of self-regulatory capacity in everyday life (Hofmann, Baumeister, et al., 2012; Muraven, Collins, Shiffman, & Paty, 2005). Multilevel modelling has been used to measure effort, progressive ego-depletion performance over time and frequency of errors made (Arber, Ireland, Feger, Marrington, Tehan, & Tehan, 2017; Lindner et al., 2017; Radel, Gruet, & Barzykowski, 2019). In addition, within-person paradigms of the ego-depletion effect have been attempted (Englert & Wolff, 2015; Z. L. Francis, Milyavskaya, Lin, & Inzlicht, 2018).

1.2.6 Evidence for the Strength Model

The seminal paper presenting the limited resource account of ego-depletion demonstrated the effect across several domains (Baumeister et al., 1998). Several experimental studies were conducted using the dual-task paradigm. The first of these experiments asked participants to eat a certain amount of either cookies or radishes in the depletion phase and then to persist at an impossible puzzle in the measurement phase. It was proposed that eating the radishes would require effort while eating the cookies would not. The results found that the participants who were asked to eat radishes reported that they had exerted more effort in the depletion phase. Those who ate radishes also persisted at the puzzle for significantly less time and made significantly less attempts to solve the puzzle than the participants who ate cookies. A second experiment found that those who had to make a counter-attitudinal speech under low choice conditions persisted for significantly longer on the same impossible puzzle than those who made a counter-attitudinal speech under high choice conditions. In a third study, participants in the ego-depletion condition were asked to suppress their emotions while watching a video clip while those in the control group were not asked to suppress their emotions. Half of the participants in each group watched a sad video clip and the other half of the participants watched a funny video clip. Participants who were asked to suppress emotions performed significantly poorer at solving anagrams than those who did not need to suppress emotion, regardless of whether it was a sad or funny video clip. In a final experiment, participants were asked to cross out any letter ‘e’ on a printed page of text in the control condition and to cross out ‘e’ only when it followed certain other letters in the ego-depletion condition. Subsequently, participants in the ego-depletion were more likely to watch a longer duration of a movie clip if it required an active rather than a passive response to quit watching.

Further evidence was gathered for the ego-depletion effect using a variety of tasks. For example, making many decisions reduced self-regulation performance with regard to physical stamina, persistence, more procrastination and solved fewer arithmetic problems (Vohs et al., 2008). In an additional field experiment, shoppers who self-reported making more decisions throughout the day performed worse on a self-regulation task (Vohs et al., 2008). Ego-depletion has also been shown to account for more aggressive responding when provoked (DeWall et al., 2007), engaging in less prosocial behaviour (DeWall, Baumeister, Gailliot, & Maner, 2008; Fennis, 2011) and lower pain tolerance (Muraven, Shmueli, & Burkley, 2006). A meta-analysis of 83 studies and 198 experiments concluded that there was a medium to large effect size of the ego-depletion effect where ego-depletion was found to have a significant effect on subjective fatigue, perceived task difficulty, effort, negative affect and blood glucose (Hagger et al., 2010).

Further evidence for the Strength Model has been provided by longitudinal studies and diary studies which have examined the applications of the ego-depletion effect. A daily diary study found that conflicts arose throughout the day which elicited attempts to resist the impulse with mixed success (Hofmann, Baumeister, et al., 2012). Self-regulatory demands have been found to be associated with alcohol consumption in a daily diary (Muraven et al., 2005). Daily stress was found to be associated with lower self-regulatory capacity and exercise adherence where self-regulatory capacity mediated the relationship (Englert & Rummel, 2016). Additional diary studies have demonstrated that on days when self-regulatory capacity was lower, the number of minutes of exercise participation was reduced (Schöndube, Bertrams, Sudeck, & Fuchs, 2017) and intention to exercise the next day was lower (Rebar, Dimmock, Rhodes, & Jackson, 2018).

1.2.7 Recent evidence and developments

Despite the abundance of initial supportive evidence for the Strength Model, conceptual and methodological problems have been identified within the literature. Although the effects found in the initial meta-analysis seemed robust (Hagger et al., 2010), controversy arose about whether the meta-analysis had estimated the true effect of ego-depletion. The conclusions drawn from Hagger et al.'s (2010) meta-analysis have been criticised as the authors did not use methods to correct for publication bias and small-study effects. It has been argued that the inclusion criteria were too broad and did not focus on studies which measured the true ego-depletion effect (Carter, Kofler, Forster, & McCullough, 2015; Carter & McCullough, 2014). Carter and colleagues (Carter et al., 2015; Carter & McCullough, 2013, 2014) conducted further statistical analysis on the meta-analytic sample used by Hagger et al. (2010) and then conducted their own meta-analysis with stricter inclusion criteria and applied a range of meta-analytic techniques. They concluded that by correcting for publication bias, the effect of ego-depletion was no different to zero.

However, it has been argued that their conclusions are misleading and, at best, their results show that there are current challenges in the ego-depletion literature and that these new meta-analytic methods need to be validated (Inzlicht, Gervais, & Berkman, 2015). For example, when Carter et al. (2015) conducted standard random-effects meta-analysis which included 40% unpublished studies and 50% non-significant results, they found a significant effect of ego-depletion of small to medium magnitude. Also, the meta-regression techniques used by Carter et al. (2015) can be unreliable and have not been validated in the field of psychology (Inzlicht et al., 2015). Two more recent meta-analyses with alternative statistical methods established that there is a small to medium effect of ego-depletion and the effect sizes are larger when the most reliable ego-depletion tasks, such as emotion suppression video and Stroop, are used (Blázquez, Botella, & Suero, 2017; Dang, 2018). It was concluded that more evidence is still required to support the Strength Model. Rather than abandoning the model or methods of investigating it, it was determined that more rigorous methods should be applied to observe the true ego-depletion effect and establish under which conditions it occurs.

To that end, several high powered studies with more rigorous methodology and further meta-analytic studies have been conducted. A large-scale, multi-lab, registered replication report was conducted using a standardised depletion task which was deemed to be a reliable (Hagger, Chatzisarantis, Alberts, Anggono, Batailler, Birt et al., 2016). The depletion task required participants to watch a screen where a series of words were presented and press a button when the "e" appeared on screen but with the added stipulation that they should inhibit the response if the "e" was adjacent to or one letter removed from a vowel. The control condition completed the same task but without the added stipulation. The dependent variable was reaction time and reaction time variability on incongruent trials of an interference task. The study conducted a meta-analysis of results from each lab and found small effect sizes (d=0.04) for both reaction time and reaction time variability but both estimates included zero within 95% confidence intervals. Only three labs found significant effects for both reaction time and reaction time variability but some of these were in the opposite of the hypothesised direction. This evidence appeared to dispute Strength Model hypotheses. Nevertheless, the study was criticised as it was suggested that the key aspect of the depletion task was missing, meaning it was insufficient to induce ego-depletion (Baumeister & Vohs, 2016a; Drummond & Philipp, 2017). That is, there should have been an initial block in the depletion condition where participants completed the "e" task without stipulations, thereby developing a habit which they needed to inhibit in the next block.

Even with improved methodological rigour, inconsistencies in the evidence remain. Another study endeavoured to determine whether the habit-forming and breaking aspect of the task was an essential condition for ego-depletion to occur (Arber et al., 2017). This study examined errors over time as the dependent variable. It was confirmed that across five studies, the letter "e" task used by Hagger et al. (2016) was sufficient to produce decreases in performance over time in the dependent variable. Further high powered studies have provided mixed evidence for the ego-depletion effect (Garrison, Finley, & Schmeichel, 2019; Lurquin, Michaelson, Barker, Gustavson, von Bastian, Carruth et al., 2016; Miguel, Natalie, & Magda, 2018; Radel et al., 2019). Inconsistent findings may be accounted for by the choice of task used, as suggested by Dang (2018). Alternatively, inconsistencies may arise from individual differences as it has been noted that some participants adapt to the ego-depletion task (Arber et al., 2017; Dang, Dewitte, Mao, Xiao, & Shi, 2013). This finding may be one explanation for the contrary results and null findings in studies which measure differences in the average performance of a group.

1.3 Limitations of current measurement of self-regulatory capacity

1.3.1 The assumption of validity

As a result of current controversy as to whether the ego-depletion effect exists and, if so, under what conditions, it is pertinent to examine the efficacy of methods used in testing the Strength Model. The employment of the dual-task paradigm has largely been relied upon to provide evidence for the Strength Model. As has been implied throughout this chapter, a lack of clear definitions and operationalisation of constructs has given rise to conceptual issues within the literature. The mechanisms whereby self-regulatory resources become depleted or are recovered, and their relationship to related constructs have been ambiguously described with the Strength Model (Lurquin & Miyake, 2017). This leaves the internal validity of the dual-task paradigm uncertain. For example, it is unclear whether self-regulatory fatigue results from reductions in self-regulatory resources, reductions in motivation, or both. Precise definitions of constructs and their relationships to one another are also essential to developing measures which have appropriate content validity and discriminant content validity.

Unambiguous measurement is critical to determining the validity of theory. Despite this, discriminant content validity is rarely examined.

1.3.2 The assumption of sufficient effort

The use of the dual-task paradigm has long been criticised as measuring self-regulatory capacity by performance on a self-regulation task introduces uncertainty around the mechanisms underlying the ego-depletion effect (Lee et al., 2016; Lurquin & Miyake, 2017). Specifically, the hypothesis that better or worse performance reflects more or less self-regulatory capacity relies on the assumption that participants exert sufficient effort to induce self-regulatory fatigue (Lee et al., 2016). This assumption is problematic as it suggests that participants are sufficiently motivated to engage in the task. Exerting effort is a critical determinant of self-regulatory fatigue. However, there must be motivation to exert effort in the first place. If performance on the measurement task is not poorer in the depletion condition compared to the control condition, then it is often assumed that the manipulation was not demanding enough or adequate to reduce self-regulatory capacity. It is also assumed that manipulation check items measuring self-reported fatigue, frustration or difficulty are evidence of sufficient effort, but effort is rarely measured objectively. Without measuring motivation to engage in the depletion task, it is impossible to know whether performance on the second task was determined by reduced self-regulatory capacity or an absence of motivation to engage in the task (Lee et al., 2016).

A further example of the confounding of self-regulatory capacity and motivation is the use of the dual-task paradigm to investigate the conservation of resources hypothesis. The conservation of resources hypothesis proposes that motivation and self-regulatory capacity are theoretically distinct but closely related constructs (Muraven & Slessareva, 2003; Muraven, Shmueli & Burkley, 2006). Yet, operationalising the constructs via frequently used dual-task paradigm tasks, such as persistence on a difficult puzzle, (e.g Baumeister et al., 1998; Muraven & Slessareva, 2003), does not allow for an examination of the separable contribution of each to performance. Persistence requires both self-regulatory capacity and motivation to perform well. Therefore, only measuring performance on the depleting task does not adequately demonstrate that a reduction in self-regulatory resources has occurred, a fundamental theoretical assumption of the Strength Model. This ambiguity means that alternative explanations of underlying mechanisms, such as shifts in motivation and attention (Inzlicht & Schmeichel, 2012; Inzlicht, Schmeichel, & Macrae, 2014) or changes in affect (Saunders & Inzlicht, 2015; Saunders, Milyavskaya, & Inzlicht, 2015), cannot be ruled out. Accordingly, the validity of such tests of ego-depletion are questionable.

1.3.3 The assumption of depletion over time

The assumptions within the Strength Model are such that when an individual engages in continuous self-regulation, it will lead to decreases in self-regulation performance over time, even when self-regulation is applied to a different domain. The use of a paradigm which only examines performance on one task after engagement in another task is problematic as it does not allow for a real test of the assumption that as resources decrease, so does performance. This issue has been identified previously, leading to the measurement of performance over several tasks, or measuring performance in the depleting task as well as the dependent variable (Arber et al., 2017; Dang et al., 2013). While there is some evidence for the assumption of reduced performance over time (Arber et al., 2017), some studies suggest that administering more tasks illustrates a different story.

This has been demonstrated where studies have measured performance on both the ego-depletion task and dependent variable. For example, participants assigned to the ego-depletion condition were administered one block of the depletion task and participants in the adaption condition were assigned three blocks of a depletion task (Dang et al., 2013). There was no difference in performance between the depletion and adaption conditions on the first block of the depletion task. However, participants in the adaption condition had a reduced depletion effect over the three blocks, showing adaption to the depletion task. Additionally, the adaption condition performed significantly better than the depletion condition on the dependent variable, despite having engaged in more blocks of the effortful inhibition task, but was no different to the control condition. This effect was replicated by Arber et al. (2017).

Furthermore, studies which have examined the conservation of resources hypothesis have examined performance beyond the typical dual-task paradigm. The pattern of performance observed when self-regulation was required across three tasks, that participants either performed better on the second task but worse on the third task or worse on the second task but better on the third, demonstrates that when performance on more than one task is measured, fluctuations in performance are captured (Muraven et al., 2006). This effect has also been demonstrated when participants in the depletion condition who were administered a 20 minute task performed better on the dependent measure than those administered a 3 minute or 10 minute depletion task (Tyler & Burns, 2009). This adaption effect when multiple tasks are used has been observed elsewhere (Converse & DeShon, 2009). These findings suggest that fluctuations in performance occur when self-regulatory performance is measured beyond the typical dual-task paradigm. Given these findings, the ecological validity of the ego-depletion effect must be questioned if it only occurs when two tasks are administered within a relatively short time frame. The evidence suggests that individuals allocate resources strategically, and that this leads to dynamic shifts in performance over time. Therefore, more studies which examine self-regulation performance for longer durations and across several tasks are needed.

1.3.4 The assumption that between-subjects designs adequately assess idiographic hypotheses

The hypothesised effects within the model are idiographic or within-person. However, an examination of within-person changes over time has rarely been examined. There have been some attempts to examine the ego-depletion effect within-person. In one attempt at a within-person design, an ego-depletion task, a recovery task, and then a control task were administered within one lab visit (Z. L. Francis et al., 2018). Although, this design demonstrated susceptibility to carry-over effects. Another study undertook a within-person design where participants were administered the control and ego-depletion conditions on separate occasions (Englert & Wolff, 2015). The use of this design found that effort and performance on a cycling task were significantly worse after an initial task of self-regulation than after a control task (Englert & Wolff, 2015). Additionally, as discussed above, some studies have examined fluctuations using diary methods and with multilevel modelling (Arber et al., 2017; Hofmann, Baumeister, et al., 2012; Lindner et al., 2017). These within-subjects repeated-measures designs do offer advantages, such as improved statistical power and modelling of individual variation.

It has been argued that self-regulation is a dynamic process which requires dynamic measurement (Neal, Ballard, & Vancouver, 2017). When investigating goal motivation during multiple-goal pursuit, it has been reported that 60-80% of the variance occurs at the within-person level (Milyavskaya, Inzlicht, Hope, & Koestner, 2015; Werner, Milyavskaya, Foxen-Craft, & Koestner, 2016). Fluctuations in self-regulatory capacity within-person may reveal more than average differences between groups. For example, evidence that reductions in self-regulatory capacity had more adverse effects on those with high trait self-control than those with low trait self-control (Imhoff et al., 2014; Lindner et al., 2017) suggests that fluctuations in state self-regulatory capacity are more influential in those who are generally successful at self-control. Dependence on the between-groups dual-task paradigm is problematic as only examining differences in performance between groups does not allow for an examination of shifts in motivation and fluctuations in effort across tasks over time. Nonetheless, most investigations of the Strength Model thus far have measured average changes between groups.

1.3.5 Alternative methods

Testing whether theory can account for intra-individual processes is vital for determining its validity (D. W. Johnston & Johnston, 2013). Multilevel designs where observations are nested within people are one method which provide the ability to model within-person variance (Hoffman & Stawski, 2009). The use of multilevel designs to test the Strength Model has been explored before now (e.g. Lindner et al., 2017). Another method which accounts for intra-individual fluctuation over time are N-of-1 designs (D. W. Johnston & Johnston, 2013). N-of-1 designs (also known as single-case designs) involve repeated measurements of variables within an individual longitudinally. This method allows for conclusions to be drawn about variation in the individual over time. N-of-1 methods have several advantages such as being able to examine temporal dynamics, improved ecological validity and the ability to personalise interventions for individuals. As a result, the adoption of N-of-1 methods to test theory and interventions has been recommended (Craig, Dieppe, Macintyre, Michie, Nazareth, Petticrew et al., 2008; McDonald, Quinn, Vieira, O'Brien, White, Johnston et al., 2017). Therefore, using methods which observe dynamic fluctuations in self-regulatory capacity and performance within the individual over time can provide a better understanding of the underlying mechanisms involved in goal pursuit.

1.4 Alternative theory

1.4.1 Conservation of resources

It was identified early on by proponents of the Strength Model that motivation may also play a role in decreased performance after engaging in prior self-regulation (Muraven & Slessareva, 2003). The conservation of resources hypothesis proposes that reduced performance after initial investment of self-regulatory resources results from both self-regulatory fatigue and decreases in motivation (Hobfoll, 1989; Kool, McGuire, Rosen, & Botvinick, 2010; Muraven & Slessareva, 2003). In a series of experiments, it was demonstrated that even when self-regulatory fatigue had been induced, incentivising participants in a range of ways attenuates the effect of self-regulatory fatigue on performance (Muraven & Slessareva, 2003). For example, increasing the perceived importance of participation or increasing participants' perceived likelihood of success by practising a persistence task led to better performance on tasks of persistence than participants with self-regulatory fatigue who believed that the task was not very important or that practising was inconsequential for success (Muraven & Slessareva, 2003). Meanwhile, providing performance incentives in the form of monetary payment also successfully eliminated the effect of self-regulatory fatigue on performance (Muraven & Slessareva, 2003). On the basis of emerging evidence of the importance of motivation in self-regulation performance, Baumeister and colleagues conceded that motivation is an essential ingredient in self-regulation (Baumeister et al., 2007).

Further research demonstrated that people may allocate resources strategically to prepare for future instances of self-regulation. Participants who were notified that they would need to complete another self-regulation task in the future or whose upcoming daily demands were made salient exhibited poorer self-regulation performance compared to those whose future energy demands were not highlighted to them (Muraven et al., 2006; Tyler & Burns, 2009). The same findings were observed when participants were made aware that the task would continue for another 20 minutes, compared to those who were told the task was finished

(Tyler & Burns, 2009). Furthermore, a pattern of performance emerged where participants in the ego-depletion condition who knew they would need to engage in self-regulation in the future performed better on a second task then poorer on a third task or poorer on a second task and then better on a third task (Muraven et al., 2006; Tyler & Burns, 2009). The effect of self-regulatory fatigue on self-regulation performance can also exhibit effects where participants with self-regulatory fatigue are more likely to engage in reward seeking behaviour than controls when low effort is required but are more likely to conserve energy than controls when high effort is required (Giacomantonio, Jordan, Fennis, & Panno, 2014). Therefore, people appear to allocate resources based on the costs and benefits of exerting energy.

1.4.2 The Process Model

A mechanistic view of ego-depletion sought to offer clear mechanisms to account for temporary reductions in self-regulation performance. The Process Model of ego-depletion (not to be confused with Duckworth et al.'s (2016) Process Model of Self-control described above) proposes that after engaging in continuous self-regulation, priorities change as a result of shifts in motivation and attention (Inzlicht & Schmeichel, 2012). These shifts occur as engaging in effortful self-control is inherently ungratifying and becomes more unpleasant over time. If progress does not appear to be leading to a reward, attention and motivation are directed toward activities that will result in reward. This process is said to be adaptive as a balance between labour and leisure is required to continue to pursue long-term goals (Inzlicht & Schmeichel, 2012; Inzlicht et al., 2014). There is some supportive evidence for the Process Model where participants were less likely to persist at tasks when the cost of persisting was too high or probability of success was low (Osgood, 2018). Additionally, depleted participants' intake of unhealthy snack food was predicted by lower level of motivation to control intake but not by increased desire for snack food, providing partial support for Process Model hypotheses (A. Haynes, Kemps, & Moffitt, 2016).

1.4.3 Resource allocation accounts

Building on previous motivational perspectives of the ego-depletion effect (Inzlicht et al., 2014), motivated resource allocation has been suggested to account for reductions in self-regulation performance over time (Kurzban, Duckworth, Kable, & Myers, 2013; Molden, Hui, & Scholer, 2016). The Motivated Effort Allocation model argues that effort will be allocated to a task depending on importance of the task, expectations of success, experience of effort and evaluations of progress (Molden et al., 2016). Judgements are made about sustaining self-regulation depending on the expected ability to sustain current self-regulation and to engage in future self-regulation, and perceived value of current self-regulation and future self-regulation. When potential conflicts arise, one must undertake a decision-making process to determine the value of continuing self-regulation. Engaging in sustained effort induces the onset of increasing fatigue which serves to signal for an assessment of the value of continued self-regulation (Hockey, 2013; Molden et al., 2016). If the value of continued self-regulation is low then individuals will decrease their efforts, and performance will suffer. The purpose of the onset of fatigue is to ensure motivational homeostasis, such that alternative opportunities for more enjoyable, leisurely pursuits are not missed.

This theoretical account explains both reductions in self-regulation performance on a second self-regulation task and the accompanying subjective fatigue, or feeling of being “depleted”. As such, this view is consistent with research which suggests that, while we may not actually have a limited capacity or resources for self-regulation, we may *act* like we do (Evans, Boggero, & Segerstrom, 2016). In addition, research which has demonstrated that having a belief that self-regulatory resources are limited leads to poorer self-regulation performance

(Job, 2016; Job et al., 2015). When engaging in sustained self-regulation, the onset of fatigue and subsequent assessment of upcoming self-regulatory needs may trigger the conservation of resources. This explains why, with appropriate incentive, more effort can be allocated and performance improved.

1.5 Self-regulatory fatigue in people with chronic pain

As discussed above, it has been hypothesised that the increased demands encountered by people with chronic pain results in a reduced capacity for self-regulation or chronic self-regulatory fatigue (Shields, Moons, & Slavich, 2017; Silvestrini, 2014; Solberg Nes et al., 2010). Having energy available to the self is thought to result from both psychological and somatic inputs (Ryan & Frederick, 1997; Shields et al., 2017; Thayer, 1996). Evidence from cross-sectional questionnaire studies indicates that people with chronic pain experience lower vitality than people with no health conditions and that factors related to control over pain, such as disability, fear and pain catastrophising, are more associated with vitality than pain itself (Lamé, Peters, Vlaeyen, Kleef, & Patijn, 2005; Ryan & Frederick, 1997). Similar to vitality, vigour (feeling energetic and lively), is negatively associated with pain interference and accounted for more variance in pain interference than physical fatigue (Boggero, Rojas-Ramirez, & Carlson, 2017). Further evidence for the hypothesis that people with chronic pain have a reduced capacity for self-regulation is provided by studies of experimentally induced pain in healthy participants.

1.5.1 Evidence from studies of experimentally induced pain

It has been demonstrated that experimentally induced pain leads to decreases in cognitive performance. In participants who had a heat pain stimulus applied to their skin, cognitive performance decreased as pain intensity was increased, illustrating that increasing pain increases cognitive load (Buhle & Wager, 2010). In another study, participants were administered nociceptive electrical stimulation while engaging in either a neutral numerical Stroop task (low cognitive demand) or an interference Stroop task (high cognitive demand). Participants received both conditions in a counterbalanced order and with a break in between and it was reported that pain tolerance was reduced in the high cognitive load condition (Silvestrini & Rainville, 2013). Participants also reported higher pain unpleasantness after the high cognitive demand condition suggesting the reduced capacity to regulate pain perception. Another study which examined the effect of cognitive inhibition on pain sensitivity found that more effective inhibition led to lower pain sensitivity (Oosterman, Dijkerman, Kessels, & Scherder, 2010). Moreover, simply priming pain, as opposed to a neutral prime, led to increased effort mobilisation when incentive was high, less perceived capability to perform and more errors (Silvestrini, 2015). This indicates that even being primed to think about pain affects performance when engaging in an effortful task. Using the dual-task paradigm, pain tolerance during a cold pressor task was reduced after making numerous decisions and after engaging in an emotion suppression task (Muraven et al., 2006; Vohs et al., 2008).

It was suggested that heart rate variability would be related to self-regulatory capacity as there is considerable overlap in the brain areas which govern autonomic inhibition and self-regulation (Segerstrom & Solberg Nes, 2007). Higher resting heart rate variability is an indicator of higher self-regulatory capacity (Segerstrom & Solberg Nes, 2007). A meta-analysis of 20 studies determined that experimentally induced pain led to lower heart rate variability (Koenig, Jarczok, Ellis, Hillecke, & Thayer, 2014), a physiological indicator of self-regulatory capacity (Reynard, Gevirtz, Berlow, Brown, & Boutelle, 2011; Segerstrom & Solberg Nes, 2007). Although a recent study reported no such relationship between pressure pain thresholds and self-regulatory capacity when measured by heart rate variability, trait self-control or experimentally induced self-regulatory fatigue in pain-free students (Boggero & Segerstrom, 2019).

1.5.2 Evidence from people with chronic pain

Using the dual-task paradigm, compared with healthy controls who performed better on the second of sequential tasks in a low self-regulation condition than those who had engaged in a high self-regulation task, patients with chronic pain associated with fibromyalgia and temporomandibular disorder performed equally as poorly regardless of condition. There also appeared to be a dose-dependent effect of pain intensity where higher pain was related to poorer performance (Solberg Nes et al., 2010). From this result, it was concluded that those with chronic pain had reduced self-regulatory capacity or resources. People with chronic pain have also demonstrated lower heart rate variability compared to healthy controls and this lower heart rate variability is negatively associated with mental inflexibility, pain interference and pain catastrophising (Allen, Struemph, Toledo-Tamula, Wolters, Baldwin, Widemann et al., 2018; Koenig, De Kooning, Bernardi, Williams, Nijs, Thayer et al., 2015; Koenig, Loerbroks, Jarczok, Fischer, & Thayer, 2016; Rost, Van Ryckeghem, Schulz, Crombez, & Vögele, 2017).

Later studies proposed that poorer self-regulation performance in people with chronic pain was better explained by the conservation of resources hypothesis (Eisenlohr-Moul, Burris, & Evans, 2013; Solberg Nes, Carlson, Crofford, de Leeuw, & Segerstrom, 2011). Conservation of resources may be moderated by individual difference factors, which potentially attenuate the effect of self-regulatory fatigue on self-regulation performance. Optimism moderated the effect of self-regulatory fatigue on performance where those who were high in optimism only persisted longer on a difficult task if they were not allocated to a high self-regulation condition (Solberg Nes et al., 2011). Pain willingness, a facet of pain acceptance where there is a willingness to engage in valued activities without attempting to reduce, avoid or change pain, was related to lower levels of cognitive self-regulatory fatigue in people with temporomandibular disorder (Eisenlohr-Moul et al., 2013). This suggests that optimism and pain willingness may be implicated in the adaptive use of resources. Self-reported self-regulatory fatigue in people with chronic pain is negatively associated with physical and mental quality of life, with strongest association observed between vitality, social functioning, emotional role limitations and mental health (Solberg Nes et al., 2017).

1.6 The aims of this thesis

The hypothesis that people with chronic pain may have reduced self-regulatory capacity or resources is grounded in the assumptions of the Strength Model. Since Solberg Nes and colleagues published their initial work in 2010, a number of methodological and conceptual concerns have arisen regarding the Strength Model. Given the uncertainties around the validity of the theory and methods, it is pertinent to re-examine the assumption that people with chronic pain have reduced self-regulatory resources or chronic self-regulatory fatigue. It would be of additional value to ascertain what effect self-regulatory fatigue in people with chronic pain has on self-regulation performance, wellbeing, and goal pursuit. This thesis aimed to address these objectives by answering the following questions:

1. Can the Strength Model explain self-regulation performance in people with chronic pain (Chapter 2)?
2. What is the relationship between self-regulatory fatigue, pain cognitions and mood (Chapter 2 and Chapter 3)?
3. Do short form versions of a measure of self-regulatory fatigue demonstrate construct validity and reliability (Chapter 4) and does the full measure of self-regulatory fatigue demonstrate content validity and discriminant content validity (Chapter 5)?
4. Can the Strength Model explain intra-individual variation in:
    a. physical activity during pursuit of a physical activity goal (Chapter 6) and
    b. conservation of resources during goal pursuit (Chapter 7)?

2 An examination of the effect of self-regulatory fatigue, self-efficacy and pain catastrophising on self-regulation performance

2.1 Abstract

Objectives: It is proposed that the taxing nature of pain means that people with chronic pain have reduced self-regulatory capacity, leading to poorer self-regulation performance. This study aimed to replicate and extend previous research by examining mechanisms underlying poorer self-regulation in people with chronic pain.

Methods: In study 1, an online sample of people with chronic pain (N=122; M_{age}=38.5 years, SD_{age}=12.6 years; 70 females) and controls (N=101; M_{age}=35.7 years, SD_{age}=11.3 years; 67 females) were recruited. Self-regulation performance was measured on a depleting task (four temporal discounting measures) as well as the dependent variable (perseverance) of the dual-task paradigm. Correlations were conducted to determine whether baseline pain, self-regulatory fatigue, pain self-efficacy and pain catastrophising were related to self-regulation performance. In study 2, another online sample of people with chronic pain (N=40; M_{age}=34.6 years, SD_{age}=9.7 years; 28 females) and controls (N=40; M_{age}=35.2 years, SD_{age}=10.8 years; 27 females) were recruited. Five blocks of a maths task were administered and within-person task self-efficacy was measured prior to each block. Multilevel modelling was conducted to examine the effect of within-person self-efficacy on resource allocation (time) and overall performance for each block.

Results: In study 1, there were no differences in self-regulation performance in either the depleting task or perseverance. Pain self-efficacy was positively correlated with self-control on the first two temporal discounting measures but was negatively related to perseverance. In study 2, higher within-person task self-efficacy predicted higher resource allocation. In people with chronic pain, there was a moderated mediation where, as within-person task self-efficacy and resource allocation increased from low to moderate, overall performance

increased. Beyond this, additional within-person task self-efficacy and allocated resources were detrimental to overall performance. In controls, there was a positive relationship between within-person task self-efficacy, resource allocation and overall performance.
Conclusion: In those with chronic pain, who have limited self-regulatory capacity, high self-efficacy is maladaptive to overall performance but not for healthy controls. Moderate self-efficacy appeared to be most adaptive when considering overall performance across tasks.

2.2 Introduction

Background

The experience of chronic pain comprises a complex relationship between sensory, cognitive and emotional aspects of pain (Gatchel et al., 2007). Pain demands attention, having interruptive effects on activities (Bushnell et al., 2013; Eccleston & Crombez, 1999). Additional burden is generated by pain-related distress and cognitions which interrupt activities and goal-pursuit by demanding attention (Eccleston & Crombez, 1999). It has been established that both pain cognitions, such as pain catastrophising and pain self-efficacy, and pain behaviours, such as avoidance of painful activity, are factors in the development and maintenance of chronic pain (Hasenbring & Verbunt, 2010; Keefe, Dunsmore, & Burnett, 1992; Turk & Rudy, 1992). Much evidence has been gathered on the relationship between psychosocial factors and pain avoidance, which often result in poorer outcomes such as higher pain and disability (Linton, 2000; Turner & Aaron, 2001; Vlaeyen & Linton, 2000). However, both pain avoidance behaviour and endurance behaviour can be problematic and maladaptive (Hasenbring, 2000; Hasenbring & Verbunt, 2010). Endurance behaviour, also known as persistence, has been less frequently investigated and there is still ambiguity as to when it can be detrimental or advantageous (Andrews et al., 2012; Hasenbring et al., 2012; Kindermans et al., 2011).

Endurance behaviour patterns are frequently addressed with activity pacing (Andrews et al., 2012). Activity pacing is the regulation of activity to facilitate adaptive goals and improve overall functioning. The assumption underlying activity pacing is that people have a limited energy capacity and people with chronic diseases expend more of these resources in managing their illness (Gill & Brown, 2009; Nielson, Jensen, Karsdorp, & Vlaeyen, 2013). The purpose of the activity pacing is to evade depletion of energy (Gill & Brown, 2009; Nielson et al., 2013). Although activity pacing is based on the assumption of reduced resources in people with chronic illness (Fordyce, 1976), it was not founded on a distinct theoretical framework. Thus, the reasons for contradictory evidence on the efficacy of activity pacing are unclear (Nielson et al., 2013). An examination of the assumptions of activity pacing within a theoretical framework may elucidate mechanisms of action of efficacious activity pacing interventions and guide practice.

The Strength Model

It has been hypothesised previously that people with chronic pain have reduced self-regulatory resources (Solberg Nes et al., 2010; Solberg Nes et al., 2017; Solberg Nes et al., 2009). A prominent resource model of self-regulation is the Strength Model. The Strength Model proposes that state capacity for self-regulation is governed by a finite self-regulatory resource (Baumeister et al., 1998). Engaging in self-regulation uses energy from the limited resource which becomes depleted after sustained effort, reducing the capacity for future self-regulation and, therefore, performance on subsequent self-regulation tasks (Baumeister et al., 1998; Muraven & Baumeister, 2000). This state of resource depletion is called ego-depletion or self-regulatory fatigue. The predominant test of the strength model is a dual-task experimental paradigm which requires participants to engage in two consecutive self-regulation tasks, one which is intended to deplete self-regulatory resources and a subsequent task which measures self-regulation performance. Performance on the second task is compared to a control group, whose initial task did not require self-regulation. Reduced self-regulatory task performance following engagement in a prior self-regulation task has been observed in a variety of studies (Baumeister et al., 1998; Hagger et al., 2010; Vohs et al., 2008) and is interpreted as indicating a depletion of limited self-regulatory resources in those who had engaged in previous self-regulation.

However, the robustness of the strength model has been questioned in more recent years. Due to ambiguous methodology, small study effects and publication bias, the evidence for the resource depletion hypothesis is weak and the effect may be close to nil (Carter et al., 2015; Carter & McCullough, 2014). Recent attempts to address these limitations by replicating the ego-depletion effect with large-scale studies using a standardised ego-depletion task has yielded mixed results (Arber et al., 2017; Hagger et al., 2016). In addition, reviews have revealed conceptual problems in the literature such as differing operational definitions of self-control (Lurquin & Miyake, 2017). In light of the ongoing debate, alternative explanations for the supposed ego-depletion effect have been suggested (Inzlicht et al., 2014; Muraven et al., 2006).

Conservation of resources

As the wider literature continues to highlight the inadequacies of the strength model, there remains a need to gain a more detailed understanding of the mechanisms underlying self-regulation across tasks. The conservation of resources hypothesis has been offered as an alternative explanation for the effect of pain on self-regulation performance (Eisenlohr-Moul et al., 2013; Muraven et al., 2006; Solberg Nes et al., 2011). The conservation of resources hypothesis takes a motivational view that self-regulation performance following exertion of self-regulation can be explained by a reduction in effort for the purpose of conserving resources (Muraven et al., 2006; Tyler & Burns, 2009). When participants were made aware that they would need to exert self-regulation resources in the future, performance was diminished compared to those told they would be asked to complete a task that did not require self-regulation. Moreover, a pattern emerged where participants who had engaged in previous self-regulation and expected future self-regulation either performed poorer on the second task then better on a third task or better on a second task and poorer on a third task, indicating a performance trade-off (Muraven et al., 2006; Tyler & Burns, 2009). Increasing performance incentive (e.g. by providing a financial reward) can also improve performance when future self-regulation is required (Muraven & Slessareva, 2003). This indicates that participants allocate resources strategically depending on future energy requirements and the availability of a reward.

Effect of pain on self-regulatory capacity

The evidence for the hypothesis that people with chronic pain have reduced self-regulatory resources has been gathered from a variety of sources. Experimental studies in healthy participants have demonstrated that experiencing acute pain taxes self-regulatory resources. For example, self-reported pain tolerance was reduced on a cold pressor task under conditions of self-regulatory fatigue after engaging in a recurrent decision-making task (Vohs et al., 2008) or an emotion suppression task (Muraven et al., 2006). Moreover, increasing cognitive demand increases subsequent self-reported pain intensity and pain unpleasantness during experimentally induced nociceptive electrical stimulation (Silvestrini & Rainville, 2013). Participants' belief that pain was more unpleasant with higher demand likely reflects the reduced capacity to regulate sensory, cognitive and affective responses to painful stimulation. Meanwhile, applying heat pain stimulus to participants' skin decreases cognitive performance as pain intensity increases (Buhle & Wager, 2010). Experimentally induced pain reduces heart rate variability (Koenig et al., 2014), a physiological indicator of self-regulatory capacity (Reynard et al., 2011; Segerstrom & Solberg Nes, 2007). Conversely, effective cognitive inhibition can decrease pain sensitivity (Oosterman et al., 2010). In sum, these findings indicate that regulating responses to pain requires self-regulatory resources, which decreases self-regulatory capacity.

Further to the evidence that experiencing acute pain depletes self-regulatory resources, the effect of chronic pain on self-regulation performance has been investigated in a sample of patients with fibromyalgia and temporomandibular disorder who experienced chronic pain (Solberg Nes et al 2010; 2011). Using the dual-task paradigm it was found that when controls completed either a low-self regulation or a high self-regulation task, performance on a subsequent self-regulation task of perseverance was significantly better in the low-self regulation condition (Solberg Nes et al., 2010). However, patients with chronic pain performed equally as poorly on the perseverance task whether they had engaged in the low self-regulation condition or the high self-regulation condition. The authors concluded that those with chronic pain had chronically reduced self-regulatory capacity. Thus, self-regulating thoughts, emotions and goals across the day may be more challenging for those with chronic pain than people without chronic pain. Additional evidence for this conclusion has been demonstrated by lower heart rate variability in people with chronic pain compared to pain-free controls (Allen et al., 2018; Koenig et al., 2015; Koenig et al., 2016; Rost et al., 2017).

Investigating individual difference factors, which facilitate adaptive use of resources in people with chronic pain, may inform our understanding of self-management of chronic self-regulatory fatigue. The effect of personality and cognitive coping factors on conservation of resources in chronic pain have been investigated previously (Eisenlohr-Moul et al., 2013; Solberg Nes, 2011). For example, people with chronic pain who were high in optimism only persisted longer on a task if they did not experience self-regulatory fatigue (Solberg Nes, et al., 2011). Also, lower levels of cognitive self-regulatory fatigue and psychological distress were related to pain willingness; a facet of pain acceptance where there is a willingness to engage in valued activities without attempting to reduce, avoid or change pain (Eisenlohr-Moul et al., 2013). Therefore, examining variables that may moderate the effect of self-regulatory fatigue on task performance may provide a better understanding of adaption to chronic pain.

Pain cognitions and self-regulation in chronic pain

Self-efficacy and pain catastrophising may have differential effects on cognitive resources. Pain catastrophising is negatively related to subjective feelings of self-regulatory energy (Lamé et al., 2005; Ryan & Frederick, 1997). Pain catastrophising is also implicated in the use of ineffective emotion regulation strategies, such as thought suppression, which may lead to greater pain (Gilliam et al., 2010; Linton & Bergbom, 2011; Wong & Fielding, 2013). Higher pain catastrophising is related to poorer attentional control (Heathcote, Vervoort, Eccleston, Fox, Jacobs, Van Ryckeghem et al., 2015). People with higher pain catastrophising frequently report higher pain intensity (Kjogx, Kasch, Zachariae, Svensson, Jensen, & Vase, 2016; Severeijns, Vlaeyen, van den Hout, & Weber, 2001) and pain intensity has a dose dependent effect on self-regulation performance where more pain leads to poorer performance (Solberg Nes et al., 2010). Pain catastrophising is associated with fear-related avoidance behaviours, lower levels of physical exertion (Vlaeyen et al., 1995; Vlaeyen & Linton, 2000) and passive coping (Geisser, Robinson, & Riley, 1999). These findings suggest that pain catastrophising reduces self-regulatory capacity.

On the other hand, higher self-efficacy is associated with increased cognitive control of pain (Bandura, Cioffi, Taylor, & Brouillard, 1988; Bandura, O'Leary, Taylor, Gauthier, & Gossard, 1987). Pain self-efficacy is also related to self-regulation of goal processes in chronic pain (Arends et al., 2013; Knittle, De Gucht, Hurkmans, Vlieland, Peeters, Ronday et al., 2011). The effect of self-efficacy on continuous self-regulation across tasks has been investigated previously. For example, engaging in a self-control task reduced self-efficacy for performance on a subsequent task and the change in self-efficacy mediated the effect of resource depletion on subsequent performance (Chow, Hui, & Lau, 2015). In another study, use of self-regulation resources during an initial physical exercise task led to increased fatigue and reduced self-efficacy, which accounted for poorer performance on a second exercise task (Graham, Martin Ginis, & Bray, 2017). These studies concluded that self-efficacy decreased as a result of the depletion of resources and suggest that self-efficacy would be reduced until self-regulatory resources were replenished.

However, an alternative view on the dynamic of sequential self-regulation across tasks is that when undertaking multiple tasks, individuals determine the amount of effort required for upcoming tasks based on feelings of self-efficacy and previous performance (Vancouver, More, & Yoder, 2008). The discontinuous model of self-efficacy proposes that there is a non-monotonic discontinuous relationship between self-efficacy and performance when it is measured within-person (Vancouver et al., 2008; Yeo & Neal, 2013) as opposed to the continuous, linear, positive relationship between self-efficacy and performance shown in group based studies (Bandura, 1982). The discontinuous self-efficacy model takes a self-regulation perspective of self-efficacy and motivation where self-efficacy beliefs are used to establish the amount of resources required for a goal. If self-efficacy is low, it may be perceived that more resources are needed to achieve the goal. If the amount of resource required exceeds available resources then goal disengagement may occur. Alternatively, if self-efficacy is high then fewer resources are perceived to be required.

Over the course of many sequential tasks, self-efficacy fluctuates when it is measured within-person and allocation of resources and overall performance depend on initial level of self-efficacy and the perceived availability of resources (J. W. Beck & Schmidt, 2012; Vancouver et al., 2008). For example, if a participant with high self-efficacy puts high effort into a task and performs well, they will surmise that they can still perform well even with reduced effort, which often results in poorer performance on a subsequent task. This was confirmed when it was found that those who are generally highly self-efficacious perform well on one task, then reduce efforts on a later task leading to poorer performance, while those who have generally low self-efficacy would perform poorly on one task, only to increase their efforts and perform better on a subsequent task (J. W. Beck & Schmidt, 2012, 2018). Furthermore, while positive within-person self-efficacy was adaptive when resources were abundant, negative within-person self-efficacy was found to be adaptive when resources were limited where allocating low to moderate resources to a task had a positive effect on performance but high resource allocation had a negative effect on performance. These findings cannot be accounted for by the strength model which assumes that self-efficacy is reduced as a result of self-regulatory fatigue leading to poorer task performance. Therefore, there are competing theoretical views on how self-efficacy will affect performance across tasks.

2.2.1 Current study aims

While there is increasing evidence that there is a negative effect of pain on self-regulation performance, the mechanisms underlying this effect are still unclear. Questions remain within the literature about whether people with chronic pain have less self-regulatory resources available, whether resources deplete faster in people with chronic pain than healthy people, or whether people with chronic pain decide to conserve resources differently to healthy people. In addition, the role of pain cognitions in self-regulation performance in people with chronic pain has not been investigated. This study aimed to replicate and extend previous findings that people with chronic pain have a reduced self-regulatory capacity compared to healthy people. It also aimed to investigate the effect of pain cognitions on self-regulation across tasks.

This study is composed of two parts: Study 1 and Study 2. In study 1, self-report self-regulatory fatigue was measured at baseline in people with chronic pain and healthy controls to determine whether people with chronic pain experience self-regulatory fatigue prior to engaging in self-regulation. Using the dual-task paradigm, there was an examination of the pattern of sequential self-regulation performance in people with chronic pain and in healthy controls. The study investigated whether performance in people with chronic pain was affected on both self-regulation tasks or was only affected on the second task. Then the relationships between self-regulation performance and baseline self-regulatory fatigue, pain catastrophising and pain self-efficacy were examined. In study 2, a closer examination of the effect of limited resources and self-efficacy on sequential self-regulation across tasks was conducted where the indirect effect of allocation of resources on the relationship between self-efficacy and performance was investigated.

2.3 Study 1

Introduction

Using the dual-task paradigm, participants first completed either a high self-regulation task of temporal discounting, or a low self-regulation task. Temporal discounting is a processing bias where the subjective value of a reward is reduced when there will be a delay in receiving the reward. Temporal discounting tasks involve making decisions between smaller, sooner, more concrete rewards and larger, later, more abstract rewards. A fundamental aspect of self-control is the ability to inhibit prepotent responses and temptations (Baumeister et al., 1998) and choose distal rather than proximal goals. For example £50 immediately or £75 in two weeks, and feeling that the subjective value of receiving £50 now may be judged to be more valuable than receiving £75 in two weeks despite the objectively higher £75 monetary reward. Those who are impulsive discount the value of a future reward by a greater degree than those who have good self-control (Kirby & Herrnstein, 1995; Kirby & Maraković, 1995). An ego-depleted state can influence the appeal of choices with different probabilities of gains and losses or different trade-offs. When self-regulatory resources are limited, it is expected that there is a decline in the use of deliberative decision-making processes and judgement, and an increase in using less effortful processing (Schmeichel, 2007). It has been established that making many decisions induces a state of ego-depletion and results in reduced performance on subsequent self-regulation tasks (Vohs et al., 2008). In addition, people with chronic pain are also more likely to experience goal-conflict than healthy controls (Karoly & Ruehlman, 1996).

Hypotheses:

The chronic pain group will:

1. Demonstrate higher baseline self-regulatory fatigue compared to the control group.
2. Perform equally poorly in the perseverance task whether they have been allocated to the high self-regulation condition or low self-regulation condition while participants in the control group will perform better in the low self-regulation condition than the high self-regulation condition.
3. Demonstrate poorer self-control on the temporal discounting task than controls.
4. Demonstrate a negative relationship between pain catastrophising and self-regulation performance on both tasks while pain self-efficacy will have a positive relationship with performance on both tasks.

2.4 Methods

2.4.1 Design

The study was a quasi-experimental 2x2 between-subjects design. Participants were either in the chronic pain group or the control group and were randomised to either a high self-regulation condition or low self-regulation condition.

2.4.2 Participants

The participants were recruited via the online crowdsourcing platform Prolific. Prolific recruit a pool of individuals willing to participate in research and the platform hosts online research distributed on experimental and survey software. Participants from the potential pool view studies available to them based on pre-screening criteria such as age group or product ownership. Potential participants also view information about task duration, a description of the task and how much they would be paid, which Prolific require to be a minimum of £5 per hour. Participation is completely voluntary and anonymous. Research has demonstrated that online samples of participants on the crowdsourcing platform Amazon Mechanical Turk (MTurk) provide equal or better quality data than student samples with regard to reliability of scales, test-retest reliability and internal validity, and responses to replications of experimental studies are consistent with previous findings (Behrend, Sharek, Meade, & Wiebe, 2011; Berinsky, Huber, & Lenz, 2017; Goodman, Cryder, & Cheema, 2013; Sprouse, 2011). Moreover, samples from Prolific have been shown to be more honest, naïve participants and to provide better quality data than its competitors such as MTurk (Peer, Brandimarte, Samat, & Acquisti, 2017).

Participants in this study were paid £3.75. Pre-screening filters were applied to the participant pool based on inclusion and exclusion criteria. The criteria for the chronic pain group required that participants (1) were between 18 and 65 years old, (2) reported chronic pain that had lasted for more than 6 months (3) spoke English as their first language (4) were current UK residents (5) had a minimum 90% approval rating from previous Prolific studies (6) were not currently experiencing an acute injury. The control group were required to meet the same criteria with the exception that they could not be experiencing chronic pain or any other health condition, with a maximum reported average pain over the past 6 months as 3 on a scale of 0 to 10. Control participants were matched to the chronic pain group by age and gender. Participants who met the pre-screening criteria were able to access a link to the study on Qualtrics. A total of 261 participants were recruited and completed the survey.

2.4.3 Measures and materials

Demographics: Participants were asked to report their age, gender, ethnicity, marital status, years' of education, employment status and annual income. Participants were additionally asked if they were experiencing any acute or long-term physical or mental health conditions and to describe any medication they were taking for acute or long-term physical or mental health conditions with a free-text response.

Pain: Pain intensity was measured by three items which assess current pain intensity ("How would you rate your pain level on a 0-10 scale at the present time, that is pain right now, where 0 is 'no pain' and 10 is 'pain as bad as could be'?"), worst pain in the past six months ("In the past 6 months, how intense was your worst pain on a 0-10 scale where 0 is 'no pain' and 10 is 'pain as bad as could be'?") and average pain over the past six months ("In the past 6 months, on the average, how intense was your pain rated on a 0-10 scale where 0 is 'no pain' and 10 is 'pain as bad as could be'? (That is your usual pain at time you were experiencing pain?"). Each of these three items were measured on an 11-point Likert scale of 0 (no pain) to 10 (pain as bad as can be). Measuring current pain intensity by numerical rating scale is a valid, reliable and sensitive method of assessing present pain level (Alghadir, Anwer, Iqbal, & Iqbal, 2018; Farrar, Young, LaMoreaux, Werth, & Poole, 2001; Ferreira-Valente, Pais-Ribeiro, & Jensen, 2011; Williamson & Hoggart, 2005).

Disability: Severity of chronic pain and disability was measured with the Chronic Pain Grade Scale (Von Korff, Ormel, Keefe, & Dworkin, 1992) which is a 7-item instrument with three subscales of 'characteristic pain intensity', 'disability score' and 'disability points'. The same three pain intensity items described in the above section were used to assess characteristic pain intensity. The scores from these three items, which are measured on an 11-point Likert scale of 0 (no pain) to 10 (pain as bad as can be), are summed together, multiplied by 10 and then divided by three.

Disability score is calculated from three items which evaluate the extent to which pain has interfered with activities in the past six months (e.g. “In the past 6 months how much has pain interfered with your daily activities rated on a 0-10 scale where 0 is 'no interference' and 10 is 'unable to carry on any activities'?”; “In the past 6 months how much has pain changed your ability to take part in recreational, social and family activities where 0 is 'no change' and 10 is 'extreme change'?”), which are all measured on an 11-point Likert Scale from 0 to 10. Disability score is calculated using the same formula as characteristic pain intensity.

Disability points are given for the total disability score and number of disability days. Chronic pain is graded on a hierarchical scale from Grade I (low intensity-low disability), Grade II (high intensity-low disability), Grade III (high disability-moderately limiting) and Grade IV (high disability-severely limiting). In populations with chronic pain, the CPGS has demonstrated good internal consistency and test-retest reliability, convergent validity with the SF-36, construct validity, responsiveness and appropriate factor structure, where all seven items loaded onto a single factor (B. H. Smith, Penny, Purves, Munro, Wilson, Grimshaw et al., 1997; Von Korff et al., 1992).

Internal consistency was calculated using the same formula as Von Kroff et al. (1992). Three items were computed from characteristic pain intensity, disability days and disability score. Characteristic pain and disability score are recoded onto a 4-point scale from 0-3 with the following cut points: <30, 30-49, 50-69, 70≥. Meanwhile, disability days were recoded on a 0-3 scale with cut points of <7 days, 7-14 days, 15-30 days, 31≥ days. These three items were used to calculate Cronbach’s alpha, which was very good (α=.87). As the purpose of the GPGS is to assign a grade on an ordinal scale, it was pertinent to calculate reliability on a Guttman’s scale. For this calculation, characteristic pain was recoded onto a dichotomous scale where 0-49 was coded as ‘0’ and ≥50 was coded as ‘1’. The recoded disability days and disability score items were treated as 4-level ordinal items. Reliability calculated on a Guttman's scale was also very good (λ_2=.83).

Pain Catastrophising: Pain catastrophising was measured with the Pain Catastrophising Scale (PCS). The PCS (Sullivan, Bishop, & Pivik, 1995) is a 13-item instrument composed of three subscales, namely magnification (3 items, e.g. "I become afraid that the pain will get worse"), rumination (4 items, e.g. "I can't seem to keep it out of my mind") and helplessness (6 items, e.g. "I feel I can't go on") which are scored on a 5-point scale from 0 (not at all) to 4 (all the time). Scores on each subscale are totalled to generate a possible score range of 0-52, with higher scores indicating greater catastrophising. The PCS has demonstrated adequate to excellent reliability of the subscales of magnification, rumination and helplessness and excellent internal consistency for the whole scale in healthy undergraduate, community and outpatient pain samples (Osman, Barrios, Gutierrez, Kopper, Merrifield, & Grittmann, 2000; Osman, Barrios, Kopper, Hauptmann, Jones, & O'Neill, 1997; Sullivan et al., 1995). The PCS has shown good criterion and construct validity in healthy samples and those with chronic pain (Osman et al., 2000; Osman et al., 1997; Sullivan et al., 1995). In addition, the PCS was found to fit well to a hierarchical factorial structure where rumination, magnification and helplessness load onto a higher order construct of catastrophising (D'Eon, Harris, & Ellis, 2004; Osman et al., 2000). Cronbach's alpha was excellent (α=.96).

Pain Self-efficacy: Pain self-efficacy was measured with the 10-item Pain Self-efficacy Questionnaire (PSEQ). The PSEQ (Nicholas, 1989) measures confidence in ability to cope despite pain in a variety of situations (e.g. "I can enjoy things, despite the pain"). Items are scored on a 7-point scale from 0 (not at all confident) to 6 (completely confident). Scores are summed to generate a scale range of 0-60 where higher scores indicate higher pain self-efficacy. The PSEQ has exhibited excellent internal consistency, test-retest reliability, good convergent validity and the intended unidimensional factor structure in a sample of patients with chronic low back pain and a heterogenous sample of people with chronic pain (Nicholas, 2007). Internal consistency for this study was very high (α=.94).

Self-regulatory fatigue: Self-regulatory fatigue was measured with the Self-regulatory Fatigue Scale (SRFS). The SRFS (Solberg Nes et al., 2013) is an 18-item measure of self-regulation fatigue, or a reduced capacity to self-regulate, in chronic multisymptom illness (e.g. “It is easy for me to set goals”). The scale measures cognitive (6 items), emotional (7 items) and behavioural (5 items) components of self-regulatory fatigue. Each item is scored on a 5-point Likert scale from strongly disagree (1) to strongly agree (5). Scores are summed to generate a scale range of 18-90 where higher scores indicate higher self-regulatory fatigue. In a sample of people with fibromyalgia and chronic fatigue syndrome, the SRFS demonstrated excellent internal consistency for the whole scale and poor to adequate internal consistency for the subscales (Solberg Nes et al., 2013). Convergent validity in the same sample was good, where the SRFS was related to, but distinct from, trait self-control and physical fatigue (Solberg Nes et al., 2013). Internal consistency was very high (α=.90).

Instructional Manipulation Checks

Because this study was conducted using an online research platform, inattention checks and instructional manipulation checks (IMC) were presented throughout the study to detect satisficing and failure to follow instructions. Satisficing is a type of responding to surveys or experimental procedures where the participant offers the minimum required effort as opposed to their true opinions or potential performance. An example of an IMC used in this study was, “It is important to focus when giving responses to this survey. Please select strongly disagree.”

Self-regulation manipulation

High self-regulation condition (temporal discounting)

Participants in the high self-regulation condition (high SR) were asked to make a series of self-control decisions between smaller-sooner and later-larger gains or between smaller-sooner and later-larger losses. The participants made 108 self-control decisions in total on four temporal discounting questionnaires. A self-control choice was considered as making larger later choices on reward measures and smaller sooner choices on loss measures. There were two measures of temporal discounting measuring self-control decisions about gains and two measures of temporal discounting measuring self-control decisions about losses.

The first measure of temporal discounting of gains was the Monetary Choice Questionnaire (Kirby & Herrnstein, 1995; Kirby & Maraković, 1995). The Monetary Choice Questionnaire (MCQ) is a 27-item delay discounting measure designed to measures the rate of discounting along a hyperbolic discounting function calculated by the *k*-value, where decisions are made between smaller or larger later rewards with variation in disparities in reward values and timescales of delay. There are three 9-item subscales which estimate discounting at small ('Would you rather have £19 today or £25 in 53 days?'), medium ('Would you rather have £34 now or £50 in 30 days') and large ('Would you rather have £78 today or £80 in 162 days?') reward magnitudes. The subsequent temporal discounting questionnaires were adapted from the MCQ for use in a chronic pain sample (Tompkins, Johnson, Smith, Strain, Edwards, & Johnson, 2016) and took the same form as the MCQ, as demonstrated below.

The second gain questionnaire was the Pain Relief Questionnaire (PRQ) which posed decisions about receiving a smaller amount of pain relief now, or larger amount of pain relief later ('Would you prefer to experience 54 days of complete pain relief starting today or 55 days of complete pain relief starting in 117 days?'). The Monetary Loss Questionnaire (MLQ) measures the rate of temporal discounting on monetary loss decisions ('Would you prefer to pay £55 today or £75 in 61 days?'). The second loss measure was the Additional Pain Questionnaire (APQ), which measured the rate of temporal discounting on decisions between receiving less additional pain now and more additional pain in the future ('Would you prefer to experience 31 days of additional pain starting today or 85 days of additional pain starting in 7 days?'). Additional attention check questions were presented within each delay discounting measure ('Would you prefer to have £50 today or £80 today?'), but these were not included in the scoring of the temporal discounting questionnaires.

Although the MCQ was originally scored by calculating the hyperbolic *k*-value (Kirby & Maraković, 1995), more recent evidence has shown that estimating the discounting rate by proportion of self-control choices is less complex than calculating the *k*-value (Myerson, Baumann, & Green, 2014). Further, the proportion of self-control choices is an atheoretical index, so does not presume that all individuals will follow the same theoretical pattern. It is highly correlated to the *k*-value meaning it is a reliable method (Myerson et al., 2014) Therefore, temporal discounting was scored on each measure as the proportion of self-control choices made out of the total of 27 decisions. For example, making 14 self-control choices out of a total of 27 would provide a proportion of 0.52, or making a self-control choice for 52% of decisions.

Low self-regulation condition

The low self-regulation condition (low SR) was a similar format to the high self-regulation condition with four sets of 27 questions about monetary and pain gains and losses. Participants in the low self-regulation condition rated their liking of receiving gains ('How much would you like to receive £54/54 days of pain relief?') or disliking of receiving losses ('How much would you dislike to lose £85/how much would you like to receive 85 days of additional pain?') on a 10-point Likert scale from 1-10. There were no attention questions in the control condition.

Perseverance task

All participants were asked to solve five anagrams but were unaware that four of the anagrams were impossible to solve. Participants were presented the following task instructions, “In the next part of the study you will be asked to solve 5 anagram puzzles. You may wish to get a pen and paper. Try to solve these as quickly as you can but it is important that you attempt to solve the anagrams on your own without any help. However, if you are finding the task difficult and feel like you would like to move on to the next task, click the arrow button at the bottom of the page to move on.” On the next page, the participants were presented with all five anagrams and time spent on the anagram page was recorded. Time spent on the instructions page was also recorded and participants who remained on the instructions page for more than five minutes were excluded from the analyses as resting before the anagram task may allow for self-regulatory fatigue to subside. Perseverance was measured in seconds and there was an undisclosed maximum time limit of 20 minutes for the anagram task.

Manipulation Check

Participants completed several manipulation check questions which measured perceptions of task difficulty (‘I really thought about my answers on the money and pain tasks’), deliberation (‘I really thought about my answers on the money and pain tasks’), and conflict (‘I felt conflicted when answering items on the money and pain tasks’). These manipulation check questions have been used in previous ego-depletion studies of decision making (Vohs et al., 2008). The manipulation check questions were evaluated on a 4-point scale of the extent to which they agreed from 1 (definitely do not agree) to 4 (definitely agree).

Mood

As with previous ego-depletion research (e.g. Muraven et al., 1998; Vohs et al., 2008), there was an assessment of whether differences in positive and negative affect was different between low and high self-regulation conditions and between chronic pain and control groups after the initial self-regulation task. The Brief Mood Introspection Scale (BMIS) was used to measure positive and negative affect (Mayer & Gaschke, 1988). The BMIS asks participants to rate the extent to which set of 16 adjectives reflects their current mood using a 4-point scale anchored with 'definitely do not feel' and 'definitely feel'. The 16-item scale is scored to give two subscales of pleasant and unpleasant mood. Eight positive adjectives e.g. 'lively', 'happy' or 'caring' form the pleasant mood scale and eight negative adjectives such as 'gloomy', 'jittery' and 'tired' produce the unpleasant mood scale. The eight items for each subscale are summed to produce a score with a range of 8-32. Reliability for the both positive (Cronbach's α=.80) and negative affect (Cronbach's α=.82) scales were excellent.

2.4.4 Procedure

The study received ethical approval from the University Ethics Committee at the University of Strathclyde (approval number: Dixon/McMillan UEC 16/44). The study was advertised on Prolific for people experiencing chronic pain. Once all data had been collected for the CP group, it was advertised for healthy controls and pre-screening filters were used to match the controls and CP group by age and gender. Participants accessed the study by a link to Qualtrics on Prolific where they read an information sheet and consent form. All participants first completed demographics information and measures of pain, self-regulatory fatigue, pain self-efficacy and pain catastrophising. Measures of anxiety and depression were also administered but these have not been assessed here. Qualtrics then randomly assigned participants to either the high self-regulation or low self-regulation condition where participants either completed the high self-regulation or low self-regulation task. Then, the manipulation check was administered to all participants. All participants then completed the anagram task. After the perseverance task, participants were given a debrief form.

2.4.5 Power analysis

The design of the study for the primary outcome (perseverance) was a 2x2 factorial design, while there were also between groups analyses conducted for the secondary outcome (temporal discounting) and correlation analyses. G*Power sample size calculations were set at the 0.05 α-level, 0.8 power and medium effect size. The required sample size for a 2x2 between-subjects ANOVA is 128 with 32 participants per condition. For between-subject *t*-tests the samples size was calculated as 102, with 51 per condition. The required sample size for correlation analysis was 55.

2.4.6 Data Analysis

Data analysis was conducted using R statistical software version 3.5.1 (R Core Team, 2018). To determine if there were differences between groups and conditions in demographics, pain variables and psychological variables, 2x2 ANOVAs were conducted. A 2x2 between-subjects ANOVA evaluated whether there were significant differences between groups and conditions in perseverance, and whether there was an interaction between group and condition. The temporal discounting measures were scored with an automated scorer (Kaplan, Lemley, Reed, & Jarmolowicz, 2014) where entering 0 indicated the participant had not made a self-control choice and entering 1 indicated the participant had made the self-control choice. The automated scorer then calculated the proportion of self-control choices for each of the four decision-making measures. Between-group *t*-tests determined whether there were significant differences between the chronic pain and control group on the temporal discounting measures. Effect sizes were calculated using the ‘compute.es’ package (version 0.2-4; Del Re, 2015). Correlations were conducted between self-regulatory fatigue, pain self-efficacy, pain catastrophising, the temporal discounting measures and perseverance.

2.5 Results

2.5.1 Participants

Two hundred and sixty one participants completed the questionnaire. Thirty-eight participants were removed from analysis as they did not meet the inclusion criteria or had failed to answer IMCs satisfactorily. This left a sample of 223.

Means and frequencies for the demographic variables of age, sex, race, years of education, marital status, employment status and annual income and are displayed in table 2.1. *T*-tests and chi-square analyses were conducted to determine whether there were differences in the sample between the two groups (chronic pain vs healthy control) and two conditions (high vs low self-regulation).

Table 2.1 Demographic variables by group and condition

	Group		**Condition**	
	Chronic Pain *N*=122	**Controls *N*=101**	**High SR *N*=112**	**Low SR *N*=111**
Age *M* (SD)	38.5 (12.6)	36.1 (11.0)	39.1 (12.4)	35.77 (11.3)
Years of education *M* (SD)	16.1 (3.7)	16.4 (3.2)	16.53 (3.5)	16.0 (3.5)
Sex *N* (%)				
Female	70 (57.4)	67 (66.3)	66 (58.9)	71 (64.0)
Male	50 (41.0)	34 (34.7)	44 (39.3)	40 (36.0)
Other	2 (1.6)	-	2 (1.8)	-
Race *N* (%)				
White British	99 (81.2)	91 (90.1)	97 (86.6)	93 (83.8)
Other	22 (18.0)	10 (9.9)	15 (13.4)	17 (15.3)
Missing	1 (0.8)	-	-	1 (0.9)
Marital Status N (%)				
Married	48 (39.3)	38 (37.6)	46 (41.1)	40 (36.1)
Living with Partner	35 (28.7)	27 (26.7)	29 (25.9)	33 (29.7)
Single	39 (32.0)	36 (35.7)	37 (33.0)	38 (34.2)
Employment *N* (%)				
Employed FT	62 (50.8)	52 (51.5)	55 (49.1)	59 (53.2)
Employed PT	28 (23.0)	28 (27.7)	30 (26.7)	26 (23.4)
Not in employment	32 (26.2)	21 (20.8)	27 (24.2)	26 (23.4)
Annual Income *N* (%)				
£0-10,000	29 (23.8)	23 (22.8)	23 (20.5)	29 (26.1)
£10,001-20,000	35 (28.7)	26 (25.7)	31 (27.7)	30 (27.0)

£20,001-35,000	27 (22.1)	34 (33.6)	33 (29.5)	28 (25.2)
£35,001-50,000	22 (18.0)	13 (12.9)	17 (15.2)	18 (16.2)
£50,000+	9 (7.4)	5 (5.0)	8 (7.1)	6 (5.5)

There were no differences between the groups or conditions on any demographic variable with one exception. Participants in the high self-regulation condition were significantly older than the low self-regulation group ($t(219.3)=2.18$, $p=.031$, 95% CI (0.32, 6.57), Cohen's $d=0.29$).

2.5.2 Descriptive statistics

Means and standard deviations for the pain variables by group and condition are displayed in table 2.2.

Table 2.2 Means and standard deviations of pain variables by group

	Group *M* (SD)		**Condition *M* (SD)**	
	Chronic Pain	**Control**	**High SR**	**Low SR**
Average Pain	5.6 (2.0)	1.6 (1.9)	3.7 (2.9)	3.8 (2.8)
Self-regulatory Fatigue	56.3 (12.2)	44.7 (10.7)	50.8 (13.0)	51.4 (12.8)
Pain Catastrophising	29.7 (11.4)	16.6 (12.4)	24.0 (13.8)	23.6 (13.3)
Pain Self-efficacy	32.8 (12.3)	39.3 (12.8)	35.7 (12.9)	35.8 (12.9)

Average pain=average pain over the past 6 months; SR=self-regulation

A series of 2x2 between-subjects ANOVAs established that the chronic pain group reported significantly higher average pain ($F(1, 219)=232.99$, $p<.001$, 95% CI (-4.57, -3.52), Cohen's $d=2.73$), and pain catastrophising ($F(1, 219)=67.22$, $p<.001$, 95% CI (-16.24, -9.94), Cohen's $d=1.10$) than controls. The chronic pain group also reported significantly lower pain self-efficacy ($F(1, 219)=15.02$, $p=.00014$, 95% CI (3.21, 9.86), Cohen's $d=-0.52$) than the control group. Self-regulatory fatigue was significantly higher in people with chronic pain than controls ($F(1, 219)=56.88$, $p<.001$, 95% CI (-14.62, -8.56), Cohen's $d=1.00$) and there was a significant interaction between group and condition, $F(1, 219)=6.04$, $p=.0148$.

Pairwise comparisons were conducted to examine the interaction between condition and group in self-regulatory fatigue. The alpha level was set at $p<.0125$ to account for multiple comparisons. These showed that there was no significant difference in self-regulatory fatigue in the control group between low SR (M=47.0) and high SR conditions (M=42.7; p=.228) or in the chronic pain group between low SR (M=54.8) and high SR conditions (M=58.0; p=.406) as was expected. In the high SR condition, the mean difference in self-regulatory fatigue between participants with chronic pain (M=58.0) and healthy participants (M=42.7) was 15.3 ($p<.001$). In the low SR condition, the mean difference in self-regulatory fatigue between participants with chronic pain (M=54.8) and healthy participants (M=47.0) was 7.8 (p=.003). The larger mean difference between chronic pain and healthy controls in the high SR condition compared to the low SR condition was unexpected.

The difference between the chronic pain group and control group in pain intensity, self-regulatory fatigue, pain self-efficacy and pain catastrophising are as expected. As baseline self-regulatory fatigue was significantly higher in the chronic pain group, this provides support for the hypothesis that people with chronic pain experience chronic self-regulatory fatigue. However, the interaction was not expected and any differences in group and condition in perseverance needed to take into account the larger difference in baseline self-regulatory fatigue between the chronic pain and control groups in the high SR condition compared to the low SR condition.

2.5.3 The effect of group and self-regulatory demand on perseverance

It was hypothesised that participants in the low self-regulation condition would persevere for significantly longer than participants in the high self-regulation condition and that healthy controls would persevere for significantly longer than would participants with chronic pain. Additionally, it was hypothesised that there would be an interaction between group and condition where there would be no difference in participants with chronic pain between high self-regulation and low self-regulation conditions. However, it was expected that controls in the low self-regulation condition would perform significantly better than controls in the high self-regulation condition. Mean and standard deviation of perseverance by group and condition is presented in Figure 2.1.

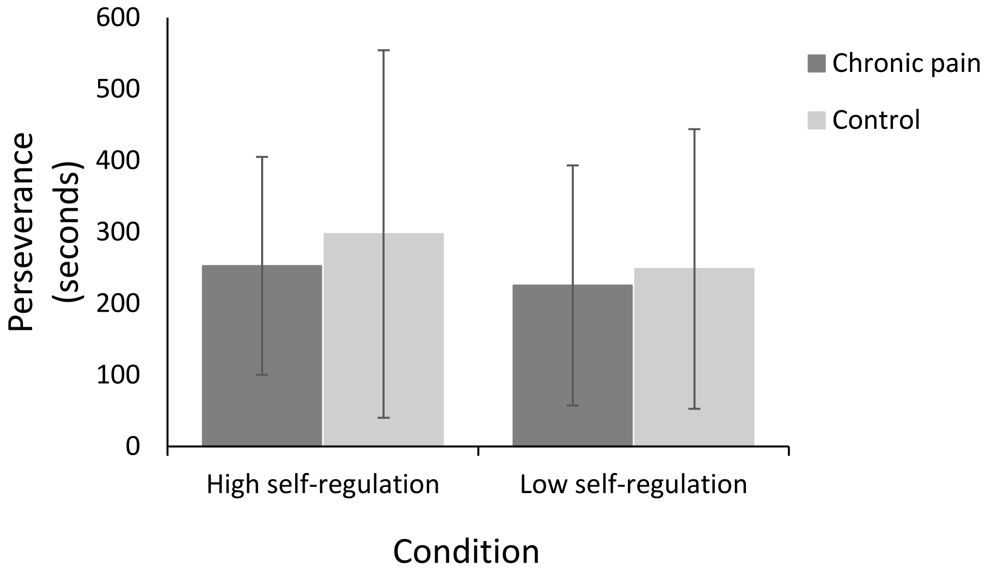

Figure 2.1 Mean perseverance (seconds) by condition and group

There were violations of normality and linearity and so, while ANOVA is generally robust to violations of assumptions (G. V. Glass, Peckham, & Sanders, 1972; Schmider, Ziegler, Danay, Beyer, & Buehner, 2010), bias-corrected bootstrapped confidence intervals were calculated (Field, Miles, & Field, 2012). A 2x2 between-subjects ANOVA found that the predicted main effect of group was non-significant as there were no significant differences in perseverance scores between participants with chronic pain (*M*=238.51s, SD=160.58) and controls (*M*=273.52s, SD=229.54), F(1, 217)=1.77, *p*=.184, 95% CI (-92.20, 17.05), Cohen's *d*=-0.18. The predicted main effect of condition was also not supported as there were no significant differences between the low self-regulation condition (*M*=235.23s, SD=179.95) and high self-regulation conditions (*M*=273.33s, SD=207.84), F(1, 217)=2.00, *p*=.158, 95%

CI (-9.80, 94.04), Cohen's *d*=0.2. There was also no significant interaction between group and condition, F(1, 217)=.17, *p*=.683. Therefore, none of the hypotheses were supported. The lack of significant differences in perseverance between chronic pain and control and high and low SR conditions occurred despite the fact that there was a larger difference in baseline self-regulatory fatigue between chronic pain and control in the high SR condition than in the low SR condition.

Manipulation check

As with previous research, several manipulation check questions were presented after the perseverance task to determine whether the manipulation was effective. It would be expected that participants in the high self-regulation condition would report higher task difficulty, deliberation and conflict than participants in the low self-regulation condition. Additionally, it was expected that positive and negative affect and pain would be similar across high and low self-regulation conditions but that pain and negative affect would be higher in the chronic pain group, while positive affect would be lower. The means and standard deviations are presented in Table 2.3.

Table 2.3 Means and standard deviations of manipulation checks

	Group *M* (SD)		**Condition *M* (SD)**	
	Chronic pain	**Control**	**High SR**	**Low SR**
Positive affect	21.3 (5.2)	25.7 (3.8)	23.4 (4.9)	23.2 (5.4)
Negative affect	19.1 (4.2)	22.4 (4.4)	20.5 (4.3)	20.6 (4.9)
Perceived task difficulty	1.8 (0.9)	1.7 (0.8)	1.7 (0.8)	1.8 (0.9)
Deliberation	3.7 (0.6)	3.7 (0.6)	3.7 (0.6)	3.6 (0.7)
Conflict	2.4 (1.1)	2.2 (1.0)	2.3 (0.9)	2.3 (1.2)

Univariate ANOVAs showed that both positive affect (F(1, 219)=49.77, *p*<.001, 95% CI (3.19, 5.66), Cohen's *d*=-0.95) and negative affect (F(1, 219)=31.80, *p*<.001, 95% CI (2.13, 4.42), Cohen's *d*=-0.76) were significantly higher in the control group while pain was significantly higher in the chronic pain group (F(1, 219)=338.72, *p*<.001, 95% CI (-4.38,

-3.53), Cohen's *d*=2.47). No other differences were found across groups or conditions. Therefore, it appears that the participants felt that there was no difference in the level of difficulty, required deliberation or amount of conflict between the low and high demand tasks and, therefore, the manipulation may not have been effective.

2.5.4 The effect of group on temporal discounting

Although it appeared that the manipulation of regulatory demand had not been successful, performance on the temporal discounting measures were examined to determine whether there was a self-regulatory deficit in the chronic pain group in the four temporal discounting measures as hypothesised. The mean and standard deviation of proportion of self-control choices for each temporal discounting measure by group are presented in Figure 2.2.

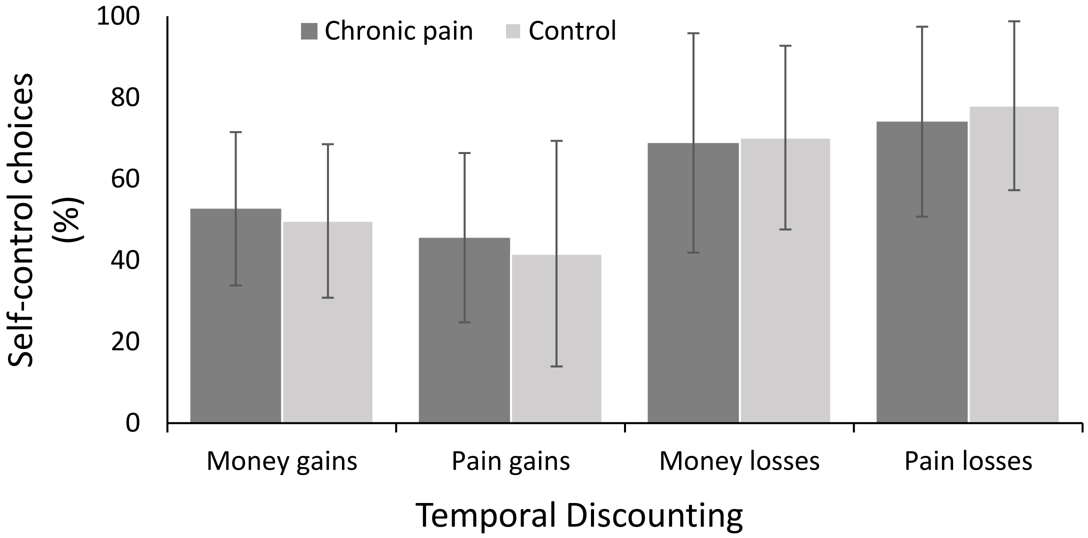

Figure 2.2 Proportion of self-control choices by group

There were no significant differences between chronic pain (*M*=52.67, SD=18.84) and controls (*M*=49.68, SD=18.86) on monetary gains, *t*(111)=.82, *p*=.412, 95% CI (-4.08, 10.06, Cohen's *d*=0.16), pain relief (*M*chronic pain=45.57, SD=20.80; *M*control=41.65, SD=27.72; *t*(111)=.92, *p*=.359, 95% CI (-5.35, 13.20), Cohen's *d*=0.16), monetary losses (*M*chronic pain=68.86, SD=26.95; *M*control=70.16, SD=22.57; *t*(111)=-.32, *p*=.747, 95% CI (-10.58, 7.98), Cohen's *d*=-0.05) or additional pain (*M*chronic pain=74.09, SD=23.35; *M*control=78.00, SD=20.75; *t*(1, 111)=-.84, *p*=.405, 95% CI (-12.19, 4.33), Cohen's *d*=-0.23). The hypothesis that the chronic pain group would have significantly poorer performance on temporal discounting was not supported.

2.5.5 Impact of self-regulatory fatigue and pain cognitions on self-regulatory performance in the chronic pain group

Due to the additional self-regulatory demands that pain would engender, it was expected that decision making and perseverance would decline with increasing levels of current pain, self-regulatory fatigue, and pain catastrophising within the chronic pain group. On the other hand, increasing pain self-efficacy would be associated with better decision-making and perseverance. Pearson's correlations were calculated and are reported in table 2.4.

Table 2.4 Pearson's correlations of study variables and self-control tasks in chronic pain group (*N*=59)

	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
1. Pain	-								
2. Self-regulatory fatigue	**.35****	-							
3. Pain catastrophising	**.49****	**.65****	-						
4. Pain self-efficacy	**-.33****	**-.59****	**-.45****	-					
5. Perseverance	-.04	.13	.07	**-.28***	-				
6. Monetary gains (MCQ)	-.19	-.18	.02	**.43****	-.22	-			
7. Pain gains (PRQ)	**-.33***	-.24	-.18	**.26***	-.14	**.47****	-		
8. Monetary Losses (MLQ)	-.22	.11	-.14	.03	-.01	.15	-.13	-	
9. Pain losses (APQ)	-.14	.00	-.16	.23	.09	.06	.01	**.30***	-

*=*p*<.05; **=*p*<.001; Pain=current pain intensity; MCQ=Monetary Choice Questionnaire; PRQ=Pain Relief Questionnaire; MLQ=Monetary Loss Questionnaire; APQ=Additional Pain Questionnaire

As seen in table 2.4, the first of the sequential tasks, proportion of self-control choices on the MCQ and PRQ, were positively related to pain self-efficacy, meaning as pain self-efficacy, proportion of self-control choices increased. In contrast, the second of the sequential tasks, perseverance on the anagram task, was negatively related to pain self-efficacy. This means that as pain self-efficacy increased, perseverance decreased. The negative relationship between perseverance and pain self-efficacy was inconsistent with the hypothesis.

2.6 Discussion

The results of study 1 demonstrated that participants with chronic pain self-reported higher baseline self-regulatory fatigue, which provided some support for the hypothesis that people with chronic pain would experience chronic self-regulatory fatigue. Despite reporting significantly higher self-regulatory fatigue, there were no differences between chronic pain and controls on either temporal discounting or perseverance tasks, which both require self-regulation resources. While this did not support the hypothesis, the manipulation check suggested that the manipulation had not been effective. Given the generally high performance on the MLQ and APQ, which are both loss temporal discounting measures, it may be assumed that these measures did not require the same level of cognitive effort as the MCQ and PRQ. Although, it may be that participants adapted to the task, as the MLQ and APQ were presented last to the participants. Adaption to the depletion task has been demonstrated previously when it encompassed more blocks, as opposed to fewer blocks (Arber et al., 2017; Dang et al., 2013).

Further analysis in participants with chronic pain demonstrated that pain catastrophising was not related to self-regulation performance. However, baseline pain self-efficacy was positively correlated with self-regulation performance in the initial self-regulation task of gain temporal discounting measures, indicating that as pain self-efficacy increased so did self-regulation performance. On the second task, pain self-efficacy was negatively correlated with self-regulation performance, indicating that higher baseline pain self-efficacy was associated with poorer perseverance. This suggests that having moderate pain self-efficacy was most adaptive for consistently good performance across both tasks.

These results partially support the hypothesis that self-efficacy would predict better self-regulation performance and do not provide support for the Strength Model. There may be partial support for the conservation of resources hypothesis where chronic pain participants with lower pain self-efficacy conserved their energy on the first task as they were aware that further exertion of self-regulatory resources would be necessary and then could persist for longer. Those with high pain self-efficacy may have expected to have the capacity to complete both tasks and so used more resources in the first task.

However, these findings may be better explained by the discontinuous model of self-efficacy (J.W. Beck & Schmidt, 2012; Vancouver et al., 2008). Initial level of self-efficacy has been found to differentially affect task performance where those with higher self-efficacy reduce their efforts because they perceive that they will perform well anyway, only for reduced efforts to lead to poorer performance (Schmidt & DeShon, 2009). Conversely, those with low initial self-efficacy may increase efforts in an upcoming task after perceiving that they have performed poorly on a previous task, resulting in better performance on a second task (J. W. Beck & Schmidt, 2012; Schmidt & DeShon, 2009). The results of this study are consistent with evidence that when resources are limited, moderate self-efficacy predicted moderate resource allocation and best overall performance, while both low and high self-efficacy had a negative effect on overall performance (J.W. Beck & Schmidt, 2018).

As pain self-efficacy was measured in this study, a comparison of the effect of self-efficacy on self-regulation performance between participants with chronic pain and controls was not conducted. Assessing the different effect of task self-efficacy on self-regulation performance between people with chronic pain and controls would reveal whether people with chronic pain allocated resources across tasks differently to controls. As pain catastrophising was not related to self-regulation performance, it was not assessed further.

2.7 Study 2

This study aimed to directly test whether the findings in study one could be explained by the discontinuous model of self-efficacy (Vancouver et al., 2008). The study investigated whether the effect of within-person self-efficacy on sequential self-regulation across tasks was different between controls and people with chronic pain, who have limited self-regulatory resources, and whether this was mediated by resource allocation.

Variable within-person self-efficacy effects are adaptive as they facilitate success in overall performance by allocating limited resources efficiently (J.W. Beck and Schmidt, 2018). This was demonstrated in an experimental task where participants were randomised to either time scarcity or time abundance conditions and were instructed that overall performance over seven consecutive maths tasks would determine whether they would receive a financial reward (Beck and Schmidt, 2018). In the scarce time condition, where resources (i.e. time) were limited, there was a negative relationship between within-person self-efficacy and resource allocation. There was also a negative curvilinear relationship between resource allocation and overall performance, where allocating a moderate amount of time per item led to better performance than either a short amount of time or a high amount of time. Resource allocation mediated the effect of self-efficacy on overall performance where the relationship between self-efficacy and performance was positive when self-efficacy increased from low to moderate, which led to increases in overall performance. However, when the level of self-efficacy increased from moderate to high, a negative relationship between self-efficacy and performance and decreases in overall performance were observed. In the abundant time condition, resource allocation mediated the relationship between self-efficacy and performance where, as self-efficacy increased so did resource allocation and performance, although there were diminishing returns. These results illustrate that when resources are not scarce, the positive relationship between self-efficacy and performance is adaptive as it results in more resource allocation and optimised performance. However, when resources are scarce, negative self-efficacy effects can be adaptive because resources are allocated efficiently.

For study 2, it was hypothesised that:

1. participants with chronic pain would report significantly higher self-regulatory fatigue than controls at baseline.
2. there would be a moderating effect of group on the relationship between within-person task self-efficacy and resource allocation where task self-efficacy would be:
    a) negatively related to resource allocation in the chronic pain group.
    b) positively related to resource allocation in the control group.
3. that group would moderate the effect of resource allocation on overall performance where:
    a) for the chronic pain group there would be a negative curvilinear relationship (inverted-U) between resource allocation and overall performance indicating that moderate resource allocation would yield better performance than low or high resource allocation.
    b) for the control group the overall effect of resource allocation would be positive but with diminishing returns.
4. there would be a moderated mediation of the effect of within-person task self-efficacy on overall performance via resource allocation where:
    a) in the chronic pain group, the effect of task self-efficacy on performance would be positive from low to moderate resource allocation then negative from moderate to high resource allocation.
    b) In the control group, the mediated effect will be positive but will get weaker as resource allocation increases

2.8 Methods

2.8.1 Design

The study was a nested design. The data had a two-level structure where observations (level 1) were nested within participants (level 2). At level 1, five observations were taken of the independent variables of task self-efficacy and resource allocation. There were five observations taken of the dependent variable, overall performance. Self-regulatory fatigue was measured at level 2.

2.8.2 Participants

Eighty participants (40 chronic pain and 40 control) were recruited from Prolific. Participants were screened as in study 1 with an additional filter added to prevent participants who had completed study 1 from taking part in study 2. Control participants were matched to the chronic pain group by age and gender. Participants who met the pre-screening criteria were able to access a link to the study on Qualtrics. Participants in the control group who did not report a current pain level of 0 were excluded. A total of 101 participants were recruited and completed the survey. Participants were paid £5 for taking part in the study. In addition, those who scored in the top 20% on overall performance were given a bonus of £2.50.

2.8.3 Measures

Demographics: The participants reported their age, gender, ethnicity, marital status, level of education and employment status. Participants additionally reported any acute or long-term physical or mental health conditions and any medication they were taking by free text response.

Pain: Participants reported their current pain level and average and worst pain level over the past 6 months and each items was measured on an 11-point nominal rating scale from 0 (no pain) to 10 (pain as bad as can be).

Self-regulatory fatigue: was measured by the Self-regulatory Fatigue Scale (Solberg Nes et al., 2013). Cronbach's alpha was excellent (α=.89).

Pain self-efficacy: Pain self-efficacy was measured by the Pain Self-efficacy Questionnaire (Nicholas, 1989). Internal consistency was excellent (Cronbach's α=.91).

Task Self-efficacy: Task self-efficacy was measured using the Problem Solving Self-efficacy Scale (PSSS; Bandura, 2006). The PSSS has 10 items rating confidence in ability to solve problems on a on an 11-point Likert scale from 0 (cannot do at all) to 10 (highly certain can do). For this study, the PSSS was adapted to have seven items as this was the number of maths problems within a block. In this study, participants were instructed to, "Rate your degree of confidence for how many of the questions you can solve in this block". Therefore each item asked participants to rate their confidence in being able to solve a certain number of the maths problems within the upcoming block ("Can solve 1 of the problems", "Can solve 2 of the problems"). Task self-efficacy for each block was calculated as the average of the seven items. The intra-class correlation (ICC) for the PSSS was .71 meaning 71% of the variance occurred at the between-person level while 29% of variance was contributed by within-person variation over time (Bliese, 2000).

Resource Allocation: Resource allocation was operationalised as the average amount of time spent on each item within a block. The time spent on each item was recorded automatically in seconds. The ICC for resource allocation was .62, therefore the majority of variance occurred at the between-person level.

Overall Performance: overall performance for each block was the composite of performance across individual tasks, i.e. the seven maths problems within each block. Therefore, the percentage of items answered correctly during each block was calculated as overall performance. The variance for overall performance was observed at both within-person and between-person levels where the ICC was .51.

Task

The participants completed five blocks of seven items each (maths problems). The maths problems were high-school Scottish National 5 level of difficulty (age 15-16 years). The items were gathered from past or practice exam papers available from the Scottish Qualifications Authority, the national body responsible for educational quality standards. Each item had four possible response options meaning chance-level performance was 25%. The participants were instructed that they could use pencil and paper and a calculator. The participants could only view and answer one problem at a time meaning they did not know the difficulty level of future maths problems in the block. The task instructions stated that participants could proceed to the next problem if they did not feel they could answer the current problem. Although the maths problems were divided into blocks, participants were told that those who scored in the top 20% for performance over all 35 items would receive a bonus payment. This was to encourage participants to be as efficient as possible while also attempting to score as highly as possible.

2.8.4 Procedure

Ethical approval was obtained from the School of Psychological Sciences and Health School Ethics Committee (approval number: 02/01/05/2018/A). As in study 1, participants were able to access the study on Prolific if they met the pre-screening criteria. The chronic pain group were recruited first. The control group was recruited second to ensure the groups matched by age and gender. The study was accessed by a link to Qualtrics where the participants read an information sheet, completed a consent form and then completed demographic information and measures of pain and self-regulatory fatigue. Then task instructions were displayed.

There were five task blocks. Prior to each block, participants completed the PSSS. Then they completed a block of seven maths problems. After all five blocks (35 maths problems in total) were completed, participants were given post-task feedback which stated that they should not consider the task to reflect their true mathematical ability. The participants were then given a brief positive mood induction task of 10 positive statements (Velten, 1968) before viewing the debrief form.

2.8.5 Analysis

Of the 101 participants who took part in the study, 21 were excluded as they either did not meet the participant criteria or failed to answer IMC's satisfactorily, giving a final sample size of 80. As measurements were repeated five times this resulted in 400 observations. The data analysis was undertaken using R statistical software version 3.5.1 (R Core Team, 2018). As the focus for this study was on the variation of task self-efficacy over blocks, within-person variance of self-efficacy was separated from between-person self-efficacy using within-person (cluster) centring. Between-person (average) task self-efficacy was calculated as the mean of the cluster (person), i.e. the mean of all five measurements of a person's task self-efficacy. Within-person self-efficacy was calculated by subtracting the individual's average task self-efficacy from each of their five observations of task self-efficacy. By subtracting the average task self-efficacy for an individual from each of their five observations, a within-person task self-efficacy score of 0 means that self-efficacy for that observation was the same as their average self-efficacy. A within-person task self-efficacy score of <0 means that self-efficacy for that observation was below the individual's average. A within-person task self-efficacy score of >0 means that self-efficacy was higher than the individual's average task self-efficacy for that observation. For overall performance, correct responses to the maths problems were coded as '1' and incorrect or missing responses were coded as '0'. The proportion of correct answers for each block was calculated.

There were two missing observations of task self-efficacy from two people. Due to the small amount of missing data and as there had to be available observations to calculate within-person self-efficacy, the mean for the cluster (person) was inputted for these observations. Model diagnostics were investigated to determine if there was normality of model residuals, homoscedasticity and whether there were outliers or observations with undue leverage. After model residuals were extracted, a histogram of residuals and Q-Q plots were produced. Homoscedasticity was examined by plotting standardised residuals against fitted values. To determine if there were outliers, Cooks distances and leverage were calculated for level 1 and level 2 of the data structure using the 'HLMdiag' package version 0.3.1 (Loy & Hofmann, 2014).

Means and standard deviations (SDs) of variables were calculated for each group. A *t*-test was conducted to determine if self-regulatory fatigue was significantly higher in the chronic pain group. When testing the hypotheses, the data was analysed using multilevel modelling with the 'nlme' package version 3.1-137 (Pinheiro, Bates, DebRoy, Sarkar & R Core Team, 2018) as the data was multilevel with observations nested within individuals. For the first hypothesis, both between-person and within-person self-efficacy were entered as fixed effects and participant was entered as a random effect when modelling the effects of self-efficacy on resource allocation. Entering participant as a random effect allows for intercepts and slopes of the fixed effects to vary by participant and, therefore, variance across participants is accounted for in model estimates. Fixed effects coefficients were estimated using maximum-likelihood ratio.

For the second hypothesis, there was a curvilinear relationship predicted between resource allocation and performance. The quadratic term of resource allocation was calculated by multiplying the linear term by itself (resource allocation x resource allocation). The effects of between and within-person self-efficacy, as well as the within-person self-efficacy and group interaction were included as fixed effects in the model to control for the direct effects of self-efficacy on performance. Next, the linear term of resource allocation was entered, as well as the quadratic term. To distinguish the effects of the linear relationship between resource allocation and performance and the curvilinear relationship between resource allocation and performance, the linear term must be held constant in the model (Aiken, West and Pitts, 2003). Interaction terms for group and both the linear and curvilinear resource allocation were entered last in the model. As previously, participant was entered as a random effect and fixed effects were estimated using maximum-likelihood ratio.

For the third hypothesis, the hypothesised moderated mediation effect was analysed separately for the chronic pain and control groups. The moderated mediation for each group at low, moderate and high levels were conducted using the SPSS 'MLmed' macro (Rockwood & Hayes, 2017). MLmed fits multilevel moderated mediation models and provides Monte Carlo confidence intervals. The predictor, mediator and moderator variables are automatically centred by MLmed. In this case, task self-efficacy was entered as the predictor (*x* variable) and only within-person effects were estimated. The quadratic term of resource allocation was entered as the mediator (*m* variable) while the linear term of resource allocation was entered as the moderator (*z* variable). Overall performance was the outcome (*y* variable). In the model, the effect of the moderator on both the *a*-path ($x \rightarrow m$) and *b*-path ($m \rightarrow y$) was estimated due to the hypothesised curvilinear relationship between resource allocation and performance. The indirect effect of within-person task self-efficacy on overall performance through resource allocation was estimated at selected conditional values of *z*, i.e. low, moderate and high resource allocation.

2.9 Results

2.9.1 Descriptive statistics

The means, standard deviations and frequencies of the demographic variables are reported in table 2.5.

Table 2.5 Descriptive statistics for demographic information

	Chronic Pain (*N*=40)	**Controls (*N*=40)**
Age (yrs) *M* (SD)	34.6 (9.7)	35.2 (10.8)
Years of Education *M* (SD)	15.9 (3.4)	15.3 (2.8)
Sex *N* (%)		
Female	28 (70.0)	27 (67.5)
Male	12 (30.0)	13 (32.5)
Race *N* (%)		
White British	38 (95.0)	39 (97.5)
Other	2 (5.0)	0 (0.0)
Missing	-	1 (2.5)
Marital Status *N* (%)		
Married	10 (25.0)	11 (27.5)
Living with Partner	17 (42.5)	11 (27.5)
Single	13 (32.5)	18 (45.0)
Employment *N* (%)		
Employed FT	10 (27.5)	20 (50.0)
Employed PT	12 (27.5)	6 (15.0)
Student	8 (20.0)	8 (20.0)
Not in employment	10 (25.0)	6 (15.0)

Independent samples *t*-tests showed there was no significant difference between the chronic pain and control groups in age or years of education. Chi-square tests determined that there were no differences in sex, race or marital status. There was a significant difference in employment status $X^2(5, N=80)=12.44, p=0.029$. More people in the control group were in full-time employment than people with chronic pain. People with chronic pain were more likely to be in part-time employments and not working than controls. The descriptive statistics for the study variables are presented in table 2.6.

Table 2.6 Means, SDs and frequencies of study variables

	Chronic Pain	**Control**
Current pain *M* (SD)	4.6 (2.2)	0.0 (0.0)
Average Pain *M* (SD)	7.7 (2.2)	2.6 (2.3)
Pain duration (*N*)		
7-12 months	4	-

1-2 years	4	-
2-5 years	9	-
5-10 years	7	-
10-20 years	14	-
Missing	2	-
Self-regulatory fatigue *M* (SD)	58.4 (12.1)	46.2 (9.5)
Pain Self-efficacy *M* (SD)	33.3 (11.7)	42.7 (12.6)
Problem solving self-efficacy *M* (SD)	4.5 (2.7)	5.1 (2.3)
Resource allocation *M* (SD)	46.7 (40.5)	53.8 (35.3)
Overall performance *M* (SD)	43.5 (24.5)	53.2 (25.4)

Average pain=past 6 months; Resource allocation=seconds; overall performance=% correct

An independent samples *t*-test revealed that people with chronic pain had significantly higher self-regulatory fatigue than controls $t(73.8)=4.96$, $p<.001$, 95% CI (7.29, 17.11), Cohen's $d=1.39$. In contrast, there was no difference in initial task self-efficacy (i.e. first measurement of task self-efficacy prior to first block of maths problems) between the chronic pain ($M=6.5$; SD=2.4) and control groups ($M=7.0$; SD=1.6), $t(68.6)=-1.12$, $p=0.267$, 95% CI (-1.42, 0.40), Cohen's $d=0.81$. Therefore, the following results cannot be explained by initial differences in task self-efficacy between the groups.

2.9.2 Effect of within-person task self-efficacy on resource allocation

When investigating model diagnostics for the multilevel model of within-person task self-efficacy predicting resource allocation, there were deviations from normality evident in the histogram of residuals. Further, the standardised vs fitted residual plot showed increasing variance as values increased, indicative of heteroscedasticity. A transformation of the response variable did not result in a normal distribution. Therefore, to reduce the influence of outliers and violations of assumptions, residual bootstrapping was undertaken with 1000 samples using the 'lmeresampler' package version 0.1.0 (Loy & Steele, 2016) and 95% confidence intervals were computed using the 'boot' package version 1.3-20 (Canty & Ripley, 2017). Bootstrapped standard errors and bias-corrected confidence intervals are reported. The relationship between within-person self-efficacy and resource allocation for each group is demonstrated in figure 2.3.

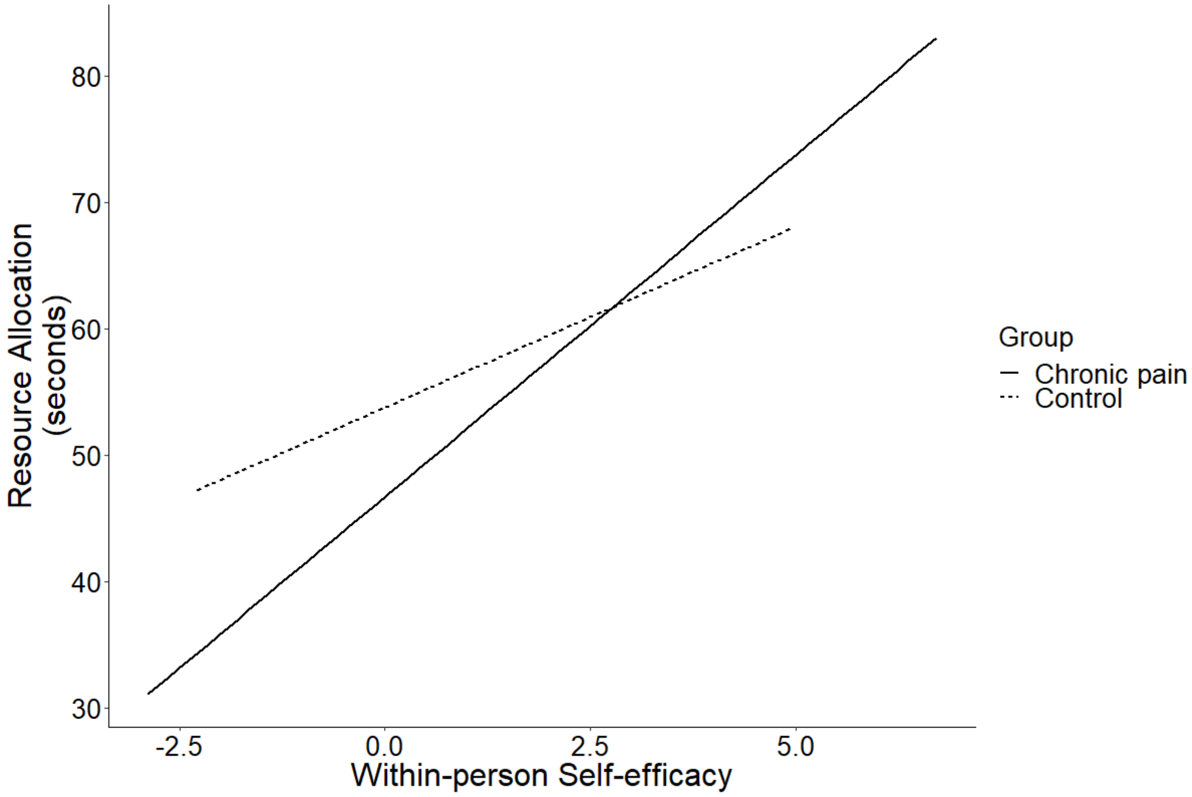

Figure 2.3 The relationship between within-person self-efficacy and resource allocation for each group

There was a positive effect of between-person self-efficacy on resource allocation, γ=6.38, *SE*=0.47, *p*<.001, 95% CI (5.57, 7.44), meaning as between-person task self-efficacy increased, resource allocation increased. Within-person task self-efficacy also demonstrated a positive relationship with resource allocation, γ=5.89, *SE*=1.24, *p*=0.0001, 95% CI (3.24, 8.15), meaning as within-person task self-efficacy increased, so did resource allocation. There was no effect of group on resource allocation, γ=3.21, *SE*=1.93, *p*=0.607, 95% CI (-0.70, 6.82). Inconsistent with the hypothesis, there was no interaction between within-person self-efficacy and group, γ=-2.91, *SE*=1.72, *p*=0.154, 95% CI (-6.81, 0.17). Therefore, although it had been hypothesised that there would be a positive relationship between within-person self-efficacy and resource allocation in the control group and a negative relationship between within-person self-efficacy and resource allocation in the chronic pain group, the relationship was positive in both groups.

2.9.3 The effect of resource allocation on overall performance

When checking model diagnostics for the multilevel model of resource allocation predicting overall performance, there were no violations of assumptions, although there were some outliers. Conducting the analysis without these outliers did not change the interpretation of the results and so the model reported includes the full sample of 400 observations. The relationship between resource allocation and performance is shown in figure 2.4.

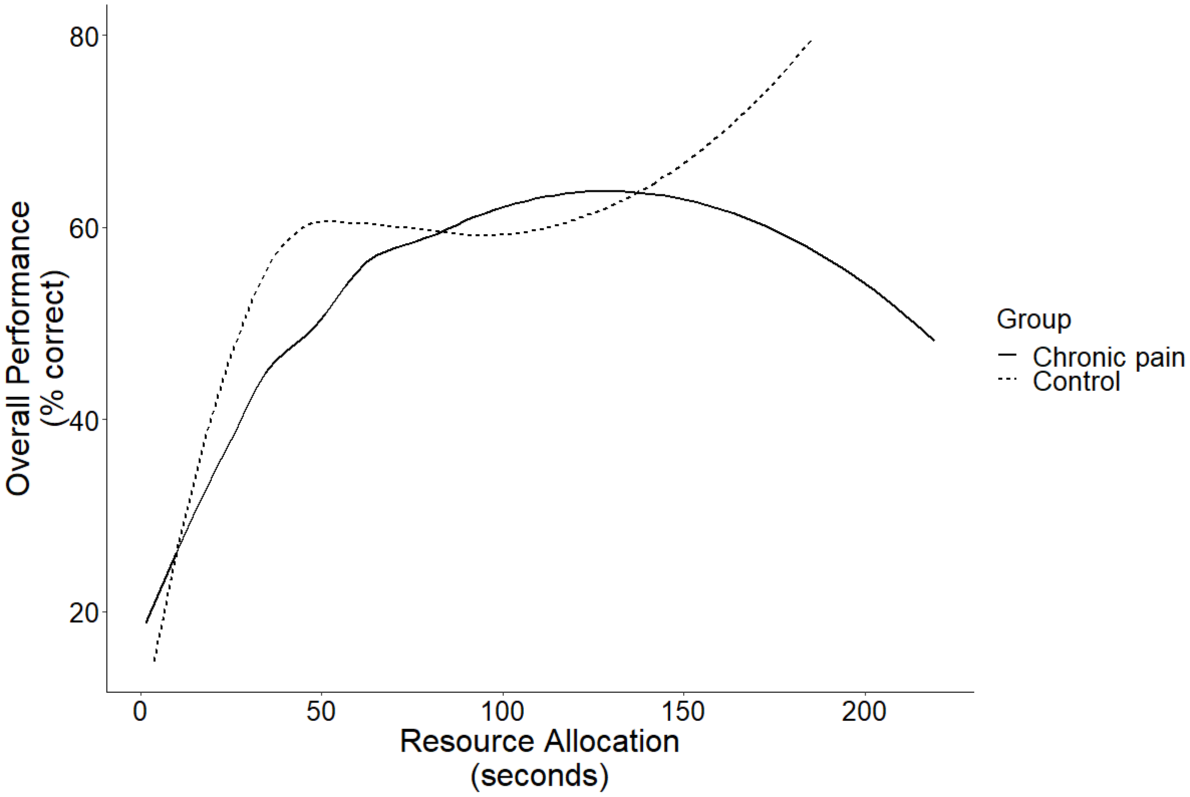

Figure 2.4 The relationship between resource allocation and overall performance by group

It was predicted that there would be a curvilinear relationship between resource allocation and performance, which would be moderated by group. These effects were hypothesised to occur while controlling for between and within-person self-efficacy and the within-person self-efficacy and group interaction. There was a positive effect of between-subject task self-efficacy on performance, γ=4.64, SE=0.62, p<.001, 95% CI (3.41, 5.87) where, as between-subjects task self-efficacy increased, so did overall performance. There was no effect on performance of within-person self-efficacy, γ=-1.30, SE=0.92, *p*=0.157, 95% CI (-3.08, 0.48) or a within-person self-efficacy and group interaction, γ=-0.47, SE=1.33, *p*=0.724, 95% CI (-3.05, 2.11). There was a positive relationship between the linear term of resource allocation and performance, γ=0.34, SE=0.11, *p*=0.003. 95% CI (0.12, 0.55) and a negative curvilinear relationship between the quadratic term and performance, γ=-0.001, SE=0.001, *p*=0.008, 95% CI (-.003, -0.0004), indicating that overall performance increased as resource allocation increased up to a point, after which overall performance decreased as resource allocation increased. Opposed to the hypothesis, there was no effect of group on performance, γ=8.69, SE=6.00, *p*=0.152, 95% CI (-3.12, 20.51) or an interaction between the linear term of resource allocation and group, γ=-0.10, SE=0.17, *p*=0.575, 95% CI (-0.43, 0.24) or quadratic term of resource allocation and group, γ=0.0003, SE=0.001, *p*=0.730, 95% CI (-0.002, 0.002), indicating that the effect of resource allocation on overall performance was no different between groups.

It had been hypothesised that there would a positive relationship between resource allocation and performance in the control group, but with diminishing returns. Inconsistent with this hypothesis, the relationship between resource allocation and overall performance in the control group, as demonstrated in figure 2.4, appears to be a cubic relationship. Therefore, although unplanned, the relationship between resource allocation and performance in the control group was further investigated to determine whether there was a cubic relationship. The linear, quadratic and cubic terms of resource allocation were included as fixed effects in the model and participants were entered as a random effect. There was a significant effect of linear resource allocation on performance, γ=1.26, *SE*=0.34, *p*<.001, 95% CI (5.96, 1.93), a significant effect of quadratic resource allocation on performance, γ=-1.72, *SE*=0.005, *p*<.001, 95% CI (-2.60, -8.41), and significant cubic effect of resource allocation on performance γ=6.31, *SE*=0.00002, *p*<.001, 95% CI (3.03, 9.60). This indicates that overall performance in the control increased as resource allocation increased up to a point, after which overall performance decreased with additional resource allocation, only for there to be a further increase in overall performance at very high levels of resource allocation.

2.9.4 The effect of within-person task self-efficacy on overall performance mediated by resource allocation

The relationship between within-person self-efficacy and performance is shown in figure 2.5.

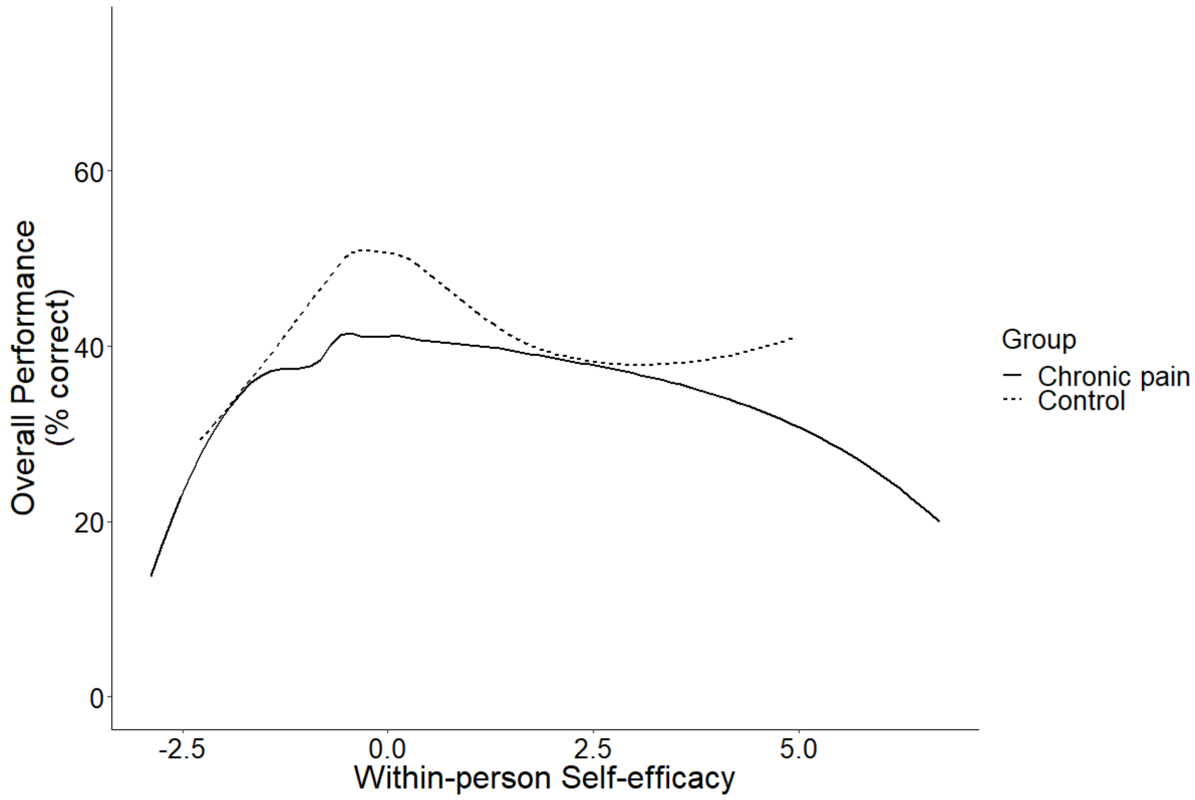

Figure 2.4 The relationship between within-person self-efficacy and performance for each group

Where within-person task self-efficacy is equal to 0, this is a moderate level of task self-efficacy for the individual (i.e. the same as their average level of self-efficacy). Where within-person task self-efficacy is <0, this is low task self-efficacy for the individual. A within-person task self-efficacy score of >0 is high task self-efficacy for the individual.

The estimates of the effect of within-person self-efficacy on overall performance mediated by resource allocation at low, moderate and high levels are displayed in table 2.7.

Table 2.7 Moderated indirect effects of resource allocation on the relationship between within-person task self-efficacy and performance by group

	γ	**SE*γ***	***Z***	**2.5%**	**97.5%**
Chronic pain					
Low RA (50 seconds)	6.55*	3.02	2.17	1.13	13.12
Moderate RA (100 seconds)	0.36	0.79	0.46	-1.23	2.06
High RA (150 seconds)	-4.18*	2.01	-2.08	-8.56	-0.83
Control					
Low RA (50 seconds)	7.76*	3.74	2.08	1.54	16.14
Moderate RA (100 seconds)	3.65*	1.61	2.26	0.93	7.29
High RA (150 seconds)	0.67	1.67	0.40	-2.63	4.15

*p<.05; **p<.001; RA=Resource allocation

In the chronic pain group, the indirect effect of self-efficacy on performance changes from positive at low resource allocation to null at moderate levels of resource allocation to negative at high levels of resource allocation. These results were consistent with the hypothesis. As demonstrated in figure 2.5, as within-person self-efficacy increased from low (-2.5) to moderate (0.0), resource allocation and overall performance also increased. An increase in within-person self-efficacy from moderate to high (2.5+) also resulted in higher resource allocation but decreased overall performance. The point at which overall performance decreased with additional resource allocation was when resource allocation was at 2 SDs above the mean (127.7 seconds). Thus, when self-efficacy was high in the chronic pain group, participants may have been overconfident in the amount of self-regulatory resources available and allocated more resources to the task, impairing overall performance. This was consistent with the hypothesis for the chronic pain group that there would be a positive effect of within-person task self-efficacy on performance from low to moderate resource allocation, then negative from moderate to high resource allocation. In the control group, the mediated effect of self-efficacy on performance was positive at low resource allocation and positive at moderate resource allocation, albeit with a smaller effect. At high resource allocation, there was no mediated effect of self-efficacy on performance. This was also consistent with the hypothesis that the relationship between within-person task self-efficacy and overall performance in the control group would be positive but would get weaker as resource allocation increased.

2.10 Discussion

The results of study 2 partially supported the hypotheses. Self-efficacy was positively related to resource allocation in the control group, as expected, but was also positively related to resource allocation in the chronic pain group, which was contrary to the hypothesis. When within-person task self-efficacy was one unit higher than the participant's average task self-efficacy, this led to an additional 5.89 seconds allocated to an individual task (i.e. one maths problem). For people with chronic pain a 5.89 second increase per unit increase of within-person self-efficacy is a 12.6% increase in time allocated and a two unit increase in within-person self-efficacy is a 25.2% increase in time allocated. For controls, a one unit increase in within-person self-efficacy was an 11% increase in time allocated to the task. Therefore, changes in within-person task self-efficacy had a significant impact on amount of time spent on individual tasks.

There was an inverted-U curvilinear relationship between resource allocation and overall performance in people with chronic pain, as predicted, but there was also a cubic relationship between resource allocation and overall performance in the control group. In the control group, the effect of self-efficacy on overall performance at low to moderate resource allocation was positive, although the effect decreased between moderate and higher resource allocation. There was no effect of self-efficacy on overall performance at high resource allocation in the control group. Therefore, the positive effect of self-efficacy reduced to null as within-person task self-efficacy increased further.

Lastly, there was a moderated mediation in the chronic pain group. Here, when within-person task self-efficacy was low to moderate, it was positively related to overall performance and when within-person task self-efficacy increased to high, it negatively affected performance. These results were consistent with the hypothesis, which predicted that self-efficacy would be positively related to performance from low to moderate resource allocation but negatively related to performance at moderate to high resource allocation. Even taking into account the unexpected positive relationship between self-efficacy and resource allocation, the moderated mediation results were consistent with the direction of relationships proposed by the dynamic self-efficacy model (J. W. Beck & Schmidt, 2018; Vancouver et al., 2008).

Therefore, it appears that higher within-person task self-efficacy was not adaptive when self-regulatory capacity was limited as excess resources were spent on individual tasks at the expense of overall performance across multiple tasks. Moderate within-person task self-efficacy and, therefore, moderate resource allocation was most adaptive in people with chronic pain. Whereas, higher within-person task self-efficacy and higher resource allocation was adaptive in the control group, who reported significantly less self-regulatory fatigue than the chronic pain group.

2.11 General Discussion

In both studies, there was no difference in task performance between people with chronic pain and healthy controls, despite participants with chronic pain reporting significantly higher self-regulatory fatigue. However, when examining self-regulation across multiple tasks, it appeared that higher self-efficacy was not adaptive when self-regulatory capacity was reduced, as in the chronic pain group. In study 1, initial level of pain self-efficacy in those with chronic pain was positively associated with performance on the first of two consecutive self-regulation tasks. Initial pain self-efficacy was then negatively related to performance in the second self-regulation task. It appeared that a moderate level of pain self-efficacy and task self-efficacy led to consistently good performance across both tasks. In study 2, this pattern was reaffirmed in people with chronic pain, where increases in within-person task self-efficacy and resource allocation were only beneficial for performance when increasing from low to moderate levels. High within-person task self-efficacy and resource allocation were detrimental to overall performance in people with chronic pain whose self-regulatory capacity is reduced. In the control group, within-person task self-efficacy also predicted higher resource allocation. The effect of within-person task self-efficacy on overall performance in controls was positive at low and moderate levels of resource allocation and became null at high levels of task self-efficacy.

The results did not support a Strength Model interpretation of the relationship between self-efficacy, self-regulatory capacity and self-regulation performance. Earlier research has concluded that people have a reduced capacity for self-regulation as demonstrated by poorer self-regulation performance under conditions of acute and chronic pain (Muraven et al., 2006; Solberg Nes et al., 2010; Vohs et al., 2008). The present research showed that people with chronic pain had significantly higher self-reported self-regulatory fatigue. Despite this, there was no significant difference in performance between people with chronic pain and controls in both study 1 and study 2. In addition, according to the Strength Model perspective of continuous self-regulation, self-efficacy is reduced after engaging in self-control and mediates the relationship between self-regulatory fatigue and performance on subsequent self-control tasks (Chow et al., 2015; Graham et al., 2017).

In study 1, those who had low initial pain self-efficacy and performed poorer on the first self-regulation task, then performed better on the second task. This is not consistent with previous findings of the relationship between self-regulatory resources, self-efficacy and performance (Chow et al., 2015; Graham et al., 2017). Alternatively, it has been hypothesised that self-regulation performance is poorer in people with chronic pain as they are motivated to conserve resources after engaging in self-regulation (Solberg Nes et al., 2011). Coping beliefs, such as optimism and pain willingness, have been proposed to facilitate the adaption to chronic pain by reducing resources allocated to a task when there is self-regulatory fatigue (Eisenlohr-Moul et al., 2013; Solberg Nes et al., 2011). As within-person task self-efficacy was positively related to resource allocation in study 2, this provides evidence that participants with chronic pain did not have poorer performance due to reduced motivation to perform.

The results of the current studies are best accounted for by the discontinuous model of self-efficacy (Vancouver et al., 2008; Yeo & Neal, 2013), although the hypotheses were not fully supported. The discontinuous model proposes that self-efficacy determines the amount of resources allocated to a task based on perceived ability to achieve a goal (Vancouver et al 2008). It is considered damaging to overall performance to allocate too few resources to an individual task when self-efficacy is high, or too many resources when self-efficacy is low (Vancouver et al., 2008). In the current studies, pain self-efficacy and task self-efficacy were fundamental in the self-regulation of resources. Allocating more resources to an individual task was only beneficial for overall performance up to a point, beyond which it became detrimental. Across both studies, when pain self-efficacy and task self-efficacy was moderate, the best overall performance was achieved.

It is argued that the functional purpose of self-efficacy beliefs is to determine the amount of resources to be allocated within the context of the availability of resources (Beck and Schmidt, 2018; Vancouver et al., 2008). Therefore, when resources are limited, it is adaptive for individuals to decrease resource allocation when they are more confident, allowing them to devote more resources to a task when they are less confident. Under conditions of reduced self-regulatory capacity, a negative relationship between within-person task self-efficacy and resource allocation is, therefore, adaptive. In participants with chronic pain, where self-regulatory capacity was reduced, high within-person task self-efficacy led to increases in resources. When within-person task self-efficacy was high, it appears that participants with chronic pain overrated their ability to perform well across all tasks, meaning they may have overestimated their self-regulatory capacity.

In the current studies, when participants with chronic pain had high pain self-efficacy or task self-efficacy, they did not appear to be motivated to conserve resources. This lack of motivation to conserve resources was maladaptive when examining performance across multiple tasks. It has been suggested that self-efficacy beliefs act similarly to cognitive heuristics, which are general decision-making rules that we automatically apply to many situations to reduce cognitive effort (J. W. Beck & Schmidt, 2018; Tversky & Kahneman, 1974). Like cognitive heuristics, self-efficacy beliefs are generally adaptive but can also be erroneous depending on the context.

The overestimation of resources in people with chronic pain when pain self-efficacy and task self-efficacy are high may explain endurance behaviour or the endurance-avoidance ("boom and bust") cycles which exacerbates pain (Andrews et al., 2012). If this is the case, self-efficacy has a complex role in the adaption to chronic pain. Pain self-efficacy is related to a number of psychosocial outcomes such as better physical, affective and social functioning (Somers et al., 2010), as well as being negatively associated with affective distress (Jackson, Wang, & Fan, 2014), pain intensity, disability and depression (Arnstein, Caudill, Mandle, Norris, & Beasley, 1999; Woby, Urmston, & Watson, 2007). Therefore, for those with chronic pain who already have high self-efficacy, whether that is pain self-efficacy or task self-efficacy, it is not advisable to attempt to adjust their level of self-efficacy. As part of activity pacing, training those with chronic pain to override immediate judgements of available resources for upcoming activities, based on self-efficacy beliefs, may be beneficial.

It is important to note that pain self-efficacy and task self-efficacy measure self-efficacy beliefs toward different objectives, i.e. toward coping with pain and toward task progress. The items of the PSEQ assess confidence in the ability to engage in activities and tasks despite pain (e.g. “I can still do many of the things I enjoy doing, such as hobbies or leisure activity, despite pain”, “I can still accomplish most of my goals in life, despite the pain”). Thus, the PSEQ addresses self-efficacy beliefs about ability to successfully engage in tasks more generally despite pain while the PSSS measured self-efficacy beliefs about ability to be successful at the specific experimental task at hand.

2.11.1 Limitations and future directions

One limitation of the study is that both samples were recruited online. It is possible that participants misrepresented their pain condition. However, the criteria for inclusion in the study required that pain had been experienced for six months and a rigorous screening process was used to assure that the data was valid. Although, the participants in this study may be more similar to a community sample than a patient sample. Patients with chronic pain tend to have low pain self-efficacy where the normative score for pain self-efficacy in patients has been reported as 25.5 of a range from 0-60 (Nicholas, Asghari, & Blyth, 2008). In this study, mean pain self-efficacy in the chronic pain groups were relatively high compared to the normative score in patient samples (study 1 M=32.8; study 2 M=33.3). Patterns of resource allocation across tasks may be different in a patient sample. In addition, this may explain why overall performance was not significantly worse in chronic pain participants, despite demonstrating a different relationship between resource allocation and performance. Therefore, it is important to replicate these results in different samples of people with chronic pain.

The study examined self-regulation across tasks but was focused on cognitive tasks which were completed within a relatively short amount of time. Therefore, further work is required to determine whether the findings can be replicated when applied to different goal contexts. For example, it would be useful to determine whether variation in self-regulatory fatigue, pain cognitions and self-efficacy affects variation in resource allocation and performance when pursuing goals day-to-day.

2.11.2 Conclusion

The present research has illustrated that self-efficacy is dynamic and directly affects the amount of resources allocated to tasks. In those with chronic pain, who have limited self-regulatory capacity, high self-efficacy is maladaptive to overall performance. This differed to that of the controls where self-efficacy was not detrimental to performance whether it was low, moderate or high. Moderate self-efficacy appeared to be most adaptive when considering overall performance across tasks. These findings do not support a limited resources view presented by the Strength Model. The above results have important implications for the psychological treatment of chronic pain as they challenge the assumption that higher self-efficacy universally leads to better outcomes in chronic pain.

3 Exploring the role of self-regulatory fatigue and pain self-efficacy in mood in chronic pain

3.1 Abstract

Objectives: The prevalence of depression and anxiety in chronic pain is higher than the general population. It has been proposed that the taxing nature of chronic pain results in chronic self-regulatory fatigue, which has been found to be related to mood. Pain coping cognitions such as pain self-efficacy and pain catastrophising may influence the relationship between self-regulatory fatigue and mood in chronic pain. This study aimed to investigate whether pain self-efficacy mediates the relationship between self-regulatory fatigue and anxiety and depression.

Methods: In a cross-sectional study, an online sample of participants (N=122) who reported chronic pain (pain>6 months) completed measures of self-regulatory fatigue, pain self-efficacy, pain catastrophising and anxiety and depression. Hierarchical multiple regressions and bias-corrected bootstrapping analyses were conducted.

Results: The analyses found that pain self-efficacy fully mediated the relationship between self-regulatory fatigue and depression, while controlling for pain catastrophising and anxiety. In contrast, after controlling for pain catastrophising and depression, there was no indirect effect of pain self-efficacy on the relationship between self-regulatory fatigue and anxiety.

Conclusion: This study is the first to examine whether pain self-efficacy could potentially mitigate the relationship between self-regulatory fatigue and negative mood in chronic pain. Increasing pain self-efficacy may facilitate decreases in depression. On the other hand, increases in pain self-efficacy may not be as effective at facilitating decreases in anxiety, but reducing self-regulatory fatigue may be.

The many physical, cognitive and emotional demands that occur when experiencing chronic pain (pain that has lasted for longer than the usual healing period of 12-16 weeks; IASP, 2019) make the management of pain in everyday life challenging. The pursuit of valued activities when experiencing chronic pain is particularly difficult due to the interruptive effects of the sensory experience of pain, as well as pain-related cognitions and distress (Bushnell et al., 2013; Eccleston & Crombez, 1999). Given that chronic pain gives rise to cognitive (e.g. catastrophic thinking styles and ruminative worry), emotional (e.g. distress related to change in social roles), behavioural (e.g. demands of employment) and physiological (e.g. pain, fatigue) demands, it is unsurprising that chronic pain is frequently associated with mood disorders.

It has been estimated that between 5-22% of community samples who self-report chronic pain experience depression (Bair et al., 2003; Munce & Stewart, 2007), while the estimate in patients with physician diagnosed chronic pain is between 6% and 46% (Atkinson et al., 1991; Bair et al., 2003; Gureje et al., 2001; Rayner, Hotopf, Petkova, Matcham, Simpson, & McCracken, 2016; Tsang et al., 2008). Similarly, estimates of the prevalence of anxiety disorders in those with chronic pain vary between 15% and 31% (Atkinson et al., 1991; Gerrits et al., 2014; Von Korff et al., 2005). When high proportions of people with chronic pain are experiencing mood disorders, it is important to examine factors that might impinge on the relationship between chronic pain and mood.

To cope with the challenges of managing chronic pain, and the effects it may have on mood, effective self-regulation is required. Self-regulation is the psychological process of adapting to challenges in the environment to ensure progress and achievement of goals and objectives (Carver & Scheier, 1998). However, capacity for self-regulation may be limited when self-regulatory demands, such as those in chronic pain, are high (Baumeister et al., 1998; Muraven & Baumeister, 2000; Muraven et al., 1998). Resource models of self-regulation

(Baumeister et al., 1998) suggest that engaging in self-regulation, such as resisting high caloric foods while attempting to lose weight or suppressing emotional responses, requires mental resources. The Strength Model proposes that capacity for self-regulation is determined by a domain-general self-regulatory resource, but these self-regulation resources are limited (Baumeister et al., 1998). The analogy of a muscle has been used to describe self-regulatory capacity where higher effort results in better performance but high levels of exertion cannot be sustained, meaning performance decreases as the muscle fatigues (Muraven & Baumeister, 2000). A central facet of the Strength Model is that after engaging in consistent self-regulatory effort, self-regulation resources are depleted or exhausted. This state of self-regulatory exhaustion is known as self-regulatory fatigue, where self-regulatory capacity is reduced and self-regulation performance is diminished (Baumeister et al., 1998).

Numerous experimental studies have found evidence for the hypothesis that self-regulatory capacity is limited, where continuing to exert self-regulatory effort results in self-regulatory fatigue (Baumeister et al., 1998; Hagger et al., 2010; Vohs et al., 2008). The standard experimental paradigm, known as the dual-task paradigm, requires participants to engage in an initial self-regulation task with the purpose of depleting self-regulatory resources. Immediately following the first task, a second self-regulation task is administered which assesses self-regulatory performance. Performance on the second self-regulation task is compared to another group of participants whose initial task did not require self-regulation. The group who completed the initial self-regulation task typically perform poorer on the assessment task than participants who did not engage in the initial self-regulation task (Baumeister et al., 1998). This is said to demonstrate that self-regulatory resources have been depleted.

In more recent years, discrepancies in the evidence base for the Strength Model have emerged (Carter et al., 2015; Hagger et al., 2016) which has led to other possible explanations for the phenomenon. For example, the conservation of resources hypothesis (Muraven et al., 2006) states that after self-regulatory exertion on an initial task, performance on the second task is affected not by depletion of resources but by conservation of resources. When participants are aware that they will need to exert self-regulation resources in the future, efforts are reduced and performance is diminished on self-regulation tasks (Muraven et al., 2006; Tyler & Burns, 2009). Furthermore, providing incentives to increase performance (e.g. monetary reward) can improve performance on subsequent self-regulation tasks after depletion of resources (Muraven & Slessareva, 2003). These findings suggest that resources were conserved after engaging in previous self-regulation, and not depleted. The act of conserving of resources after engaging in self-regulatory effort alludes to a role for motivation in self-regulation performance, where motivation for engaging in further effort is reduced and motivation to conserve resources increases when in a state of self-regulatory fatigue, although increasing motivation via increased performance incentives can overcome the performance deficits of those who were depleted (Baumeister et al., 2007; Giacomantonio et al., 2014; Muraven & Slessareva, 2003).

It has been hypothesised that people with chronic pain experience chronic self-regulatory fatigue, due to the taxing nature of experiencing chronic pain (Solberg Nes et al., 2010; Solberg Nes et al., 2009). Evidence for this hypothesis has been established when comparing a sample of healthy people and people with chronic pain due to fibromyalgia and temporomandibular disorder in an experimental study (Solberg Nes et al., 2010). In this experimental study, healthy participants who had engaged in a task requiring low levels of self-regulation performed significantly better than healthy controls who had engaged in a task requiring high self-regulation. However, people with chronic pain performed equally poorly in both the low and high self-regulation conditions. The authors concluded that people with chronic pain experience chronic self-regulatory fatigue and that this impacts on self-regulation performance even when the task only requires low levels of self-regulation. Furthermore, there was a dose-dependent relationship between pain and performance, whereby higher levels of pain were associated with poorer task performance. On the other hand, study one (chapter two) found that although the chronic pain group reported significantly higher self-regulatory fatigue than controls, no difference in performance between people with chronic pain and healthy controls or between high and low self-regulation conditions was found. This finding appeared to dispute the hypothesis that experiencing chronic self-regulatory fatigue as a result of persistent pain affects self-regulation performance.

Despite the mixed evidence that people with chronic pain perform poorer on self-regulation tasks after engaging in previous self-regulation compared to healthy controls, it has been suggested that self-regulatory fatigue may be useful in explaining outcomes in complex chronic conditions such as fibromyalgia (Solberg Nes et al., 2017). There is evidence for a concurrent negative relationship between self-regulatory fatigue and quality of life, particularly mental quality of life which is a composite construct composed of vitality, social functioning, role limitations due to emotional problems and mental health subscales of the Short Form (SF-36) quality of life measure (Hays, Sherbourne, & Mazel, 1993). This relationship was observed after controlling for anxiety, depression and fatigue in people with chronic pain (Solberg Nes et al., 2017).

Given the negative association between self-regulatory fatigue and outcomes in chronic pain, variables, which may augment or buffer the effects of self-regulatory fatigue on the management of chronic pain conditions have been identified. For example, people with chronic pain who were optimists only persisted longer on a task if they did not experience self-regulatory fatigue (Solberg Nes et al., 2011). Furthermore, pain willingness, a facet of pain acceptance where there is a willingness to engage in valued activities without attempting to reduce, avoid or change pain, was associated with lower levels of cognitive self-regulatory fatigue and psychological distress in people with chronic pain due to temporomandibular disorder (Eisenlohr-Moul et al., 2013). In addition, pain duration moderated the effect of pain willingness on psychological distress where the effect was stronger in those who had experienced pain for longer, and self-regulatory fatigue fully mediated this moderation. The authors concluded that pain willingness may buffer the effects of self-regulatory fatigue on psychological functioning, particularly for those who have experienced chronic pain for a longer duration (Eisenlohr-Moul et al., 2013). It has been argued that buffer variables, such as optimism and pain willingness, may exert their protective influence on self-regulatory fatigue via conservation of resources when future self-regulatory effort will be required (Eisenlohr-Moul et al., 2013; Solberg Nes et al., 2011).

An adaptive response to chronic pain may be achieving a balance between conservation and allocation of resources. Achieving this balance between allocation and conservation of resources has been demonstrated to be indicative of higher persistence and humour and lower depression and anxiety (Hasenbring et al., 2012). The findings from chapter two suggest that self-efficacy may affect whether resources are allocated or reserved. Self-efficacy beliefs determine how much effort will be exerted in the face of challenges, how long to persist on a task, and whether coping efforts are required (Bandura, 1977). Chapter two showed that self-efficacy influences self-regulation performance in those with chronic pain through its effect on allocation of resources. Using the dual-task paradigm, study one found that baseline pain self-efficacy was a significant predictor of self-regulation performance in the initial self-regulation task, indicating that as pain self-efficacy increased, so did self-regulation performance. On the second task, pain self-efficacy was a negative predictor of self-regulation performance, indicating that as baseline pain self-efficacy increased, self-regulation performance got poorer. It appeared that those with poorer initial pain self-efficacy conserved resources on the first task, only to perform well on the second task. Meanwhile, those with high initial pain self-efficacy used self-regulation resources and performed well on the first task, only to have reduced performance on the second task.

Study two (chapter two) found that higher task self-efficacy predicted higher allocation of resources (time) to a maths task in those with chronic pain. In addition, there was a negative curvilinear relationship between amount of resources allocated and performance where higher resource allocation led to higher performance up to a point, then overall performance decreased with additional resources allocated. Therefore, higher self-efficacy and resource allocation may not be adaptive when resources are limited. This may mean that there was support for the conservation of resources hypothesis dependent on level of pain self-efficacy, as also reported with levels of optimism and pain acceptance (Eisenlohr-Moul et al., 2013; Solberg Nes et al., 2011).

There is evidence of an association between both pain self-efficacy and pain catastrophising and mood in chronic pain. Pain catastrophising is a pain coping cognition characterised by a negative maladaptive thinking style with a tendency to amplify the threat value of pain (Quartana et al., 2009). A recent meta-analysis concluded that self-efficacy is significantly negatively related to affective distress in those with chronic pain (Jackson et al., 2014). Self-efficacy also mediates the relationship between pain intensity and disability and depression (Arnstein et al., 1999; Woby et al., 2007). Pain catastrophising is associated with depression in people with chronic pain (Edwards, Cahalan, Mensing, Smith, & Haythornthwaite, 2011; Sullivan & D'Eon, 1990), and higher psychological distress (Somers, Kurakula, Criscione-Schreiber, Keefe, & Clowse, 2012). The effects of self-efficacy and pain catastrophising on the relationship between self-regulatory fatigue and mood in chronic pain have not yet been examined.

It has been suggested that self-efficacy and pain catastrophising may have differential effects on the conservation of resources. Pain catastrophising is associated with fear-related avoidance behaviours and lower levels of physical exertion (Vlaeyen et al., 1995; Vlaeyen & Linton, 2000). Whereas, pain self-efficacy is related to active coping (e.g. task persistence) and physical, affective and social functioning in patients with rheumatoid arthritis (Somers et al., 2010; Turner et al., 2005). Pain self-efficacy is also associated with self-regulation of goal processes in chronic pain (Arends et al., 2013). Pain self-efficacy may be a protective factor in the relationship between self-regulatory fatigue and mood. Therefore, pain self-efficacy may mediate the relationship between self-regulatory fatigue and mood in chronic pain.

3.1.1 Study aims

In this study, the contribution of pain cognitions, namely pain self-efficacy and pain catastrophising, to the relationship between self-regulatory fatigue and mood was examined. Particularly, the aim was to identify factors which may protect against the effects of self-regulatory fatigue on mood. Pain catastrophising and pain self-efficacy are cognitions that are often targeted during psychological treatment for chronic pain such as pain education and cognitive-behavioural therapy (Burns, Day, & Thorn, 2012). Pain catastrophising and pain self-efficacy can effectively be modified through psychological treatment and changes in pain catastrophising and pain self-efficacy during treatment are significantly associated with improvements in outcomes (Altmaier et al., 1992; Burns et al., 2012; Craner, Sperry, & Evans, 2016; Smeets, Vlaeyen, Kester, & Knottnerus, 2006; Turner et al., 2007). Therefore, understanding the influence of these cognitions on the relationship between self-regulatory fatigue and mood may provide a better understanding of the mechanisms underlying the relationship as well as treatment for improving self-regulatory fatigue and mood.

As pain self-efficacy was the only pain cognition related to self-regulatory performance in study 1 and as the focus of this study was on factors associated with adaption in the relationship between self-regulatory fatigue and mood, pain self-efficacy was examined as a potential mediator in the relationship between self-regulatory fatigue and mood in chronic pain. Pain catastrophising is a pain cognition, which is also related to mood in chronic pain, and therefore, the influence of pain catastrophising on mood was controlled for.

3.2 Methods

3.2.1 Design

The study was an observational cross-sectional design. The data were collected as part of a larger study (see chapter 2, p50) where questionnaire data were collected prior to completing an experimental task.

3.2.2 Participants

The sample for this study was the participants from the chronic pain group recruited for study one of chapter two. For details on the recruitment method and inclusion criteria for this sample, see chapter two (p50). The sample for this study comprised of 122 participants (70 female, 50 male, 2 other).

3.2.3 Measures

Demographics: Participants self-reported their age, gender, marital status, years' of education, employment status and annual income.

Health assessment: Participants were asked to self-report any mental and physical health conditions they were experiencing, for how long they had experienced chronic pain and any medications they were taking.

Pain and Disability: The severity of chronic pain and disability were determined by the Chronic Pain Grade Scale (Von Korff et al., 1992). The Chronic Pain Grade Scale (CPGS) has three subscales with which chronic pain grade is calculated: pain intensity, disability points and disability score. Pain intensity is measured by three items which are all scored on an 11-point Likert Scale from 0-10: current pain, average pain over the past six months and worst pain in the past six months. These three items are summed, multiplied by ten and then divided by three to establish a composite overall pain intensity score. Disability score is calculated from three items which evaluate the extent to which pain has interfered with activities in the past six months and is calculated using the same formula as pain intensity. Disability points are given for the total disability score and number of disability days. Chronic pain is graded on a hierarchical scale from Grade I (low intensity-low disability), Grade II (high intensity-low disability), Grade III (high disability-moderately limiting), and Grade IV (high disability-severely limiting).

Self-regulatory fatigue: Self-regulatory fatigue, or a reduced capacity to self-regulate, was measured by the self-report Self-Regulatory Fatigue Scale (SRFS; Solberg Nes et al., 2013). The SRFS measures the extent to which capacity to self-regulate is reduced or fatigued by asking participants to rate how much they agree with statements which indicate either good self-regulation, "It is easy for me to set goals" or poorer self-regulation, "I get easily upset". The SRFS is an 18-item questionnaire with three subscales of emotional (7 items), cognitive (6 items) and behavioural (5 items) components of self-regulation. All items are scored on a 5-point Likert scale from 1-5 anchored with 'Strongly disagree' to 'Strongly agree' to provide a range of 18-90. Internal consistency for the scale was very good (Cronbach's α=.89).

Pain self-efficacy: The Pain Self-efficacy Questionnaire (PSEQ; Nicholas, 1989) measured pain self-efficacy. The PSEQ measures confidence in the ability to carry out a variety of tasks despite pain, for example, “I can enjoy things, despite the pain”. The scale has 10 items which assess pain self-efficacy on a 7-point Likert scale ranging from 0 (not at all confident) to 6 (completely confident). Item scores are summed to produce a range of 0-60 for the scale and lower scores indicate lower self-efficacy. Internal consistency was excellent (Cronbach’s α=.93).

Pain catastrophising: Pain catastrophising was measured using the Pain Catastrophising Scale (Sullivan et al., 1995). Pain catastrophising is a negative maladaptive thinking style where there is a tendency to amplify the threat value of pain (Quartana et al., 2009). The Pain Catastrophising Scale (PCS) measures three subcomponents of pain catastrophising: magnification (3 items, e.g. “I become afraid that the pain will get worse”), helplessness (6 items, e.g. “I feel I can't go on”) and rumination (4 items, e.g. “I can't seem to keep it out of my mind”). The 13-item scale is measured on a 5-point scale from 0-4, producing composite scores ranging from 0-52. Internal consistency for the PCS was high (Cronbach’s α=.94).

Depression and Anxiety: Depression and anxiety were assessed with the Hospital Anxiety and Depression Scale (Zigmond & Snaith, 1983). The Hospital Anxiety and Depression Scale (HADS) is a screening tool which measures the frequency that symptoms of depression and anxiety have occurred in the preceding week. The HADS consists of both depression (e.g. “I have lost interest in my appearance”) and anxiety (e.g. “I get sudden feelings of panic”) subscales. Each subscale consists of 7 items and the frequency of symptoms is evaluated on a scale form 0-3, producing a range of 0-21 per subscale where higher scores indicate symptoms have been experienced more frequently. The scale was designed for use in health populations by excluding measurement of physical symptoms of anxiety and depression such as aching muscles or palpitations to reduce confounding. The reliability for the anxiety subscale (Cronbach’s α=.84) and depression subscale (Cronbach’s α=.83) were very good.

3.2.4 Procedure

The study received ethical approval from the University Ethics Committee at the University of Strathclyde (approval number: Dixon/McMillan UEC 16/44). The survey was released to participants on Prolific who met the pre-screening filters discussed above. Participants viewed the title and a brief explanation of the study before proceeding to the survey via the Qualtrics link. The participants were presented with an information sheet and consent form and consent was gained from all participants. The participants completed the measures and then proceeded to an additional experimental task, as discussed in chapter two (p51). The participants were then presented with a debrief form. Data quality was checked prior to payment of the participants.

3.2.5 Analysis

The data were screened to detect the amount of missing data and the pattern of missing data as well as to determine the normality of the data and whether any assumptions had been violated (Tabachnick & Fidell, 2007). Normality was determined by viewing histograms and values for asymmetry and kurtosis between -2 and +2 were considered acceptable in order to demonstrate normal univariate distribution (George & Mallery, 2010). Univariate outliers were determined by a Z-score of more than three while the influence of multivariate outliers was assessed in several ways. Studentised residuals and Cooks distances were calculated. The cut offs of ±3 was applied for Studentised residuals and cut of 1 for Cooks distance were applied (Field, 2009). Multicollinearity was determined by a variance inflation factor of more than ten and tolerance of below one. Linearity and homoscedasticity were assessed by standardised residual plots where standardised residuals of ±3 were considered problematic (Field, 2009).

Means, standard deviations for each variable and bivariate correlations were calculated. To test the hypothesis, a series of hierarchical multiple regression analyses were carried out to test whether self-efficacy was a mediator of self-regulatory fatigue and anxiety and depression. For all regression analyses, age, sex and number of comorbidities and pain intensity were controlled for by entering them into the regression model at step one. If any of the control variables did not contribute significant variance after predictors were entered, they were removed from the model. Pain catastrophising and either anxiety or depression, depending on the DV, were entered as co-variates at step two. The predictor variable was entered at step three. The final models reported in the results only include those control variables which contributed significant variance to the model.

A mediation effect may be present when the IV is a significant predictor of the DV, the IV is a significant predictor of the proposed mediator, and when only the proposed mediator significantly predicts the DV when the IV and mediator are entered into a regression model together (Baron & Kenny, 1986). The first regression (*c'*-path or direct effect) established whether self-regulatory fatigue (*x* variable) predicted depression or anxiety (*y* variables). The second regression (*a*-path) tested whether self-regulatory fatigue predicted pain self-efficacy (*m* variable). Then, the last regression tests the total effect (*c*-path) and the indirect effect (*ab*-path) which encompasses the effect of the *x* variable on the *y* variable via the *m* variable. For this regression, self-regulatory fatigue and pain self-efficacy were entered into the model together as predictors of depression or anxiety. Additionally, to confirm that there was an indirect effect, bias-corrected bootstrapping was carried out using PROCESS (Hayes, 2013). Bootstrapping was carried out with the recommended 5000 samples (Efron & Tibshirani, 1993) with 95% confidence intervals (CIs).

3.3 Results

All variables had less than 5% missing data and so no further action was required (Tabachnick & Fidell, 2007) with missing data. Skewness and kurtosis statistics were not above 2 or below -2 for any variable and there were no univariate outliers. There were no variables where multi-collinearity or non-linearity was indicated. There were no cases where Cook's Distance was above one. When conducting regression (a), where self-regulatory fatigue was entered as the predictor of depression, there was one case where both the standardised residual and studentised residual were more than 3. There was also one case in regression (b), where self-regulatory fatigue was entered as the predictor of pain self-efficacy, in which the studentised residual was below -3. Regression analyses were conducted with these two cases removed and with these cases included. Including the cases did not affect the analyses and so analysis on the full sample is presented throughout. No assumptions were violated in any of the multiple regression analyses when investigating whether pain self-efficacy mediated the relationship between self-regulatory fatigue and anxiety.

Means and frequencies were calculated for demographic information, which are presented in table 3.1. As noted above (section 3.2.2, p100), these participants also took part in study one (chapter two). Therefore, the information in table 3.1 has been presented previously in table 2.1 (p61).

Table 3.1 Descriptive statistics for demographic information

Demographic information	**Total (*N*=122)**
Age (yrs) *M* (SD)	38.5 (12.6)
Years of education *M* (SD)	16.1 (3.7)
Gender *N* (%)	
Female	70 (57.4)
Male	50 (41.0)
Other	2 (1.6)
Race *N* (%)	
White British	99 (81.2)

Other	22 (18.0)
Missing	1 (0.8)
Marital Status *N* (%)	
Married	48 (39.3)
Living with Partner	34 (27.9)
Single	35 (28.7)
Employment *N* (%)	
Employed FT	62 (50.8)
Employed PT	28 (23.0)
Not in employment	32 (26.2)
Annual Income *N* (%)	
0-10,000	29 (23.8)
10,001-20,000	35 (28.7)
20,001-35,000	27 (22.1)
35,001-50,000	22 (18.0)
50,000+	9 (7.4)

As can be seen from table 3.1, the majority of the sample was Caucasian and British, female, married, in full-time or part-time employment and the majority earned less than £20,000 per year. Health status information is presented in table 3.2 below.

Table 3.2 Descriptive statistics for health status (*N*=122)

Health Descriptive Information (%)							
Pain Duration		**Source of pain**		**Comorbidities**		**CPG**	
3m-1yr	11.5	Back/shoulder/neck	35.2	Physical	10.2	Grade I	24
1-2yr	13.1	Knee/leg/foot	9.8	Mental	17.2	Grade II	27
2-5yr	31.1	Pelvis/hip	5.7	Both	8.2	Grade III	28
5-10yr	21.3	Arthritis	9.8	None	63.9	Grade IV	26
10-20yr	19.7	Sciatica	3.3				
		Fibromyalgia	4.1				
		CFS/ME	4.1				

*CPG =Chronic Pain Grade

Table 3.2 indicates that three quarters of the sample had experienced pain for more than 2 years, back, shoulder or neck pain was the most frequently reported source of pain, and a third had co-morbid health conditions. Descriptive data and bivariate correlations of the measured predictor and outcome variables are reported in table 3.3.

Table 3.3 Mean scores and Pearson's correlations between study variables

Variable	*M* (SD)	1	2	3	4	5	6
1. Pain	5.6 (2.0)	-					
2. Self-regulatory fatigue	56.3 (12.2)	.30**	-				
3. Anxiety	10.7 (4.5)	.28**	.73**	-			
4. Depression	8.4 (4.3)	.38**	.65**	.68**	-		
5. Pain Catastrophising	29.7 (11.4)	.52**	.57**	.54**	.56**	-	
6. Pain Self-Efficacy	32.8 (12.3)	-.41**	-.52**	-.36**	-.61**	-.53**	-

**=p<.001; Pain=average pain over past 6 months

It can be observed in table 3.3 that levels of anxiety and depression can be characterised as mild (Stern, 2014) and are equivalent to previously reported levels of anxiety and depression in chronic pain samples (Pallant & Bailey, 2005). Also, the relationships between self-regulatory fatigue and anxiety, depression, pain catastrophising and pain self-efficacy were stronger than the relationships between pain intensity and anxiety, depression, pain catastrophising and pain self-efficacy.

3.3.1 Mediation of self-regulatory fatigue and depression by pain self-efficacy

A series of hierarchical multiple regression analyses were conducted. Age, sex and number of comorbidities were excluded from the final model as these did not contribute significant variance to the model. The series of multiple regression steps explored the proposed mediation model, which is shown in figure 3.1.

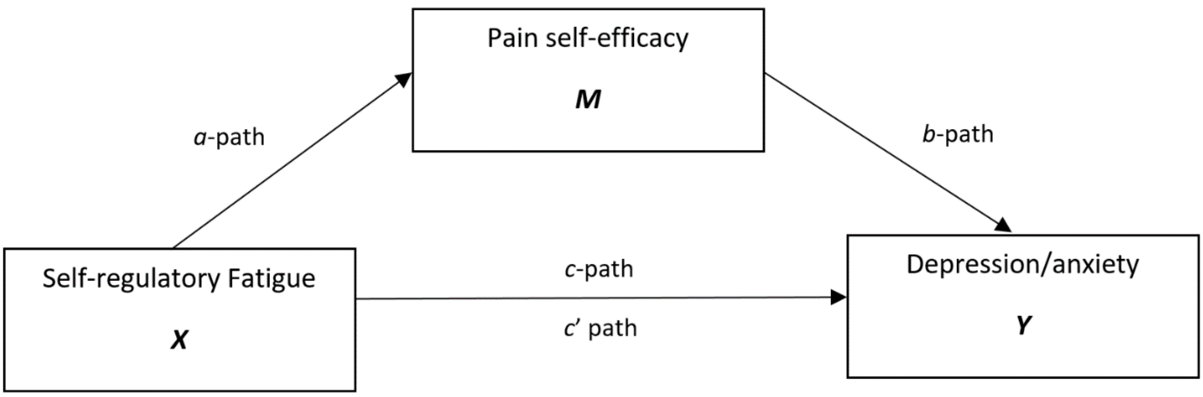

Figure 3.1 Proposed relationships between self-regulatory fatigue (IV), pain self-efficacy (mediator) and anxiety and depression (DVs).

The results of each multiple regression analyses are presented in table 3.4.

Table 3.4 Mediation effect of pain self-efficacy between self-regulatory fatigue and depression

Dependent variable Predictor variables	**F-test**	**Total R^2**	**ΔR^2**	**β**	***p*-value**
Depression (x→y)					
Step 1.	F(2, 119)=62.33, *p*<.001	.51	.51	.27	.001
Anxiety				.54	<.001
Step 2.	F(3, 118)=46.07, *p*<.001	.54	.03	.20	.011
Anxiety				.39	<.001
Self-regulatory fatigue				.26	.009
Pain self-efficacy					
Step 1.	F(2, 119)=24.30, *p*<.001	.28	.28	-.48	<.001
Anxiety				-.10	.295
Step 2.	F(3, 118)=22.23, *p*<.001	.35	.07	-.38	<.001
Anxiety				.14	.195
Self-regulatory fatigue				-.41	<.001
Depression *(x→m→y)*					
Step 1.	F(2, 119)=62.33, *p*<.001	.51	.51	.27	.001
Anxiety				.54	<.001
Step 2.	F(4, 117)=47.98, *p*<.001	.62	.11	.07	.386
Anxiety				.44	<.001
Self-regulatory fatigue				.11	.238
Pain self-efficacy				-.36	<.001

As table 3.4 shows, self-regulatory fatigue significantly predicted depression and accounted for a significant amount of variance over and above the contribution of pain catastrophising and anxiety. Self-regulatory fatigue was also a negative predictor of pain self-efficacy over and above the contribution of pain catastrophising. When self-regulatory fatigue and pain self-efficacy were entered into the model together at step two, the effect of self-regulatory fatigue on depression became non-significant and pain self-efficacy was a significant negative predictor of depression. This indicated that pain self-efficacy mediated the relationship between self-regulatory fatigue and depression. The bias-corrected bootstrapping mediation analysis was conducted without pain catastrophising as it did not add significant variance to the model. Figure 3.2 illustrates the mediation model.

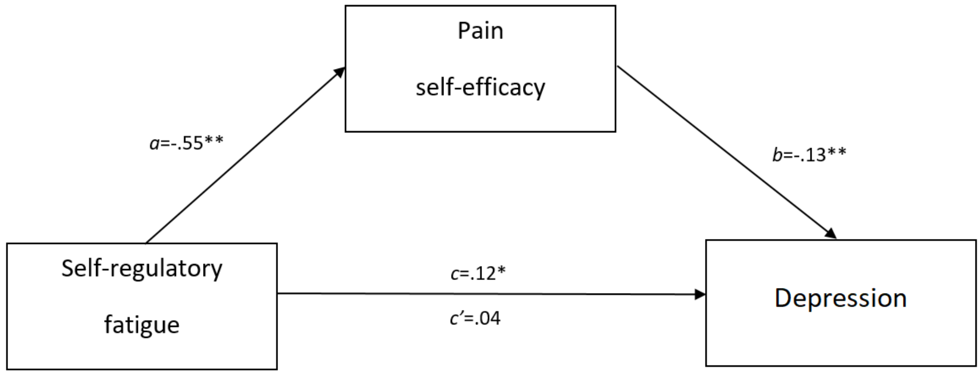

Figure 3.2 Standardised regression coefficients of the direct effect (*c'* path) and total effect (*c* path) between self-regulatory fatigue and depression

*p<.05, **p<.001

The bias-corrected bootstrapping analysis confirmed that the total effect of self-regulatory fatigue on depression was significant (TE=.12, t=3.55, p=.0005, 95% CIs .05, .18). The direct effect was non-significant (DE=.04, t=1.35, p=.180, 95% CIs -.02, .11). As shown in figure 3.2, there was an indirect effect meaning pain self-efficacy fully mediated the relationship between self-regulatory fatigue and depression (κ^2=.20, 95% CIs .10, .31) while controlling for the influence of anxiety.

3.3.2 Mediation of self-regulatory fatigue and anxiety by pain self-efficacy

The same analysis protocol was used to determine whether pain self-efficacy mediated the effect of self-regulatory fatigue on anxiety. Table 3.5 displays the results of each of the multiple hierarchical regression analyses. While age, sex, number of comorbidities and pain were controlled for, none of these variables contributed significant variance and so they were excluded from final analyses.

Table 3.5 Mediation effect of pain self-efficacy between self-regulatory fatigue and anxiety

Dependent variable Predictor variables	**F-test**	**Total R^2**	**ΔR^2**	**β**	***p*-value**
Anxiety (x→y)					
Step 1.	F(2, 119)=59.91, *p*<.001	.50	.50	.24	.003
Depression				.55	<.001
Step 2.	F(3, 118)=61.01, *p*<.001	.61	.11	.10	.174
Depression				.33	<.001
Self-regulatory fatigue				.46	<.001
Pain self-efficacy					
Step 1.	F(2, 119)=43.49, *p*<.001	.42	.42	-.28	.001
Depression				-.45	<.001
Step 2.	F(3, 118)=29.78, *p*<.001	.72	.00	-.24	.007
Depression				-.39	<.001
Self-regulatory fatigue				-.13	.186
Anxiety (x→m→y)					
Step 1.	F(2, 119)=59.91, *p*<.001	.50	.50	.24	.003
Depression				.55	<.001
Step 2.	F(4, 117)=51.59, *p*<.001	.64	.14	.16	.034
Depression				.42	<.001
Self-regulatory fatigue				.49	<.001
Pain self-efficacy				.23	.002

The first multiple hierarchical regression suggested that, controlling for pain catastrophising and depression, self-regulatory fatigue significantly predicted anxiety and contributed 46% of the variance. When controlling for pain catastrophising and depression, there was no relationship between self-regulatory fatigue and pain self-efficacy. Additionally, in the final hierarchical regression, where self-regulatory fatigue and pain self-efficacy were entered together in the model, pain self-efficacy was positively related to anxiety (β=.23, *p*=.002), despite a negative correlation between pain self-efficacy and anxiety (*r*=-.36, *p*<.001) demonstrated in table 3.3. In addition, the beta coefficient of self-regulatory fatigue increased from (β=.46, *p*<.001) to (β=.49, *p*<.001). This change in the valence of the relationship between pain self-efficacy and anxiety was unexpected, as was the increase in the beta weight of self-regulatory fatigue when pain self-efficacy was included. The unexpected findings may have resulted from shared variance between depression and the independent variables.

However, as the IV did not predict the proposed mediator in this case, we can conclude that pain self-efficacy did not act as a mediator in the relationship between self-regulatory fatigue and anxiety (Baron & Kenny, 1986). As a result, it was not necessary to conduct bias-corrected bootstrapping analysis in this case.

3.4 Discussion

The study has extended the current literature on the effects of self-regulatory fatigue on outcomes in chronic pain, and pain cognitions, which influence this relationship. The results indicated that self-regulatory fatigue is a significant predictor of both anxiety and depression in chronic pain. When controlling for pain catastrophising and anxiety, pain self-efficacy fully mediated the relationship between self-regulatory fatigue and depression, as hypothesised. When controlling for pain catastrophising and depression, self-regulatory fatigue was directly related to anxiety and contributed a large unique proportion of variance, but pain self-efficacy did not mediate this relationship.

Previous studies have suggested that self-regulatory fatigue, which occurs due to excess burden on the self-regulatory system, is related to outcomes that indicate adaption to chronic pain conditions (Solberg Nes et al., 2017). The findings of this study provide further supportive evidence of this by showing that self-regulatory fatigue predicts depression and anxiety. The results are also consistent with earlier research that has highlighted the significant and mediating role of self-efficacy on outcomes in chronic pain. The role of pain self-efficacy in mediating the effect of pain intensity on negative outcomes such as disability, distress and depression, has been demonstrated previously (Arnstein et al., 1999; Turner et al., 2005; Woby et al., 2007). Moreover, the results further contribute to our understanding of the factors which can potentially protect against the negative effects of self-regulatory fatigue, such as the observed protective effects of pain acceptance (Eisenlohr-Moul et al., 2013) and optimism (Solberg Nes et al., 2011).

This is the first study to examine pain self-efficacy as a potential protective factor against the negative effects of self-regulatory fatigue on depression and anxiety. Our current understanding of the factors that may buffer the impact of self-regulatory fatigue on outcomes in chronic pain, and the mechanisms by which this occurs, is limited. One mechanism, which has been proposed to explain the effect of protective factors on the relationship between self-regulatory fatigue and outcomes, is the conservation of resources. It was proposed that optimism facilitated the conservation of resources as optimism was not predictive of persistence in those with high self-regulatory fatigue (Solberg Nes et al., 2011). It was also suggested that the conservation of resources accounted for the mediating effect of self-regulatory fatigue on the relationship between pain willingness and psychological distress, although self-regulatory fatigue was measured using the mental fatigue subscale of the MFSI-SF only, the emotional and behavioural scales were not used (Eisenlohr-Moul et al., 2013). Therefore, the findings in this study build on previous research suggesting that buffer variables exert their influence over self-regulatory fatigue by facilitating conservation of resources when necessary (Eisenlohr-Moul et al., 2013; Solberg Nes et al., 2011).

Further to the evidence for the effects of buffer variables on self-regulatory fatigue (Eisenlohr-Moul et al., 2013; Solberg Nes et al., 2011), the findings in this study may suggest that pain self-efficacy facilitates allocation and conservation of resources when necessary. Recent evidence suggests that the role of self-efficacy in self-regulation is to determine appropriate resource allocation (J. W. Beck & Schmidt, 2018; Yeo & Neal, 2013) and that the effect of self-efficacy on resource allocation depends on availability of resources (J.W. Beck & Schmidt, 2018), such as self-regulatory resources. When resources are limited, self-efficacy is a moderator of resource allocation, which mediates the relationship between resources and performance (J.W. Beck & Schmidt, 2018). Those with high self-efficacy will perform well on one task and then reduce efforts on a later task which leads to poorer performance (J. W. Beck & Schmidt, 2012). Meanwhile those with low self-efficacy exhibit the opposite pattern where they tend to perform poorer on one task, only to increase their efforts and perform better on a subsequent task (J. W. Beck & Schmidt, 2012). This demonstrates that self-efficacy influences when resources are exerted and when they are conserved. Evidence for the effect of pain self-efficacy on the allocation of resources across tasks was found in the chronic pain group in study one (Chapter two), where higher initial pain self-efficacy predicted better self-regulation in an initial task but predicted poorer performance on a subsequent self-regulation task.

The role of pain self-efficacy in the allocation and conservation of resources may be particularly important in the management of depression in people with chronic pain. Previous research has shown that balance between avoidance and persistence is related to lower helplessness/hopelessness and depression in people with chronic pain (Hasenbring et al., 2012). The measurement of pain self-efficacy in this study asked participants to rate their confidence in their ability to participate in a variety of valued activities despite pain (Nicholas, 1989). Previous research has shown that pain self-efficacy is a predictor of active coping (Turner et al., 2005) and that low self-efficacy for pursuing valued activities related to self-worth is associated with depression (Bandura, 1982, 1986). And so, these results could demonstrate that feeling loss due to perceived inability to engage in behaviours which facilitate goal pursuit, under the circumstances of pain and self-regulatory fatigue, is associated with depression. The role of pain self-efficacy in facilitating allocation and conservation of resources may explain the full mediation of the relationship between self-regulatory fatigue and depression.

On the other hand, the threat caused by actual or perceived loss of physical or psychological resources, such as that experienced in self-regulatory fatigue, is a more important factor in the development of anxiety than confidence in one’s ability to partake in activities (A. T. Beck &

Emery, 1985; Clark, Beck, & Brown, 1989). For example, previously valued activities may be perceived as threatening when they draw on resources that are perceived to be limited. Therefore, it follows that pain self-efficacy has less influence on the relationship between self-regulatory fatigue and anxiety than between self-regulatory fatigue and depression. This may explain why self-regulatory fatigue contributed a substantial amount of variance toward anxiety, and why pain self-efficacy did not mediate this relationship. An earlier study of people with rheumatoid arthritis, found that loss of resources was the most significant factor in predicting anxiety and that the relationship between arthritis self-efficacy and anxiety became non-significant when loss of resources was entered into the regression model. However, loss of resources and arthritis self-efficacy were both important factors in predicting depression (Dirik & Karanci, 2010). Therefore, the findings of this study are consistent with the assertion that variables, such as pain self-efficacy, facilitate conservation of resources in those with chronic pain.

3.4.1 Limitations

This study demonstrated a potential mediatory relationship between self-regulatory fatigue, pain self-efficacy and depression. However, the relationship between self-regulatory fatigue, pain self-efficacy, anxiety and depression cannot be elucidated given the design of this study. Partly, this is a result of using the HADS as a measure of anxiety and depression. The HADS was designed to assess non-somatic symptoms of anxiety and depression to prevent confounding with symptoms from physical illness, such as aching muscles and heart palpitations (Snaith, 2003). The HADS has consistently demonstrated good internal consistency of subscales, concurrent validity, and sensitivity and specificity for caseness of anxiety and depression (Bjelland, Dahl, Haug, & Neckelmann, 2002). It has also been recommended that the HADS is considered the 'gold standard’ for assessing anxiety and depression in people with fibromyalgia (Boomershine, 2012). That said, the focus on measuring anhedonic depression and autonomic arousal may have diminished the ability of HADS to discriminate between anxiety and depression dimensions (Norton, Cosco, Doyle, Done, & Sacker, 2013).

There has been debate around the appropriate factor structure of the HADS (Cosco, Doyle, Ward, & McGee, 2012; Dunbar, Ford, Hunt, & Der, 2000; Norton et al., 2013). While a variety of factor structures have been demonstrated, there is mounting evidence for a bifactor structure where anxiety and depression have distinct components but there is a higher order dimension of general psychological distress or negative affectivity (Dunbar et al., 2000; Norton et al., 2013). This is opposed to the two-factor dimensionality hypothesised by Zigmond and Snaith (1983). The higher order 'general' factor has been found to account for the majority of common variance, meaning there is high saturation of this factor in the HADS (Norton et al., 2013). There are also mixed findings of the factor structure of the HADS in people with chronic pain (Luciano, Barrada, Aguado, Osma, & García-Campayo, 2014; Turk, Dworkin, Trudeau, Benson, Biondi, Katz et al., 2015). Therefore, it is unclear whether the HADS can measure separate anxiety and depression dimensions (Cosco et al., 2012; Norton et al., 2013). The heterogeneity is likely due, in part, to differences in statistical methods and populations (Cosco et al., 2012; Norton et al., 2013; Straat, van der Ark, & Sijtsma, 2013).

To attempt to measure the unique relationships between the predictors and anxiety and depression in this study, the anxiety dimension was controlled for when depression was the outcome variable, and vice versa. Given the evidence on the presence of a general psychological distress factor, controlling for each dimension may not have been sufficient. The presence of a higher order psychological distress factor may explain the changed relationships between the predictors and anxiety when controlling for depression. Although, ambiguity about the ability of self-report measures to discriminately measure anxiety and depression domains due to the presence of a general causal factor is not unique to the HADS

(Alfonsson, Wallin, & Maathz, 2017; Osman, Wong, Bagge, Freedenthal, Gutierrez, & Lozano, 2012; Steer, Clark, Beck, & Ranieri, 1999; Subica, Fowler, Elhai, Frueh, Sharp, Kelly et al., 2014).

The study recruited an online sample of participants who reported that they experienced pain for more than six months and it is possible that participants misrepresented their pain condition. However, the use of pre-screening filters, IMC's and stringent screening of data provides assurance that participants who were included in the sample were accurate in their reporting, both about their health status and when completing study questionnaires. Additionally, the study was a cross-sectional design and so the direction of relationships cannot be inferred.

3.4.2 Future directions and conclusions

Future research can rectify these limitations. Examining how self-regulatory fatigue and self-efficacy are related to the conservation of resources in chronic pain over time will provide more sound evidence for the hypothesis that self-efficacy buffers the effect of self-regulatory fatigue in determining outcomes in chronic pain. Methods that allow for the investigation of within-individual variation in self-regulatory fatigue and self-efficacy longitudinally may further elucidate the circumstances under which the exertion and conservation of resources occur in people with chronic pain. Therefore, longitudinal N-of-1 designs could provide the opportunity to examine the within-individual variation in depth and across time.

This study is the first to examine the influence of self-regulatory fatigue and pain self-efficacy on depression and anxiety in people with chronic pain. the findings here illustrate that pain self-efficacy plays a more important role in predicting depression than anxiety, as pain self-efficacy fully mediated the relationship between self-regulatory fatigue and depression. On the other hand, self-regulatory fatigue was a more significant factor in the prediction of anxiety, as demonstrated by a lack of mediation by pain self-efficacy. Although, it is important to note that the level of depression and anxiety in this sample was mild. Research continues to find that self-regulatory fatigue is associated with outcomes in chronic pain. Examining the mechanisms by which this occurs over time may enhance the ability of those with chronic pain to self-manage their condition.

4 Development and psychometric evaluation of short-forms of the Self-regulatory Fatigue Scale

4.1 Abstract

Objectives: The replication crisis within the ego-depletion literature has highlighted the need for reliable and robust research designs and methods. The development of valid and reliable measures of self-regulatory capacity are required. In the present study, 6-item (SRFS-6) and 3-item (SRFS-3) short-forms of the Self-regulatory Fatigue Scale (SRFS-18), a questionnaire measure of general self-regulatory capacity composed of three subscales, were developed and validated.

Methods: Items for the short-forms were selected by conducting secondary data analysis on a sample of people with chronic pain (*N*=122). Item-total and item-subscale correlations were examined to select one item for each subscale, which provided items for the SRFS-3. To select further items for the SRFS-6, a series of hierarchical regressions were performed to determine which items contributed the highest proportion of variance to the subscales and whole scale. Reliability and correlation analyses were then conducted on a separate sample of 201 healthy adults to determine whether the short-forms demonstrated adequate internal consistency and convergent validity.

Results: The SRFS-6 showed good internal consistency and there was minimal shrinkage in effect sizes between the SRFS-18 and SRFS-6. The SRFS-3 did not demonstrate good reliability or validity.

Conclusion: The study provides preliminary evidence that the SRFS-6 can be used to assess self-regulatory capacity in situations where quick administration or reduced participant burden is required.

It has been established that effective self-regulation and self-control supports positive outcomes such as educational attainment, psychosocial adjustment (e.g. higher self-esteem) and better social relationships than those with poorer self-control (Blackhart, Williamson, & Nelson, 2015; De Ridder et al., 2012; Tangney et al., 2004). Self-regulation is defined as the process of modulating thoughts, emotions and behaviours to expedite the pursuit of short and long-term goals (Carver & Scheier, 1998). Self-control is an aspect of self-regulation, most commonly understood as a range of mental processes that enable the inhibition of urges, impulses and temptations which threaten goal pursuit (Baumeister et al., 1998; Baumeister et al., 1994; Inzlicht & Berkman, 2015). Moreover, poor self-regulation and self-control are implicated in negative outcomes such as psychopathology (Karoly, 1993, 1999), negative health behaviours, such as excessive alcohol consumption (Hagger et al., 2009; Hall & Fong, 2007; Hustad, Carey, Carey, & Maisto, 2009; Whiteside, Chen, Neighbors, Hunter, Lo, & Larimer, 2007), and poorer adaption to chronic health conditions (De Ridder et al., 2008; Leventhal et al., 2005). Specifically, it has been proposed that deficits in self-regulation are a factor in the poor adaption to, and maintenance of, chronic pain conditions (Solberg Nes et al., 2010; Solberg Nes et al., 2009). Given that self-regulation and self-control are vital to optimal functioning, it is necessary to design research which will adequately capture the mechanisms of self-regulation as well as their effects on behaviour.

Dispositional self-control, or innate self-control ability, is primarily measured using self-report scales such as the Self-control Scale (Tangney et al., 2004). Associations have been found between trait self-control and other dispositional indicators of functioning such as attachment style, proneness to shame and aggression, conscientiousness, emotional stability and personality types such as avoidant and antisocial personality (Tangney et al., 2004). In addition to trait self-control, it has been hypothesised that there is a state capacity for self-control. The Strength Model proposes that state capacity for self-control is governed by a domain-general self-regulatory resource which is finite (Baumeister et al., 1998; Baumeister et al., 1994; Muraven & Baumeister, 2000). When self-regulatory resources are available this has been described as a subjective feeling of having energy available to the self (Ryan & Deci, 2008). Vitality has been described as subjectively experiencing feelings of physical and mental energy (Ryan & Frederick, 1997), while vigour can be explained as having physical and mental strength. Therefore, there is overlap between having self-regulatory resources available and the constructs of vitality and vigour. Self-regulatory resources have been described as similar to a muscle, where performance is higher with more effort but high levels of exertion cannot be sustained, meaning performance diminishes as the muscle fatigues. In a similar way, engaging in self-regulation uses energy from the limited resource which becomes fatigued and performance diminishes over time (Baumeister et al., 1998; Muraven et al., 1998). When self-regulatory resources are exhausted, this is known as ego-depletion or self-regulatory fatigue. A state of ego-depletion induces feelings of subjective fatigue (Baumeister et al., 1998; Hagger et al., 2010) which has been described as mental fatigue (Z. L. Francis & Job, 2018; Inzlicht & Berkman, 2015). While ego-depletion may contribute to feelings of physical fatigue (Dorris, Power, & Kenefick, 2012), there is evidence that an ego-depleted state is distinct from physical fatigue (Solberg Nes et al., 2013; Vohs et al., 2011).

However, in recent years the robustness of the ego-depletion effect has been challenged (Carter et al., 2015). Recent large-scale replication studies, using the usual dual-task paradigm, did not provided evidence for the Strength Model (Hagger et al., 2016). An updated meta-analysis, which used more unpublished work and updated methods, suggested that the ego-depletion effect is close to zero (Carter et al., 2015). Further, the early literature was plagued by small study effects, publication bias and ambiguous methodology which need to be addressed (Carter et al., 2015; Carter & McCullough, 2014). In addition, it is unclear whether even stringent dual-task paradigm tasks are measuring self-regulatory capacity. Two large-scale studies which used meta-analytic techniques found that there was no strong evidence for convergent validity between self-report self-control and inhibition-related experimental tasks such as the Stroop task and go/no-go task, as well as delay of gratification tasks (Duckworth & Kern, 2011; Saunders et al., 2018).

To address uncertainty within the literature, reliable and valid measures of self-regulatory capacity are required. The Self-regulatory Fatigue Scale (SRFS-18) was designed to be a measure of general self-regulatory capacity in the domains of cognitive, emotional and behavioural self-regulation (Solberg Nes et al., 2013). General self-regulatory capacity is said to encompass both trait and state components (Solberg Nes et al., 2013). Higher self-regulatory fatigue reflects lower self-regulatory capacity. The main purpose of the scale was to produce a measure that could demonstrate the extent of self-regulatory fatigue in people with chronic multisymptom illnesses, although the items are not specific to illness so could also be used in the general population. The final 18-item scale demonstrated good internal consistency and was distinct from, but related to, trait self-control and physical fatigue. The SRFS-18 was also more strongly related to emotional and mental fatigue (Solberg Nes et al., 2013) than physical fatigue. Self-regulatory fatigue, measured by the SRFS-18, is associated with quality of life, anxiety and depression in those with the complex pain condition of fibromyalgia syndrome (Solberg Nes et al., 2017).

Study designs that employ alternative ways to measure self-regulatory capacity may be useful in understanding the underlying mechanisms of self-regulatory fatigue. A problematic aspect of measurement within the ego-depletion literature is the reliance on the dual-task paradigm to test theory predictions. The Strength Model makes ideographic predictions (i.e. within-person), in that, an individual who engages in self-regulation efforts will exhaust self-regulatory resources over time and performance will be negatively affected. However, the majority of the Strength Model literature has used between-person designs (Hagger, 2010; Hagger et al., 2010). The use of within-subjects, repeated-measures paradigms have only recently been published and need further development. A within-subjects experimental design where participants completed an ego-depletion task, a recovery task, and then a control task within one lab visit have demonstrated susceptibility to carry-over effects (Z. L. Francis et al., 2018). Despite this, within-subjects repeated-measures designs do offer advantages, such as improved statistical power and modelling of individual variation. To that end, repeated-measures designs where participants undertake both ego-depletion and control conditions on different occasions could be more suitable. The use of this design found that effort and performance on a cycling task was significantly worse after an initial task of self-control than after a control task (Englert & Wolff, 2015).

Diary methods such as experiential sampling methods (ESM) and single-case designs, also known as N-of-1 studies, may also prove useful in capturing self-regulatory resources. A primary advantage of diary methods is that there is enhanced ecological validity of data due to measurement of psychological processes within an individual’s natural environment (Wheeler & Reis, 1991). Using these methods allows for more flexibility in examining how daily fluctuations in self-control resources are related to variables such as health behaviours, mood, psychosocial functioning and goal pursuit longitudinally.

While there are advantages to diary methods, there are also limitations. Obtaining data depends on the commitment of participants and so the most notable disadvantage of diary methods is potential for participant burden (Kwasnicka, Inauen, Nieuwenboom, Nurmi, Schneider, Short et al., 2019). Participant burden can arise from the length of time required to complete a diary entry, the frequency of diary entries or length of the data collection period (Iida, Shrout, Laurenceau, & Bolger, 2012). Participant burden can be problematic when it leads to poor adherence or attrition and addressing it requires balancing the need to generate valid and reliable data with managing burden (Bolger, Davis, & Rafaeli, 2003; Iida et al., 2012). For example, when daily diary entries are required for an extended time (e.g. 30 days) then it is advisable to reduce the length of time taken to complete the diary. This can be done by employing shortened versions of questionnaires that measure the desired constructs.

There are examples of diary studies of self-regulatory depletion that have employed short measures. For example, using four items which assessed how much participants had regulated their mood and thoughts and how much they had felt overwhelmed and handled stress through the day, it has been demonstrated that on days when self-control demands were higher than usual, more alcohol was consumed and levels of intoxication were higher (Muraven et al., 2005). On days when self-control capacity was lower, as measured by the Dutch version of the Self-control Scale, more binge-eating in female adolescents took place (Verstuyf, Vansteenkiste, Soenens, Boone, & Mouratidis, 2013). Under conditions of stress, self-regulatory ego-depletion was predicted by increased self-regulatory effort to regulate anxiety when job autonomy was low (Prem, Kubicek, Diestel, & Korunka, 2016). Meanwhile on more stressful days, higher self-regulatory fatigue as measured by the State Self-control Capacity Scale (Bertrams, Unger, & Dickhäuser, 2011) were associated with more negative behaviours within couples (Buck & Neff, 2012). Another diary study reported that those with higher chronic ego-depletion engaged in higher mental effort towards goals but had poorer goal adherence over the course of one week (Wang, Tao, Fan, Gao, & Wei, 2015). Chronic ego-depletion was measured with an adapted Chinese version of the Self-regulatory Fatigue Scale but only at baseline, which would not have allowed daily variation in ego-depletion to be recorded. While diary methods provide further means to evaluate the Strength Model, they are infrequently used, particularly in populations with chronic illness. Currently, it is not clear whether the reliability and validity of self-report measures of self-regulatory depletion used in previous diary studies have been established in general and, in particular, for daily measurement.

4.1.1 Study aims

As chronic self-regulatory fatigue is experienced in those with long-term chronic illness, the availability of methods, which can capture daily variation in self-regulatory fatigue may highlight mechanisms involved in effective self-management of pain conditions. Therefore, the aim of this study was to develop and validate short-form versions of the SRFS-18 (Solberg Nes et al., 2013) which could measure daily variation in self-regulatory fatigue.

First, items for a 6-item version and a 3-item version of the SRFS-18 were selected by conducting secondary data analysis on a sample of people with pain conditions. Then, in an independent adult healthy sample, the short-forms were examined for internal consistency, strength of association to the original SRFS-18 and convergent validity with related constructs. It was hypothesised that both short-forms would correlate very highly with the original scale as well as each other ($r \geq .70$). It was hypothesised that the short-form subscales would correlate highly with the subscales of the SRFS-18, namely, cognitive, behavioural and emotional subscales. It was expected that the SRFS-18 would have a moderate negative association with dispositional self-control, a moderate positive association with physical fatigue, a high positive association with mental and emotional fatigue and a high negative association with vigour and vitality. Evidence for convergent validity of the short-forms would be provided if the short-forms maintained these relationships with trait self-control, physical fatigue, mental fatigue, emotional fatigue, vigour and vitality and if there was only a small reduction in the relationship effect sizes between the original scales and the short-forms.

4.2 Methods

4.2.1 Design

The study was a cross-sectional correlational design.

4.2.2 Participants

Stage 1: Participants for Item selection. As the Self-Regulatory Fatigue Scale (Solberg Nes et al., 2013) is intended to measure self-regulatory capacity in those with chronic multisymptom illnesses, the item selection process was conducted with a sample of people with chronic pain. The participants for stage 1 were the sample of people with chronic pain recruited for study one (chapter two, p50). There were 122 (70 female, 50 male, 2 other) participants included in the final sample (M_{age}=38.5 years, SD=12.6 years). Most participants (52.4%) reported that they had experienced pain for 2-10 years while participants less frequently reported shorter pain durations (3 months-1 year=11.5%; 1-2 years=13.1%) and longer pain durations (10-20 years=19.7%). The majority of participants reported that they had no comorbidities in addition to their pain conditions (63.9%) while some participants reported physical comorbidities (10.3%), mental comorbidities (17.3%) and both physical and mental comorbidities (8.4%).

Stage 2: Scale validation of 3 & 6-item short forms. A sample of 203 healthy participants completed measures of Self-regulatory fatigue, trait self-control, fatigue and subjective vitality and the 3-item and 6-item short forms. Participants were recruited through the University of Strathclyde (N=162), the University of West of Scotland (N=14), social media (N=8) and recruitment websites Call For Participants (N=10) and SurveyCircle (N=9). The inclusion criteria for the study was that participants must be over 18 years old and not be experiencing any physical or mental health conditions. Two participants were removed from the final sample as they had engaged in satisficing (e.g. chosen the same response on every item), leaving a final sample of *N*=201 (166 females; M_{age}=23.6 years, SD=9.8 years).

4.2.3 Measures

Self-regulatory Fatigue: The SRFS-18 is an 18-item scale which evaluates self-regulatory capacity in cognitive, emotional and behavioural domains in people with chronic multisymptom illnesses (Solberg Nes et al., 2013). Items measure self-regulatory fatigue on a 5-point Likert scale from 1 (Strongly Disagree) to 5 (Strongly Agree) to produce a score range of 18-90 where higher scores indicate higher self-regulatory fatigue and lower self-regulatory capacity. As the SRFS-18 measures general self-regulatory capacity, items capture both trait and state components (e.g. "I feel moody" and "It's easy for me to set goals"). Therefore, the SRFS-18 is not a measure of phasic "in-the-moment" resource depletion. There are 6 items in the cognitive subscale (e.g. and "I have difficulties remembering things"), 5 items in the behavioural subscale (e.g. "I have urges to hit, throw, break, or smash things") and 7 items in the emotion subscale (e.g. "I handle stress well").

Trait Self-control: The Brief Self-control Scale (Tangney et al., 2004) is a 13-item abbreviated version of the 36-item Self-control Scale (Tangney et al., 2004). The BSCS measures dispositional self-control in several domains such as controlling thoughts and emotions (e.g. "I have trouble concentrating"), regulating impulses and behaviour (e.g. "I am able to work effectively toward long-term goals"), and breaking habits (e.g. "I have a hard time breaking habits"). Trait self-control is measured on a 5-point Likert scale from 1 (Not at all) to 5 (Very much) producing a range from 13-65 where higher scores indicate higher self-control. The reliability of the BSCS in this study was high (Cronbach's α=.86).

Fatigue: The Multidimensional Fatigue Symptom Inventory Short Form (MFSI-SF) (Stein, Jacobsen, Blanchard, & Thors, 2004; Stein, Martin, Hann, & Jacobsen, 1998) is a 30-item scale which assesses fatigue across five facets of general fatigue (e.g. "I am worn out"; Cronbach's α=.88), emotional fatigue (e.g. "I feel upset"; Cronbach's α=.68), mental fatigue (e.g. "I have trouble remembering things"; Cronbach's α=.84), physical fatigue (e.g. "My muscles ache"; Cronbach's α=.87) and vigour (e.g. "I feel lively"; Cronbach's α=.66). Fatigue is described on a 5-point Likert scale from 0 (Not at all) to 4 (Extremely) and a total fatigue score is produced by summing all subscales and then subtracting the vigour subscale. Each subscale has a range of 0-24 where higher scores demonstrated higher fatigue.

Subjective Vitality: The Subjective Vitality Scale (Ryan & Frederick, 1997) measures subjective feelings of vitality or having energy. The scale measures subjective vitality on a 7-point Likert scale from 1 (Not at all true) to 7 (Very True). There is a trait version (e.g. "I have energy and spirit") and state version (e.g. "At this moment, I feel alive and vital") of the scale. In addition, while the original version had 7 items, further validation of the scale demonstrated that a 6-item version which removed the only reverse scored item from the original scale demonstrated better reliability and validity (Bostic, Rubio, & Hood, 2000). Therefore, the 6-item trait version was used in this study and this provided score range of 6-42 where higher scores indicated higher trait vitality. The reliability of the SVS in this study was excellent (Cronbach's α=.91).

4.2.4 Procedure

Stage 1. The study received ethical approval from the University Ethics Committee at the University of Strathclyde (approval number: Dixon/McMillan UEC 16/44). The Qualtrics survey was released to participants on Prolific who met the inclusion criteria. Participants viewed the title and a brief explanation of the study before proceeding to the survey via the Qualtrics link. The participants were presented with an information sheet and consent form and consent was gained from all participants. The participants completed the SRFS-18 and measures of mood and pain-related coping, although only analyses conducted on the SRFS-18 are discussed here. The participants were then presented with a debrief form. Data quality was checked prior to payment of the participants.

Stage 2. Ethical approval for this study was obtained from the Psychological Sciences and Health School Ethics Committee (approval number: 05/14/12/17/A). Participants were invited to take part through online advertising for the department of psychology participant pool, through social media or participant recruitment websites. Participants either contacted the researcher to access the study or used the anonymous Qualtrics link to access the study online. The participants completed the study online in their own time. Participants were presented with the information sheet and consent form then completed the SRFS-18, BSCS, MFSI-SF, the 6-item SRFS short form (SRFS-6), the SVS and the 3-item SRFS short form (SRFS-3). The debrief form was then presented.

4.3 Analysis

4.3.1 Stage 1: Item selection

The item selection process followed an analytical strategy recommended and used previously to construct short-forms from original scales (Jensen, Strom, Turner, & Romano, 1992; Nicholas, McGuire, & Asghari, 2015; Riddle & Jensen, 2013; Widaman, Little, Preacher, & Sawalani, 2011). Step 1 included selecting items which would represent the scale as a whole, and each of the cognitive, behavioural and emotion subscales. Therefore, the three items which had the highest item-total and item-subscale correlation for each subscale were selected first. This produced the 3-item version. the item with the highest item-total and item-subscale correlation was selected. To develop the 6-item version, a second step was included to select a further three items, i.e. another one item per subscale. Step 2 entailed conducting a series of multiple hierarchical regressions with the SRFS-18 subscales as dependent variables. The item with the highest item-total and item-subscale correlation was entered first into a regression and the remaining items for the subscale were next entered as predictors one at a time. For example, to construct the 6-item short form cognitive subscale, 4 regressions were conducted sequentially where the SRFS-18 cognitive subscale (which has 5 items) was the dependent variable. This procedure was conducted to determine which two items accounted for the most variance in each subscale. Where there were negligible differences in beta weights between items of the subscales, additional consideration was given to which items provided the best indications of content of the construct.

4.3.2 Stage 2: Scale Validation

For the validation of the scales, missing data was checked initially with a missingness map. Univariate outliers were identified as having a Z-score of ±3. Skewness and kurtosis statistics were calculated and histograms were checked visually to determine variables demonstrated a normal distribution. Spearman's correlation coefficients were reported where normality and linearity assumptions were violated. The means and standard deviations of the original SRFS-18, the 6-item short form and 3-item short forms of the SRFS and the other measures were calculated. The analysis followed recommended steps of examining reliability and construct validity (Cronbach & Meehl, 1955; Widaman et al., 2011). For step 1, the internal consistency of all measures and subscales was calculated using Cronbach's alpha (Cronbach, 1951). In step 2, correlations were conducted to determine whether the short form subscales were correlated to the original SRFS-18 subscales. To complete step 3, construct validity of the short-forms was assessed by conducting correlations to determine whether the original SRFS-18 and short forms were associated with measures of related constructs. Scatterplots were examined to determine whether associations met the assumption of linearity. It has been recommended that to demonstrate convergent validity, the short form should maintain the same relationships within the nomological network as the original scale (Cronbach & Meehl, 1955; Widaman et al., 2011).

4.4 Results

4.4.1 Stage 1: Item selection

Step 1: Item-total and item-subscale correlations. As stated in chapter three (p105), all variables had less than 5% missing data and so no further action was required. First, Pearson's correlations were conducted to examine the item-total and item-subscale correlations of the SRFS-18 to determine which items were most highly correlated with the whole scale and the subscales. Pearson's correlations are presented in table 4.1.

Table 4.1 Item-total correlations and item-subscale correlations for the SRFS-18

Item	Item-total	Cognitive	Emotion	Behaviour
SRFS 1	$.58^{**}$	$.76^{**}$	-	-
SRFS 2	$.47^{**}$	$.74^{**}$	-	-
SRFS 3	$.29^{**}$	$.52^{**}$	-	-
SRFS 4	$.61^{**}$	-	-	$.84^{**}$
SRFS 5	$.69^{**}$	$.77^{**}$	-	-
SRFS 6	$.67^{**}$	-	-	$.73^{**}$
SRFS 7	$.72^{**}$	-	$.83^{**}$	-
SRFS 8	$.32^{**}$	-	-	$.53^{**}$
SRFS 9	$.34^{**}$	-	$.49^{**}$	-
SRFS 10	$.62^{**}$	-	$.73^{**}$	-
SRFS 11	$.62^{**}$	-	-	$.77^{**}$
SRFS 12	$.51^{**}$	$.66^{**}$	-	-
SRFS 13	$.50^{**}$	-	$.73^{**}$	-
SRFS 14	$.40^{**}$	$.65^{**}$	-	-
SRFS 15	$.30^{**}$	-	$.51^{**}$	-
SRFS 16	$.65^{**}$	-	$.74^{**}$	-
SRFS 17	$.51^{**}$	-	-	$.74^{**}$
SRFS 18	$.59^{**}$	-	$.65^{**}$	-

$^{**}p<.001$, SRFS=Self-regulatory Fatigue Scale

Table 4.1 demonstrates that 12 of the 18 items were highly correlated with the total scale where $r \geq .50$ (Cronbach, 1951). The remaining six items were correlated moderately with the total scale. All items correlated highly with their intended subscale except item 9. Table 4.1 indicates that the item with the highest item-total correlation was item 7 and this item was also most highly correlated to the emotion subscale and so it was selected for the emotion subscale of the short-forms. Item 5 was selected for the cognitive subscale as it was most highly correlated with the cognitive subscale, as well as demonstrating the second highest item-total correlation. Item 4 was very strongly correlated with the behaviour subscale as well as demonstrating a strong item-total correlation and so was selected as an indicator of the behaviour subscale.

Step 2: Additional item selection. A series of hierarchical regressions were conducted to select additional items for each subscale. Items that accounted for the largest proportion of variance in each subscale after accounting for the proportion of variance explained by item 5, item 7 and item 4 for the cognitive, behaviour and emotion subscales respectively. The regressions are presented in table 4.2, for efficiency and to avoid repetition, results for item 4, 5 and 7 have been provided initially but not for each subsequent regression, i.e. step 2 for each item within each subscale shows data after the variance explained by the item in step 1 has been accounted for.

Table 4.2 Proportion of variance contributed by items to the corresponding subscale while controlling for the item with highest item-subscale correlation (item in step 1 for each subscale)

Predictors	**Total R^2**	**R^2 Change**	**F change**	**Std Beta**
Dependent variable: Cognitive subscale				
Step 1: Item 5	.60	.60	$F(1, 120)=175.78$, $p<.001$	$.77^{**}$
Step 2: Item 1	.79	.19	$F(2, 119)=222.05$, $p<.001$	$.51^{**}$
Step 2: Item 2	.76	.16	$F(2, 119)=183.85$, $p<.001$	$.47^{**}$
Step 2: Item 3	.68	.08	$F(2, 119)=127.67$, $p<.001$	$.31^{**}$
Step 2: Item 12	.62	.12	$F(2, 119)=96.43$, $p<.001$	$.18^{**}$
Step 2: Item 14	.74	.14	$F(2, 119)=222.05$, $p<.001$	$.41^{**}$
Dependent variable: Emotional subscale				
Step 1: Item 7	.68	.68	$F(1, 120)=255.04$, $p<.001$	$.83^{**}$
Step 2: Item 9	.74	.06	$F(2, 119)=173.03$, $p<.001$	$.27^{**}$
Step 2: Item 10	.78	.10	$F(2, 119)=212.56$, $p<.001$	$.39^{**}$
Step 2: Item 13	.75	.07	$F(2, 119)=181.48$, $p<.001$	$.33^{**}$
Step 2: Item 15	.77	.09	$F(2, 119)=194.32$, $p<.001$	$.30^{**}$
Step 2: Item 16	.77	.09	$F(2, 119)=200.99$, $p<.001$	$.38^{**}$
Step 2: Item 18	.78	.10	$F(2, 119)=207.05$, $p<.001$	$.35^{**}$
Dependent variable: Behaviour subscale				
Step 1: Item 4	.71	.71	$F(1, 120)=294.78$, $p<.001$	$.84^{**}$
Step 2: Item 6	.83	.12	$F(2, 119)=297.24$, $p<.001$	$.40^{**}$
Step 2: Item 8	.83	.12	$F(2, 119)=284.60$, $p<.001$	$.35^{**}$
Step 2: Item 11	.79	.08	$F(2, 119)=218.58$, $p<.001$	$.37^{**}$

Step 2: Item 17	.80	.09	F(2, 119)=235.58, *p*<.001	.37**

**p<.001

As shown in table 4.2, for the cognitive subscale, the item which provides the highest additional proportion of variance is item 1. For the emotional subscale, the R^2 change was similar for items 10, 15, 16 and 18. Item 10 had the highest beta weight (β=.39, *p*<.001) but item 16 (β=.38, *p*<.001) was only lower by .01. Therefore, to select an additional item for the emotion subscale, item-total and item-subscale correlations, and content of the remaining 4 items were also considered. As can be seen from tables 4.1 and 4.2, item 16 performed the best overall with the second highest item-total correlation and second highest item-subscale correlation as well as high R^2 change and additional proportion of variance. Item 15 ("I find it easy to stick to a healthy diet") was discarded as it was judged by the author (GM) to be the least representative of the emotional component of the self-regulatory capacity construct. It was judged that item 16 ("I feel moody") provided the best coverage of the emotional subscale. Item 16 was therefore selected for use. For the behaviour subscale, the R^2 change of items 6 and 8 after including item 4 at step 1 were the same, but item 6 accounted for the highest proportion of variance (β=.40, *p*<.001) of the behaviour subscale and was selected for use. Therefore, items 1, 4, 5, 6, 7 and 16 were selected for the 6-item short-form and items 4, 5 and 7 were selected for the 3-item short-form. Please see appendix 1 (p244) for the full list of 18 items and items included in the SRFS-6 and SRFS-3.

4.4.2 Stage 2: Psychometric evaluation

After items were selected for the short forms in step 1, analysis was conducted on a different healthy adult sample to determine the reliability and validity of the new short form scales. Missing data was checked using a missingness map in SPSS. One participant had not completed the 3-item SRFS short form due to error but there were no other missing data. This meant no variable had more than 5% missing data and so missing data was not deemed problematic (Tabachnick & Fidell, 2007). There were four univariate outliers. Analyses were conducted with and without outliers to determine if outliers effected associations. Analyses are reported with outliers included as there was no difference in magnitude of associations when outliers were included or excluded.

Step 1: Reliability. The internal consistency for each scale and the subscales of the SFRS-18 and SRFS-6 were calculated. The Cronbach's alpha of each of the original scales and subscales are presented in table 4.3.

Table 4.3 Internal consistency of original and short form scales and subscales

	Cronbach's α		
Subscale	**SRFS-18**	**SRFS-6**	**SRFS-3†**
Cognitive	.62	.50	-
Emotional	.74	.71	-
Behaviour	.67	.51	-
Total	.82	.71	.25

†Note. Cronbach's alpha could not be calculated for the 3 item version subscales as there was only 1 item per subscale.

The internal consistency of the SRFS-18 and SRFS-6 were good. The Cronbach's alpha coefficients for the subscales of the SRFS-18 and SRFS-6 were also acceptable. While there was little change in the internal consistency of the emotion subscale from the SRFS-18 to the SRFS-6, the behaviour and cognitive subscales had lower internal consistency on the SRFS-6.

However, the internal consistency of the 3-item SRFS was very poor. Further investigation found that item 2 on the SRFS-3 (item 5 from the SRFS-18) was not correlated to item 1 (item 4 from the SRFS-18), r=-.08, p=.284, although there was a small positive correlation between item 3 (item 7 on the original scale) and item 2, r=.19, p=.007. There was also a small positive correlation between item 1 and item 3 on the SRFS-3, r=.19, p=.025. Additionally, the Cronbach's alpha if item 1 was deleted would be higher (Cronbach's α=.27) as well as if item 2 was deleted (Cronbach's α=.32), albeit still poor. If item 3 was deleted, Cronbach's alpha would be negative (Cronbach's α=-.17) suggesting item 3 was vital to the scale. The negative Cronbach's alpha indicates that the scale has poor internal consistency and that there is negative average covariance between items.[1]

Step 2: Relationship between SRFS-18 and short-form subscales. Associations between SRFS-18 and the short-form subscales were investigated and are presented in table 4.4. Pearson's correlations were conducted between SRFS-18 and SRFS-6 subscales and between the SRFS-18 and SRFS-3 cognitive and emotional subscales. Spearman's rho was conducted between the SRFS-3 behaviour subscale and SRFS-18 subscales due to skewness of the SRFS-3 behaviour subscale.

Table 4.4 Associations between SRFS-18 and short-forms

	Correlation coefficients			
	SRFS-18	**Cognitive**	**Emotional**	**Behaviour**
SRFS-6	.82**			
Cognitive		.60**	.49**	.24**
Emotional		.46**	.79**	.39**
Behaviour		.45**	.39**	.79**
SRFS-3	.63**			
Cognitive		.20**	.15*	.03
Emotional		.41**	.75**	.33**
Behaviour		.28**	.27**	.67**

**p<.001, *p<.05

Table 4.4 demonstrates that the relationship between the SRFS-18 and SRFS-6 was very strong. The correlations between the SRFS-18 and the corresponding SRFS-6 subscales were

[1] A negative Cronbach's alpha value can also indicate that coding or reverse scoring has not been conducted correctly. The coding and reverse scoring of the item (SRFS-18 item 5; "I have no trouble making decisions") was checked on the SRFS-18 and short-forms. Inter-item correlations of item 5 demonstrated it was not negatively correlated to other items on the SRSF-18 or SRFS-6 and would not increase Cronbach's alpha if deleted. In another study, a participant communicated that they had responded to this item inversely using the SRFS-6 while completing daily diaries (e.g. "I have trouble making decisions") and had then realised their mistake. It is possible that some participants in the current study also made this mistake.

good (e.g. were 0.6 or above). Moderate to strong relationships were demonstrated between the remaining SRFS-18 and SRFS-6 subscales.

The relationship between the SRFS-18 and SRFS-3 was strong but with discernible shrinkage from the relationship between the SRFS-18 and SRFS-6 (*r*=.19). The correlations between the SRFS-18 and SRFS-3 emotional and behaviour subscales were good. However, there was only a small association between the SRFS-18 and SRFS-3 cognitive subscale.

Step 3: Construct Validity. Construct validity was assessed by associations between scales which measure related constructs and the SRFS-18 and short-forms. The means and standard deviations of each scale are presented in table 4.5.

Table 4.5 Means and standard deviations of scales

Scale	**Score range**	***M* (SD)**
Self-regulatory Fatigue Scale (18 –item)	18-90	49.6 (9.1)
Self-regulatory Fatigue Scale (6 –item)	6-30	16.0 (4.1)
Self-regulatory Fatigue Scale (3 –item)	3-15	7.7 (2.0)
Multidimensional Fatigue Scale Short		
General Fatigue	0-24	9.1 (5.4)
Physical Fatigue	0-24	4.4 (4.5)
Mental Fatigue	0-24	6.8 (4.7)
Emotional Fatigue	0-24	8.1 (4.0)
Vigour Fatigue	0-24	11.4 (3.6)
Brief Self-control Scale	13-65	39.6 (8.9)
Subjective Vitality Scale	6-42	23.0 (7.3)

Correlations between the related constructs and the SRFS-18 and short-forms are presented in table 4.6.

Table 4.6 Pearson correlations between scales of related constructs and the SFSR-18 and short-forms

Related variables	SRFS-18	SRFS-6	SRFS-3†
Fatigue (MFSI-SF)			
General	.59**	.59**	.41**
Physical†	.30**	.30**	.24**
Mental	.54**	.55**	.45**
Emotional	.60**	.67**	.54**

Vigour	-.50**	-.57**	-.37**
Trait self-control (BSCS)	-.57**	-.51**	-.36**
Vitality (SVS)	-.55**	-.58**	-.30**

†Spearman's rho is reported where correlations included the SRFS-3 and the MFSI-SF physical fatigue subscale due to violations of normality and linearity.
** $p<.001$, MFSI-SF= Multidimensional Fatigue Symptom Inventory Short-form, BSCS=Brief Self-control Scale, SVS=Subjective Vitality Scale

As displayed in table 4.6, the SRFS-18 was more strongly related to mental fatigue, emotional fatigue and vigour than physical fatigue. The SRFS-18 was also strongly associated with trait self-control and strongly negatively related to vitality. These were consistent with the hypotheses. The relationships between the SRFS-6 and the related variables were comparable to the SRFS-18 although there were slight increases in the associations with emotional fatigue, mental fatigue, vigour and vitality compared to the SRFS-18. In contrast, only associations between the SRFS-3 and physical fatigue, mental fatigue and emotional fatigue did not decrease by more than r=.10 compared to the original scale. Therefore, the hypothesised relationships between the SRFS-18 and SRFS-6 and the related constructs were observed. The proposed relationships between related constructs and the SRFS-3 were not always observed. The results provide evidence that the SRFS-6 demonstrated adequate construct validity but construct validity for the SRFS-3 was less satisfactory.

4.5 Discussion

The purpose of this study was to develop short-form versions of the self-regulatory fatigue scale which could be used in daily diary research and to validate them. Two short-forms were developed, one with 6-items and one with 3-items. The SRFS-6 was highly correlated with the original SRFS-18 and its three subscales. Given that a lower Cronbach's alpha value of 0.6 is considered acceptable when a scale has less than 10 items (Loewenthal, 2001), the SRFS-6 displayed acceptable internal consistency. The SRFS-6 was moderately negatively related to trait self-control, moderately positively related to physical fatigue, highly positively related to mental and emotional fatigue and highly negatively related to vitality and vigour. These results provide evidence for the SRFS-6 as a reliable and valid measure of self-regulatory fatigue.

On the other hand, internal consistency of the SRFS-3 was less satisfactory. It is important to note that Cronbach's alpha is a measure of unidimensionality, and that the items of the SRFS-3 were selected to represent three different subscales. It has been suggested that, when questionnaires contain subscales, internal consistently may be more appropriately applied to subscales rather than the whole scale (Cronbach, 1951). This could not be applied in this case as each subscale only contained one item. Taking this into account, as well as the low number of items, it is unsurprising that the SRFS-3 did not meet criteria for acceptable internal consistency.

The SRFS-3 maintained the hypothesised strength of relationships with related constructs, although the shrinkage from the SRFS-18 to SRFS-3 was higher than the applied a-priori criteria for acceptable shrinkage with some variables. The relationship between the SRFS-3 and mental and emotional fatigue was satisfactory. Given that mental and emotional fatigue are hypothesised to be the most closely related constructs to self-regulatory fatigue, this provide evidence that the SRFS-3 still taps the construct of self-regulatory fatigue. Therefore, the SRFS-3 may be a less reliable measure of self-regulatory fatigue than the SRFS-18 and SRFS-6. However, the SRFS-3 may still be an adequate measure when there are practical reasons for its use, such as when reducing participant burden is a primary concern.

Item 5 of the original scale, which was included in both the SRFS-6 and SRFS-3, was problematic as it was negatively related to the other two items of the SRFS-3. It seems that the negative relationship of this item may account for the issues of validity and reliability of the SRFS-3. On the other hand, item 5 was not negatively related to the other items in the SRFS-6 or the SRFS-18. While the reasons for this are unclear, it may explain why there was only a small correlation between the SRFS-3 cognitive subscale and the original cognitive subscale. Previous research has identified that negatively worded items are problematic for internal consistency as they do not always reflect the reverse of the intended construct (Chang, 1995; Schriesheim & Eisenbach, 1995). For example, a study examining the factor structure of the Perceived Health Competence Scale (PHCS) in a sample of patients found that negatively worded items loaded onto a separate factor despite intending to measure the inverse of positively worded items (Bonetti, Johnston, Rodriguez-marin, Pastor, Martin-aragon, Doherty et al., 2001). However, the factor structure of the PHCS which emerged in a sample of students was a single factor (Bonetti et al., 2001). In addition, it has been recommended that the single negatively worded item from the original Subjective Vitality Scale be removed after model fit for a one-factor model of vitality was improved by removing this item (Bostic et al., 2000). Therefore, it is recommended that item 5 of the Self-regulatory Fatigue Scale be removed from all scales or that the wording be reversed.

The rationale for developing and validating short-form versions of the SRFS-18 was for use in diary studies such as EMA and N-of-1 designs. The aim of developing and validating the short-forms was to capture daily variation in general self-regulatory capacity, whilst not overburdening participants and thus reducing levels of non-adherence and missing data. The original SRFS-18 is intended to measure general self-regulatory capacity in cognitive, emotional and behavioural domains (Solberg Nes et al., 2013) consistent with the Strength Model (Baumeister et al., 1998). Self-regulatory fatigue, which is the state of having reduced self-regulatory capacity, is commonly experienced chronically in people with complex mulitsymptom illness (Solberg Nes et al., 2010; Solberg Nes et al., 2009). Self-regulatory fatigue in people with complex chronic pain disorders, such as fibromyalgia, is associated with negative outcomes such as poorer quality of life, anxiety and depression (Solberg Nes et al., 2017). Therefore, using assessments which are quick to administer and sensitive to changes in self-regulatory fatigue may provide better insight into the impact of chronic self-regulatory fatigue on people with chronic illnesses, how changes in self-regulatory fatigue are related to improved or worsened outcomes, what other factors compound or alleviate the effects of self-regulatory fatigue, and what mechanisms underlie the effects of self-regulatory fatigue on behaviour.

For example, previous EMA studies have demonstrated that when self-regulatory capacity was lower, participants engaged in more binge eating, more negative behaviours toward partners and had poorer goal adherence (Buck & Neff, 2012; Verstuyf et al., 2013; Wang et al., 2015). However, there has been variation in how self-regulatory capacity was measured and previously validated measures are not always used. The SRFS-6, which has demonstrated good reliability and strong associations with the original scale and other measures of related constructs, may be a useful tool in research which aims to capture daily variation in self-regulatory capacity. When there are good practical reasons, the SRFS-3 may also be appropriate for daily diaries.

To ensure that the short-forms were valid to use in place of the SRFS-18, it was vital that the construct of self-regulatory capacity was reflected in the measure. The items were selected not just on the basis of whether they best represented the construct, contributed to overall scale variance and also contributed to the pertaining subscale. This was to ensure that self-regulatory capacity was adequately measured in cognitive, emotional and behavioural domains. When the number of items in scales are reduced, there is always a risk that the shortened scale will not adequately reflect the construct it is intended to measure (Widaman et al., 2011). Ascertaining whether hypothesised relationships with related constructs are maintained when using short-forms as opposed to full versions is vital to determine the convergent validity of the short-form.

The proposed relationships between self-regulatory fatigue and general, physical, emotional and mental fatigue, vigour, trait self-control and vitality were upheld when utilising the SRFS-6. Indeed, the SRFS-6 was more strongly associated with mental and emotional fatigue, vigour and vitality than the SRFS-18 was to these constructs. This could indicate that the selection of items chosen for the SRFS-6 more closely tap into these constructs. The experience of mental and emotional fatigue in a state of ego-depletion is a central facet of the Strength Model, while feelings of vitality and vigour are elemental in exhibiting high self-regulatory capacity (Z. L. Francis & Inzlicht, 2016; Muraven & Baumeister, 2000; Ryan & Deci, 2008). This provides good evidence that the SRFS-6 is related to “in-the-moment” state feelings of self-regulatory energy, but was still distinct from these. This indicates that the SRFS-6 reflects the construct of a more general self-regulatory capacity.

4.5.1 Strengths, limitations and future directions

The current study followed an analysis strategy for item selection and scale validation which has been recommended and used successfully in previous studies of short-form development (McCracken & Dhingra, 2002; Nicholas et al., 2015; Widaman et al., 2011). However, previous studies have reported the development of single scale short-form measures, whereas, the SRFS-6 is composed of three subscales (McCracken & Dhingra, 2002; Nicholas et al., 2015). Therefore, in this study, items were identified using a combination of indices of overall scale variance, variance contributed to subscales, and judgements of construct content. The current study also administered the actual shortened versions of the scales to a separate sample to conducted validation analyses, as recommended (Widaman et al., 2011).

Despite the strengths of the study, there were also some limitations to note. While the items were selected using a sample of people with chronic pain, the short-form validation analyses were conducted using a sample of healthy people. There is a potential lack of comparability between the samples and this introduces bias. For example, as well as the differences in health status between the samples in stage 1 and stage 2, the mean age of participant was older in the first sample than the second sample. Although, use within the general population was not the original intended use for the SRFS-18 (Solberg Nes et al., 2013), the current study does provide further evidence of the validity and reliability of the SRFS-18 in a sample of healthy people.

Nonetheless, it would be beneficial to examine the validity and reliability of the SRFS-6 in samples of people with chronic multisymptom illnesses. Replicating these results in both healthy populations and samples with health conditions is particularly important given the inconsistent reliability of item 5. Items may be interpreted differentially by different samples depending on their experience, as was found with Bonetti et al. (2001). The current study also did not examine sensitivity to change, discriminant validity or criterion validity in either the SRFS-18 or short-forms or confirm the proposed factor structure (Solberg Nes et al., 2013). Therefore, future research should aim to determine further the overall reliability, validity and factor structure of the SRFS-6 and SRFS-3, particularly in a sample of people with chronic illness.

4.5.2 Conclusion

Although the original SRFS-18 is the most reliable version of the scale when time is not a factor, in situations where a brief measure of self-regulatory fatigue is required, the SRFS-6 is a reliable and valid alternative. The SRFS-3 did not demonstrate adequate reliability or validity so use of this scale could affect the reliability of results within research. Future research should confirm the findings here as well as aim to demonstrate that the SRFS-6 provides additional measures of reliability and validity.

5 An examination of the discriminant content validity of the Self-regulatory Fatigue Scale

5.1 Abstract

Objectives: Inconsistent findings within the Strength Model literature have highlighted the need for robust and valid designs and measurement of ego-depletion, also known as self-regulatory fatigue. Scales which measure self-regulatory fatigue must demonstrate good content validity without overlap from other constructs. This study examined whether items of the Self-regulatory Fatigue Scale (SRFS) measured the construct of self-regulatory fatigue without contamination from other related constructs, such as motivation. This method is known as discriminant content validation.

Methods: A standard quantitative method of discriminant content validation was used. Judges (N=24) were presented with items of the SRFS, motivation and an unrelated construct, anxiety. The judges rated whether items measured construct definitions and their confidence in each judgement was assessed (%). One-sample Wilcoxon signed ranks tests were conducted to assess whether judges' confidence that items did or did not measure the constructs was significantly >0.

Results: While 2/18 items showed content validity for the construct of self-regulatory fatigue, none of the SRFS items demonstrated discriminant content validity. Using measures of self-regulatory fatigue, which do not demonstrate discriminant content validity, may limit the ability to test theoretical assumptions.

Conclusion: More precise definitions of the construct of self-regulatory fatigue may improve the operationalisation of the construct.

Self-regulation is the process of modifying thoughts, emotions and behaviours to further the pursuit of short and long-term goals (Carver & Scheier, 1998). The importance of self-regulation in influencing outcomes such as educational attainment, psychosocial adjustment and employment has been well-documented (Converse et al., 2018; Duckworth, 2011; Fergusson et al., 2013; Tangney et al., 2004). Poor self-regulation has also been linked to negative outcomes such as criminal offending, harmful health behaviours such as substance use, poor mental health (Fergusson et al., 2013; Hagger et al., 2009) and has been implicated in poorer adjustment to chronic health conditions (De Ridder et al., 2008; Leventhal et al., 2005). In particular, it has been proposed that difficulties in the management of chronic pain conditions can be accounted for by deficits in self-regulation and executive function (Solberg Nes et al., 2017; Solberg Nes et al., 2009).

However, there has been much debate around how self-regulatory capacity and self-regulatory fatigue are conceptualised and measured (Carter & McCullough, 2013; Lurquin & Miyake, 2017). Early papers defined ego-depletion as a lack of capacity to engage in volitional acts caused by prior exercise of volitional control (Baumeister et al., 1998), although later work suggested ego-depletion can only be induced by effortful inhibition (Baumeister & Vohs, 2016a). Yet, it is unclear whether even stringent effortful inhibition dual-task paradigm tasks are measuring self-regulatory capacity. Two large-scale studies which used meta-analytic techniques found that there was no strong evidence for convergent validity between self-report self-control and inhibition-related experimental tasks such as the Stroop task and go/no-go task, as well as delay of gratification tasks (Duckworth & Kern, 2011; Saunders et al., 2018). In chapter two, self-reported self-regulatory fatigue, as measured by the SRFS, was also unrelated to self-regulation performance (p67).

Meanwhile, there has been criticism around the non-specific explanations of what ego-depletion is and what mechanisms underlie the effect due to poor operationalisation and definitions of self-regulatory capacity and self-regulatory fatigue (Lurquin & Miyake, 2017). The ability to test the theoretical assumptions of the Strength Model, and the ability to rule out alternative explanations, has been impeded by poorly defined concepts. A lack of clearly defined concepts has led to circular logic in selecting tasks for the dual-task paradigm, which have not been externally validated, and a lack of falsifiable predictions.

Ascertaining whether hypotheses have been supported is even more tenuous when the mechanisms of self-regulatory fatigue have been vaguely described within the Strength Model. For example, recent theoretical developments of the Strength Model (Baumeister & Vohs, 2016b) may have compounded the lack of clarity through the inclusion of several more concepts in the model, making it so malleable that it could not be refuted (Lurquin & Miyake, 2017). It is unclear how self-regulatory resources become depleted, or re-energised, and what their relationship is to other factors, such as motivation (Lurquin & Miyake, 2017).

There is frequent confounding of self-regulatory capacity and motivation within ego-depletion research. The conservation of resources hypothesis proposes that motivation and self-control are theoretically distinct but closely related constructs (Muraven & Slessareva, 2003; Muraven et al., 2006). Frequently used dual-task paradigm tasks, such as persistence at solving difficult anagrams or a frustrating puzzle (e.g Baumeister et al., 1998; Muraven & Slessareva, 2003), require both self-regulatory resources and motivation to perform well. Reliance on measuring the proposed mechanisms by task performance, which confound self-control capacity and motivation, makes it impossible to measure separately the individual contribution of each. This calls into question the validity of such tests of ego-depletion.

In addition, the phrasing of self-report items of state self-regulatory capacity provide ambiguous measurement of the construct of self-regulatory capacity. For example, a frequently used state measure has items such as, “Right now, it would take a lot of effort for me to concentrate on something”, “If I were given a difficult task right now, I would give up easily”, “A new challenge would appeal to me right now” and “If I were tempted by something right now, it would be difficult to resist” (Twenge, Muraven, & Tice, 2004). The wording of these items assumes that motivation is sufficient, and that these items accordingly measure whether self-regulatory resources are either available or reduced. Within the SRFS, there are also ambiguous items such as, “I find it difficult to exercise as much as I should”. Assessing proposed theoretical mechanisms by measuring task performance, and by self-report items that assume sufficient motivation, confound self-control capacity and motivation. This makes it impossible to measure separately the individual contribution of each. It is difficult to ascertain whether self-regulatory fatigue reflects reductions in self-regulatory resources, reductions in motivation, or both.

Assessing the usefulness of theory relies on appropriate measures of the proposed theoretical constructs. Measures of constructs should have adequate content validity as well as construct validity. Indeed, it is vital to establish content validity as this pertains to the relevance and representativeness of items in measuring the construct (S. N. Haynes, Richard, & Kubany, 1995). Content validity likely affects additional psychometric properties such as construct validity and reliability (Dixon & Johnston, 2019). Furthermore, assessing the discriminant content validity (DCV) of measures is necessary when there may be contamination from a closely related construct. DCV is the ability of measures to assess the target construct without overlap from other constructs and is rarely assessed in examinations of the validity of measures. A real test of theory depends on a pure operationalisation of component constructs within them without overlap with related constructs (M. Johnston, Dixon, Hart, Glidewell, Schröder, & Pollard, 2014). Testing theory with measures that overlap with related constructs may result in spurious findings and conclusions due to confounding measurement (Dixon & Johnston, 2019; M. Johnston et al., 2014).

5.1.1 Study aims

It is currently unclear whether the operationalisation of self-regulatory fatigue within the SRFS confounds the constructs of self-control strength and motivation. While the SRFS has demonstrated good internal consistency and construct validity in a population with chronic multisymptom illness (Solberg Nes et al., 2013) and in a student population (Chapter four, p133), the discriminant content validity (DCV) has not been tested. This uncertainty has particular implications for people with chronic pain as lack of a clear theoretical understanding of self-regulatory fatigue makes it difficult to develop and guide interventions.

The main aim of this study was to establish the DCV of the items of the SRFS. A standard method of establishing DCV was used as described by Johnston et al. (2014). This standard method has been used to demonstrate DCV in a range of measures aiming to assess illness representations (Johnston et al., 2014), pain and disability (Dixon, Pollard, & Johnston, 2007), work stress (Bell, Johnston, Allan, Pollard, & Johnston, 2017) and self-efficacy (Burrell, Allan, Williams, & Johnston, 2018).

Due to the frequent confounded measurement of self-regulatory capacity and motivation within the literature, this study assessed whether the items of the SRFS measured self-regulatory fatigue or not and whether SRFS items did nor did not also measure motivation. In addition, the DCV of the items of the Intrinsic Motivation Inventory (Deci, Eghrari, Patrick, & Leone, 1994; Ryan, 1982), a measure of motivation, were assessed in relation to the construct of self-regulatory fatigue and motivation. Another construct which is not a theoretically related to either motivation or self-regulatory fatigue, namely anxiety, was also assessed for DCV. The purpose of including an assessment of anxiety was to establish the general ability of judges to distinguish between constructs.

5.2 Methods

5.2.1 Design

The study used a standard method for determining discriminant content validity (DCV) as described by Johnston, et al. (2014). Each of the six steps are described below.

5.2.2 Participants

The study recruited 24 Psychology PhD students (18 female) through word-of-mouth and social media. The mean of participants' age was 28.2 years (SD=4.6 years). The majority of participants (*N*=19) reported that they had no experience with the limited-resource model of self-regulation, while four participants reported they had "a little" experience with the model and one participant reported they had "some" experience.

5.2.3 Procedure

The School Ethics Committee for the School of Psychological Sciences and Health reviewed and approved the ethics application for this study (approval number: 02/01/05/2018/A). The judges were first provided with an information sheet. This described that the purpose of the study was an examination of whether items from a measure of self-regulatory fatigue adequately assess the construct. Consent was recorded for all judges. The judges were provided with the definitions of motivation, self-regulatory fatigue and anxiety labelled as construct 1, construct 2 and construct 3 respectively. Instructions and two examples were provided to demonstrate how to complete the DCV task. Then, items from each of the three measures were provided in a random order. The participants judged whether the items matched the definition of each construct and then reported how confident they were in each of their judgements. The judges were then provided with a debrief.

Step 1: Identify clear definitions of constructs

Table 5.1 Definitions of the constructs and their sources

Construct	Definition	Source
Self-regulatory fatigue	The temporary depletion of individuals' capacity for self-control. In this state, individuals find it harder to resist making impulsive purchases, inhibit prejudice, or regulate their own emotions. This state arises from the extended use of self-regulation, which is thought to be a limited resource.	Cameron D., Webb T. (2013) Self-Regulatory Fatigue. In: Gellman M.D., Turner J.R. (eds) Encyclopedia of Behavioral Medicine. Springer, New York, NY
Motivation	The impetus that gives purpose or direction to behaviour and operates in humans at a conscious or unconscious level.	American Psychological Association (2018) APA Dictionary of Psychology. Retrieved from https://dictionary.apa.org/motivation
Anxiety	An emotion characterized by apprehension and somatic symptoms of tension in which an individual anticipates impending danger, catastrophe, or misfortune. The body often mobilizes itself to meet the perceived threat: Muscles become tense, breathing is faster, and the heart beats more rapidly.	American Psychological Association (2018) APA Dictionary of Psychology. Retrieved from https://dictionary.apa.org/anxiety

5.2.4 Step 2: Item generation

The self-regulatory fatigue items were the 18 items of the Self-regulatory Fatigue Scale (Solberg Nes et al., 2013). Anxiety items were generated from the Hospital Anxiety and Depression Scale anxiety subscale (HADS-A; Zigmond & Snaith, 1983). The HADS-A is a 7-item screening tool generally used in health populations which assesses frequency of symptoms experienced in the past week. Nine items from the Intrinsic Motivation Inventory effort/importance and value/usefulness subscales (Deci et al., 1994; Ryan, 1982) were used as measures of motivation. The value/usefulness items were deemed to be most relevant to the question of overlap between constructs as this subscale measures the extent to which an activity is internally valued, and value is required to motivate self-regulatory effort (Deci et al., 1994). The effort/importance subscale items were selected as current measurement of self-regulatory fatigue assumes that there is already sufficient motivation for engage in effort (Lee et al., 2016; Lurquin & Miyake, 2017).

5.2.5 Step 3: Identify appropriate judges

The judges were PhD students studying Psychology. Therefore, it was assumed that judges would have a foundation knowledge of psychological constructs but not a specific expertise in self-regulation or the Strength Model (Baumeister et al., 1998) It is recommended that there are at least 15 judges to assess whether there is statistically significant DCV (M. Johnston et al., 2014; Saito, Sozu, Hamada, & Yoshimura, 2006). Twenty-six judges were recruited but 2 did not complete any items on the DCV task, leaving 24 judges. Interrater agreement was determined with the intraclass correlation coefficient (ICC). The ICC for the SRFS was .74, 95% CIs (.63, .83); for the IMI items was .81, 95% CIs (.69, .90) and the ICC for the HADS-A was .80, 95% CIs (.66, .91), indicating good reliability for each type of item.

5.2.6 Step 4: Establish a scale

The judges were asked to indicate whether an item matched the definition of constructs 1, 2 and 3 with a ‘Yes’ or ‘No’ response. The judges then indicated how confident they were in each judgement on a scale from 0% (not at all confident) to 100% (completely confident), increasing in 10% increments. Each judge made 102 judgements in total. An example of the DCV task is presented in figure 5.1.

Construct 1	Construct 2	Construct 3
The impetus that gives purpose or direction to behaviour and operates in humans at a conscious or unconscious level.	The temporary depletion of individuals' capacity for self-control. In this state, individuals find it harder to resist making impulsive purchases, inhibit prejudice, or regulate their own emotions. This state arises from the extended use of self-regulation, which is thought to be a limited resource.	An emotion characterized by apprehension and somatic symptoms of tension in which an individual anticipates impending danger, catastrophe, or misfortune. The body often mobilizes itself to meet the perceived threat: Muscles become tense, breathing is faster, and the heart beats more rapidly.

Item: I feel full of energy		
Theoretical Definition	**Item matches Definition?**	**How confident are you in each of your judgments?**
Construct 1	YES / NO	0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%
Construct 2	YES / NO	0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%
Construct 3	YES / NO	0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%

Figure 5.1 Example presentation of the DCV task with demonstrative responses

The confidence ratings were multiplied by -1 for a 'No' judgement and by +1 for a 'Yes' judgement, providing a scale from -100 (very confident the item *does not* match the construct) to +100 (very confident the item *does* match the construct).

5.2.7 Step 5: Test the content validity

The content validity of questionnaire items was assessed with a one-sample Wilcoxon signed ranks test compared to a test value of 0. This was to determine whether there was sufficient evidence (median confidence scores significantly > 0, two-tailed) that items measured each of the constructs. Given the number of hypothesis tests required, a Benjimini-Hochberg correction was applied to the alpha level (M. Johnston et al., 2014). Effect sizes were estimated for each item using Spearman's rank correlation, calculated as the Wilcoxon W statistic divided by the total rank sum (Kerby, 2014). Positive Wilcoxon signed ranks test scores and rank correlations indicate that items were judged to match the construct while negative Wilcoxon signed ranks test scores and rank correlations indicate that items were judged to not match a construct.

5.2.8 Step 6: Evaluate the DCV

Following previous research (Bell et al., 2017; Burrell et al., 2018) items were judged to have DCV if they assessed only one construct at a threshold of $r_s \geq .8$ (equivalent to 64% shared content). Items which were judged to assess more than one construct indicated that there was contamination, meaning the item did not have DCV.

5.3 Results

The results of the single sample Wilcoxon signed ranks tests and calculated effect size (r_s) are presented in table 5.2.

Table 5.2 Wilcoxon signed ranks test statistic (standardised *Z*) and rank correlations for judgements of each item to each construct

Items		**Constructs**					
SRFS		**SRF**		**Motivation**		**Anxiety**	
		Z	**Effect**	***Z***	**Effect**	***Z***	**Effect**
1	I feel full of energy	-2.52*	-.48	0.55	.22	-2.37	-.48
2	It’s easy for me to set goals	-1.56	-.30	2.83*	.60	-3.94*	-1
3	I find it difficult to exercise as much as I should	0.96	-.39	-0.72	.13	-3.54*	-.83
4	I have urges to hit, throw, break or smash things	2.03	.48	-0.26	-.13	-0.28	-.13
5	I have no trouble making decisions	-0.59	-.08	0.78	.08	-3.12*	-.58
6	I experience repeated unpleasant thoughts	0.09	.10	-3.33*	-.60	2.14	.60
7	I get easily upset	2.93*	.50	-2.49	-.50	1.64	.47

8	I try not to talk or think about things that bother me	-0.60	-.10	-1.39	-.10	-3.50*	-.70
9	I never feel like yelling, swearing or shouting	-1.01	.30	-0.21	.00	-2.83*	-.65
10	I handle stress very well	-0.88	-.20	-1.72	-.47	-0.62	.00
11	I experience uncontrollable temper outbursts	2.56*	.40	-3.58*	-.90	1.56	.40
12	I can easily keep up with my friendships and relationships	-2.72*	-.70	-0.45	.00	-3.62*	-.90
13	I cry easily	1.39	.40	-3.94*	-1	2.08	.20
14	I have difficulties remembering things	0.28	.10	-3.86*	.20	-1.20	-.20
15	I find it easy to stick to a healthy diet	-2.06	-.39	2.20	.48	-4.19*	-.91
16	I feel moody	1.85	.40	-3.12*	-.70	0.20	.26
17	I have urges to beat, injure or harm someone	1.97	.50	-2.67*	-.40	0.67	.30
18	I rarely get frustrated	-0.56	-.10	-1.70	-.60	-1.52	-.50
IMI items		**SRF**		**Motivation**		**Anxiety**	
		Z	**Effect**	***Z***	**Effect**	***Z***	**Effect**
1	I believe this activity could be of some value to me	-3.32*	-.80	**3.47***	**.90**	-3.93*	-1
2	I would be willing to do this again because it has some value to me	-2.77*	-.70	**3.13***	**.80**	-3.94*	-1
3	I believe doing this activity could be beneficial to me	-3.43*	-.80	**3.56***	**.90**	-3.94*	-1
4	I think this is an important activity	-3.53*	-.74	2.36	.65	-4.10*	-.91
5	I put a lot of effort into this	-3.74*	-.80	3.13*	.70	-3.95*	-1
6	I didn't try very hard to do well at this activity	-0.90	-.20	1.22	.40	-3.93*	-1
7	I tried very hard on this activity	-2.75*	-.50	2.87*	.67	-3.99*	-.73

		SRF		Motivation		Anxiety	
8	It was important to me to do well at this task	-3.45*	-.90	**3.55***	**.90**	-3.94*	-1
9	I didn't put much energy into this	-0.09	.00	-0.52	.00	-4.03*	-.92
HADS-A		**SRF**		**Motivation**		**Anxiety**	
		Z	**Effect**	***Z***	**Effect**	***Z***	**Effect**
1	I feel tense or 'wound up'.	-0.41	-.10	-3.59*	-.80	**3.68***	**.89**
2	I get a sort of frightened feeling as if something awful is about to happen	-0.97	-.20	-3.53*	-.70	**3.84***	**.90**
3	Worrying thought go through my mind	-1.60	-.39	-3.57*	-.74	1.91	.57
4	I can sit at ease and feel relaxed	-2.22	-.30	-1.60	-.30	-1.14	-.22
5	I get a sort of frightened feeling like 'butterflies in my stomach	-1.81	-.40	-3.33*	-.68	**3.85***	**1**
6	I feel restless as if I have to be on the move	1.17	.20	-2.50	-.50	3.42*	.70
7	I get sudden feelings of panic	-2.18	-.30	-3.68*	-.74	**4.26***	**1**

SRF=Self-regulatory fatigue; SRFS=Self-regulatory Fatigue Scale; HADS-A=Hospital Anxiety and Depression Scale Anxiety subscale; IMI=Intrinsic Motivation Inventory. Note: Positive figures=item assesses construct; negative figures=item does not assess construct; items which do or do not assess a construct significantly >0 (with Benjimini-Hochberg correction applied) are indicated with *; items which have discriminant content validity are marked in **boldface**.

Do the questionnaire items measure the constructs they intend to measure?

There were 2/18 items in the SRFS which were judged to assess the SRF construct. On the other hand, there were 6/9 IMI items which were judged to assess motivation and 5/7 items from the HADS-A were considered to assess anxiety.

5.3.1 Do the questionnaire items measure a construct(s) that they are not intended to measure?

One SRF item ('It's easy for me to set goals') was judged to measure motivation, although this did not meet the threshold for DCV.

5.3.2 *Do the items which were allocated to the construct they intend to measure have discriminant content validity (DCV)?*

Items were considered to have DCV if they were allocated to only the target construct and met the threshold of $r_s \geq .8$. There were no SRFS items which demonstrated DCV. Four of the nine IMI items demonstrated DCV. In addition, four of the seven HADS-A items were classified as only measuring anxiety.

5.4 Discussion

This study used the DCV method to assess discriminant content validity of items of the self-regulatory fatigue scale. The results demonstrated that only 2 of the 18 items of the SRFS were judged to have content validity for the construct of self-regulatory fatigue and one item of the SRFS was judged to measure motivation. However, no SRFS items met the criteria for DCV for self-regulatory fatigue or either of the other constructs. Overall, it appeared that the judges were uncertain about what construct SRFS items intended to measure. Most of the items of the IMI and HADS-A were judged to measure motivation and anxiety respectively. Further, four items on each of the IMI and HADS-A met the criteria for DCV for the intended construct. The judges reported a high degree of certainty that most IMI items did not reflect self-regulatory fatigue and all IMI items did not reflect anxiety. The judges were also able to discern that HADS-A items did not measure motivation.

The results further highlight the need for providing clear definitions of how states of self-regulatory fatigue occur and designing valid measures of self-regulatory fatigue. It appears that the imprecise operationalisation of self-regulatory fatigue extends beyond experimental tasks to self-report measurement. One SRFS item was judged to have content validity for motivation ("It's easy for me to set goals"), although this item was not judged to have DCV for any construct. It seems that while the operationalisation of self-regulatory fatigue within SRFS items is problematic, conflation with motivation is generally not the source of problem.

The general lack of content validity of SRFS items is very problematic. The reasons for the lack of content validity could be that the items do not reflect appropriate representativeness or relevance of the construct (S. N. Haynes et al., 1995), or it could be that the definition of self-regulatory fatigue is not appropriate, or it could be both. Given the vague explanations provided by the Strength Model of the mechanisms by which self-regulatory fatigue arises (Baumeister & Vohs, 2016a) and the lack of conceptual clarity within the literature, the most likely explanation for the findings of this study is that the definition is inadequate.

It seems that to address the need for accurate measurement of self-regulatory fatigue, the adoption of theory that clearly describes the constructs and mechanisms by which self-regulatory fatigue arises, and its relation to motivation and similar constructs is crucial. One such model which may address the definitional uncertainty of the construct of self-regulatory fatigue is the Process Model (Inzlicht et al., 2014). According to the Process Model, there is a devaluation of the task, which leads to motivational shifts away from deliberative control and towards gratifying activities. There are also simultaneous shifts in attention away from conflict monitoring and towards reward cues (Inzlicht & Schmiechel, 2012; Inzlicht et al., 2014). As opposed to viewing self-regulatory failure in these instances as being a uniformly undesirable outcome, it is proposed that shifting priorities can either result in increased vigour for the task and the up-regulation of cognitive control or engagement in a rewarding activity to moderate mental fatigue (Saunders & Inzlicht, 2015; Saunders et al., 2015). Therefore, recent developments in the literature have provided several explanations of distinct mechanisms of self-regulatory fatigue states. In future, these accounts of self-regulatory fatigue should be considered when operationalising the construct in measures of self-regulatory fatigue.

Although there is a clear need for providing more precise accounts of the mechanisms of self-regulatory fatigue and its effects on goal pursuit and performance, it may be that the definition of self-regulatory fatigue used in this study was not broad enough. The construct definition of self-regulatory fatigue in this study was gathered from The Encyclopaedia of Behavioral Medicine (Cameron & Webb, 2013), a reference text which encompasses definitions of constructs relevant to behavioural medicine. While this is not an English-language dictionary, it has been previously noted in studies of discriminant content validity that only using dictionary definitions of constructs, as opposed to descriptions from seminal theoretical papers, is a limitation (Bell et al., 2017). The definition of self-regulatory fatigue used here did not make specific reference to cognitive, emotional and behavioural components of self-regulation. Future studies should additionally examine whether DCV can be found for SRFS items when using descriptions from theoretical papers. Although, as suggested previously, if the definition of self-regulatory fatigue used in the study is insufficient, this indicates a lack of clarity within the literature.

Additionally, eight of the total 18 items of the SRFS are reverse scored. It may be that judges found it difficult to allocate reverse scored items when the definition of self-regulatory fatigue was not described in relation to a lack of self-regulatory capacity. Two SRFS items (e.g. "I can easily keep up with my friendships and relationships", "I feel full of energy") were judged not to indicate self-regulatory fatigue. This could reflect that judges felt that these statements were compatible with an absence of self-regulatory fatigue. It has been noted previously that negatively worded items can be problematic. It has been demonstrated that, even when a measure is purported to measure one single construct, negative items load onto a separate factor in a factor analysis (Bonetti et al., 2001; Bostic et al., 2000). This indicates that, in general, negatively worded items may not measure the inverse of positively worded items and, therefore, the construct. Nevertheless, it is not possible to draw strong conclusions given that most SRFS items, whether reverse scored or not, were not judged to measure any of the constructs and no SRFS items met the criteria for DCV. Further research should be conducted to assess whether DCV can be determined for SRFS items when a definition of self-regulatory capacity is used as opposed to self-regulatory fatigue. Moreover, it should be determined whether an instruction to judges that some items may be reverse scored aids in allocating items to the correct construct.

5.4.1 Conclusion

This study assessed the DCV of items of the SRFS, which had not been previously examined. No items of the SRFS were judged to have DCV for the definition of self-regulatory fatigue but there generally did not appear to be contamination from motivation. To ensure the validity of findings of studies measuring self-regulatory fatigue, more precise definitions of the construct of self-regulatory fatigue are necessary to ensure the adequate operationalisation of the construct.

6 An examination of the effect of daily fluctuations in self-regulatory fatigue on daily variation in physical activity

6.1 Abstract

Objectives: Despite the noted benefits of physical activity for the management of chronic pain, the uptake of exercise in this group is poor. It has been proposed that people with chronic pain experience chronic self-regulatory fatigue, which is a reduced capacity for self-regulation. Self-regulatory fatigue may be a factor in the lack of engagement with physical activity and may be related to other determinants of physical activity such as motivation and self-efficacy. Previous investigations of these relationships have been assessed with between-subjects designs. This study investigated the effect of daily variation in self-regulatory fatigue, motivation and self-efficacy on physical activity and daily variation in self-regulatory fatigue and motivation on self-efficacy within-individuals.

Method: A series of N-of-1 studies were conducted. Four participants with chronic pain who were recruited from the community (24-60 years old; 3 female) completed daily diaries of measures of self-regulatory fatigue, motivation and self-efficacy for 30 days. Each participant wore an accelerometer that measured physical activity objectively for the duration of the study. Analyses were conducted individually for each participant using dynamic modelling.

Results: Dynamic models demonstrated that day-to-day fluctuations in self-regulatory fatigue, self-efficacy and motivation did not predict fluctuations in physical activity. There were differential relationships between self-efficacy, motivation and self-regulatory fatigue observed in the participants. In one participant, there was no significant relationship between self-regulatory fatigue, motivation and self-efficacy.

Conclusion: Examining within-person relationships in goal pursuit is necessary to determine the validity of self-regulation theory and to identify individual factors that can increase

physical activity in people with chronic pain. This study illustrated that further research investigating within-individual process during goal pursuit are required.

It is well established that avoidance behaviour in people with chronic pain, defined as a decrease in general daily activity and physical activity (Vlaeyen & Crombez, 1999), is a factor that contributes to the maintenance of chronic pain (Philips, 1987; Vlaeyen & Linton, 2000; Vlaeyen & Linton, 2012). Further, there is evidence that sedentary behaviour is related to back pain and lower limb pain (Hanna et al., 2019; Santos et al., 2018). Pain-avoidance behaviour is related to higher disability (Lin, McAuley, Macedo, Barnett, Smeets, & Verbunt, 2011). Engaging in physical activity is necessary to prevent the onset, or aid the management of, comorbid health conditions such as type II diabetes and cardiovascular disease (Morales-Espinoza, Kostov, Salami, Perez, Rosalen, Molina et al., 2016).

Physical activity interventions for people with chronic pain improve outcomes such as pain, physical function, fatigue, sleep and mood (Ambrose & Golightly, 2015; Geneen et al., 2017; Polaski et al., 2019). Despite the efficacy of exercise programmes in improving outcomes in chronic pain, non-adherence to prescribed exercise is reportedly as high as between 50-70% (Friedrich et al., 1998; Härkäpää, Järvikoski, Mellin, Hurri, & Luoma, 1991; Peek et al., 2018). Therefore, examining determinants of physical activity in people with chronic pain may inform the development of effective interventions.

Recent theoretical perspectives have advocated for the examination of activity in people with chronic pain within the affective-motivational context of pursuing other valued goals and activities (Crombez et al., 2012; Van Damme & Kindermans, 2015). That is, the adoption of different physical activity patterns depends on the individual and the context. For example, within this self-regulation view, avoidance behaviour has been proposed as the result of devaluing activities which are perceived to cause more pain and negative affect (Van Damme & Kindermans, 2015). A recent theoretical framework proposed that when costs outweigh benefits during goal pursuit (e.g. increasing pain), the induction of fatigue leads to decreases in motivation. The purpose of the onset of fatigue during activity is to ensure the optimisation of resources in the face of increasing demands (Van Damme et al., 2018). It is proposed that cognitive control is employed when engaging in goal pursuit to supress pain and goal-discrepant cognitions. This delays the onset of fatigue and goal disruption (Van Damme et al., 2018). However, recruiting cognitive control is effortful and cannot be continually sustained (Baumeister et al., 1998).

Employing cogntive control may be particularly difficult for people with chronic pain as it has been proposed that they experience self-regulatory fatigue, or reduced self-regulatory capacity (Solberg Nes et al., 2010; Solberg Nes et al., 2013; Solberg Nes et al., 2009). One prevailing view of self-regulation, the Strength Model, argues that the availability of limited self-regulatory resources determines capacity for self-regulation. Engaging in self-regulation temporarily depletes the limited self-regulatory resource and performance depends on the amount of available resources (Baumeister et al., 1998; Muraven & Baumeister, 2000).

It has been suggested that limited self-regulatory capacity may prevent people with chronic pain engaging in physical activity (Solberg Nes et al., 2009). A negative effect of reduced self-regulatory capacity on physical activity performance has been demonstrated (Dorris et al., 2012; Englert & Rummel, 2016; Englert & Wolff, 2015). Although, there is debate around whether decreases in self-regulation performance result from a reduction of self-regulatory capacity, or reductions in motivation, or both. The conservation of resources hypothesis argues that decreased self-regulatory performance is a consequence of reductions in both motivation and self-regulatory resources (Hobfoll, 1989; Muraven & Slessareva, 2003).

The exact mechanisms of poorer self-regulation in people with chronic pain are still unclear. However, there is evidence that people with chronic pain experience chronic self-regulatory fatigue as demonstrated in experimental studies (Solberg Nes et al., 2010, 2011), by self-report (Chapter's two & three) and by lower heart rate variability, a physiological indicator of lower self-regulatory capacity (Rost et al., 2017). The effect of self-regulatory fatigue on engaging in physical activity has not been investigated in people with chronic pain.

Cognitive factors, such as self-efficacy, may be implicated in the allocation and conservation of resources during goal pursuit in people with chronic pain. Self-efficacy beliefs are defined as confidence in one's ability to complete a task and they determine how much effort will be exerted in the face of challenges, how long to persist on a task, and whether coping efforts are required (Bandura, 1977). Self-efficacy beliefs are used to establish the amount of resources required for a goal (Yeo & Neal, 2012). Self-efficacy is a robust predictor of outcomes in chronic pain such as lower pain severity, better functioning and less affective distress (Jackson et al., 2014; Karasawa, Yamada, Iseki, Yamaguchi, Murakami, Tamagawa et al., 2019). Self-efficacy beliefs may be a protective factor against the effects of self-regulatory fatigue in people with chronic pain. For example, in chapter three (p109), pain self-efficacy mediated the relationship between self-regulatory faitgue and depression. Self-efficacy is also associated with better adherence to exercise in people with chronic pain (Medina-Mirapeix, Escolar-Reina, Gascón-Cánovas, Montilla-Herrador, Jimeno-Serrano, & Collins, 2009).

Although there is no dispute that self-efficacy is associated with better outcomes in chronic pain, negative effects of self-efficacy on performance have been observed (Vancouver et al., 2008; Beck & Schmidt, 2009). Negative effects of self-efficacy on performance are at odds with the view that there is a continuous, linear, positive relationship between self-efficacy and performance (Bandura, 1998, 2002). It has been argued that self-efficacy fluctuates over the course of several tasks (Vancouver et al., 2008) to ensure adaptive use of resources. Self-efficacy may have a negative effect on concurrent task performance but a positive effect on overall performance across many tasks (Vancouver et al., 2008; Yeo & Neal, 2012). When measured between-person, people with higher self-efficacy tend to set higher goals and persevere for longer, meaning that people with high self-efficacy tend to allocate more resources to a task and have better performance than those with low self-efficacy (Chen, Gully, & Eden, 2004). However, when measured within-person, as task demands decrease then self-efficacy increases and less resources are allocated (Yeo & Neal, 2012). In study 1 of chapter two (p67), baseline pain self-efficacy had a differential effect on performance during an initial and subsequent self-regulation tasks in participants with chronic pain. Pain self-efficacy was associated with better task performance on an initial task of self-regulation, and worse task performance on a subsequent self-regulation task. In study 2 (p80), higher within-person self-efficacy was related to higher resource allocation on individual tasks in participants with chronic pain. However, when resources are limited, continuous effort cannot be sustained. This meant that higher within-person self-efficacy was only beneficial for overall performance across several tasks up to a point, then became detrimental. Therefore, within-person processes may not be the same as between-person processes.

6.1.1 Within-person process

Testing whether theory can account for within-person processes as well as between-person processes is vital for determining its validity (D. W. Johnston & Johnston, 2013). The Strength model and conservation of resources hypothesis make ideographic predictions, whereby changes in self-regulatory resources and motivation over time within the individual lead to changes in performance. To date, there has not been much consideration as to whether the hypothesised theoretical processes account for behaviour within individuals. Some studies have examined how within-person variance in self-regulatory fatigue affected behaviour (Verstuyf et al., 2013), but most tests of the Strength Model have assessed average change between groups (Hagger, 2010; Hagger et al., 2010). The dual-task paradigm does not allow for an examination of dynamic shifts in variables which affect allocation of resources and performance over time, such as self-regulatory capacity, motivation and self-efficacy. Using methods which assess intra-individual variation in these variables will provide a better understanding of the validity of assumptions of the Strength Model and conservation of resources hypothesis.

6.1.2 N-of-1 designs

One method of assessing within-person variability are N-of-1 designs (D. W. Johnston & Johnston, 2013). N-of-1 designs (also known as single-case designs) involve repeated measurements of variables within an individual longitudinally. Therefore, conclusions can be drawn about variation in the individual over time. N-of-1 methods have several advantages such as being able to examine temporal dynamics, improved ecological validity and the ability to personalise interventions for individuals. As a result, the adoption of N-of-1 methods to test theory and interventions has been recommended (Craig et al., 2008; McDonald et al., 2017). For example, N-of-1 methods have been used to examine the effect of social cognitive constructs on variation in physical activity (Hobbs, Dixon, Johnston, & Howie, 2013; O'Brien, Philpott-Morgan, & Dixon, 2016; G. Smith, Williams, O'Donnell, & McKechnie, 2019).

6.1.3 Study aims

The aim of the current study was to examine the relationship between daily variation in physical activity and self-regulatory fatigue, motivation and self-efficacy in people with chronic pain. Additionally, the effect of daily variation in self-regulatory fatigue and motivation on daily variation in self-efficacy was examined.

6.2 Methods

6.2.1 Design

A series of observational N-of-1 studies were conducted for 30 days. A daily diary method was used as well as daily accelerometer measurement. Study variables were measured by self-report twice daily, once in the morning (between 7am and 10am) and again 12 hours later. Sixty observations were taken in total for each participant. Therefore, there were 30 observations of morning variables and 30 observations of evening variables.

6.2.2 Participants

Participants who reported that they had experienced persistent pain for 6 months or longer were recruited. Recruitment was conducted by poster advertisement on the University of Strathclyde Campus, in the community and on social media. The participants were required to be above the age of 18 and not be experiencing acute injury. The sample size for N-of-1 studies is determined by the number of observations within each individual as opposed to the number of participants (McDonald et al., 2017). Reliable estimates can be obtained using dynamic modelling with as few as 30-50 observations (Borckardt, Nash, Murphy, Moore, Shaw, & O'Neil, 2008; McDonald et al., 2017). Eight participants (5 female, 3 male) who met the inclusion criteria were invited to take part and were given at least 48 hours to consider their decision to participate. From this, four participants took part meaning four N-of-1 studies were conducted here. Participants were remunerated with £25 upon completion of the study. Ethical approval was granted for the study by the University Ethics Committee of the University of Strathclyde (approval number: UEC17/87 Dixon/McMillan).

6.2.3 Apparatus

Physical activity was measured using ActiGraph GT3X accelerometer devices (ActiGraph GT3X; ActiGraph LLC, Pensacola, FL, USA). The GT3X collects tri-axial accelerometry data and takes measurements of wear time, energy expenditure, bouts of physical activity including duration and intensity of activity bout, metabolic rates, sedentary bouts, heart rate, an inclinometer which determines whether subjects are standing, sitting or lying down or if the device has been removed, and sleep activity. Acceleromters have demonstrated good reliability and validity in measuring physical activity (Eyler, Brownson, Bacak, & Housemann, 2003; Kelly, McMillan, Anderson, Fippinger, Fillerup, & Rider, 2013). The main outcome in this study was number of daily physical activity bouts (defined below).

6.2.4 Measures

Baseline

Demographics: Each participant provided their age, gender, ethnicity, marital status, years of education and employment status. Participants were asked to describe any physical or mental health conditions they were experiencing with free text response.

Pain: Participants were asked to provide the duration of their pain (years). Current and average pain intensity was rated on an 11-point Likert scale from 0 (no pain) to 10 (pain as bad as can be).

Physical functioning: Physical functioning was assessed by self-report using the PROMIS Physical Function Short Form 20a (PROMIS PF-20). The PROMIS PF-20 (Cella, Riley, Stone, Rothrock, Reeve, Yount et al., 2010) is a 20-item measure developed from the PROMIS items bank of 124 physical functioning items which measure mobility, dexterity, movement of neck and back and instrumental activities. The PROMIS PF-20 assesses current ability to perform basic activities of daily living. Four items on the measure (e.g. “Are you able to push open a heavy door?”; “Are you able to shampoo your hair?”) are rated on a 5-point Likert scale anchored by 5 (“Without any difficulty”) to 1 (“Unable to do”). Six items (e.g. “Does your health now limit you in bending, kneeling, or stooping?”; “Does your health now limit you in climbing one flight of stairs?”) are measured on a 5-point Likert scale anchored by 5 (“Not at all”) to 1 (“Cannot do”). All items are summed and the scale provides a score range of 20-100 where higher scores indicate better physical functioning.

Self-regulatory fatigue: The Self-regulatory Fatigue Scale (Solberg Nes et al., 2013) measures self-regulation fatigue, or a reduced capacity to self-regulate, in chronic multisymptom illness (e.g. "It is easy for me to set goals"). Each item is scored on a 5-point Likert scale from strongly disagree to strongly agree. The scale measures cognitive (6 items), emotional (7 items) and behavioural (5 items) components of self-regulatory fatigue to produce an 18-item scale with a range of 18-90 where higher scores indicate higher self-regulatory fatigue.

Pain self-efficacy: The Pain Self-efficacy Questionnaire (Nicholas, 1989) measures confidence in ability to cope despite pain in a variety of situations (e.g. "I can enjoy things, despite the pain"). It is a 10-item instrument where items are scored on a range of 0 (not at all confident) to 6 (completely confident). Total score is summed across items giving a total range of 0-60 where higher levels indicate higher pain self-efficacy.

Mood: The Hospital Anxiety and Depression Scale (Zigmond & Snaith, 1983) was designed to screen for anxiety and depression in those with illness where symptoms may be conflated (e.g. aching muscles). The Hospital Anxiety and Depression Scale (HADS) has depression and anxiety subscales of 7 items each. Each item is scored on a scale of 0 to 3 relating to the frequency that a symptom has been experienced over the past 7 days. A sum score is calculated for each subscale and each has a score range of 0-21.

Pain catastrophising: The Pain Catastrophising Scale (Sullivan et al., 1995) is a 13-item instrument that measures pain catastrophising which is a set of exaggerated negative beliefs about an actual or perceived painful event. The range for the total score is 0-52 and is based on three subscales of magnification (3 items; e.g. "I become afraid that the pain will get worse"), rumination (4 items; e.g. "I can't seem to keep it out of my mind") and helplessness (6 items; e.g. "I feel I can't go on") which are scored from 0 (not at all) to 4 (all the time).

Fear of movement: The 17-item version of the Tampa Scale of Kinesiophobia (Miller, Kori, & Todd, 1991) was used to assess pain-related fear of movement. The Tampa Scale of Kinesiophobia (TSK) assesses pain-related fear beliefs (e.g. “Pain always means I have injured my body”; “Just because something aggravates my pain does not mean it is dangerous”) and fear of movement (e.g. “No one should have to exercise when he/she is in pain”; “It’s really not safe for a person with a condition like mine to be physically active”) on a scale from 1 (strongly disagree) to 4 (strongly agree) resulting in a scale range from 17 to 68. Higher scores indicate higher fear of movement.

6.2.5 Daily Diary Measures

Self-regulatory fatigue: Current self-regulatory fatigue was assessed by the Self-regulatory Fatigue Scale six-item short form (SRFS-6) developed in chapter four. The behavioural, cognitive and emotional facets of self-regulatory fatigue were measured by two items each from the behaviour, cognitive and emotion subscales. For a full list of items see p244. The scale was framed to measure current self-regulatory fatigue (e.g. “Please indicate how much you agree that the following statements apply to how you feel RIGHT NOW.”). The scale range was from 6 to 30.

Goal Self-efficacy: Goal self-efficacy was measured by several personalised self-efficacy items which were constructed using a standard method of developing self-efficacy measures (J. J. Francis, Eccles, Johnston, Walker, Grimshaw, Foy et al., 2004). These self-efficacy items were specific to the participant’s individual physical activity goal. One item assessed general confidence in the ability to achieve the goal. Then several further items assessed current confidence in ability to achieve the goal in the presence of increasingly difficult conditions, for example, when barriers arise (e.g. “Right now, I am confident that I can increase my walking from 40 mins per day to 1 hour per day”). Potential barriers included in self-efficacy items were also specific to the participant. Goal self-efficacy score was the sum of four items for each participant, each measured on an 11-point Likert scale from 0 (Not at all confident) to 10 (Completely confident), providing a score range of 0-40. The full list of goal self-efficacy items for each participant can be found in appendix 2 (p245).

Goal Motivation: Goal motivation for the current day was measured with one item ("How motivated are you to pursue your goal today?") on a scale from 0 (Not at all) to 6 (Very much).

6.2.6 Procedure

Baseline: An initial meeting took place where participants provided written consent. Then a brief semi-structured interview was conducted to illicit valued activities, and to identify a physical activity goal and its barriers, which were used to construct the personalised self-efficacy items. Participants then completed the baseline measures and were given a demonstration of the accelerometer and shown an example of the daily diary.

Daily diary phase: The participants began the daily diary phase the day following the initial meeting. The accelerometer was worn every day, including when sleeping, on either the wrist or hip, depending on the participant's preference. The daily diary was completed online via Qualtrics. A link to the diary was sent via a text message to participants' smartphones at the agreed morning interval. The morning diary, assessed self-regulatory fatigue, goal motivation and self-efficacy. The participants also completed measures of pain intensity, pain catastrophising, pain self-efficacy, self-efficacy for managing emotions, mood, physical functioning, goal importance and goal effort but these do not form part of this study. Two weeks after beginning the diary phase, a face-to-face meeting was conducted to exchange the accelerometer with a fully charged one. Participants could discuss any issues they were experiencing about the study at this meeting. Participants were also encouraged to contact the researcher if any problems arose throughout the diary phase. After the 30-day diary phase was complete, another face-to-face meeting was arranged to return the accelerometer and to provide a debrief and remuneration to the participant.

6.2.7 Data Analysis

Data processing: Raw data were downloaded from the accelerometers and participants' data files from each accelerometer were combined into one file for each participant. The downloaded raw data files were recorded in epochs of 10 seconds. Wear-time validation was conducted and a non-wear period was defined as 60 consecutive minutes of 0 counts using ActiLife software v6.13.3. Bouts of physical activity were calculated using the Freedson adult cut-points algorithm (Freedson, Melanson, & Sirard, 1998) in ActiLife. The calculation of physical activity bouts, based on the Freedson algorithm, took into account whether participants wore the accelerometer on their wrist or hip. A bout of PA was defined as 10 consecutive minutes of physical activity of any intensity. The purpose of this study was to determine psychological factors which may influence how much PA participants engaged in throughout their daily lives. Therefore, given the study sample (i.e. people with chronic pain), bouts of continuous PA of light (101-1951 counts/minute), moderate (1952-5724 counts/minute) or vigorous (>5725 counts/minute) were included in the definition of PA. PA bouts were considered a continuous variable.

Statistical analysis: The data were analysed individually for each participant using R statistical software v3.4.4. Where there was a very small number of observations missing at random (e.g. <0.05%), the mean of prior and subsequent observations was input. Time plots were examined for trends in the data. Autocorrelation, the correlation between a variable at t_0 and the same variable at earlier time points or lags (e.g. t_1 or t_2), can arise when there are many repeated measurements of the same variables. Autocorrelograms were assessed for each variable to determine whether there was autocorrelation (Naughton & Johnston, 2014). Dynamic modelling was conducted to examine the relationship between the predictor variables and physical activity. Using dynamic models to analyse N-of-1 data has been recommended because it is a flexible modelling approach (Vieira, McDonald, Araújo-Soares, Sniehotta, & Henderson, 2017). Dynamic regressions can account for autocorrelation by including lags of the predictors and outcome variables as well as exogenous variables including trends in time and periodicity (e.g. morning, evening). Including lagged variables in the model which represent autocorrelation allows for independence between data points to be assumed. Dynamic models will not be formally described here as this has been done previously (Vieira et al., 2017).

Descriptive and multivariate analysis was conducted. As the purpose was to determine which variables had the most impact on bouts of physical activity and goal self-efficacy, a stepwise approach was used to determine the model with the best model fit which was established by Akaike's Information Criterion. Based on examination of the time plots and autocorrelograms, lags of outcome variables and day and week were included as control variables as needed prior to the inclusion of predictor variables. The effect of self-regulatory fatigue, goal self-efficacy and goal motivation on physical activity bouts and the effect of self-regulatory fatigue and goal motivation on goal self-efficacy was examined for each participant. Normality of model residuals were examined by histograms and Q-Q plots while autocorrelation of model residuals was examined by ACF and PACF plots.

6.3 Results

6.3.1 Descriptive statistics

Adherence to the diary completion was impeccable. All participants completed 100% of diary occasions. There were no missing observations of any variables for participants 1, 2 & 3.

Participant 4 had one missing observation. The participants' demographic information is displayed in table 6.1.

Table 6.1 Demographic information for each participant

Participant	Age	Sex	Ethnicity	Marital	Years of education	Employment
1	42	Female	White other	Living with a partner	23	Employed FT
2	60	Female	White British	Married	20	Retired
3	28	Female	White British	Living with a partner	20	Employed FT
4	24	Male	White British	Living with a partner	13	Employed FT

A description of physical health condition and baseline recordings of pain, physical functioning, self-regulatory fatigue, pain self-efficacy, pain catastrophising, fear of movement, mood and PA goal are shown in table 6.2.

Table 6.2 Baseline descriptive statistics for each participant

	Participant 1	Participant 2	Participant 3	Participant 4
Pain condition	Back pain	Fibromyalgia	Knee pain	Low back pain
Pain duration	2-5 years	10-20 years	1-2 years	5-10 years
Average pain intensity	3	3	5	4
Physical functioning	98	84	91	87
Self-regulatory fatigue	51	46	41	52
Pain self-efficacy	52	51	49	52
Pain catastrophising	12	5	21	18
Fear of movement	21	42	33	30
Anxiety	7	8	1	5
Depression	1	2	6	3
Goal	Improve Canicross time to 7.5 minutes per mile	Increase walking from 40 minutes per day to 1 hour per day	Walk 15,000 steps per day	Go to the gym 4 times a week

All participants reported high physical functioning, moderate self-regulatory fatigue, high self-efficacy, low to moderate pain catastrophising and fear of movement and mild symptoms of anxiety and depression. Time plots of daily variation in the variables are presented below.

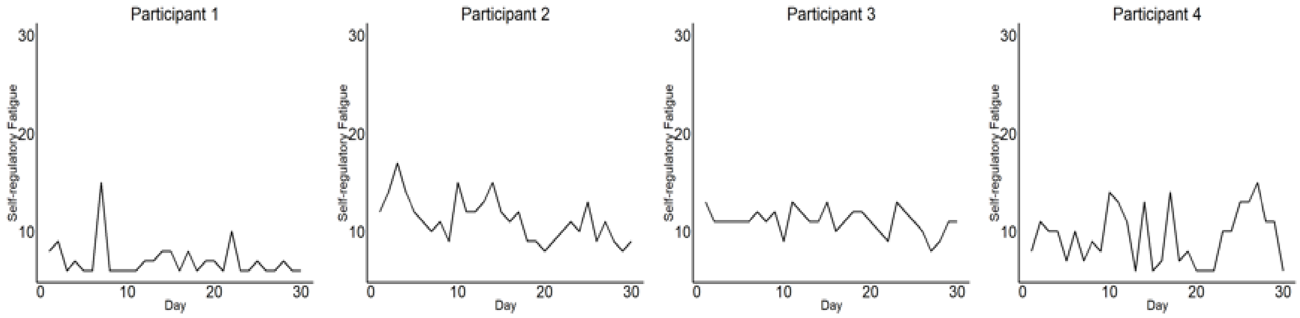

Figure 6.1 Time plots of self-regulatory fatigue of each participant by day

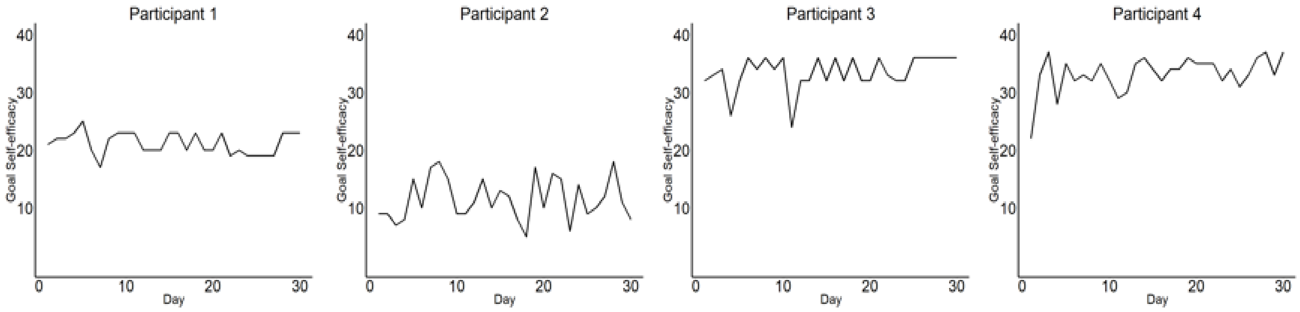

Figure 6.2 Time plots of goal self-efficacy of each participant by day

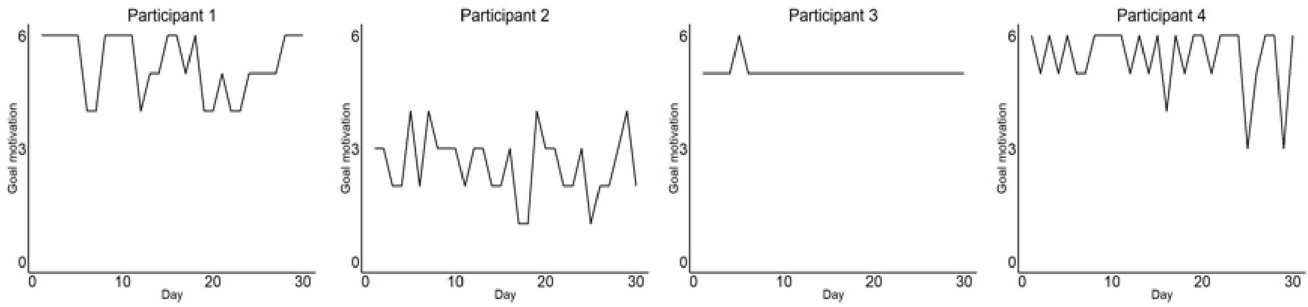

Figure 6.3 Time plots of goal motivation of each participant by day

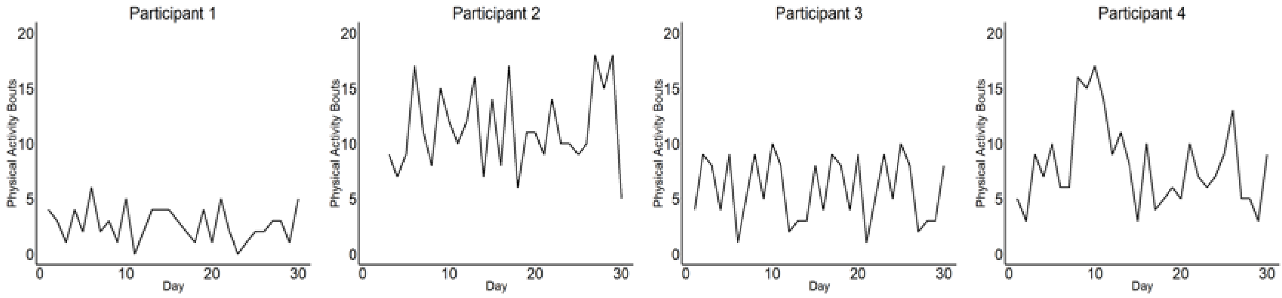

Figure 6.4 Time plots of bouts of physical activity of each participant by day

There was variation between all participants in each of the variables. Also, other than goal motivation in participant 3, fluctuations were evident over time in all variables. Descriptive statistics of each variable recorded during the diary phase are displayed for each participant in table 6.3.

Table 6.3 Means and standard deviations of each variable during diary phase for each participant

	Participant 1	**Participant 2**	**Participant 3**	**Participant 4**
Variable	***M* (SD)**	***M* (SD)**	***M* (SD)**	***M* (SD)**
Physical activity bouts	2.7 (1.6)	11.7 (4.0)	5.9 (2.9)	8.1 (3.9)
Self-regulatory fatigue	7.0 (1.8)	11.2 (2.3)	11.1 (1.3)	9.5 (2.9)
Goal self-efficacy	21.2 (1.9)	11.5 (3.7)	33.5 (2.9)	33.2 (3.1)
Goal motivation	5.3 (0.8)	2.6 (0.9)	5.0 (0.2)	5.4 (0.9)

6.3.2 The effect of self-regulation variables on physical activity and goal self-efficacy

Within each model, the reference measurement (t_0) was current morning.

Participant 1

The results of the dynamic regression modelling for participant 1 indicated that there were no significant associations between predictor variables and bouts of physical activity. Although, there was a significant effect of previous day goal self-efficacy, b=.27, SE=.11, p=.019, and concurrent goal motivation, b=1.88, SE=.24, p<.001 on current self-efficacy.

Participant 2

The results for participant 2 also demonstrated that bouts of physical activity were not associated with any of the predictor variables. For participant 2, same-day goal motivation significantly predicted goal self-efficacy, b=2.71, SE=.63, p<.001.

Participant 3

Dynamic modelling showed that daily variation in physical activity was predicted by week, b=3.95, SE=1.74, p=.032, meaning the amount of physical activity varied depending on what week it was. There was also a slight decrease in physical activity over the measurement period, b=-.58, SE=.25, p=.03. There was a significant negative effect of concurrent morning self-regulatory fatigue on morning goal self-efficacy, b=-1.16, SE=.38, p=.006, meaning as self-regulatory fatigue increased, goal self-efficacy decreased.

Participant 4

For participant 4, past behaviour was the only predictor of current behaviour, in that there was a significant effect of previous day physical activity bouts on current day physical activity bouts, b=.42, SE=.17, p=.021.

6.4 Discussion

This study examined the effect of daily fluctuations in self-regulatory fatigue, goal motivation and goal self-efficacy on daily variation in physical activity in four people with chronic pain. In addition, the effect of daily variation in self-regulatory fatigue and goal motivation on variations in goal self-efficacy. None of the self-regulation variables were associated with daily fluctuations in physical activity in any of the participants. On the other hand, previous day self-efficacy and concurrent goal motivation predicted goal self-efficacy for one participant (participant 1). Goal motivation also predicted goal self-efficacy in participant 2. Self-regulatory fatigue predicted goal self-efficacy in another participant (participant 3). The only significant association found in participant 4 was a positive effect of previous day physical activity on current physical activity. The significant effects of goal motivation and self-regulatory fatigue on goal self-efficacy were all concurrent. This suggests that changes in goal motivation and self-regulatory fatigue did not precede changes in self-efficacy but that variation in these variables occurred together.

This is the first study to examine daily fluctuation in self-report self-regulatory fatigue in people with chronic pain. The study demonstrated that daily self-regulatory fatigue varied between and within participants. This is consistent with the Strength Model, which assumes that self-regulatory capacity is determined by the availability of limited self-regulatory resources that fluctuate over time (Baumeister, 2016; Muraven et al., 1998). It has also been suggested that self-regulatory capacity can vary due to contextual factors such as stress, fatigue or alcohol consumption (Baumeister & Heatherton, 1996; Buck & Neff, 2012; Muraven et al., 2005). In the context of chronic pain, fluctuations in self-regulatory fatigue may be partially accounted for by daily fluctuations in pain intensity, as there is evidence of a dose dependent effect of pain intensity on self-regulatory fatigue (Solberg Nes, 2011).

That said, the evidence for the participants in this study experiencing chronic self-regulatory fatigue was limited. Previous research has suggested that people with chronic pain may have increased vulnerability to experiencing self-regulatory fatigue (Rost et al., 2017; Solberg Nes et al., 2011; Solberg Nes et al., 2017). This may be due to a chronic reduction in self-regulatory capacity due to increased demands when managing chronic pain (Solberg Nes et al., 2011; Solberg Nes et al., 2009). However, all investigations of self-regulatory fatigue in people with chronic pain thus far have investigated average self-regulatory fatigue in groups of patients. In the current study, fluctuations in reported self-regulatory fatigue for each participant appeared to range from low to moderate (<15, range 6-30). Also, the mean of daily self-regulatory fatigue for each participant in this study was lower than the mean of self-regulatory fatigue, as measured by the SRFS-6, in a healthy sample in chapter four

(*M*=16.0, p135). The sample in this study comprised of participants, recruited from the community, who reported low to moderate average pain intensity, high physical functioning, high pain self-efficacy, low fear-avoidance and mild symptoms of anxiety and depression. Therefore, people with chronic pain who are high functioning may be less vulnerable to experiencing self-regulatory fatigue or the levels experienced may not generally have a significant impact on activity levels. Additionally, exclusive use of between-subjects designs in previous research will not have allowed for the capture of individual-differences in self-regulatory fatigue.

Unexpectedly, fluctuations in self-regulatory fatigue had no effect on pursuing a physical activity goal. This conflicts with the Strength Model assumptions that fluctuations in self-regulatory capacity have a direct impact on fluctuations in self-regulation performance (Baumeister et al., 1998; Baumeister, Muraven, & Tice, 2000). The current findings are also inconsistent with previous within-person studies, which have shown that engaging in prior self-regulation to induce ego-depletion led to decreased exercise performance (Dorris et al., 2012; Englert & Wolff, 2015). Fluctuations in goal self-efficacy and goal motivation also did not have an effect on fluctuations in physical activity in any participants. The lack of associations between fluctuations in self-efficacy and physical activity was unanticipated. This finding contradicts previous research that has consistently demonstrated that self-efficacy predicts engagement in physical activity in both between-subjects studies (Huffman, Pieper, Hall, St Clair, & Kraus, 2015; McAuley, Szabo, Gothe, & Olson, 2011) and N-of-1 studies (Hobbs, Dixon, et al., 2013; O'Brien et al., 2016; G. Smith et al., 2019). Although, it is important to note that while self-efficacy beliefs measured in this study were directed at a particular physical activity behaviour (e.g. “Walk 15,000 steps per day”), physical activity was measured generally. This may explain the lack of relationship between self-efficacy, motivation and physical activity.

Additionally, there is evidence that physical activity enjoyment, which was not measured here, is a more important determinant of physical activity behaviour than self-efficacy (Lewis, Williams, Frayeh, & Marcus, 2016). The participants in the current study chose their own exercise goal. This suggests that goal motivation was most likely intrinsic, which usually means higher motivation and enjoyment (Ryan & Deci, 2000; Ryan, Frederick, Lepes, Rubio, & Sheldon, 1997; Waterman, 2005). In line with this, goal motivation was generally high in this study. Therefore, the potential effects of self-efficacy and motivation on physical activity may have been masked by another motivational or cognitive factor that had a stronger effect.

While the reasons are unclear, the current study is not the first to find that changes in self-report motivation and self-efficacy were not related to changes in objectively measured physical activity (Bond, Graham, Vithiananthan, Webster, Unick, Ryder et al., 2016). Slight fluctuations in motivation, or self-regulatory fatigue, which was generally low, may not have made a meaningful difference to effort and performance in this study. This may suggest that there was a general threshold effect, where fluctuations in self-regulatory variables may not have been sufficient for there to be a noticeable change in mental state in participants. In this study, the lack of associations between the self-regulatory variables and physical activity may also reflect that relationships observed with aggregated data may be inflated and this can mask the true nature of relationships. The relationships observed within disaggregated data, as in this study, can demonstrate different associations than expected. Given that none of the variables predicted physical activity, this research also highlights that engagement in physical activity is determined by individual-specific factors. Therefore, when designing interventions to increase physical activity in people with chronic pain, taking a personalised approach may yield better results (Hobbs, Godfrey, Lara, Errington, Meyer, Rochester et al., 2013; Noar, Benac, & Harris, 2007).

Motivation and self-regulatory fatigue were related to goal self-efficacy in the current study, albeit with different patterns of associations for each participant. Fluctuations in motivation predicted fluctuations in concurrent goal self-efficacy in two participants. Variability in self-regulatory fatigue was negatively related to concurrent goal self-efficacy in one participant. In one participant, there were no significant associations with self-efficacy. Self-efficacy beliefs are proposed to determine the amount of resources allocated to a task and when resources should be conserved (Vancouver et al., 2008; Yeo & Neal, 2012). The results of this study demonstrated that when an association between self-efficacy and motivation and self-regulatory fatigue was observed, the relationships were in the direction that would be expected. That is, on days when motivation was higher, self-efficacy was higher and on days when self-regulatory fatigue was higher, self-efficacy was lower. The findings in the current study are consistent with the conservation of resources view that fluctuations in motivation and self-regulatory capacity are both implicated in allocating resources and self-regulatory effort (Muraven & Slassereva, 2003; Muraven et al., 2006). However, the participants did not exhibit the same pattern of relationships, highlighting the importance of testing theoretical assumptions within individuals.

6.4.1 Limitations and future research

Some limitations of the current study must be considered. Firstly, it is important to note that the study design and analysis provide an examination of the relationship in the variability between these variables and do not allow for conclusions to be drawn about the causal direction. While a strength of the study is that physical activity was measured objectively, progress specific to the physical activity goal was not measured. Future research which uses ambulatory methods and measures specific goal progress may be more sensitive in determining how shifts in self-regulatory fatigue, motivation and self-efficacy effect a physical activity goal.

Another limitation of the current study was the low number of observations, which may have resulted in low statistical power. While Monte-Carlo simulations have shown that a modest number of observations produced good coefficient estimates, a minimum of 50 is suggested for dynamic modelling with time series data (Keele & Kelly, 2006). It was reported that using as few as 25 observations increased the rate of false rejections of the null hypothesis (Keele & Kelly, 2006). However, this conclusion drawn from simulations assumed that there was a degree of autocorrelation of the model residuals. This study had 30 observations of each variable but there was no significant autocorrelation of model residuals in any of the models. Therefore, the low number of observations in this study may still have provided reliable coefficient estimates.

6.4.2 Conclusion

This study found that variations in self-regulatory fatigue, motivation and goal self-efficacy did not have a significant effect on variations in physical activity in four participants with chronic pain, recruited from the community. There were differential patterns of relationships between self-regulatory fatigue, motivation and goal self-efficacy, illustrating that motivational and cognitive processes in goal pursuit differ between individuals. Further examination of goal processes within-person is important for determining the validity of theory. Therefore, study designs, which go beyond investigations of between-subjects relationships to assess goal processes at the intra-individual level are necessary.

7 An examination of the effect of daily fluctuations in self-regulatory fatigue on daily variation in motivation to conserve resources

7.1 Abstract

Objectives: There is evidence that people with chronic pain have reduced capacity for self-regulation, or self-regulatory fatigue, which may negatively impact goal pursuit. The underlying mechanisms by which self-regulatory fatigue affects self-regulation performance in chronic pain is unclear as existing evidence has been examined with between-subjects designs measuring average group differences. This study used a within-subject design to examine potential processes that might explain the relationship between self-regulatory fatigue and motivation to conserve resources.

Method: A series of N-of-1 studies were conducted. Four participants with chronic pain who were attending a pain management programme (PMP; 41-59 years old; 3 female) completed daily diaries with self-report measures of self-regulatory fatigue, goal self-efficacy, goal striving, perceived demands, pain and motivation to conserve resources for the duration of the PMP. The data collection period lasted between 11-12 weeks. Analyses were conducted individually for each participant.

Results: Dynamic regression models demonstrated that predictors of motivation to conserve resources varied for each participant and participants did not demonstrate identical patterns of associations. All of the predictors were related to motivation to conserve resources in at least one participant. Motivation to conserve resources was predicted by at least three predictors in three participants; in one participant it was not predicted by any of the predictors. Most associations occurred concurrently where the most frequent relationship observed was a negative association between goal striving and motivation to conserve resources.

Conclusion: This study identified mechanisms which predict whether participants are motivated to conserve resources or not. Daily fluctuation in the self-regulation predictors

were associated with daily fluctuations in motivation to conserve resources during goal pursuit. Examining within-person relationships in self-regulation is essential to determine the validity of self-regulation theory. The identification of self-regulatory mechanisms that facilitate or impede goal pursuit in people with chronic pain will support the design of individually tailored activity pacing to enable adaptive goal pursuit.

A commonly reported outcome of experiencing chronic pain is interference with valued goals and activities (Affleck, Tennen, Urrows, Higgins, Abeles, Hall et al., 1998; Affleck, Tennen, Zautra, Urrows, Abeles, & Karoly, 2001; Karoly & Ruehlman, 2007). As a result of the interruptive nature of pain, pain is often considered a barrier to engaging in valued activities and goals (Bushnell et al., 2013; Eccleston & Crombez, 1999). For example, it has been reported that in women with fibromyalgia, there was more interference and less progress in pursuing social and health goals on days when they were experiencing higher pain intensity (Affleck et al., 1998). Engagement in valued goals and activities is fundamental in constructing self-identity. The negative impact of chronic pain on goal pursuit is problematic as loss of social roles (e.g. friend, employee), and associated attributes, are related to depression (Goossens, Kindermans, Morley, Roelofs, Verbunt, & Vlaeyen, 2010; Harris, Morley, & Barton, 2003). Moreover, there is evidence that goal pursuit reduces attentional bias toward pain and pain-avoidance behaviour (Claes, Karos, Meulders, Crombez, & Vlaeyen, 2014; Schrooten, Van Damme, Crombez, Peters, Vogt, & Vlaeyen, 2012; Van Damme, Van Ryckeghem, Wyffels, Van Hulle, & Crombez, 2012). Therefore, examining factors that enhance or impede goal pursuit in people with chronic pain is important for understanding adaption to chronic pain.

To facilitate the adoption of goal-contingent goal pursuit, as opposed to pain-contingent or fatigue-contingent goal pursuit, activity pacing is frequently administered to people with chronic pain (Andrews et al., 2012; Torrance, Smith, Elliott, Campbell, Chambers, Hannaford et al., 2010). It is assumed that activity pacing will enable conservation of limited energy resources in people with chronic illnesses (Fordyce, 1976; Gill & Brown, 2009; Nielson et al., 2013). Therefore, the purpose of the activity pacing is to reduce energy depletion (Gill & Brown, 2009; Nielson et al., 2013). There is mixed evidence for the effectiveness of activity pacing to conserve resources (Nielson et al., 2013). Due to the lack of a theoretical framework within which to design activity pacing interventions, the reasons for its inefficacy are unclear (Nielson et al., 2013). It has also been suggested that the psychosocial context of activity patterns, such as motivation for pain avoidance behaviour or endurance behaviour, needs to be considered (Murphy, 2015). Chapter two examined whether there was evidence for the assumption that people with chronic pain have reduced energy resources and found partial support for this. Therefore, it would be useful to assess the assumption that people with chronic pain have reduced energy and motivation for activity within individuals in daily life.

It has been hypothesised that goal pursuit is more taxing in people with chronic pain due to a chronic self-regulatory fatigue, or a reduced self-regulatory capacity (Solberg Nes et al., 2010; Solberg Nes et al., 2013; Solberg Nes et al., 2009). The Strength Model proposes that self-regulatory capacity is a limited resource (Baumeister et al., 1998; Muraven et al., 1998) and there is evidence that this is the case (Hagger et al., 2010). Lower self-regulatory capacity has been observed in people with chronic pain compared to healthy controls using experimental methods (Solberg Nes et al., 2010, 2011), self-report (chapters two and three) and lower heart rate variability, a physiological indicator of lower self-regulatory capacity (Rost et al., 2017). However, more recently, inconsistencies in the findings and some methodological and conceptual issues of the Strength Model have been highlighted (Arber et al., 2017; Carter et al., 2015; Carter & McCullough, 2013, 2014; Hagger et al., 2016; Lurquin & Miyake, 2017).

There is debate around whether decreases in self-regulation performance result from a reduction of self-regulatory capacity or reductions in motivation. The conservation of resources hypothesis argues that reductions in both motivation and self-regulatory resources are implicated in decreases in self-regulation performance (Hobfoll, 1989; Muraven & Slessareva, 2003). However, decreases in self-regulation performance after engaging in a prior self-regulation task have traditionally been viewed as a negative outcome, labelled as self-regulation failure (Baumeister et al., 1998). Recent affective-motivational accounts have proposed that fluctuations in motivation and performance are adaptive as accompanying cognitive discomfort (e.g. mental fatigue, pain) can result in either up-regulation of goal pursuit, or temporary down-regulation allowing for future increased efforts (Inzlicht et al., 2014; Saunders & Inzlicht, 2015; Saunders et al., 2015; Van Damme et al., 2018).

It has been previously suggested that the conservation of resources hypothesis can explain the effect of pain on self-regulation performance (Eisenlohr-Moul et al., 2013; Muraven et al., 2006; Solberg Nes et al., 2011). Within the context of chronic pain, persisting on a task beyond the point at which costs outweigh benefits (e.g. increasing pain) is a maladaptive strategy which induces fatigue (Hasenbring, Marienfeld, Kuhlendahl, & Soyka, 1994; Legrain, Crombez, Verhoeven, & Mouraux, 2011; Van Damme et al., 2018). The induction of fatigue serves to decrease motivation for further effort, the purpose of which is to optimise resource allocation when increasing demands arise (Van Damme et al., 2018).

Personality and cognitive factors may also have an effect on the cost-benefits analysis of continuing to engage in tasks. For example, optimism in people with chronic pain has been found to moderate self-regulation performance where those high in optimism only persisted on the task if they did not experience self-regulatory fatigue (Solberg Nes et al., 2011). In study 1 of chapter two (p67), pain self-efficacy was related to better task performance on an initial task of self-regulation, and negatively related to task performance on a subsequent self-regulation task in participants with chronic pain. In study two (p79), when within-person task self-efficacy was higher in participants with chronic pain, resource allocation was higher. However, higher within-person task self-efficacy was only beneficial for overall task performance up to a point, beyond which it became detrimental. This suggests that when experiencing self-regulatory fatigue, some factors, such as optimism, aid the allocation of resources for optimal goal pursuit. Meanwhile, when self-regulation capacity is reduced in people with chronic pain, higher self-efficacy, when measured within-person, may not be facilitative of adaptive resource allocation.

The majority of psychological theory make idiographic predictions and so determining whether theory or models account for changes in proposed mechanisms within individuals is vital (D. W. Johnston & Johnston, 2013). The Strength Model is no exception to this, hypothesising that an individual who engages in self-control efforts will exhaust self-control resources over time. Despite this, the majority of the literature have tested the model using between-subjects experimental designs (Hagger, 2010; Hagger et al., 2010). It has been argued that self-regulation is a dynamic process, which requires dynamic measurement (Neal et al., 2017). Moreover, when investigating goal motivation during multiple-goal pursuit, it has been reported that 60-80% of the variance occurs at the within-person level (Milyavskaya et al., 2015; Werner et al., 2016). Therefore, sole reliance on the dual-task paradigm to test the Strength Model and conservation of resources hypothesis is problematic, as only examining differences in performance between groups does not allow for an examination of shifts in motivation and fluctuations in effort across tasks. Therefore, using methods that observe dynamic fluctuations in motivation, effort and performance over time can provide a better understanding of the underlying mechanisms involved in goal pursuit.

N-of-1 designs, which involve longitudinal repeated measurement within an individual, are one such method of assessing within-person variability (D. W. Johnston & Johnston, 2013). These designs allow conclusions to be drawn about variation in the individual over time. It has been recommended that N-of-1 methods are used to test theory and interventions (Craig et al., 2008; McDonald et al., 2017). For example, N-of-1 methods have been used to assess whether social cognitive constructs predict physical activity within individuals (Hobbs, Dixon, et al., 2013; O'Brien et al., 2016; G. Smith et al., 2019). The aim of the current study was to examine the relationship between motivation to conserve resources and self-regulatory fatigue, self-efficacy, pain, goal striving and perceived demands during goal pursuit in individuals with chronic pain.

7.2 Methods

7.2.1 Design

A series of observational N-of-1 studies were conducted for approximately 84 days (12 weeks) over the duration of a Pain Management Program (PMP). A daily diary method was used to measure study variables by self-report twice daily, once in the morning (between 7am and 10am) and again 12 hours later. Therefore, there were around 168 observations in total for each participant on each variable (84 in the morning and 84 in the evening).

7.2.2 Participants

Participants who were due to attend an NHS based PMP in Scotland were recruited by clinician referral. Inclusion criteria for this study were that patients were between the age of 18-65 years old, experienced chronic pain (defined as persistent pain lasting longer that 3 months), fluent in English language, not currently experiencing acute injury and that they were due to begin the PMP within 3 months. Patients who were interested in participation were provided a letter of invitation and participant information sheet. Patients who expressed interest were asked to provide contact information to be contacted one week later. After this one-week consideration period, patients were invited to participate in the study. Seven participants (6 female, 1 male) were invited to take part. Of those seven invitees, one decided not to take part prior to the baseline meeting and one participant had to withdraw as they could not commence the PMP until after the data collection period would end. Another participant began the study but withdrew less than half way through the PMP and a technical issue compromised their evening data collection meaning the available data could not be examined. Therefore, four participants completed the study. Participants were remunerated with £50 upon completion of the study. The study was granted ethical approval by the NHS South West-Central Bristol Research Ethics Committee (reference number: 18/SW/0076).

7.2.3 Measures

Baseline

Demographics: Each participant provided their age and gender. Participants were asked to describe any physical or mental health conditions they were experiencing as a free text response.

Pain: Participants provided the duration of their pain (years). Current and average pain (pain over the past 6 months) intensity was rated on an 11-point Likert scale from 0 (no pain) to 10 (pain as bad as can be).

Physical functioning: Physical functioning was assessed by self-report using the PROMIS Physical Function Short Form 8a (PROMIS PF-8a). The PROMIS PF-8a (Cella et al., 2010) is an eight item measure developed from the PROMIS items bank of 124 physical functioning items which measure mobility, dexterity, movement of neck and back and instrumental activities. The PROMIS PF-20 assesses current ability to perform basic activities of daily living. Fourteen items on the measure (e.g. "Are you able to go up and down stairs at a normal pace"; "Are you able to run errands and shop?") are rated on a 5-point Likert scale anchored by 5 ("Without any difficulty") to 1 ("Unable to do"). Four items (e.g. "Does your health now limit you from doing 2 hours of physical labour?"; "Does your health now limit you in lifting and carrying groceries?") are measured on a 5-point Likert scale anchored by 5 ("Not at all") to 1 ("Cannot do"). All items are summed and the scale provides a score range of 8-40 where higher scores indicate better physical functioning.

Self-regulatory fatigue: The Self-regulatory Fatigue Scale (Solberg Nes et al., 2013) measures self-regulation fatigue, or a reduced capacity to self-regulate, in chronic multisymptom illness (e.g. “It is easy for me to set goals”). Each item is scored on a 5-point Likert scale from ‘strongly disagree’ to ‘strongly agree’. The scale measures cognitive (6 items), emotional (7 items) and behavioural (5 items) components of self-regulatory fatigue to produce an 18-item scale with a range of 18-90 where higher scores indicate higher self-regulatory fatigue.

Pain self-efficacy: The Pain Self-efficacy Questionnaire (Nicholas, 1989) measures confidence in ability to cope despite pain in a variety of situations (e.g. “I can enjoy things, despite the pain”). It is a 10-item instrument where items are scored on a range of 0 (not at all confident) to 6 (completely confident) for a total range of 0-60 where higher levels indicate higher pain self-efficacy.

Mood: The Hospital Anxiety and Depression Scale (Zigmond & Snaith, 1983) was designed to screen for anxiety and depression in those with illness where symptoms may be conflated (e.g. aching muscles). The HADS has a depression subscale and an anxiety subscale with 7 items each. Each item is scored on a scale of 0 to 3 relating to the frequency that a symptom has been experienced over the past 7 days, thus each subscale has a range of 0-21.

Fear of Movement: The 13-item version of the Tampa Scale of Kinesiophobia (Miller et al., 1991) is a modified version of the original Tampa Scale of Kinesiophobia (TSK) where reverse-scored items were removed. The TSK was used to assess pain-related fear of movement. The TSK assesses pain-related fear beliefs (e.g. “Pain always means I have injured my body”) and fear of movement (e.g. “No one should have to exercise when he/she is in pain”) on a scale from 1 (strongly disagree) to 4 (strongly agree) resulting in a scale range from 13 to 52. Higher scores indicate higher fear of movement.

7.2.4 Daily Diary Measures

Motivation to Conserve Resources: Motivation to conserve resources during the current day was measured with one item ("How important was it for you to conserve energy or strength today?"). This was measured on a scale from 1 (Not at all) to 5 (Very much).

Pain: Current pain intensity with one item ("How would you rate your pain level at the present time, that is pain right now, where 0 is 'no pain' and 10 is 'pain as bad as can be' was rated on an 11-point Likert scale.

Self-regulatory fatigue: Self-regulatory fatigue was assessed by the Self-regulatory Fatigue Scale three-item short form (SRFS-3) developed in chapter four. The behavioural, cognitive and emotional facets of self-regulatory fatigue were measured by one item each from the behaviour, cognitive and emotion subscales. For a list of items see p244. Each item was framed to measure current self-regulatory fatigue (e.g. "Rate how much you agree that you feel this way right now"). The scale range was from 3 to 15. Although the SRFS-3 displayed less satisfactory reliability and validity than the SRFS-6 (section 4.4.2), the SRFS-3 was selected to measure self-regulatory fatigue in this study to minimise daily burden on the participants. This was deemed necessary due to the participant sample (i.e. patients) and the duration of measurement (i.e. 12 weeks).

Goal Selection: Participants were presented with an item to assess which goal they would pursue each day ("Which goal is most important to you today?"). Participants could respond by selecting the goal they chose at the baseline meeting (see Baseline Procedure section below) or by selecting "other" and providing their daily goal response within a free-text box.

Goal Self-efficacy: As in chapter six, goal self-efficacy was measured by several personalised self-efficacy items (J. J. Francis et al., 2004). These self-efficacy items were specific to the participant's individual goal. One item assessed general confidence in the ability to achieve the goal during the present day ("I am confident I can pursue my goal today") in all participants. Then, further items assessed confidence in ability to achieve with increasing difficulty, for example, when barriers arise. Potential barriers included in self-efficacy items were also specific to the participant (e.g. "I am confident that I can pursue my goal when I have a flare-up of pain"). Goal self-efficacy was measured with three or four items for each participant (depending on number of identified barriers) on a 5-point Likert scale from 1 (Not at all confident) to 5 (Completely confident), providing a score range of 1-20. The full list of additional goal self-efficacy items for each participant can be found in appendix 3, p246.

Goal Striving: Two items were used to measure goal striving over the during the current day. One item measured goal efficiency ("How efficiently have you worked on your goal today?") and was measured on a scale from 1 (Not at all) to 5 (Very much). One item measured goal pursuit frequency ("How often did you work on your goal today?") on a scale from 1 (Not time at all) to 5 (All the time). The two items were summed to generate a score range from 1-10 where higher scores indicated higher goal striving.

Perceived Demand: Perceived demand during the current day was measured with one item ("Overall, how demanding was your day?") on a scale from 1 (Not at all) to 5 (Very much).

7.2.5 Procedure

Baseline: An initial meeting took place where participants provided written consent. Then a brief semi-structured interview was conducted to illicit valued activities, and to identify a goal and barriers, which were used to construct the personalised self-efficacy items. Participants then completed the baseline measures and were given a demonstration of the daily diary. To reduce participant burden, measures of fear of movement and mood were not recorded by the researcher at the initial meeting as they were recorded at the first session of the pain management programme by clinicians. The scores for these variables were retrieved after participants provided consent.

Pain management programme: The PMP was delivered within a Scottish NHS secondary care setting by clinicians (e.g. clinical psychologist, specialist nurse, and physiotherapist). The programme was a weekly group intervention based on Acceptance and Commitment therapy (ACT) principles and included pain education, physiotherapy, acceptance and mindfulness strategies as well as commitment to values and behaviour change. Each participant engaged in a pain management programme, which lasted either 10 or 12 weeks regardless of their participation in the research study.

Daily Diary Phase: The participants were provided the opportunity to complete the daily diary from the day following the baseline meeting, which was up to one week prior to the first day of the PMP. Completion of diary entries prior to the commencement of the PMP was to allow participants to get accustomed to the procedure, and so were not included in the analysis. The daily diary was completed online on the Qualtrics platform. A link to the diary was sent via a text message to participants' smartphones at the agreed morning time. The morning diary included measures of pain intensity, goal identification, self-regulatory fatigue, goal self-efficacy, mood, goal motivation, expected demand, expected progress and expected fatigue. The evening diary, which was administered 12 hours after the morning diary measured pain intensity, self-regulatory fatigue, mood, perceived demand, goal effort, goal striving, motivation to conserve resources and pain medication taken that day. Additional morning diary questions and evening diary variables were measured but are not examined in this study. Every two weeks after beginning the diary phase, a face-to-face meeting was conducted at the delivery site of the PMP to discuss any issues with the study and ensure continued consent to participate. Participants were also encouraged to contact the researcher if any problems arose throughout the diary phase. After the 12 week diary phase was complete, another face-to-face meeting was arranged to debrief the participant and provide the remuneration for their participation.

7.2.6 Data Analysis

The data were analysed individually for each participant using R statistical software v3.4.4. Where there was a very small number of observations missing at random (e.g. <0.05%), the mean of prior and subsequent observations was input. Otherwise, missing data was managed with multiple imputation using the AMELIA II package v1.7.5 (Honaker, King, & Blackwell, 2011). The AMELIA II package uses an expectation-maximisation bootstrapping (EMB) algorithm to model missing cases, specifically designed for time series data (Honaker et al., 2011). Five imputed datasets were produced where missing cases were imputed. All analysis was conducted on each of the five datasets and statistic estimates were calculated by pooling the results from each imputed dataset using Rubin's rules (Rubin, 1996). Using Rubin's rules to calculate parameter estimates accounts for the within and between variance of the combined results and calculating estimates with this method provides 95% confidence in inference when using multiply imputed datasets.

Time plots were examined for trends in the data and autocorrelograms were assessed for each variable to determine whether there was autocorrelation. Examining the relationship between the predictor variables and motivation to conserve resources was conducted using dynamic modelling, as has been recommended for analysing N-of-1s (Vieira et al., 2017). Descriptive and multivariate analysis was conducted.

As the purpose was to determine which variables had the most impact on motivation to conserve resources, a stepwise approach was used to ascertain the model with the best model fit as determined by Akaike's Information Criterion. The approach to determine the model with the best fit was a process of adding predictors to determine whether they accounted for significant variance in the model and, if not, removing them at the next step. First, an empty model was tested. Then, based on examination of the time plots and autocorrelograms, lags of motivation to conserve resources and day, week and month were included as control variables as necessary prior to the inclusion of predictor variables. For example, if lags 1 and 2 of motivation to conserve resources were entered into the model but lag 2 was non-significant, it was removed from further models. Meanwhile, lag 1 was retained in later models, even if it became non-significant as predictors were entered, because it was a control variable. Next, a predictor variable at lag 0, lag 1 and lag 2 was added to the model (including control variables). If lag 0, lag 1 or lag 2 of said predictor was non-significant it was removed. If the predictor at lag 0, lag 1 or lag 2 was significant, it was retained in future models unless it became non-significant in later models. The order in which predicters were entered was always pain, self-regulatory fatigue, goal self-efficacy, goal striving and, lastly, perceived demand. Akaike's information criterion was checked for each model to determine best fit and the model with the best fit was reported. The effect of pain, self-regulatory fatigue, goal self-efficacy, goal striving and perceived demand on motivation to conserve resources was examined for each individual participant. The model residuals were then assessed for normality using a histogram and Q-Q plots and autocorrelation using ACF plots and PACF plots.

7.3 Results

7.3.1 Participant characteristics

The participants' demographic information, description of physical health condition(s) and baseline recordings of pain, self-regulatory fatigue, pain self-efficacy, fear of movement, mood and personal goal are shown in table 7.1. Questionnaire scores for fear of movement, anxiety and depression for participant 3 are missing as this was not recorded at the first session. Additional goals pursued by participants over the course of the study can be found in appendix 4 (p247).

Table 7.1 Baseline descriptive information for each participant

	Participant 1	Participant 2	Participant 3	Participant 4
Age	48	41	50	59
Gender	Female	Male	Female	Female
Pain condition(s)	Neck, shoulder and lower back pain	Arthritis, trapped nerve in neck, diabetic neuropathy	Persistent pain	Osteoarthritis, polymyalgia rheumatica
Comorbid condition(s)	-	Diabetes type 1, retinopathy, nephropathy, high blood pressure, angina	Suspected spastic paraplegia	Post viral depression
Pain duration	2-5 years	10-20 years	10-20 years	1-2 years
Current Pain	5	9	6	5
Average pain intensity	7	8	10	8
Physical functioning	27	18	10	13
Self-regulatory fatigue	49	67	43	68
Pain self-efficacy	33	22	10	19
Fear of movement	27	19	-	36
Anxiety	6	16	-	8
Depression	11	12	-	9
Goal	Enjoy activities more	Manage emotions when unexpected setbacks arise	Improved management and maintenance of relationships	Feeling more confidence in managing pain
PMP length	10 weeks	12 weeks	12 weeks	10 weeks

7.3.2 Descriptive statistics

Compliance with diary completion was very high. Participants 1, 2 and 3 completed 100% of diary entries and there were no missing observations. Participant 4 completed the diary on 97.5% of possible occasions and 4% of observations were missing. Evening observations were more likely to be missing than morning observations. Therefore, MI was undertaken in participant 4’s data to provide a full dataset. The results for participant 4, reported below, are the product of pooled estimates from five imputed datasets. Time plots of motivation to conserve resources and predictor variables are shown in figures 7.1 to 7.6.

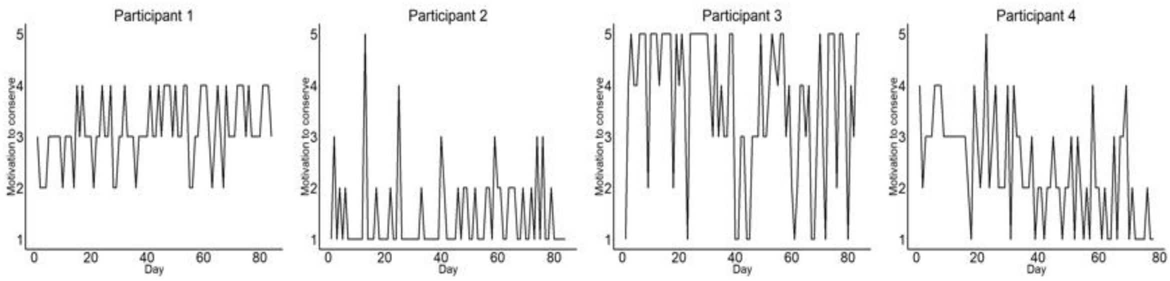

Figure 7.1 Motivation to conserve resources of each participant over time

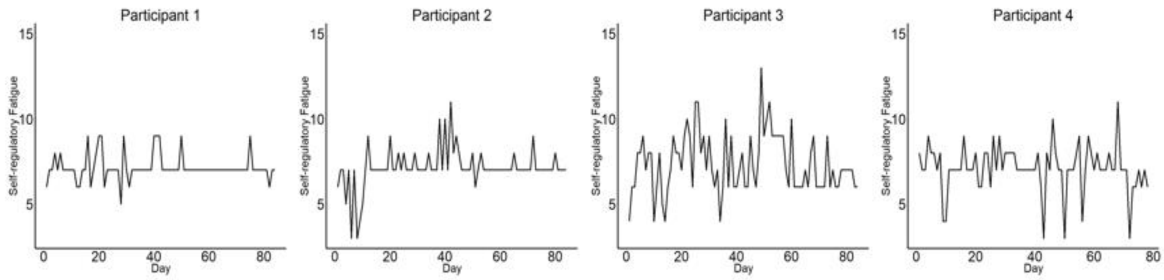

Figure 7.2 Self-regulatory fatigue of each participant over time

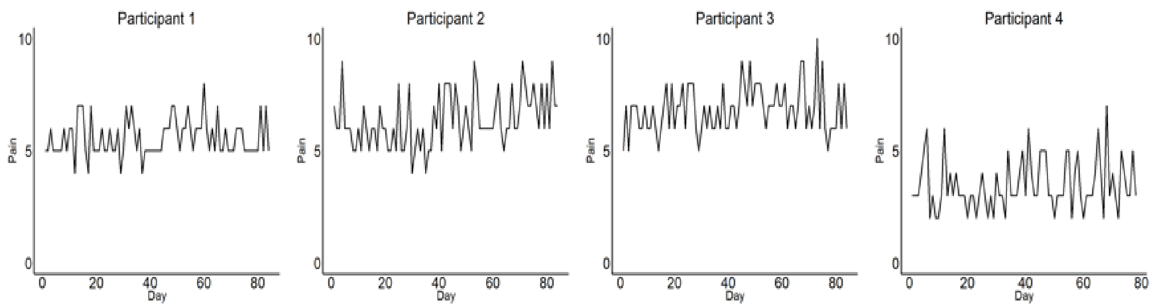

Figure 7.3 Pain intensity of each participant over time

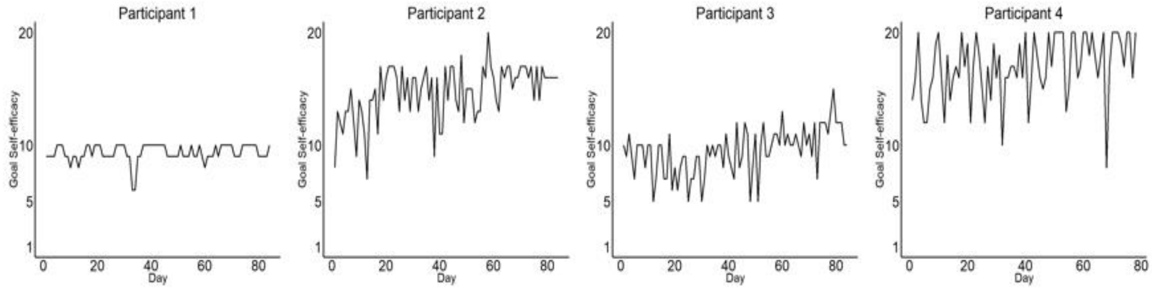

Figure 7.4 Goal self-efficacy of each participant over time

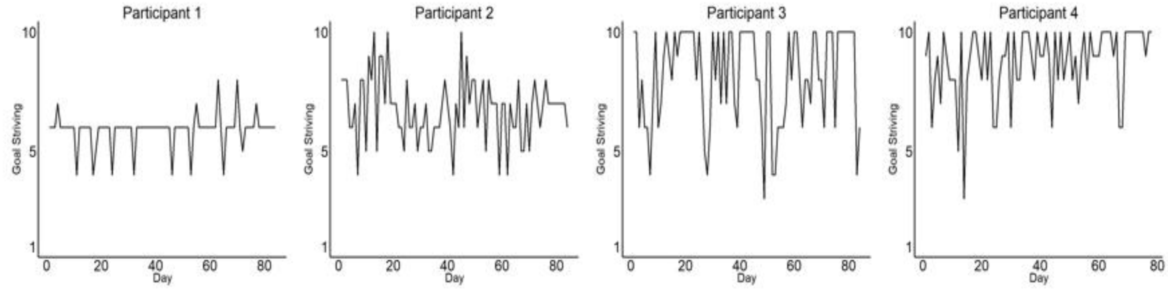

Figure 7.5 Goal striving of each participant over time

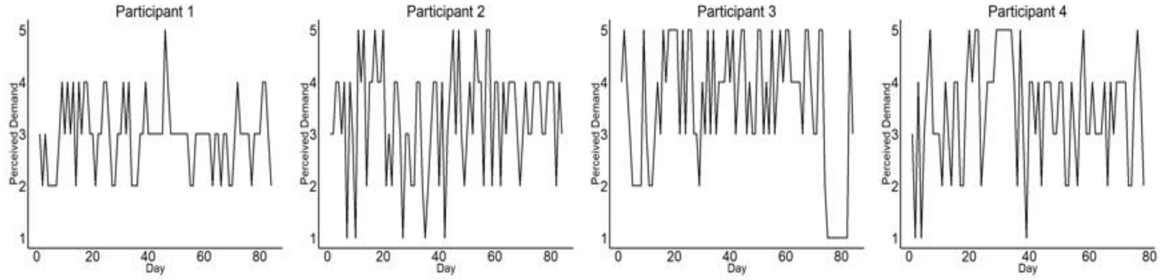

Figure 7.6 Perceived demand of each participant over time

Figures 7.1-7.6 illustrate that there is evidence of variance across participants and within participants over time on all variables. There may have been ceiling effects for participants 3 and 4 on goal striving and for participant 4 on self-efficacy. The means and standard deviations for motivation to conserve resources, pain, self-regulatory fatigue, goal self-efficacy, goal striving and perceived demand for each participant are displayed in table 7.2.

Table 7.2 Descriptive statistics for daily motivation to conserve resources and the predictor variables

	Participant 1	Participant 2	Participant 3†	Participant 4
Variable	***M* (SD)**	***M* (SD)**	***M* (SD)**	***M* (SD)**
Motivation to conserve	3.1 (0.7)	1.4 (0.8)	3.7 (1.4)	2.3 (1.0)
Pain	5.7 (0.9)	6.8 (1.2)	7.3 (1.1)	3.7 (1.3)
Self-regulatory fatigue	7.1 (0.7)	7.5 (1.2)	7.6 (1.7)	7.1 (1.5)
Goal self-efficacy	9.3 (0.8)	14.7 (2.4)	9.5 (2.1)	17.2 (2.7)
Goal striving	5.9 (0.7)	6.8 (1.3)	8.2 (2.0)	8.9 (1.4)
Perceived demand	3.0 (0.7)	3.3 (1.1)	3.6 (1.3)	3.5 (1.1)

†The possible goal self-efficacy score ranged from 1-15 for participant 3 and 1-20 for participants 1, 2 & 4

7.3.3 The effect of pain, self-regulatory fatigue, goal self-efficacy, goal striving and perceived demand on motivation to conserve resources

An overview of the results of the dynamic modelling for each participant is displayed in table 7.3. Within each model, the reference measurement (t_0) is current evening. Lag 1 (t_1) is morning of the current day, lag 2 (t_2) is previous evening and so forth.

Table 7.3 Multivariate associations between predictor variables and motivation to conserve resources[2]

	Participant 1	Participant 2	Participant 3	Participant 4
Week	0.06^{***}	-	-	-
Motivation to conserve	-	-	-	0.24^{**} (lag 2)
Pain	0.20^{**} (lag 0) 0.11^{*} (lag 2)	-	-0.36^{*} (lag 0) -0.25^{*} (lag 3)	-
Self-regulatory fatigue	0.14^{*} (lag 3)	-	0.37^{***} (lag 0)	-
Goal self-efficacy	-	-	-	-0.08^{*} (lag 0)
Goal striving	-0.19^{*} (lag 0)	-	-0.34^{***} (lag 0)	-0.24^{***} (lag 0)
Perceived demand	0.23^{*} (lag 0)	-	-	0.37^{***} (lag 0)

$^{*}p$<.05, $^{**}p$<.01, $^{***}p$<.001

Pain had a variable effect on motivation to conserve resources. In participant 1, there was a small positive effect of week on motivation to conserve resources, suggesting that motivation to conserve resources varied week to week. Concurrent pain intensity and the previous

[2] The effect of motivation to conserve resources at lag 1, day and month were also controlled for to account for possible autocorrelation or trends in the data. These did not have a significant effect on any of the models for any of the participants.

evening's pain intensity predicted motivation to conserve resources. Meanwhile in participant 3, current pain intensity and pain intensity from the previous morning negatively predicted motivation to conserve resources. In contrast, pain was not predictive of motivation to conserve resources for participants 2 and 4.

Similarly, the relationship between self-regulatory fatigue and motivation to conserve resources was also variable. Again, motivation to conserve resources was not predicted by self-regulatory fatigue in participants 2 and 4. However, concurrent self-regulatory fatigue predicted motivation to conserve resources in participant 3, while previous morning self-regulatory fatigue predicted motivation to conserve resources in participant 1.

Goal striving was predictive in three of the participants. Current days' goal striving negatively predicted motivation to conserve resources in participants 1, 3 and 4.

Goal self-efficacy recorded in the morning negatively predicted motivation to conserve resources in the evening for one participant (participant 4).

Perceived demand predicted concurrent motivation to conserve resources in participants 1 and 4, but was not predictive in participants 2 and 3.

No variables significantly predicted motivation to conserve resources in participant 2.

7.4 Discussion

None of the predictor variables were associated with motivation to conserve resources in all participants. The most consistent predictor of motivation to conserve resources was goal striving, where motivation to conserve resources was lower on days when goal striving was higher (participants 1, 3 and 4). On days when perceived demands were higher, motivation to conserve resources was higher in participants 1 and 4. Pain intensity was associated with motivation to conserve resources in two participants, but the direction of the relationship was positive for participant 1 and negative for participant 3. Self-regulatory fatigue predicted motivation to conserve resources in participants 1 and 3; concurrently for participant 3 and from the previous morning in participant 1. An association between goal self-efficacy and motivation to conserve resources was only observed in one participant (participant 4), where high goal self-efficacy in the morning predicted lower motivation to conserve resources in the evening. In one participant (2), no significant relationships between predictor variables and motivation to conserve resources were observed.

Previous research has demonstrated that people with chronic pain have lower self-regulatory capacity, which can impact self-regulation performance (Rost et al., 2017; Solberg Nes et al., 2010). The conservation of resources hypothesis argues that reductions in self-regulation performance result from shifts in motivation toward conserving energy when a reduction of self-regulatory resources occurs (Hobfoll, 1989; Muraven & Slessareva, 2003). The findings within this study demonstrate that variation in self-regulatory fatigue was associated with variation in motivation to conserve resources in two of the four participants. While participant 3 demonstrated a concurrent relationship between self-regulatory fatigue and motivation to conserve resources, the association observed in participant 1 was between motivation to conserve resources and previous morning self-regulatory fatigue. It can also be noted that where a relationship between self-regulatory fatigue and motivation to conserve resources was observed during the diary measurement, those participants (participants 1 and 3) reported lower self-regulatory fatigue at baseline than for participants where there was no association between daily variation in self-regulatory fatigue and motivation to conserve resources (participants 2 and 4). Although the mean daily self-regulatory fatigue was very similar across participants, as reported in table 7.2.

Therefore, there was some support for the assumption that people with chronic pain have reduced self-regulatory energy, which affects motivation to conserve resources. The findings suggest that variation in self-regulatory fatigue may affect some people with chronic pain during goal pursuit, but not others. For example, some people with chronic pain may modulate resources based on self-regulatory fatigue, whereas other factors, such as external demands, may be more important in determining activity for others. Additionally, the temporal pattern of associations may vary between people. If variation in self-regulatory capacity affects variation in performance for some people but not others, this may provide an explanation for the discrepancy in findings when using between-group designs (Arber et al., 2017; Carter et al., 2015; Carter & McCullough, 2014; Hagger et al., 2016). Between-subjects designs, which assess mean difference in self-regulation performance between groups, cannot detect fluctuations in motivation and effort. The inconsistent associations observed between self-regulatory fatigue and motivation to conserve resources may also provide an explanation for the mixed evidence on the efficacy of activity pacing to conserve energy resources (Nielson et al., 2013). The findings of this study support the need for further research on within-individual variation in self-regulatory fatigue, motivation, and effort on goal pursuit.

The most consistent associations found in the study were that same-day perceived demands predicted motivation to conserve resources (participants 1 & 4), while same-day goal striving negatively predicted motivation to conserve resources (participants 1, 3 and 4). Taken together, these findings may reflect that motivation to conserve resources can be adaptive and facilitate optimal resource allocation in goal pursuit in people with chronic pain (Solberg Nes et al., 2011; Van Damme et al., 2018). On days when goal striving was high, motivation to conserve resources was lower, meaning that participants demonstrated engagement with goal pursuit. Although, for some participants, when demands were higher, motivation to conserve resources was also higher which could be demonstrative of the function of motivation to conserve resources in mitigating effort when the demands of the day outweigh the benefits of persistence (Van Damme et al., 2018). These findings are also consistent with affective-motivational views that decreasing efforts temporarily, and therefore decreasing performance temporarily, is adaptive as it allows for better allocation of resources across goals and days (Molden et al., 2016; Saunders & Inzlicht, 2015; Yeo & Neal, 2013). The negative association between same day goal self-efficacy and motivation to conserve resources in one participant is also consistent with previous findings (J. W. Beck & Schmidt, 2018; Vancouver et al., 2008) and the findings from chapter two (p79) which showed that when within-person task self-efficacy was higher, resource allocation was higher. While the findings in the current study are consistent with recent theoretical views of self-regulation, variation between participants was still evident.

While it was expected that pain would be related to motivation to conserve resources, an unexpected result was the negative relationship between pain and motivation to conserve resources in one participant (participant 3). This meant that when evening pain was higher, motivation to conserve resources for the day was lower. It is possible that the difference in direction of the relationship between participant 1 and participant 3 reflects a difference in activity. For example, in participant 1, higher pain throughout the day may motivate conservation of resources but not decrease activity levels, meaning pain is higher in the evening. Meanwhile, in participant 3, higher pain throughout the day may motivate conservation of resources and a reduction of activity, meaning pain is lower in the evening. Previous research has also observed that relationships between variables can differ when examined using between-subjects designs and longitudinal within-person designs. For example, while it has been proposed that higher self-efficacy predicts better performance at the group level (Bandura, 1977), a negative relationship between self-efficacy and performance has consistently been found when examined within-person (J. W. Beck & Schmidt, 2018; Vancouver et al., 2008). In addition, a recent N-of-1 study found that there was a negative relationship between social support and engagement in physical activity (G. Smith et al., 2019) within participants, despite previous claims that social support predicts more physical activity (Bandura, 1997; Mendonça, Cheng, Mélo, & de Farias Júnior, 2014; Molloy, Dixon, Hamer, & Sniehotta, 2010). Therefore, although it is expected that pain intensity would negatively predict motivation to conserve resources, the within-person processes may differ from frequently observed between-person processes.

Lastly, evidence that there are differential effects of self-regulatory fatigue, motivation and self-efficacy on motivation to conserve resources suggests that individuals would benefit from tailored, data driven activity pacing plans. Data-driven tailored interventions to facilitate physical activity has been conducted previously with action planning and control cognitions in people with osteoarthritis (O'Brien et al., 2016).

Further, a tailored, data driven activity pacing intervention which used accelerometer data reduced fatigue interference in those with osteoarthritis (Murphy, Lyden, Smith, Dong, & Koliba, 2010). It has been suggested that individually tailored activity pacing which takes into account the psychosocial context of activity, such as motivation for engagement in activity, is needed (Murphy, 2015).

7.4.1 Limitations and future research

This study has added to our understanding of the dynamic nature of self-regulation during goal pursuit in people with chronic pain. Although, some limitations should be noted. It would have been useful to determine whether motivation to conserve resources was related to actual daily activity. The study measured all variables by self-report, some of which were retrospective and some of which were measured by single items. There was an attempt to limit the number of diary items to reduce participant burden and reduce the number of missed observations. Particularly, using the SRFS-3 may not have provided a sensitive measurement of self-regulatory fatigue and may have introduced more measurement error than if using a longer version of the scale. Chapter four demonstrated that while the SRFS-3 was highly correlated with the full SRFS-18, it did not meet standards for good reliability and validity overall. That said, the SRFS-3 demonstrated the hypothesised relationships with measures of mental and emotional fatigue (Chapter four, p135) and so the SRFS-3 may still closely tap into the construct of self-regulatory fatigue. Therefore, the effects of self-regulatory fatigue on motivation to conserve resources may have been underestimated.

Future research, which uses ambulatory methods to measure the variables “in the moment” may be useful and provide more reliable estimate of relationships, as opposed to using retrospective items. In addition, it would be useful for future research to examine the effects of self-regulatory fatigue, goal self-efficacy, goal striving and demands on actual activity or performance, as well motivation to conserve resources, using within-person methods in people with chronic pain. Future research should also ascertain the usefulness of individually tailored data-driven activity pacing interventions, which takes into account the motivational and self-regulatory context of the individual.

7.4.2 Conclusion

This study showed that the effect of self-regulatory fatigue, goal self-efficacy, goal striving and perceived demands on motivation to conserve resources varied. The observed relationships generally supported recent affective-motivational theory that motivation to conserve resources is an adaptive function, which aids optimal resource allocation for goal pursuit in people with chronic pain. The relationships between predictors and motivation to conserve resources varied for each participant. The results from this study supports the need for further research on within-individual variability of goal processes, the development of measures to support these research designs, and the development of individually tailored activity pacing interventions.

8 General Discussion

8.1 Position of the literature prior to this thesis

This thesis explored the hypothesis that people with chronic pain have a reduced capacity for self-regulation and that this may have an impact on self-regulation performance, well-being and goal pursuit. In chapter one, it was identified that chronic pain is a leading cause of disability globally (Palazzo et al., 2016; Vos et al., 2012) and that self-management is recommended to support long-term management (SIGN, 2013). Although, self-managing chronic pain may be difficult due to a number of factors including cognitive (e.g. catastrophic thinking styles and ruminative worry), emotional (e.g. distress related to change in social roles), behavioural (e.g. demands of employment) and physiological (e.g. pain, fatigue) demands that must be managed daily. These demands give rise to a high prevalence of mood disorders (Atkinson et al., 1991; Bair et al., 2003; Tsang et al., 2008), pain catastrophising (Quartana et al., 2009; Vlaeyen & Linton, 2000), low pain self-efficacy (Asghari & Nicholas, 2001; Nicholas, 1989), physical inactivity (Geneen et al., 2017; Vlaeyen et al., 1995) and difficulties in self-regulation (Solberg Nes et al., 2010; Solberg Nes et al., 2009).

Within chapter one, an overview of the theoretical framework was provided for the hypothesis that people with chronic pain experience a reduced capacity for self-regulation. The foundations, evidence and conceptual and methodological limitations of Strength Model were discussed. The evidence for the hypothesis that people with chronic pain experience chronic self-regulatory fatigue was reviewed. Given the mixed evidence for the Strength Model in light of recent large-scale methodologically rigorous replication attempts (Arber et al., 2017; Garrison et al., 2019; Hagger et al., 2016), it was considered pertinent to determine whether further evidence could be gathered for the premise that people with chronic pain experience reduced self-regulatory capacity. Alternative explanations for the effect of reduced self-regulatory capacity on chronic pain, namely the conservation of resources, had been considered previously (Eisenlohr-Moul et al., 2013; Solberg Nes et al., 2011). Although, supportive evidence for theoretical explanations of reduced self-regulatory performance in people with chronic pain were generally lacking. More specifically, further examination of the hypothesis that people with chronic pain have lower self-regulatory resources than people with no health conditions was required. Moreover, the implications of reduced self-regulatory resources in people with chronic pain was identified as an important avenue for research. Particularly, the relationship between self-regulatory fatigue and self-efficacy had never been examined previously. Considering the evidence of the role of self-efficacy in adaption to chronic pain, an exploration of the relationship between self-regulatory fatigue and self-efficacy was undertaken.

8.2 What this thesis contributes

This thesis has contributed to the understanding of the effect of self-regulatory fatigue in people with chronic pain and its relationship to self-efficacy. The findings of this thesis have demonstrated that people with chronic pain consistently report experiencing self-regulatory fatigue and identified that self-regulatory fatigue is negatively related to self-efficacy. Despite self-reporting self-regulatory fatigue, this did not appear to have a detrimental effect on self-regulation performance compared to controls. Self-regulatory fatigue and self-efficacy also did not have an effect on physical activity levels during pursuit of a physical activity goal. On the other hand, self-regulatory fatigue and pain self-efficacy were both related to mood, where pain self-efficacy mediated the relationship between self-regulatory fatigue and depression, but not the relationship between self-regulatory fatigue and anxiety.

Even although differences in performances were not observed at the between-groups level, an examination of within-person effects illustrated a different relationship between self-efficacy and overall performance in people with chronic pain and pain-free controls. The findings suggest that self-regulatory fatigue and self-efficacy influence allocation of resources, as demonstrated in cognitive self-regulation tasks in chapter two and in the relationship to motivation to conserve resources in chapter seven. Of particular significance were the findings that higher allocation of resources to individual tasks, facilitated by higher self-efficacy, may not always be adaptive in people with chronic pain who experience higher demands and self-regulatory fatigue. It was also identified that the Self-regulatory Fatigue Scale (SRFS) may not adequately operationalise self-regulatory fatigue as defined in terms of reduced self-regulatory resources. This may be accounted for by ambiguous definitions of constructs related to the Strength Model.

8.3 Implications and future directions

8.3.1 Theory

This thesis sought to determine whether the Strength Model (Baumeister et al., 1998) could explain reduced self-regulation performance in people with chronic pain. That is, whether people with chronic pain have reduced self-regulatory resources, as had been proposed by Solberg Nes and colleagues (2010, 2013). To that end, a conceptual replication and extension of previous experimental findings was conducted in chapter two. This was deemed an important place to begin the research due to the number of failed replication studies of the ego-depletion effect (Hagger et al., 2016; Lange & Eggert, 2014; Lurquin et al., 2016). Prior to this thesis, there was a limited number of experimental applications of the Strength Model in people with chronic pain (Solberg Nes et al., 2010, 2011). This thesis did not find evidence to support the Strength Model explanation of self-regulatory fatigue in people with chronic pain. Using the dual-task paradigm, study one found that there was no significant difference in performance between people with chronic pain and controls in either the depletion task or the subsequent persistence task, despite significantly higher self-regulatory fatigue in the chronic pain group. These findings are inconsistent with previous applications of the dual task-paradigm in people with chronic pain (Solberg Nes et al., 2010). There was also no dose dependent effect of pain intensity on performance found as had been reported previously (Solberg Nes et al., 2010). However, baseline pain self-efficacy was related to better performance on the depletion task and worse performance on the persistence task.

The Strength Model could also not account for performance in a subsequent study in study two (chapter two), or the results of chapter six. In study two, performance was also not significantly poorer between the chronic pain group and control group despite higher self-regulatory fatigue in people with chronic pain. However, the relationship between within-person task self-efficacy and overall performance was mediated by resource allocation where, for people with chronic pain, there was a positive relationship between task self-efficacy and performance up to a point. After this point, higher self-efficacy and allocating additional resources to individual tasks had a detrimental effect on overall performance. In controls, there was a positive relationship between within-person task self-efficacy and overall performance, which became weaker as resource allocation increased. In chapter six, four N-of-1 studies were conducted to investigate whether the Strength Model could account for intra-individual variation in physical activity during pursuit of a physical activity goal. It was observed that fluctuations in self-regulatory fatigue, goal motivation and goal self-efficacy were not related to fluctuations in physical activity in any of the participants.

These findings are not consistent with the Strength Model predictions where it has been suggested that an ego-depleted state reduces task self-efficacy, which leads to reduced performance (Chow, Mui & Lau, 2015; Graham, Martin Ginis & Bray, 2017). In particular, participants in study one who had reported lower pain self-efficacy at baseline appeared to have performed worse on the depleting task but then better on the dependent variable, while the opposite appeared true for those with high baseline pain self-efficacy. Given the evidence presented in this thesis, it appears that fluctuations in self-efficacy are associated with fluctuations in resource allocation. The use of the dual-task paradigm, and sole measurement of performance on the dependent variable, may have obscured this effect in previous research. However, as the N-of-1 studies (chapter six) demonstrated, within-person fluctuations in self-regulatory fatigue, self-efficacy and motivation did not consistently have an effect on within-person fluctuations in performance.

There was some evidence to support the conservation of resources hypothesis. In chapter three, a cross-sectional study demonstrated that pain self-efficacy mediated the relationship between self-regulatory fatigue and depression. Although, the relationship between self-regulatory fatigue and anxiety was strong and was not mediated by pain self-efficacy. The results of this study suggested that pain self-efficacy may buffer the effects of self-regulatory fatigue on depression but not anxiety. Pain self-efficacy was measured as the perception of ability to participate in a range of activities despite pain (Nicholas, 1989). Engagement in previously valued activities may be perceived as threatening to those with anxiety when self-regulatory capacity is limited (A. T. Beck & Emery, 1985; Clark et al., 1989), triggering conservation of resources even when self-regulatory fatigue is not high. Whereas perceived inefficacy to engage in valued activities is associated with depression (Bandura, 1982, 1986). Therefore, pain self-efficacy may buffer the effects of self-regulatory fatigue on depression by facilitating allocation of resources toward beneficial activities when self-regulatory capacity is limited.

In daily diaries (chapter six), it was observed that fluctuations in motivation were positively related to fluctuations in self-efficacy while fluctuations in self-regulatory fatigue were negatively associated with self-efficacy. Although, these patterns were not consistent across participants. These findings, demonstrated within-person, provide further illustration of the role of self-efficacy in allocating resources. Feelings of self-efficacy may be founded in the perception of self-regulatory capacity and the strength of goal motivation. In chapter seven, the most consistently observed associations in the N-of-1 studies were a negative relationship between goal striving and motivation to conserve resources (three participants) and the positive relationship between perceived demands and motivation to conserve resources (two participants). Positive associations were also observed between self-regulatory fatigue and motivation to conserve resources (two participants), as well as a negative association between self-efficacy and motivation to conserve resources in one participant. Meanwhile, fluctuations in pain were positively related to fluctuations in motivation to conserve resources in one participant but the converse relationship was observed in another participant. The allocation or conservation of resources during goal striving may be based upon perception of demands (including pain) and self-regulatory capacity and this may be mediated by self-efficacy.

Taken together, the findings of this thesis indicate that reduction of resources or reduced self-regulatory capacity is not a sufficient explanation for the effects of self-regulatory fatigue on self-regulation performance, well-being and goal pursuit. People with chronic pain did not appear to have a reduced amount of limited resources. While there was some support for the conservation of resources hypothesis gathered within this thesis, this explanation lacks clarity around the mechanisms by which conservation or allocation of resources occurs, particularly in the context of chronic pain. Overall, the evidence is supportive of a motivated resource allocation perspective where people with chronic pain allocate resources based on their capacity beliefs (e.g. self-regulatory fatigue and self-efficacy) and motivation. Within a motivated resource allocation perspective, poorer self-regulation performance due to seemingly limited resources can be accounted for by the tendency of individuals to avoid unpleasant states such as mental fatigue (Evans et al., 2016; Molden et al., 2016; Saunders & Inzlicht, 2015). Therefore, individuals reduce effort long before reaching their capacity limit. This may explain previous findings of poorer self-regulation performance in people with chronic pain (Solberg Nes et al., 2010).

The importance of the role of motivation in coping with chronic pain and activity patterns has been highlighted previously (Van Damme, Crombez, & Eccleston, 2008; Van Damme & Kindermans, 2015). It seems that, as with physical fatigue (Van Damme et al., 2018), the motivational context is important in determining when and why conservation occurs. Fatigue in chronic pain is proposed to be a motivational signal indicating that goal adjustment is necessary when the costs of continued goal pursuit outweigh the benefits. However when the benefits are perceived to outweigh the costs, motivational drive is the outcome (Van Damme et al., 2018). The evidence in this thesis suggests that self-efficacy may be a factor in determining cost-benefits in goal pursuit in chronic pain. Currently, research is lacking on the effects of motivational shifts on goal directed behaviour in chronic pain.

To advance our understanding, the development of a motivational-affective theoretical account, which provides clear mechanisms of the purpose of self-regulatory fatigue in adaption to chronic pain is needed. One such explanation, in a similar vein to Van Damme et al. (2018), may be that self-regulatory fatigue signals that an adjustment in self-regulatory strategy, standard or monitoring is required to continue goal pursuit. Self-regulatory fatigue may, therefore, prevent "irrational" persistence (Osgood, 2018). This conceptualisation of self-regulatory fatigue is consistent with findings that persistent attempts to solve the problem of pain and control pain are maladaptive and result in worse outcomes (Crombez, Eccleston, De Vlieger, Van Damme, & De Clercq, 2008; Eccleston, 2010; Eccleston & Crombez, 2007; Notebaert, Crombez, Vogt, De Houwer, Van Damme, & Theeuwes, 2011). Balancing the pursuit of valued goals with managing pain levels is difficult in those with chronic pain (Gandhi, Becker, & Schweinhardt, 2013; Roy, 2010). Therefore, it would beneficial for future research to examine a motivational-affective understanding of the relationship between self-regulatory fatigue and attention to pain cues and reward cues during goal pursuit. Moreover, the development of experimental paradigms, which can assess the mechanisms of self-regulatory fatigue would facilitate the assessment of a novel affective-motivational theoretical framework.

8.3.2 Methodology

To enable the within-person longitudinal measurement of self-regulatory fatigue in daily diaries, there was a need to develop short-forms of the Self-Regulatory Fatigue Scale (SRFS; Solberg et al., 2013). Within chapter four, six-item and three-items short forms of the SRFS were developed and there was an examination of the validity and reliability of the SRFS and six-item (SRFS-6) and three-item (SRFS-3) versions in a healthy sample. The SRFS-6 demonstrated good reliability and validity but the SRFS-3 had poor reliability and did not demonstrate a strong correlation with the SRFS or the proposed associations with related variables. The poor reliability and validity of the SRFS-3 most likely occurred as one item (item five of the SRFS) was negatively correlated with the other two items in the scale. The reason for this may have been that item five was negatively worded. It is unclear why this same negative correlation between item five and the remaining items on the SRFS or SRFS-6 did not occur. Therefore, the reliability of the SRFS and short-forms may improve if the wording of item 5 is reversed.

Problems with negatively worded items have been noted previously (Chang, 1995; Schriesheim & Eisenbach, 1995). For example, negatively worded items have been found to load onto a separate factor, suggesting that negatively worded items are not perceived by respondents to measure the converse of positively worded items (Bonetti et al., 2001; Bostic et al., 2000). In addition, in chapter five, the judges appeared to have difficulty allocating negatively worded items to the construct of self-regulatory fatigue. For instance, two items of the SRFS (“I feel full of energy”, “I can easily keep up with my friendships and relationships") were judged to not measure the self-regulatory fatigue construct. This may reflect that judges perceived these items to measure an *absence* of self-regulatory fatigue.

Further to the concerns with negatively worded items, the SRFS did not demonstrate adequate content of discriminant content validity (chapter five). The DCV study illustrated that only two of the eighteen items of the SRFS were judged to reflect content validity for the self-regulatory fatigue construct. No SRFS items displayed DCV. This suggests that the definition of self-regulatory fatigue, which described the construct of self-regulatory fatigue in Strength Model terms, was problematic or that SRFS items did not reflect this definition. These findings (chapter four and five) may mirror the current state of the Strength Model literature where there is a lack of clear definitions and the relationship between self-regulatory capacity and related constructs are vaguely described. Moreover, the conclusions from chapter's four and five are also indicative of problems with the operationalisation of constructs and measurement within the self-control literature as demonstrated by the weak relationship between trait self-control and tasks of inhibition, and overlap between self-control and related constructs of grit and conscientiousness (Duckworth & Kern, 2011; Saunders et al., 2018). To ensure the validity of findings, it is necessary to identify measures, which purely measure the construct and are not contaminated. Inadequate operationalisation of constructs can result in spurious findings.

Even so, the SRFS-6 did exhibit adequate internal consistency and construct validity (chapter four). Indeed, the findings suggest that the SRFS-6 demonstrated stronger relationships with mental fatigue, vigour and vitality than the SRFS. This highlights that the SRFS-6 may be a valid measure of self-regulatory capacity as defined as having energy available to the self (Ryan & Frederick, 1997). Although, self-regulatory capacity has been described as having input from both trait and state components (Solberg Nes et al., 2013). This may explain why the SRFS-6 is strongly correlated with the subjective states of mental fatigue, vigour and vitality, but is still a distinct construct. Therefore, the SRFS-6 may be a valid measurement of self-regulatory fatigue which can be administered for use in longitudinal daily measurement.

The implementation of methods that capture fluctuations in self-regulatory fatigue can provide a better test of theory. As the Strength Model makes idiographic predictions about fluctuations in self-regulation, measurement of performance on only the dependent variable is not an adequate paradigm. The N-of-1 studies, described in chapters six and seven, are the first to investigate intra-individual fluctuations in self-regulatory fatigue. These studies highlighted the importance of measuring relationships within-person as it appears that increases in self-efficacy are adaptive when measured at the group level but not necessarily the within-person level (chapter two). Also, the same pattern of observations was not consistent across individuals.

It can be concluded that the validity of the SRFS may be uncertain given the results of chapter five. Although, within chapter four, the SRFS demonstrated good internal consistency and construct validity in a student population. The SRFS may demonstrate DCV with the development of a clear theoretical framework and definitions of self-regulatory fatigue. Therefore, future research should assess the DCV of the SRFS against improved definitions of the construct of self-regulatory fatigue. Future research should further validate the SRFS-6, particularly in a chronic pain sample. Additionally, it should be determined whether the factor structure of the SRFS replicates previous research and whether the SRFS-6 also demonstrates the proposed factor structure.

8.3.3 Treatment

Across both studies in chapter two, the findings suggested that self-efficacy is implicated in resource allocation across tasks in people with chronic pain but that there was an overestimation of self-regulatory capacity when self-efficacy is high, which provided partial support for the discontinuous self-efficacy model (Vancouver et al., 2008). It has been argued that self-efficacy is a like heuristic and is used to determine the amount of resources required for upcoming tasks (J. W. Beck & Schmidt, 2018). In study two (chapter two), it was hypothesised that when resources are not limited, increases in self-efficacy would predict increased resource allocation. Conversely, when resources were limited, as with the experience of self-regulatory fatigue, increases in within-person self-efficacy would lead to reductions in resource allocation for individual tasks. This is purported to be adaptive as resources must be managed across tasks when they are limited. However, when self-efficacy was high, people with chronic pain appear to have increased resource allocation to the detriment of overall performance. Indeed, across both tasks in chapter two, it appeared that moderate self-efficacy was most adaptive and led to consistently good performance across tasks. This suggests that in people with chronic pain, self-efficacy beliefs are not always a useful heuristic.

Nevertheless, the findings of chapter three indicate that pain self-efficacy may attenuate the relationship between self-regulatory fatigue and depression. This conclusion is in line with previous research, which has established that pain self-efficacy is related to better outcomes such as physical, affective and social functioning (Altmaier et al., 1992; Jackson et al., 2014; Somers et al., 2010). Higher pain self-efficacy is clearly important for wellbeing and functioning in people with chronic pain. People with high self-efficacy also set higher standards for their goals and persist at goal pursuit for longer (Chen et al., 2004). This means that people with high self-efficacy tend to allocate more resources and have better performance than people with low self-efficacy (Chen et al., 2004; Yeo & Neal, 2013). Within-person fluctuations in self-efficacy, which leads to fluctuations in resource allocation (chapter two), may account for the “boom and bust” cycle of activity often observed in people with chronic pain (Hasenbring et al., 2012; Hasenbring & Verbunt, 2010). For example, if people with chronic pain who are generally high in self-efficacy experience an increase in self-efficacy, they may overestimate their capacity and increase activity. However, this usually leads to increases in pain, stiffness and disability (Hasenbring & Verbunt, 2010), meaning there is a subsequent period of activity avoidance.

Taken together, higher self-efficacy is clearly related to better outcomes but determining activity levels based on increases in self-efficacy may not always be beneficial for people with chronic pain. While reducing self-efficacy is not a solution, setting activity quotas that are not contingent on feelings of self-efficacy may be. Activity pacing, the regulation of activity to facilitate adaptive goals and improve overall functioning, is frequently administered in the treatment of chronic pain (Torrance et al., 2010). The approach to activity pacing is usually to extinguish the reliance on pain-contingent activity levels. This may occur where, for example, an individual with chronic pain stops activity due to their fear of increased pain, or where an individual continues activity levels until it results in increased pain intensity. Activity pacing, therefore, applies quota-contingent rules for activity where activity duration, distance and taking breaks are pre-determined, regardless of pain intensity (Nielson et al., 2013). The findings in this thesis suggest that pacing should also be applied when people with chronic pain determine activity levels by perceived capacity via self-regulatory fatigue and self-efficacy. This may facilitate the adoption of adaptive activity patterns and more consistent performance. Particularly, personalised, data-driven pacing plans may be of a particular benefit (Murphy, 2015; Murphy et al., 2010).

8.4 Thesis strengths and limitations

This thesis examined the association of self-regulatory fatigue and self-efficacy with self-regulatory performance using methods, which measured both group averages and within-person fluctuations. This is a strength as this is the only research thus far to assess the effect of fluctuations in self-regulatory fatigue and self-efficacy in people with chronic pain. While both approaches are important, they answer slightly different questions. It has been argued that it is an ecological fallacy to make inferences about individuals based on aggregated data as this can mask the direction of relationships (Yeo & Neal, 2013). For example, it was highlighted within this thesis that higher self-efficacy may be adaptive at the group level, but not at the within-person level. Therefore, this thesis has contributed knowledge to the understanding of both group and within-person processes in self-regulation in chronic pain.

The main limitation of the thesis is the use of the SRFS and short-forms to measure self-regulatory fatigue. The findings here suggested that it is unclear whether the items of the SRFS measure the construct of self-regulatory fatigue and the reliability of negatively worded items is questionable. A lack of discriminant content validity and reliability may introduce measurement error and result in spurious conclusions. The appropriateness of the SRFS and short-forms as measures of self-regulatory fatigue needs to be further verified in more samples. The findings in this thesis need to be replicated and validated with appropriate measures.

Another limitation of this thesis is the samples of people with chronic pain recruited, with the exception of chapter seven, were generally high functioning and so were more indicative of community samples of chronic pain. Accordingly, the level of pain self-efficacy was higher than normative scores of pain self-efficacy in people with chronic pain (Nicholas et al., 2008). It is important to note that within-person increases in self-efficacy in people with chronic pain who have generally low self-efficacy may be adaptive. The conclusions drawn from the research within this thesis may only apply to people who are generally high in self-efficacy and so may not apply to patient samples who tend to have poor functioning.

8.5 Overall conclusion

This thesis examined the application of the Strength Model to self-regulation in people with chronic pain. Over seven studies, it was established that conceptual and methodological limitations of the Strength Model and its measurement meant that the evidence did not support Strength Model assumptions. The evidence pointed to a motivated resource allocation explanation of self-regulation in people with chronic pain. An examination of both group and within-person processes suggested that higher self-efficacy may be adaptive at the group level, but not at the within-person level when self-regulatory capacity is reduced. However, further research is required to refine theoretical explanations of underlying mechanisms of the effect of self-regulatory fatigue on self-regulation in chronic pain and methods by which to investigate them.

9 References

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10 Appendix 1

Items of the SRFS-18, SRFS-6 and SRFS-3

Item	Subscale	
SRFS-18		
1	Cognitive	I feel full of energy
2	Cognitive	It’s easy for me to set goals
3	Cognitive	I find it difficult to exercise as much as I should
4	Behaviour	I have urges to hit, throw, break, or smash things
5	Cognitive	I have no trouble making decisions
6	Behaviour	I experience repeated unpleasant thoughts
7	Emotion	I get easily upset
8	Behaviour	I try not to talk or think about things that bother me
9	Emotion	I never feel like yelling, swearing, or shouting
10	Emotion	I handle stress well
11	Behaviour	I experience uncontrollable temper outbursts
12	Cognitive	I can easily keep up with my friendships and relationships
13	Emotion	I cry easily
14	Cognitive	I have difficulties remembering things
15	Emotion	I find it easy to stick to a healthy diet
16	Emotion	I feel moody
17	Behaviour	I have urges to beat, injure, or harm someone
18	Emotion	I rarely get frustrated
SRFS-6		
1	Cognitive	I feel full of energy
4	Behaviour	I have urges to hit, throw, break, or smash things
5	Cognitive	I have no trouble making decisions
6	Behaviour	I experience repeated unpleasant thoughts
7	Emotion	I get easily upset
16	Emotion	I feel moody
SRFS-3		
4	Behaviour	I have urges to hit, throw, break, or smash things
5	Cognitive	I have no trouble making decisions
7	Emotion	I get easily upset

11 Appendix 2

Full list of self-efficacy items for each participant in study 6

Participant	Item	Self-efficacy item
1	**1.**	Right now, I am confident I can improve my Canicross time to 7.5 minutes per mile
	2.	Right now, I am confident that I can improve my Canicross time to 7.5 minutes per mile when I have a flare up of pain
	3.	Right now, I am confident I can improve my Canicross time to 7.5 minutes per mile when I have a heavy workload
	4.	Right now, I am confident I can improve my Canicross time to 7.5 minutes per mile when I have not planned the training into my schedule
2	**1.**	Right now, I am confident I can increase my walking from 40 mins per day to 1 hour per day
	2.	Right now, I am confident that I can increase my walking from 40 mins per day to 1 hour per day when the weather is bad
	3.	Right now, I am confident I can increase my walking from 40 mins per day to 1 hour per day when I have low motivation
	4.	Right now, I am confident I can increase my walking from 40 mins per day to 1 hour per day when I am in a bad mood
3	**1.**	Right now, I am confident I can walk 15,000 steps a day.
	2.	Right now, I am confident that I can walk 15,000 steps a day when I have a heavy workload.
	3.	Right now, I am confident I can walk 15,000 steps a day when I have recently cycled.
	4.	Right now, I am confident I can walk 15,000 steps a day when I am experiencing knee pain.
4	**1.**	Right now, I am confident I can go to the gym 4 times per week
	2.	Right now, I am confident I can go to the gym 4 times per week when I've had a stressful day
	3.	Right now, I am confident I can go to the gym 4 times per week when I have family responsibilities
	4.	Right now, I am confident I can go to the gym 4 times per week when my pain is worse than usual

12 Appendix 3

Full list of additional goal self-efficacy questions for each participant in study 7

Participant	Item	Self-efficacy item
1	**1.**	I am confident that I can pursue my goal when I feel stressed
	2.	I am confident that I can pursue my goal when I have low mood
	3.	I am confident that I can pursue my goal when I have long working hours
2	**1.**	I am confident that I can pursue my goal when I have a flare-up of pain
	2.	I am confident that I can pursue my goal when I feel low mood
	3.	I am confident that I can pursue my goal when I feel anxious
3	**1.**	I am confident that I can pursue my goal when I have a flare-up of pain
	2.	I am confident that I can pursue my goal when I have work to do
4	**1.**	I am confident that I can pursue my goal when I’m trying to push through pain
	2.	I am confident that I can pursue my goal when I have a flare-up of extra pain
	3.	I am confident that I can pursue my goal when I feel low mood

13 Appendix 4

Full list of goals for each participant in study 7

Participant	Goal	No. days pursued
1	Enjoy activities more	84
2	Manage emotions when unexpected setbacks arise	33
	To manage everything on my to-do list	15
	Manage tasks of the day without feeling overwhelmed	36
3	Improved management and maintenance of relationships	54
	Going for lunch	8
	Shopping	2
	Attend pain management programme	5
	Shopping & lunch	1
	Shopping & pain management	2
	Go on holiday	1
	Go to church	3
	Go to church and dinner	2
	Shopping and wedding reception	1
	Attending a funeral	2
	Hospital appointment	1
	Hospital appointment & pain management	1
	Hospital appointment & shopping	1
	Visiting*	1
	Podiatry and shopping	1
	Appointments	1
	Church and cinema	1
4	Feeling more confident in managing pain	78

*This was the exact response entered by the participant