Chapter 6

Title: Pain and Attention: Towards a Motivational Account

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Abstract

Attention plays a pivotal role in the experience of pain and its impact upon daily activities. Accordingly, research on the interplay between attention and pain has a long scientific history. Within this chapter, we discuss the theoretical frameworks that aim to explain the relationship between attention and pain. We argue for a motivational perspective on pain that highlights the critical role of cognitive, affective and contextual factors in explaining the interplay between attention and pain. To substantiate this argument, we provide an overview of available research addressing the bottom-up capture of attention by pain and the top-down modulation (both inhibition and facilitation) of attention for pain. We conclude this chapter with guidelines and suggestions for future research and discuss clinical implications of adopting a motivational perspective on pain.

Key words: Attention, top-down modulation, bottom-up modulation, motivation

Imagine a person called Ruben walking in the park on a sunny day. The wind blows through his hair. He is thinking of a friend who is waiting at the other side of the park. Enjoying this walk, he does not see the nail in front of him and steps straight into it. Suddenly, he feels a sharp pain in his foot. The nail has just pierced through his shoe sole. His attention automatically shifts towards the pain, and he tries quickly to remove the nail. He is no longer aware of the surrounding sounds, or feels the wind blowing. For a moment, he even forgets that a friend is waiting on the other side of the park….

This example clearly illustrates that pain demands attention and interrupts ongoing behavior. Indeed, if pain did not capture attention and urge us to react, the nail would have pierced deeper, possibly resulting in a devastating wound. This example also shows that pain is adaptive (Auvray, Myin, & Spence, 2010; Eccleston & Crombez, 1999; Eccleston & Crombez, 2007). Pain's adaptive value is well illustrated in patients suffering from congenital analgesia who are unable to perceive pain, and who typically incur cumulative injuries and die early (Melzack, 1973, Weingarten et al., 2006).

When pain becomes chronic, it seems to lose its adaptive value. Just think about Ruben, but now in a different scenario. During his walk he feels an aching pain in his lower back from which he has suffered for several years. Although medical examinations have revealed no damage to his back, his back pain will probably continue to demand attention. It may well be that the pain will become overwhelming and Ruben may decide to cancel the meeting with his friend to return home. This scenario exemplifies that even when pain is a false alarm, it may nevertheless interfere with ongoing and planned activities. It may then result in heightened distress, impaired work ability, and reduced social functioning (Gatchel, Peng, Peters, Fuchs, & Turk, 2007; Kovacs et al., 2004; McDonald, DiBonaventura, & Ullman, 2011; Niv & Kreilter, 2001). Additionally, it may result in excessive attention to pain and pain-related information (e.g., Eccleston & Crombez, 2007; Vlaeyen & Linton, 2000). Excessive levels of attention for pain or pain-related information in general, have been discussed under varying labels, such as hypervigilance for pain (Chapman, 1978; Crombez, Van Damme, & Eccleston, 2005) and attention bias for pain-related information (Crombez, Eccleston, Van Damme, Vlaeyen, & Karoly, 2013).

In this chapter, we introduce the construct of attention and present an overview of available cognitive, affective, and motivational accounts that aim to explain how pain affects attention and vice versa (Sections 1 and 2). Next, we discuss available research within a motivational framework (Section 3). We focus on task interference brought about by pain, often called bottom-up capture of attention and discuss top-down modulation of attention in the context of pain. For top-down modulation, we address both the factors that facilitate attention to pain and the factors that reduce attention to pain. In section 4, we broaden the scope and discuss research on attention to symbolic representations of pain (e.g., pain words and pictures), an often used paradigm to investigate attentional bias for pain-related information in chronic pain patients. Although this line of research stems from a different background, it has attracted substantial empirical efforts. We end this chapter with suggestions for future research (section 5) and discuss the clinical implications of a motivational perspective on pain (section 6).

1. Attention: A complex psychological construct

Attention is a well-known, but complex psychological construct. According to William James, one of the first psychologists to discuss the topic, *"everyone knows what attention is. It is taking possession by the mind in clear and vivid form, of one out of what seem several simultaneously possible objects or trains of thought… It implies withdrawal from some things in* *order to deal effectively with others*" (James, 1890). Since William James, many others have offered additional thoughts. Broadbent (1958), for example, proposed a filter theory of attention wherein he stated that multiple stimuli can simultaneously gain access to a sensory buffer which holds this information for a brief time. Whether a sensory input passes through this filter depends on its physical attributes. According to Broadbent, the filter is necessary to prevent the overloading of an information-processing system with limited capacity. Most of the early theories on attention are structural accounts based on the assumption that the information-processing system is capacity- and resource-limited (see also Kahneman & Treisman, 1984). More recently, several scholars have proposed a functional account of attention.

Within cognitive psychology, Allport (1989) provided one of the most comprehensive functional accounts of attention. Defining attention as the selection of information for action, he argued that a functional attentional system serves two contradictory functions First, attention ensures that actions run smoothly, without interference from distracting (i.e., less important) information. Second, Allport argued that a successful attentional system must take into account the fact that ongoing behavior may need to be interrupted when more important contextual demands emerge (see also Norman & Shallice, 1986). Indeed, in a world containing various threats and opportunities, people need to be able to flexibly switch their attention to unexpected events in order to both protect themselves from danger and to notice (and seize upon) possible opportunities. An example may help to clarify both functions. Imagine, a professor who is teaching a course in a lecture hall. Outside, students are laughing and yelling. If the professor failed to maintain a focus upon teaching, he would become distracted and might not be able to continue lecturing. However, if the students outside yell for help, the professor's focus on teaching would need to be interrupted, as he must now react to this new priority. By looking outside, he may discover that a fire started and that an evacuation of the building is necessary. A functional attention system should therefore balance between both attentional functions in order for a person to survive in a complex and uncertain world. Constantly shifting to new events would result in chaotic behavior, whereas failing to shift to environmental threats is potentially dangerous.

Similar to the functional account of Allport, which states that attention is directed as a function of a person's action, social psychology theories of goal pursuit have investigated the link between attention and peoples' actions. These theories propose that attention is guided by the goals people pursue (for a definition, see Chapter 1 of the present volume). In particular, it has been suggested that attention is drawn towards stimuli that are congruent with or relevant for activated goal(s) (e.g., Johnson, Chang, & Lord, 2006; Moskowitz, Li, & Kirk, 2004; Soto, Hodsoll, Rotshtein, & Humphreys, 2008), whereas goal-irrelevant information is inhibited (Goschke & Dreisbach, 2008; Shah, Friedman, & Kruglanski, 2002). Here also, the attention system needs to balance two apparently contrasting functions - goal shielding (i.e., shield attention from non-goal-relevant information) and background monitoring (i.e., monitoring the environment for potentially important stimuli that may afford a goal switch) - in order to be successful (Goschke & Dreisbach, 2008).

Subsequently, scholars have addressed some of the underlying moderators of attentional processing. Research indicated that attentional capture by goal-relevant stimuli depends upon the strength with which a goal is pursued (Förster, Liberman, & Friedman, 2007). This is of particular importance, as in most cases multiple goals are active and may demand attention. Shah and colleagues (2002) furthermore revealed that the activation of a goal leads to the inhibition of conflicting goals (e.g., activation of the goal to study leads to the inhibition of the goal to party in students; see also Fishbach, Friedman, Kruglanski, 2003).

2. Theoretical accounts of the interplay between attention and pain

Our theoretical understanding of the ways in which the attentional system operates in the presence of pain has been informed by the above-mentioned models. Below, we present an overview of the most prominent models developed to describe how pain acts upon attention and vice versa.

Limited attentional capacity/resource theory. According to the limited attentional capacity theory, people have a limited amount of attention. Thus, it is a commodity that must be competitively allocated (e.g., McCaul & Malott, 1984). Pain may be one of the demands that receives attention, as well as other tasks that may also need to be achieved. Attention is then divided over several demands until the request for attention exceeds the maximal capacity. When a task requires attentional resources, fewer resources remain for processing pain, and hence pain may be felt as less intense. The hypotheses generated by this account have been tested mainly using distraction paradigms, in which individuals are instructed to perform a cognitive task in the presence of pain. According to limited attentional capacity theories, the effects of a cognitive task on the experience of pain will be most salient when the task requires a large amount of attentional resources. Findings of studies that have directly manipulated the difficulty of such a distraction task are mixed. Veldhuijzen and colleagues found support for the limited capacity theory in a small study of 12 students. In that study, students performed an easy distraction task (demanding little attentional resources) and a difficult distraction task (demanding many attentional resources) during the presence of cold pressor pain (Veldhuijzen et al., 2006). Self-reported pain was lower during the performance of the difficult task than during the performance of the easy task. Other studies did not find an effect of task difficulty on pain experience. For example, McCaul, Monsoon,

& Maki (1992) found no influence of the difficulty of a distraction task on pain perception in a study with 74 students receiving cold pressor pain. Similarly, Seminowicz & Davis (2007) found no modulation of task difficulty on pain reports in a study with 23 healthy volunteers receiving transcutaneous electrical pain. Mathur and colleagues (2015) extended these findings in a group of healthy and chronic pain patients who experienced heat pain. Again, no effect of task difficulty was found upon pain report. Taken together, the majority of studies show that task difficulty does not systematically influence the experience of pain, indicating that limited capacity models do not hold for pain processing.

A multiple resource theory. According to the multiple resource theory, adopted from research investigating multitasking in daily life (Wickens, 1980; Wickens, 1984; Wickens, 2008), separate pools of information processing resources exist. These pools are assumed to be characterized by the following three dimensions: (1) the ‘stages of processing dimension’, which indicates that perceptual and cognitive tasks use resources different from those underlying the selection and execution of action (Isreal, Chesney, Wickens, & Donchin, 1980); (2) the ‘codes of processing’ dimension, which indicates that spatial activity uses resources different from those used by verbal/linguistic activity (Liu & Wickens, 1992; Wickens & Liu, 1988); and (3) the ‘modalities’ dimension (nested within the previous dimension), which indicates that auditory perception uses resources that are distinct from those of visual perception. The multiple resource theory proposes that the interference between two tasks depends on the extent to which the two tasks use resources from the same resource pool. Research using this reasoning in the study of pain is scarce. We are aware of only one study that applied the multiple resource theory to pain, and attempted to identity the specific resources during the processing of pain (Johnson, Breakwell, Douglas, & Humphries, 1998). The multiple resource model shares with the limited capacity model the idea that if two tasks use resources from the same pool, performance in one of the two tasks will be degraded. Following this reasoning, Johnson & colleagues designed tasks (i.e., a thermal detection task, a visual detection task, and an imagery task) that were presumed to compete for specific resources of pain processing, and would lead to pain reduction. The authors assumed that there was an extra pool of resources for somatosensory information, one that was clearly distinct from the pool of resources for visual or auditory information (the "modalities" dimension). They further reasoned that pain processing requires spatial resources rather than verbal ones ("codes of processing" dimension). Finally, they decided to use a pain detection task they considered as an early (perceptual/cognitive) task rather than a late (response) task ("stages of processing" dimension). This study was cleverly designed to test the multiple resource theory. If true, one would expect that the task that shares the most specific resources with pain, i.e. the thermal detection task, would interfere the most with the pain detection task. However, these hypotheses were not confirmed. Indeed, although the detection tasks increased the pain threshold more than the imaginary task, no difference was found in participants' threshold while performing the thermal detection task or the visual detection task. Since no other pain studies have tested the multiple resource theory, evidence in support of this theoretical framework in the pain domain is largely lacking.

Cognitive-affective model of the interruptive function of pain (Eccleston & Crombez, 1999). According to the cognitive-affective model of pain, the relationship between noxious stimuli and pain experience is profoundly influenced by a variety of affective and cognitive factors (Eccleston & Crombez, 1999). In contrast with the previous resource models, this model suggests that the attentional system cannot be wholly resource bound. In line with Allport (1989), Eccleston & Crombez suggested that the attentional system can best be described as a regulatory system that serves two functions: (1) protecting the pursuit of current goals and (2) interrupting ongoing behavior when more important demands, such as threat, emerge. The authors propose that pain, which is the archetypical warning signal of danger, may then be an ideal candidate to interrupt ongoing behavior and to urge the person to escape from the dangerous situation. Furthermore, this theoretical framework identifies several factors related to pain (intensity, threat value, novelty, predictability) and environmental demands (e.g. emotional arousal, task importance, etc.) that moderate the interruptive function of pain. Later models have built upon this view to explain the interrelationship between pain and attention.

A neurocognitive model of attention to pain (Legrain et al., 2009b). The neurocognitive model of attention to pain extends the cognitive-affective model of the interruptive function of pain by articulating two modes of selection: bottom-up attentional capture by pain and top-down modulation of attention for pain (Legrain et al., 2009b) and their accompanying brain structures. This model describes how attention to pain depends upon a dynamic interplay between top-down and bottom-up variables. The bottom-up capture of attention by pain is defined as the involuntary capture of attention by pain. Although it is reasonable to assume that the involuntary capture is largely produced by low-level features of a noxious stimulus, top-down variables also play an important role. Next, we describe some of these variables.

An important top-down variable is attentional load, which refers to the amount of attention invested in a task. When the attention load is high, there is less opportunity for attention to be captured by noxious stimuli (Legrain, Crombez, Verhoeven & Moureaux, 2011b). A second variable is attentional set, which refers to the collection of stimulus features that an individual keeps in mind in order to identify goal-relevant information (Yantis, 2000). The attentional set depends on the specific goals that individuals are pursuing. The more features a stimulus shares with those in the attentional set, the more likely that this stimulus will capture attention, even when it is completely irrelevant for the current goal (e.g. Folk, Remington, & Johnston, 1992). Accordingly, when a noxious stimulus, even when it is task-irrelevant, matches one of the features present in the attentional set, it will capture attention (Legrain et al., 2009b).

Finally, the model proposes that top-down modulation of attention may function better when people have good executive functions. Indeed, it is reasonable to assume that well-developed executive functions (inhibition, switching ability and working memory capacity) are a prerequisite to control the attentional capture and interference by painful stimuli. Although this model is a step forward by (1) explicating how goals may facilitate or inhibit attention to pain, and (2) pointing at the role of executive functioning in modulating attention in the context of pain, the model mainly focuses upon cognitive factors and largely ignores motivational and affective factors.

A motivational account of attention to pain (Van Damme, Legrain, Vogt, & Crombez, 2010). The motivational account of attention to pain builds upon both the cognitive-affective model of the interruptive function of pain (Eccleston & Crombez, 1999) and the neurocognitive model of attention to pain (Legrain et al., 2009b). Yet, it explicitly adopts a goal and self-regulation perspective in which people attempt to gain control over behavior, cognitions or emotions in order to attain goals (Fishbach & Ferguson, 2007; Goschke & Dreisbach, 2008; Karoly, 1985; Karoly & Jensen, 1987; Shah et al., 2002; see also chapter 1 of this volume). The authors put forward the idea that the interrelationship between attention and pain has to be considered within a context of goal pursuit (see also Karoly, 1985; Karoly & Jensen, 1987, chapter 1 of the present volume). By adopting this perspective, pain and pain-related information can become the focus of attention in two ways. First, pain can occur during the pursuit of a non-pain-related goal, and it can unintentionally capture attention (bottom-up driven). Whether such capture occurs is not only dependent upon the pain characteristics, but also on the characteristics of the pursued goal (Van Ryckeghem, Crombez, Eccleston, Legrain, & Van Damme, 2013). Second, attention to pain and pain-related information might also be guided by the activation of a pain-related goal. For example, when people are in pain, an important goal is the search for a solution for the pain or to try to control the pain. Indeed, people are motivated to deal with their pain in order to proceed with the pursuit of other important goals (Hamilton et al., 2008). Eccleston and Crombez (2007) have elaborated this idea within the "misdirected problem solving" model. They argue that when pain has no direct solution and continues to interfere with other goals, people typically tend to worry about their pain. Worrying about pain (i.e., the presence of pain concerns) increases attention toward pain and pain-related information. In this context, the selection of pain and pain-related information at the cost of other information can be considered as a top-down mechanism (Van Ryckeghem et al., 2013). When pain has become a central feature of a goal (e.g., try to avoid or control pain), it is hypothesized that attentional processing of pain information will be facilitated, and hypervigilance for pain-related information will emerge (Eccleston and Crombez, 2007; Vlaeyen, Morley, & Crombez, 2016).

In sum, theorizing about the interplay between attention and pain has evolved from offering a purely structural account over a functional account towards a motivational account. Until now, only a limited number of studies has investigated the interplay between attention and pain using this motivational account (Vlaeyen, Morley, & Crombez, 2016). Notwithstanding, there is a wealth of research on attention and pain that we will review in the next section.

3. Research on attention and pain

Research on attention and pain has been informed by the theories and models discussed above. Each theoretical account has taken a different lens and has focused upon particular aspects of the interplay between attention and pain. Here, we review the available evidence and structure this evidence along three research lines that can be identified from a motivational account. The first research line looks into factors that influence the bottom-up capture of attention by pain. Within this framework, researchers have investigated the attention-demanding nature of pain while individuals are pursuing a non-pain-related goal (e.g., attention might be drawn to a blister while an individual is running a marathon). A second line focuses on the top-down variables that inhibit attention for pain. This research investigates the individual differences (e.g. executive functioning) and task features (e.g., motivational relevance) that shield attention from interference by pain during the pursuit of non-pain-related goals. A third line addresses top-down facilitation of attention for pain. This research focuses upon the attentional consequences when goals related to pain are being pursued. This may occur when people anticipate the presence of pain, catastrophize about pain (i.e. ruminate about irrational worst-case outcomes; Crombez et al., 2012; Vlaeyen & Linton, 2002), or are looking for a solution to cope with their pain (Eccleston & Crombez, 2007).

3.1. Bottom-up capture of attention by pain

Bottom-up capture of pain refers to the involuntary demand of attention by pain during the pursuit of a non-pain-related goal. The initial example in this chapter - in which a man steps into a nail and interrupts ongoing activities because of pain - is a clear example of how the capture of attention by pain can be understood as a stimulus-driven or bottom-up process. Abundant research has investigated the bottom-up capture of attention by pain, most often using primary task paradigms (e.g., Crombez, Baeyens, & Eelen, 1994). In these paradigms people are instructed to perform a primary task, such as the detection of or the discrimination between auditory stimuli, while ignoring a painful stimulus that is occasionally administered. Research using primary task paradigms has consistently shown impairment of participants' task performance during the simultaneous experience of pain (Buhle & Wager, 2010; Crombez, Eccleston, Baeyens, & Eelen, 1997, 1998; Seminowicz, & Davis, 2007; Richardson, et al., 2010). Using these paradigms, researchers have also looked at the stimulus characteristics that affect task interference by pain, in particular in studies with healthy volunteers and those using experimental pain stimuli. First, pain interferes more with performance of the primary task when the pain is more intense (Van Ryckeghem, Crombez, Eccleston, Liefooghe, & Van Damme, 2012). Second, pain interferes more with task performance when the pain is novel (Crombez, Eccleston, Baeyens, & Eelen, 1996; Legrain, Bruyer, Guérit & Plaghki, 2003). Third, larger interference effects of pain are reported when the pain stimulus is unpredictable (Crombez et al., 1994, Legrain, Perchet, & García-Larrea, 2009a). Finally, larger interference effects of pain are found when the pain stimulus is more threatening (Crombez et al., 1998). Although the threat value of pain has been suggested to be a bottom-up feature of pain, a debate is ongoing whether this is the case (Notebaert, Crombez, Van Damme, De Houwer, & Theeuwes). We can equally argue that the threat value of pain is a top-down variable. Research has not yet resolved this issue.

The impact of pain on task performance has also been investigated using naturally occurring forms of pain, such as recurrent pain (e.g., menstrual pain; Keogh, Cavill, Moore & Eccleston, 2014) or headaches (Moore, Keogh & Eccleston, 2013) increasing the ecological validity of earlier findings. Results confirm the findings of studies using experimental pain, and indicate that acute pain may interfere with the performance of a multitude of cognitive tasks. These findings have also been extended to chronic pain patients (e.g., Eccleston, 1994). In general, these studies show that chronic pain patients have difficulties performing well on attention-demanding tasks (for a review see Moriarty, McGuire, & Finn, 2011). In a recent meta-analysis, Berryman and colleagues (2014) indicated that chronic pain patients tend to show small to moderate impairments on cognitive tasks assessing a variety of cognitive components, such as response inhibition and set shifting. To date, it remains unknown which cognitive processes are specifically affected by pain. The research of Attridge and colleagues (2017) is one of the few studies that has extensively addressed this question, albeit in healthy volunteers experiencing occasional headache and with experimental stimuli (Attridge, Eccleston, Noonan, Wainwright, & Keogh, 2017). Despite an intense research program over several years, these investigators were unable to show consistently that pain affects only one or a limited number of cognitive processes. Although more research is needed in order to draw clear conclusions, we argue that pain has the capacity to overrule all possible cognitive processes. It may then prove futile to attempt to identify which specific cognitive processes are affected by pain (i.e., a structural approach). A motivational account, one which focusses upon goal and self-regulation processes that take place when individuals pursue a goal while experiencing pain, may be more worthwhile. A motivational approach also puts at the forefront the role of task strategies and self-regulation processes used by participants. It then becomes more important to know how participants are trying to perform specific tasks in presence of pain than to identify the specific cognitive processes affected by pain.

3.2.Top-down modulation of attention for pain

Whereas the bottom-up capture of attention by pain refers to the involuntary demand of attention by pain while attempting to attain a non-pain related goal, top-down modulation of attention focuses on the role of self-regulatory and goal-directed processes that prioritize information relevant for current actions or goals. As discussed above, the content of the goal that is being pursued may or may not be related to pain. Depending upon the content of the goal, top-down modulation of attention may then result in increased attention to pain or to pain-related information (top-down facilitation) or it may lead to decreased attention to pain or pain-related information (top-down inhibition). We review research relevant to both scenarios.

Top-down inhibition. Research investigating top-down inhibition of pain has typically adopted distraction paradigms in which the experience of pain is studied while people direct their attention away from pain (e.g., by engaging in a competing demand). Attentional distraction is a popular and commonly used self-regulatory strategy to cope with pain (Elomaa, Williams, & Kalso, 2009; Leventhal, 1992; Verhoeven et al., 2012). A large number of studies has investigated the efficacy of distraction to inhibit the experience of pain. In most of these studies pain is reduced when people are directing their attention away from it (e.g., Tracey et al., 2002; Tracey & Mantyh, 2007; Van Damme, Crombez, Van Nieuwenborgh-De Wever, & Goubert, 2008; Van Ryckeghem, Crombez, Van Hulle & Van Damme, 2012; Veldhuijzen et al., 2006; Verhoeven et al., 2011). However, a remarkable number of studies has found that performing a distraction task does not reduce pain (e.g., Hadjistavropoulos, Hadjistavropoulos, & Quine, 2000; Roelofs, Peters, van der Zijden, & Vlaeyen, 2004), or has reported that distraction resulted in increased pain experience (e.g. Goubert, Crombez, Eccleston, & Devulder, 2004; Keogh, Hatton, & Ellery, 2000). Various reasons have been put forward to explain these inconsistencies. Often the reasons offered depend on the theoretical framework that researchers endorse: a structural framework, a cognitive framework, or a self-regulatory/motivational framework.

Based upon a structural framework, scholars have investigated the impact of the difficulty of paradigms used to investigate distraction efficacy. A large variety of tasks/strategies have been employed to distract people from pain, such as thinking of something else (Hadjistavropoulos et al., 2000), looking at distraction cards (Inal & Kelleci, 2012), or walking around in a virtual world (Wiederhold, Gao, Sulea, & Wiederhold, 2014). As mentioned earlier (section 2), studies directly investigating the role of task difficulty revealed that increasing task difficulty is most often not related to a stronger reduction in pain.(e.g., McCaul et al., 1992).

In addition to the use of a structural framework, researchers have been guided by cognitive frameworks in their search for variables that may enlarge our understanding of top-down inhibition from pain. Here, there is a strong inclination to identify cognitive mechanisms that lead to pain reduction. This search has met with variable success. We highlight the most important findings.

Legrain and colleagues investigated the impact of loading peoples' working memory with pain-unrelated information (Legrain, Crombez, and Mouraux 2011; Legrain, Crombez, Verhoeven and Mouraux, 2011). They hypothesized that loading working memory with pain-unrelated information would reduce the impact of pain stimuli upon task performance. Results confirmed their hypotheses and indicated that loading working memory with pain-unrelated information (i.e., rehearsing features of the preceding visual targets) indeed resulted in less interference by pain stimuli. However, this finding proved to be independent from the amount of attentional load induced by the tasks. A second factor, addressed by Van Ryckeghem and colleagues (2012), relates to the attentional set hypothesis (cf., the neurocognitive model of attention to pain) which states that the more features (e.g., spatial location, modality) a stimulus shares with those in the attentional set, the more likely that this stimulus will draw attention. In particular, Van Ryckeghem and colleagues investigated the impact of the similarity between the features of pain and the features of the distraction task in terms of spatial location and modality. Results revealed that the effectiveness of the distraction task, at least partially, depended on the degree to which the task-relevant features were distinct from pain-related features. The more overlap between the features of the distraction task and the features of the pain, the smaller the distraction effect. A third factor relates to the level of executive functioning of people. Executive functions refer to a set of competencies that are of importance in goal planning and goal-directed action (Jurado & Rosselli, 2007, see also Chapter 1 by Karoly). In particular, competencies such as inhibition, switching ability, and updating are suggested as essential to goal-directed behavior. The argument has been made that people who have better executive functions would be better able to pursue their goal (such as distraction task performance) despite the presence of pain. Verhoeven and colleagues (2014) investigated the role of inhibitory control, task switching abilities, and working memory capacity on the top-down modulation of pain in a group of undergraduate students who performed an attention-demanding tone-detection task while experiencing cold pressor pain. Participants' performance improved with better inhibition abilities, indicating that inhibitory control plays a role in focusing on a task despite the presence of pain. No influence was found of switching ability or updating. The results of this study were further extended by Karsdorp and colleagues (2014) who reported poorer response inhibition to be associated with such factors as: (1) worse performance on a tone-detection task while experiencing cold pressor pain and (2) lower pain tolerance levels. Some scholars have suggested that a deficit in executive functioning might be related to the maintenance of pain (Karsdorp, Geenen, & Vlaeyen, 2014). In line with this idea, Berryman and colleagues (2014) showed that executive functioning was reduced in chronic pain patients. However, it remains to be investigated whether this reduction in executive functioning in chronic pain patients relates to an actual structural deficit or to the repeated presence of pain and/or negative emotions (Van Ryckeghem, Van Damme, Eccleston, & Crombez, Under review).

Taken together the use of cognitive accounts has been fruitful in researching variables influencing top-down inhibition of attention to pain. Nevertheless, available cognitive accounts do not provide a clear and detailed understanding of how and when affective and motivational factors play a role in the interplay between attention and pain. The influence of these factors becomes central in motivational accounts of pain (see earlier). One such factor is the importance of the goals that individuals pursue. Indeed, according to a motivational perspective on attention to pain, the importance of the distraction task is essential in drawing attention away from the pain. When the outcome of a task is important, people may be more motivated or engaged to perform well on that particular task. Yet, only a few studies have addressed the importance of the motivational value of the task on top-down inhibition of attention for pain. For example, Verhoeven and colleagues manipulated the importance of the distraction task by making the task motivationally relevant for one group of participants (money for good performance) and not for the other group. The motivational relevance of the task mattered. It increased the efficacy of distraction in people that catastrophized about their pain. These findings suggest that when people pursue a "valued" goal (i.e. good task performance in order to receive a monetary reward), they may increase their focus upon this goal, so that stimuli related to other, less important goals (i.e. experience of cold pressor pain) may become inhibited. Later research further substantiated the idea that goal importance may lead to a top-down inhibition of attention for pain. For example, Schrooten and colleagues (2012) demonstrated that attentional bias to pain signals can be inhibited when individuals are engaged in the pursuit of another salient, non-pain-related goal (e.g. monetary reward and punishment contingent on the performance on a second task).

A motivational account of attention and pain also assigns a central role to emotions. Indeed, emotions (1) may provide feedback about the extent of goal attainment and (2) energize goal-directed behavior. According to Carver and Scheier (1996), emotions may also lead to the disengagement from the pursued goal and to the reprioritization of other (earlier less important) goals. Nonetheless, the role of emotions within the interplay between attention and pain is not well understood. The studies investigating the impact of emotions have mainly looked at the influence of pain-related fear/ anxiety on top-down inhibition of attention for pain. In general, this research shows that increased fear of pain reduces the effect of distraction in healthy participants experiencing experimental pain (Roelofs et al., 2004; Van Damme et al., 2008, but see also Arntz et al., 1994). Similar findings have been obtained in chronic pain patients, where Hadjistavropoulos and colleagues (2000) showed that top-down inhibition of pain failed in health anxious chronic pain patients, although it succeeded in non-health-anxious chronic pain patients. Karsdorp and colleagues (2013) performed one of the few studies in which the impact of positive and negative mood upon top-down inhibition of attention for pain was investigated. In particular, they sought to determine whether induced mood (via the presentation of either positive or negative video excerpts) and type of goal (hedonic versus achievement goal) influenced pain intensity and unpleasantness during goal pursuit. They hypothesized that participants striving for achievement goals would experience less pain as compared to participants striving for hedonic goals, because achievement goals would allocate attention towards the cognitive task and consequently lead to distraction. However, no evidence for these hypotheses was found; as goal pursuit and mood did not result in differential distraction effects (but see also Villemure et al., 2003). Karsdorp and colleagues did however find effects of mood and goal pursuit on task performance during pain, indicating the importance of affective and goal-related factors. In particular, they reported that participants performed better in the achievement condition than in a hedonic goal condition and that the participants performed better when positive mood was induced than when negative mood was induced.

Top-down facilitation. Research on top-down facilitation of attention for pain has received far less empirical interest than research on top down inhibition. Recently, research has shifted to factors that facilitate top-down modulation of attention for pain or pain-related information. The shift towards a motivational account of pain has been particularly influential in research on top-down facilitation. A motivational account of pain stresses the role of the content of goal pursuit, which may be not related to pain (e.g., work to earn money), or may be related to pain (e.g., try to reduce/control pain). A first obvious reason to pursue pain-related goals is the expectancy of pain in near future. Expectancy of pain may increase an individual's attentional focus toward signals that could predict the onset of pain. Van Damme and colleagues investigated attention bias for cues that are predictive of potential pain (Van Damme, Crombez, & Eccleston, 2004a; Van Damme, Crombez, Eccleston, & Koster, 2006). These studies used a cueing paradigm with two coloured cues. Employing a classical conditioning approach, one cue became predictive of electrocutaneous pain, whereas the other cue was never followed by pain. Results indicated that people show an attention bias for the cue that is predictive of pain. This finding has been replicated in later studies (e.g., Van Damme et al., 2006). Additionally, Van Damme and colleagues found that retarded disengagement from signals predicting pain only occurred for participants with high levels of catastrophic thinking about pain (Van Damme, Crombez, & Eccleston, 2004b). Using a Temporal Order Judgment task (TOJ), based upon Titchener's law of prior entry, Vanden Bulcke and colleagues extended this line of research by investigating if the threat of pain at a certain body location biased attention to that body location (Vanden Bulcke, Crombez, Spence, & Van Damme, 2013; Vanden Bulcke, Van Damme, Durnez, & Crombez, 2014). In these studies, participants were asked to report which one of two tactile stimuli - one administered to each hand at a range of different stimulus onset asynchronies (SOAs) - was perceived first. Crucial in these studies, participants were informed that one cue preceding each TOJ trial would signal the possible delivery of a painful stimulus, whereas the other predicted its absence. In line with expectations an attentional shift was found to the threatened hand (Vanden Bulcke et al., 2013).

A second reason to adopt pain-related goals relates to the presence of catastrophic thoughts. Catastrophic thinking has been defined as “an exaggerated mental set brought to bear during actual or anticipated pain experience” (Sullivan et al., 2001). It is likely that people who catastrophize about pain are highly attentive to the presence of pain because they worry about pain-produced catastrophic outcomes. According to the fear-avoidance model, catastrophic thinking results in heightened attention to pain, but also to increased avoidance of situations that could increase or induce pain (Vlaeyen & Linton, 2002). High levels of catastrophizing are accordingly supposed to interfere with the goal of performing a competing task while experiencing pain, as attention will be prioritised to pain rather than to the task. This possibility was explored by Campbell and colleagues (2011) who investigated the relationship between catastrophic thinking and the efficacy of distraction in healthy volunteers experiencing experimental pain. Results indicated that distraction proved to be less effective for high catastrophizers than for low catastrophizers. These results are in line with those of a study conducted by Verhoeven and colleagues (2010, 2012) who also found that catastrophizing reduced the efficacy of distraction. Low catastrophizers who executed a distraction task while experiencing cold pressor pain reported less pain and distress compared with a control group that did not perform the distraction task. In contrast, for high catastrophizers, performing a distraction task while experiencing pain did not result in less pain, again pointing at the facilitative role of catastrophic thoughts on attention to pain.

A third reason to pursue pain-related goals relates to people’s desire to avoid or control pain. Indeed, trying to control pain is commonly considered to be the primary goal when one is being confronted with pain. Most often taking control over pain results in diminishing pain and its consequences. However, recent theory has suggested that the persistent pursuit of pain relief may increase distress and vigilance to pain (Eccleston & Crombez, 2007). To investigate prioritization of pain signals, Notebaert and colleagues (2011) addressed this hypothesis by using a visual search paradigm wherein one stimulus became a signal for pain. During this task, half of the participants could attempt to control pain by pressing the spacebar as fast as possible when a certain stimulus was presented. Results indicated that people who attempted to control pain demonstrated an enhanced prioritization of signals of pain compared with individuals who did not have this goal. Durnez and Van Damme (2015) furthered this research by investigating whether attempting to control pain augments attention towards somatosensory input. Using a Temporal Order Judgment task (see earlier), participants were presented with visuo-tactile stimulus pairs, and were asked to judge which stimulus they had perceived first. Half of the sample was encouraged to avoid the administration of pain by means of a specified behavioral response, whereas the other half was not. Results supported the idea that the pain goal exerted top-down control by prioritizing pain-relevant sensory information. Finally, Crombez and colleagues (2013) investigated the impact of losing control over pain. Results indicated that losing control over pain and, relatedly, attempting to control uncontrollable pain resulted in increased fear of looming pain, and retarded the performance on a secondary task. Findings of this study suggest that when attempts to avoid pain are blocked, individuals persist in their attempts, try harder, and narrow their focus of attention upon the problem to be solved (see also Brandstatter & Renner, 1990).

In sum, over the past years research has investigated the impact of several variables upon top-down modulation of attention for pain. The focus has mainly been upon cognitive factors.

Research investigating the influence of affective and motivational factors upon the interplay between attention and pain is scarce and still in its infancy. Future research is needed to further our insight in how cognitive, affective and motivational factors (and probably the interaction between these factors) affects top-down modulation of attention for pain.

4. Attention bias for symbolic representations of pain

As indicated in the introduction of this chapter, different strands of the interplay between attention and pain have been the subject of study. The models and research discussed above fit within a tradition in which attentional processes directed at actual somatosensory stimuli or signals for these stimuli have been the focus. There is yet a different research tradition in which interplay between attention and pain has been investigated, more specifically attention directed at symbolic representations of pain, such as words or pictures. This research tradition is inspired mainly by information processing accounts of psychopathology (MacLeod, Matthews, & Tata, 1986). A key idea in these models of psychopathology is that patients with a phobia and anxiety display a preferential processing of threat-related information. Extrapolating this notion towards a chronic pain context suggests that chronic pain patients also show preferential processing of pain-related information. The concept of attentional bias has shown to be a robust phenomenon in many forms of psychopathology, such as anxiety (Bar-haim, Lamy, Pergamin, Bakermans-Kranenburg, & van Ijzerdoorn, 2007). For example, patients with anxiety disorders display an attentional bias to threat-related words or pictures. Similarly, the paradigms that have been used to investigate attention biases have been adapted from research in psychopathology. Two paradigms have frequently been applied to investigate the existence of an attentional bias towards pain-related information:

The Modified Stroop paradigm. The modified Stroop paradigm is an adaptation of the classic Stroop task (Stroop, 1935) for which participants are required to identify the ink color of the presented color word. The Stroop interference effect refers to the general finding that people are slower to identify incongruent trials (the word RED printed in blue ink) than congruent trials (BLUE printed in blue ink) due to a failure to inhibit their dominant response (reading the word rather than stating its colour). To study the interference of pain-related information with attention, researchers have used pain-related words instead of color words and have compared the reaction time to identify these words with the reaction time to identify neutral words (Pearce & Morley, 1989).

Visual-probe paradigm. The visual-probe paradigm was developed to assess attentional bias towards threat-related information (MacLeod, Matthews, & Tata, 1986) and has been adapted to assess attentional bias towards pain-related information (Asmundson, Kuperos, & Norton, 1997). During this visual probe task, people are simultaneously shown two cues (words or pictures) on the computer screen. These cues are quickly followed by a dot which can appear at the location of both cues. One cue is pain-related, whereas the other cue is neutral. An attentional bias index is calculated by subtracting the reaction time on trials in which the dot followed the pain-related cue from the reaction time on trials in which the dot followed the neutral cue.

In contrast to research in psychopathology that has used these paradigms, research in pain has achieved only variable success. Indeed, whereas some studies showed that chronic pain patients have an attentional bias towards pain stimuli, others found that chronic pain patients have an attentional bias away from pain stimuli. To combine available research, a number of reviews have been performed over the past years. An early narrative review on cognitive biases (including attentional bias for pain) was presented by Pincus and Morley (2001) who suggested that chronic pain patients showed a bias for sensory pain information, but not for affective pain information. In an early meta-analysis, including Stroop studies, Roelofs, Peters, Zeegers, and Vlaeyen (2002) found evidence of attentional biases towards both sensory and affective pain stimuli. Schoth, Nunes, and Liossi (2012) conducted a meta-analysis to investigate the presence of attention biases in chronic pain patients in 10 studies using the visual probe paradigm. This meta-analyses revealed evidence of attentional biases at shorter (Hedges' g = 0.29) and longer (Hedges' g = 0.42) stimulus presentation times. A more comprehensive review that investigated attentional bias for pain-related information was performed by Crombez and colleagues who examined the presence of attention biases in healthy people, in people anticipating pain, in people with acute pain, and in individuals experiencing chronic pain (Crombez, Van Ryckeghem, Eccleston, & Van Damme, 2013). Within this meta-analysis, a range of factors was investigated that could explain the variation in the findings on attention biases for pain. These factors included type of attention bias paradigm used (visual probe paradigm, Stroop, modified cueing paradigm), stimulus type (words, pictures, predictive cues), specific stimulus category (e.g. sensory words and affective words), length of stimuli presentation (<500ms, 500-1000ms, >1000ms), and individual difference variables (such as pain severity, pain related fear, depression, anxiety). Results indicated that chronic pain patients display an attention bias for pain-related words or pictures. However, this bias was small (d = 0.134), and did not differ from the bias displayed in control groups (d = 0.082). No evidence emerged for an attentional bias towards pain-related words and pictures in other samples of persons with a current pain concern. Moderator analyses in the chronic pain groups identified two important procedural variables that affected the presence and magnitude of an attentional bias, i.e. (1) type of pain-related information and (2) exposure time of the stimulus material. Surprisingly, none of the coded individual difference variables such as pain severity or pain-related fear or anxiety, affected the magnitude of the attentional bias.

One potential explanation for the relatively poor evidence of attentional biases in chronic pain patients may relate to the fact that symbolic representations of pain, such as pain words, do not automatically activate pain memories and/or schemata in patients, an assumption held in many models (Crombez et al., 2013). In addition, the use of pictorial stimuli may have its restrictions. Indeed, although pictures may be more ecologically valid than words, it is not yet clear whether they are better suited to activate pain schemata/memories. Indeed, in contrast with research in, for example spider phobics, pain-related pictures often depict complex visual scenes (e.g., threatening movements) that are not quickly appraised as pain-related. This suggestion has been supported by the findings of studies that have used signals of impending pain to investigate attentional bias towards pain cues in healthy volunteers (e.g., Van Damme et al., 2004).

In sum, current findings show that the evidence for dysfunctional processing of pain-related information is far less convincing in chronic pain patients than in the anxiety literature (Bar-haim et al., 2007). Indeed, if dysfunctional processing of pain-related information were to occur, it might be expected that chronic pain patients would show selective attention for symbolic representations of pain. Furthermore, this view suggests that directly modifying people's attentional bias by training them to direct their attention away from pain-related information (e.g., training away from symbolic pain information; see, for example, Sharpe et al., 2012) would result in improved pain outcomes. Research findings on this topic are still accruing, but tend to be inconsistent (Todd et al., 2015). In contrast, a motivational view suggests that pain-related stimuli only draw attention when they relate to peoples' concerns or pursued goals. As such, attentional bias may be considered a normal process that emerges when individuals pursue goals that relate to pain (e.g., when they expect pain or try to control/avoid pain). Within this view, various factors contribute to the presence of an attention bias for pain-related information, such as catastrophic thinking about pain or attempts to control pain. Switching from a dysfunctional information processing account to a motivational account is not without consequences. The standard paradigms that use symbolic representations may no longer be appropriate paradigms to assess attention bias for pain-related information. In fact, attentional bias for pain-related information may be better investigated using stimuli that are relevant to the pain that people are fearing or experiencing. Additionally, clinicians should aim to directly target factors that contribute to the presence of an attention bias for pain-related information, rather than aiming to modify attention bias via attention bias modification training. In order to do so, clinicians have a plethora of techniques, such as de-catastrophizing (Thorne et al., 2007), exposure therapy (Vlaeyen, Morley, Linton, Boersma, & de Jong, 2012) or techniques employed by Acceptance and Commitment Therapy (McCracken & Gutiérrez-Martínez, 2011).

5. Future challenges to investigate the interplay between attention and pain.

Despite a growing interest in a motivational account of the links between attention and pain, a number of challenges remain and require further consideration. Here we discuss three topics that we believe are important to further research in this arena.

The relationship between attention to pain/task interference and self-reports of pain experience. A first issue relates to the limited amount of research that investigates the link between attention for pain and the self-report of pain experience. This separation is remarkable because both phenomena, task interference by pain, on the one hand, and the (self-reported) reduction of pain by directing attention away from it, are conceptually grounded within similar theoretical accounts (e.g., Eccleston & Crombez, 2007, Vlaeyen et al., 2016). Moreover, the same factors presumably affect both phenomena. For example, catastrophic thinking about pain increases task interference, and reduces distraction effectiveness. One reason for the lack of research may relate to the absence of paradigms that allow for the investigation of task interference by a pain stimulus while reporting on its intensity using self-report. One of the few exceptions is a study by Romero, Straube, Nitsch, Miltner, and Weiss (2013). They investigated the interaction between perceptual load -induced by a visual task- and the intensity of noxious stimulation upon task interference and pain report. Results indicated that task interference and the self-report of pain differed, and therefore they should not be interpreted as representing two sides of the same coin. It will be important to investigate which variables affect only task interference or pain report, or both. It may be that repeated presentation of pain reduces the level of interference with task performance (due to habituation), whereas pain reports of the stimulus remain the same.

The absence of a systematic program to investigate the interplay between attention and pain from a motivational perspective. Research investigating the relationship between attention and pain from a motivational perspective is still in its infancy. Most current research is informed by structural or cognitive accounts. Investigating the role of other factors that may affect people's motivation to pursue a particular goal in the context of pain has just began. Only few studies have investigated the impact of emotions upon the interplay between attention and pain. Most of these studies have looked at the impact of pain-related fear upon attention to pain. Other emotions, such as anger but also happiness, have largely been neglected. This is surprising, as the manifestation and intensity of particular emotions may affect the planning (Maglio, Gollwitzer, & Oettingen, 2014) and the pursuit of goals. Indeed, emotions are involved in the prioritization of goals and thereby mobilize energy and give direction to behavior (Bagozzi, Baumgartner, Pieters &

Zeelenberg, 2000; Frijda, 2006). As such, emotions have a key motivational function. Similarly, only a few studies have investigated the impact of goal features (e.g., goal importance, goal specificity, goal proximity; see chapter 1 of this book) of the attained goal upon attention when being confronted with pain. A systematic research program would not only allow the investigation of how these factors affect the interplay between attention and pain in isolation, but should also address their interactions (which is common in everyday situations).

Ecological validity. Research addressing the interplay between attention and pain has been performed mainly in the lab. Although laboratory investigations have advantages (e.g., increased level of standardization), they limit the possibility for the use of everyday and realistic goals in determining how attention and pain interact. We contend that the investigation of attentional processes in chronic pain patients outside the lab, i.e. in daily life contexts, is an important step in this research area. Migrating the research outside the lab may, for example, allow for the investigation of processes, such as attention biases, while patients perceive daily threats and pursue ecologically valid goals. Although challenging, novel technologies permit us to pursue this research line (Kaplan & Stone, 2013). Indeed, real-time assessment of emotions, thoughts, and pain outcomes is possible via handheld computers or smart cell phones. Sampling relevant information during the day in combination with specific instructions to modulate attention may provide insights into how the context (e.g., presence of others, pursuance of an important goal etc.) affects the interplay between pain and attention. Crombez and colleagues (2013) used this approach to investigate the link between self-reported attention for pain and pain outcomes. They found that, during moments with more intense pain, more fearful thinking about pain, and less positive emotions, the participants reported more attention toward the pain. This study only used self-report-measures. Novel technology may also allow for investigating the relationship between attention for actual perceived (pain-related) bodily sensations and other situational information (e.g., momentary pain experience, presence of others, worrying about pain). Pursuing this line of research may further our current understanding of attentional dynamics and expand the investigation of the role of contextual factors on attention for pain-related information.

6. Clinical implications

Adopting a motivational perspective that highlights the pivotal role of cognitive, affective, and contextual factors in explaining the interplay between attention and pain has several implications for the clinic. First, this perspective suggests that the goals people pursue should be taken into account within a therapeutic context. Indeed, goals are central to understanding how attention is directed and how people behave in the presence of pain. Therefore, it is important that goals be identified and their properties understood (Van Ryckeghem & Crombez, 2014). One way of doing this is by means of motivational interviewing (Van Damme & Kindermans, 2015; cf., also the chapter by Jensen in the present volume) or via personal project analysis (Crombez et al., 2016, cf., also the chapter by Claes and Gebhardt in the present volume). Once goals are identified, self-regulation strategies may be instantiated to help individuals reach their goals despite the presence of pain (cf., Chapter 1 of this volume)

Second, the proposed account suggests that targeting only cognitive processes may not be sufficient, or even necessary, to influence pain outcomes. Indeed, we propose that it is of importance to also deal with the emotions of threat and anger. This suggestion is corroborated by the disappointing findings of pure cognitive strategies. For example, attentional strategies, such as distraction and sensory monitoring, have not been particularly successful in helping chronic pain patients or people who catastrophize about their pain (Van Ryckeghem et al., Under review;

Verhoeven et al., 2010). Making the strategies motivationally relevant or reducing the threat value of the pain (e.g., by challenging erroneous beliefs about pain) may prove more helpful in this context.

7. Conclusion

In this chapter, we provided an up-to-date overview of available theoretical frameworks dealing with the relations between attention and pain. In addition, we showed that a motivational perspective offers a comprehensive framework within which the available research investigating the interplay between attention and pain may be better understood. Moreover, the proposed motivational framework offers an explanation for contradictory findings concerning the interplay between attention and pain. Future research will need to further validate this framework by explicitly modulating people's goals (and its features) and by investigating their effects upon the demand and deployment of attention. The current chapter furthermore shows that several challenges remain, and more systematic research from a motivational perspective is needed addressing the factors that may influence the complex interplay between attention and pain. We hope that current chapter serves to guide future researchers toward the goal of unraveling the relationship between attention and pain by examining factors that moderate or mediate that relationship.

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