# Keeping pain in mind: a motivational account of attention to pain

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## Abstract

Attention is a key concept in many theories of pain perception.  A clinically popular idea is that pain is more intense in persons who are hypervigilant for or bias their attention to pain information. So far, evidence for such bias in pain patients as compared to healthy persons is inconclusive. Furthermore, studies investigating the effects of distracting attention away from pain have shown contradictory results. In this review, we present a motivational perspective on attentional processing of pain that accounts for these inconclusive research findings. We argue that pain always has to be considered within a context of goal pursuit. From this perspective, two largely unexplored theoretical assumptions are introduced. First, when pain occurs during the pursuit of a certain goal, it may unintentionally capture attention although it is not relevant for the goal. Whether such unintentional attentional capture happens is not only dependent upon the characteristics of the pain but also on the characteristics of the focal goal. Second, attention to pain and pain-related information might be driven by a focal goal related to pain. Attentional processing of pain information will be particularly enhanced when the focal goal is related to pain management (e.g., attempting to gain control). Future research has to systematically investigate the role of motivation and goal pursuit in the attentional processing of pain-related information. This motivational perspective offers a powerful framework to explain inter- and intra-individual differences in the deployment of attention to pain-related information.

*Keywords*: pain; attention; hypervigilance; goals; motivation; distraction

## 1. **Introduction**

Although the presence of pain is used as an indicator of many medical problems, pain is not always in proportion to the magnitude of the identified problem. Often large variations in pain perception are observed which cannot be accounted for by differences in tissue damage or (patho)physiological processes. As a result there is a consensus that pain can only be understood from a biopsychosocial perspective. Fundamental to this view is the distinction between nociception and pain. Nociception occurs when information about (potential) tissue damage is transferred to the brain by means of specialized nerves. Pain is the perception resulting from this nociceptive process. The transition from sensory input to perception is known to be modulated by a broad range of biological and psychosocial factors (for a comprehensive review see Gatchel et al., 2007).

Within this multi-factorial framework, attention has been put forward as a prominent mechanism to help explaining pain perception in acute and chronic conditions (Crombez et al., 2005). Patients with continuing pain problems are often assumed to be excessively attentive for their symptoms, and this is referred to as hypervigilance. Chapman (1978) was one of the first researchers who applied the concept of hypervigilance in the context of pain. He stated that persons who associate bodily sensations with danger will display a perceptual habit of scanning the body for threat. This idea has been applied in several clinical pain disorders. For example, it has been argued that patients with fibromyalgia - a medically unexplained syndrome characterized by whole body pain as the primary feature - are characterized by increased attention to a variety of bodily sensations, and in particular pain (Peters et al., 2000; Rollman & Lautenbacher, 1993). This dysfunctional attentional style has been assumed to maintain and amplify bodily sensations (McDermid et al., 1996). A similar mechanism has also been assumed in patients suffering from chronic low back pain. In the fear-avoidance model (Vlaeyen et al, 1995), those patients who fear their pain or further injury are at risk for developing chronic problems. This model assumes that fearful patients become increasingly vigilant for signals of bodily threat, which in turn leads to avoidance behaviour and increased disability (Leeuw et al., 2007).

The idea of attention as a potentially important factor in the development of chronic pain has been informed by two assumptions. First, the amount of attention paid to nociceptive stimulation is believed to modulate the experience of pain (Villemure & Bushnell, 2002). Second, it is often thought that chronic pain patients are characterized by hypervigilance (i.e., excessive attention) for pain-related information (Pincus & Morley, 2001). Although these ideas are intuitively appealing, empirical evidence is inconsistent and inconclusive. With regard to the first assumption, some studies have shown that attending to pain increases pain perception and attending away from pain attenuates pain perception, whereas other studies failed to demonstrate such effect or even found the opposite (Seminowicz & Davis, 2007a). Also the second assumption is controversial, as many studies have failed to detect differences in attention to pain-related information between chronic pain patients and healthy persons (Van Damme et al., 2004c).

In this review, we attempt to resolve the inconsistent findings from the literature by proposing a motivational account of attentional processing of pain. We begin with general psychological theories arguing that attention plays an important role in the pursuit and management of goals, and review evidence in favour of it (Section 2). Next we apply this view to attentional processing of pain (Section 3), review the available research, and provide recommendations for future research

(Section 4). Finally, we discuss research on hypervigilance to pain in chronic pain patients (Section 5), and implications for methods attempting to manipulate attention away from pain (Section 6).

## 2. The role of attention in the pursuit and management of goals

Within cognitive psychology, Allport (1989) has provided one of the most detailed functional accounts of attention. Defining attention as the selection of information for action, he argued that an efficient attentional system serves two apparently contradictory functions: First, it protects the pursuit of current goals and ongoing behaviour from less important demands. Second, in an unpredictable and potentially dangerous environment, it is necessary that ongoing behaviour can be interrupted at any time when more important demands such as threat emerge (see also Norman & Shallice, 1986).

An effective balance between both functions is necessary for survival: Constantly shifting to new events would result in chaotic behaviour, whereas failing to shift to environmental threats is hazardous and potentially dangerous. For example, when studying an article, we focus our attention on the text we are reading, and become less aware of new sensory events in our environment. However, when we would perceive the smell of smoke, we will immediately interrupt reading and check whether there is a fire.

A central assumption of Allport's view is that the deployment of attention is influenced by goals. A goal can be understood as the mental representation of a desired end state that differs from the current state of an individual (Austin & Vancouver, 1996; Fishbach & Ferguson, 2007). Several theories posit that the activation of a goal automatically directs attention to matching stimuli in the environment (e.g., Johnson et al., 2006; Moskowitz et al., 2004; Soto et al., 2008). It is likely that the strength with which a goal is pursued influences how much attention is deployed to goal-relevant stimuli (Förster et al., 2007). Until now, such motivational account of attention has been typically used in the context of evolutionarily evolved motives related to survival.

### *2.1. Attention and evolutionary motives*

There is conclusive evidence that attention is preferentially allocated to stimuli that people appraise as threatening or potentially dangerous (for a review, see Bar-Haim et al., 2007). These findings have been considered as evidence for the existence of a “fear module” that guides attentional orienting so that it allows the rapid detection of potential dangers in the environment (Öhman et al., 2001). For example, it has recently been demonstrated that viewing pictures implying physical threat prioritizes tactile attention to the threatened body part (Van Damme et al., in press b). We will argue later (see Section 3) that pain is a prototypical example of an evolutionarily determined threat. However, other basic motives and needs seem to influence attention in a similar way. For instance, it has been shown that hungry people display an attentional bias to food-related words (Mogg et al., 1998). More recent studies have also found attentional biases to stimuli that refer to the motive of reproduction, such as attractive persons of the opposite gender (Maner et al., 2003) or babies (Brosch et al., 2007). For example, Light and Isaacowitz (2006) showed that women who approached the childbearing age limit and wished to have a baby, showed an attentional bias to baby pictures. In contrast, women who just passed this limit and had given up their baby wish, did not display such bias. However, the powerful influence of motivation on attention is not limited to basic needs or evolutionary motives.

### *2.2. Attention and actual goals*

There are also indications that actual, more concrete goals affect attentional deployment. A classic example of this is the so-called cocktail party phenomenon initially described by Cherry (1953). The cocktail party phenomenon reflects the ability to focus attention on a conversation partner among a mixture of other conversations and background noise. Empirical evidence for this was provided by Broadbent (1958). In a series of dichotic listening experiments he showed that subjects receiving auditory information through different signal channels at the same time were able to select one channel for further semantic analysis. Broadbent proposed that the signal that is relevant for perception according to subjects' goals is filtered by attention (for a recent review, see Spence & Santangelo, in press), and the neurobiological basis of this process has been identified (e.g., Hillyard et al., 1998).

More recent demonstrations are available from studies using the Inattentional Blindness paradigm (see Mack & Rock, 1998). A well-known example is the study by Simons and Chabris (1999), in which participants watched a video showing two teams playing basketball and were instructed to count the number of passes of one of the teams. One team played in white T-shirts, the other one in black T-shirts. In the middle of the video a person in a black gorilla costume appeared between the players for 5 seconds. This gorilla turned the face to the camera and beat its chest. Most of the participants that were instructed to count the number of passes of the white team, failed to report the occurrence of the highly salient gorilla when asked afterwards. Probably, the task goal resulted in a strong focus of attention on goal-relevant white stimuli, whereas goal-irrelevant black stimuli were inhibited (see also Rock & Gutman, 1981).

These studies indicate that individuals are capable of intentionally focusing attention to events that are relevant to their goals at the costs of other events (see also Posner, 1980; Yantis, 2000). However, there is also evidence for unintentional attentional capture by stimuli that are related to a task goal. Folk et al. (1992) showed that having the goal of localizing a coloured target stimulus led to involuntary attention shifts towards coloured cues briefly presented just before the target but not towards new cues. In contrast, having to detect a new target led to involuntary attention shifts to new cues but not to coloured cues. These findings suggest that attention capture is contingent on attentional control settings induced by task demands (see also Folk & Remington, 2008).

### *2.3. The management of multiple goals by attention*

Most of the time more than one goal is activated, for example while being at work, different tasks have to be done, and also private goals might be activated in the background. Multiple goals often result in goal conflict because the different goals cannot be pursued in parallel and one goal hinders the achievement of the other goals. Such situations require the prioritization of a focal goal in order to ensure successful goal achievement. Recently it has been shown that such goal conflicts trigger a “goal shielding” mechanism, in which commitment to a focal goal inhibits the accessibility of alternative goals and distracting information (Fishbach & Ferguson, 2007; Goschke & Dreisbach, 2008; Shah et al., 2002). Attention has been put forward as a central process of goal shielding (see Johnson et al., 2006; Shah, 2005).

Empirical evidence in support of this view has been recently reported. Papies et al. (2008) demonstrated that restraint eaters who normally display an attentional bias to tempting, tasty food did not show this bias when a dieting goal was activated.

Similarly, Maner et al. (in press) found that participants who were in a relationship and who were highly committed to remain faithful were inattentive to pictures of attractive persons, whereas individuals who were looking for a relationship partner showed an attentional bias to these pictures.

### *2.4. Summary*

In this section, we discussed theoretical accounts for a motivational basis of attention and we reviewed evidence suggesting that motivation and attention are closely linked. First, attention prioritizes information that is relevant in the context of inborn motives and needs. Second, not only general motives but also concrete goals activate mental representations in memory that guide attention to matching stimuli. The stronger the activated goal, the more attention is allocated to goal-relevant information. Third, multiple goals and goal conflicts are managed by goal shielding, a mechanism that protects the focal goal and inhibits competing goals by the regulation of attention.

As goals are often different between persons and between situations within one person, we argue that a motivational perspective offers a powerful framework to explore inter- and intra-individual differences in the deployment of attention to pain-related information.

## **3. Toward a motivational account of attentional processing of pain**

Although the motivational account on attentional deployment is typically described and investigated in the context of visual attention, it can easily be extended to information processing in other perceptual modalities. We argue that pain is never an isolated event, it always occurs within a context of goal pursuit. As such, pain-related information might become the focus of attention in two different ways.

First, pain is often unrelated to the goal that is currently pursued. Nevertheless, pain is an evolutionarily acquired alarm signal of bodily threat, and therefore is hardwired to draw attention and interrupt ongoing goals. In other words, the protection of ongoing goals (goal shielding) is not absolute. Evolutionarily important threats such as pain must be able to interrupt current goal pursuit. Eccleston and Crombez (1999) argued that the interruptive quality of pain is related to the activation of a primitive defensive system urging escape (see also Auvray et al. in press). The unintentional selection of pain by the attention system is believed to be a stimulus-driven or bottom-up effect that depends upon the interaction of pain-related and goal-related characteristics. An example might clarify this. Imagine a man working at the office and suddenly experiencing shooting pain. It is plausible that he will interrupt his work when the pain is intense or novel. However, it is equally possible that interruption will be less when the current task is highly interesting or related to an important goal (for instance a report that is needed before a certain deadline).

Second, the currently pursued goal might be about pain. Typical pain-related goals are trying to get rid of the pain, attempting to control the pain, and searching a solution for the problem causing the pain. In patients, such goals are often related to a biomedical frame of the problem (Eccleston & Crombez, 2007). From our motivational account on attention it is expected that the prioritization of pain-related goals will be accompanied by increased processing of pain and pain-related information whereas the processing of other information will be inhibited. The selection of pain-related information at the expense of other information could then be conceived as a goal-directed or top-down mechanism. Think again about the example of the man with back pain. Imagine now that this man has been surgically treated for a hernia the year before. He might interpret the sensations in his back as a re-injury and find this extremely threatening. In this context, adequately dealing with the problem will probably become the central goal. The man will worry about the potential consequences, try to avoid back-stressing behaviours, and carefully monitor further signals of damage in his back. Attentional processing of other information that is not related to the back problem will be inhibited, probably resulting in less efficient task performance at the office.

In sum, fully understanding attention to pain requires taking into account the motivational context in which pain occurs. Goals might differ between persons but might also differ within persons depending on the situation. This has been largely overlooked in theoretical models and empirical research on attention and pain. In the next section we will review the literature on studies which have investigated the attentional processing of pain.

## 4. Investigating attentional processing of pain: a review

We will discuss studies according to two research lines: (1) studies in which pain was irrelevant for people’s current goals and (2) studies in which pain was goal-relevant.

### *4.1. Attentional processing when pain is irrelevant for the focal goal*

Many studies investigating attentional capture by pain that is irrelevant to the focal goal have used behavioural paradigms. A well-known example is the primary task paradigm proposed by Crombez et al. (1994) and Eccleston (1994). The rationale of this paradigm is that in an environment with multiple demands the selection of pain will result in decreased attention to other demands. Participants are asked to perform a task, e.g., an auditory detection or discrimination task, and on several moments during the task a task-irrelevant pain stimulus is administered. The degradation of task performance on trials with pain relative to trials without pain, in terms of speed and accuracy, is considered a measure of the attentional demand of pain. In a series of empirical studies using the primary task paradigm in healthy volunteers, interruption of attention by pain has been consistently demonstrated. Of particular interest, it was found that attentional interruption is short-lived as it was most pronounced during the first part of the pain stimulus (Crombez et al., 1994, 1996, 1998a, 1998b). This indicates that after initial interruption, attention is re-engaged to the focal goal (i.e., the tone discrimination task).

Because in the primary task paradigm attention to pain is only indirectly measured, other paradigms have been developed to examine more directly attentional capture by pain-related information irrelevant for the focal goal. A good example is the exogenous cueing task, originally developed by Posner (1978), in which participants are asked to detect visual target stimuli presented on the left or right. Before each target, a cue is briefly presented at either the same spatial position (congruent trial) or at the opposite position (incongruent trial). Slower responses on incongruent relative to congruent trials are indicative of exogenous orienting to the cue. A number of studies using a modified version of this paradigm have suggested that exogenous orienting is enhanced when the cue is painful (Van Damme et al., 2007) or when the cue is a signal of impending pain (Van Damme et al., 2004a, 2006). Note that these studies could be criticized because the differences in reaction times might reflect criterion shifts or response biases rather than genuine changes in perceptual processing (see Spence et al., 2004; Van Damme et al., in press a).

The findings of several studies using neurobiological paradigms provide further support for attentional capture by pain that is irrelevant for the focal goal.

There is a consensus that nociceptive stimuli can activate a cortical network involved in attentional processing (e.g., prefrontal and posterior parietal areas) even when these stimuli are not relevant for current task goals (Dowman & Ben-Avraham, 2008; Seminowicz & Davis, 2007c). In electro-encephalographic (EEG) research, this was concluded from the P2 evoked response, which is supposed to be generated mainly in the middle part of the cingulate gyrus, a brain area involved in attentional orienting (Downar et al., 2000), conflict monitoring (Bush et al., 2000), and adequate motor reaction (Garcia-Larrea et al., 2003). Several studies have shown that rare sudden nociceptive stimuli enhance the amplitude of the P2 component when presented outside the focus of attention (Dowman, 2001; Legrain et al., 2002, 2003b) or when such stimuli were irrelevant for current task goals (Legrain et al., 2003a, 2005). Additionally, it was recently demonstrated that nociceptive stimuli that evoked the larger P2 amplitude also slowed down reaction times to contingent task-relevant visual targets (Legrain et al., 2008), in accordance with previous behavioural studies (e.g., Crombez et al., 1994).

Although the review of the above studies is supportive of the idea that pain that is irrelevant for a focal goal attracts attention, we cannot be sure that this is a completely automatic effect that is purely driven by bottom-up processes. In most of these studies behavioural and neurobiological paradigms were used in which there was repeated pain stimulation throughout the experiment (for an exception, see Crombez et al., 1994). Participants were obviously aware of this, as a result of which some pain-related goal might have been activated (for instance monitoring the body for threat). Consequently, it is possible that top-down processes have started to play a role in these experiments. Indeed, a closer look at the results of several of these studies learns that attentional capture by pain was further enhanced when participants were threatened with the possibility that in some trials a pain stimulus with a higher intensity would be applied (Crombez et al., 1998a), or when participants were characterized by a high level of catastrophic thinking about pain (Crombez et al., 1998b; Van Damme et al., 2004a). This suggests that at least part of the effect might result from top-down regulation (see also Crombez et al., 2005; Dowman & Ben-Avraham, 2008).

An implication of the potential role of top-down processing of task-irrelevant pain is that attentional capture by the pain might be controlled to some extent. From our motivational perspective it could be hypothesized that attentional capture by goal-irrelevant pain will depend on the characteristics of the focal goal. In line with the idea of goal-shielding, it might be that when the currently pursued goal is highly valued, attention will be strongly engaged to information that is relevant to this goal, whereas goal-irrelevant information will be inhibited (Fishbach & Ferguson, 2007; Goschke & Dreisbach, 2008; Shah et al., 2002). Indeed, it has been demonstrated that attentional capture by visual and auditory exogenous cues was eliminated when attention was strongly focused to a concomitant visual or auditory task (Santangelo et al., 2007). It would be interesting to examine whether this effect would be replicated for exogenous cues related to pain.

There are indications that the processing of nociceptive stimuli is suppressed when attention is strongly focused to a focal task goal. In an EEG study by Legrain et al. (2005), subjects were presented with concomitant visual and nociceptive stimuli. The task was to report the number of items (between one and four) on each visual display. The effect of cognitive engagement was examined by manipulating the cognitive load of the visual task. Higher cognitive load resulted in decreased amplitude of the P2 cortical potential evoked by the concomitant nociceptive stimuli, reflecting attenuated orienting of attention to these stimuli (see Section 4.1). In a similar task using fMRI, Bantick et al. (2002) showed decreased BOLD (blood oxygenation level-dependent) signals in the midcingulate region of the Anterior Cingulate Cortex (ACC), indicating decreased attention to pain. Other neuroimaging studies were able to demonstrate that engaging more resources on visual processing decreased nociceptive processing in somatosensory areas (Bingel et al., 2007; Seminowicz & Davis, 2007b).

The above findings support the idea that cognitive engagement to a focal task goal reduces attentional capture by pain by inhibiting sensory analyses of nociceptive inputs (Legrain, 2008). However, in real life, one could expect that cognitive engagement to a focal task will only be strong enough to inhibit attentional processing of pain when it is related to a strong goal. We are not aware of studies that have systematically examined the effect of the motivational characteristics of the focal task (for example, how important, interesting, or pleasant is a task) on the strength of cognitive engagement, and consequently on its ability to inhibit interruption by pain. This is an important avenue for future research, and could also be helpful in optimizing distraction techniques in the context of clinical or procedural pain (see Section 6).

### *4.2. Attentional processing when pain is goal-relevant*

Goal-dependent attention to pain has typically been investigated in paradigms in which the pain stimulus was relevant for the task to be performed. For instance, Peters et al. (2000) introduced a body scanning paradigm in which innocuous electrocutaneous stimuli gradually increasing in intensity were administered to one of four different body locations. Participants were instructed to detect these stimuli as quickly as possible by pressing a button corresponding to the correct body location. It was found that detection was faster in participants reporting higher pain-related fear. More recently, Esteve and Camacho (2008) used a similar paradigm and found superior detection of electrocutaneous stimuli in participants with high levels of anxiety sensitivity. This might have been due to increased attentional processing of bodily signals in fearful participants, because the goal to scan the body for potential threats is strongly activated in these participants. However, non-attentional explanations in terms of central sensitisation (Crombez et al., 2005) and response biases (Spence et al., 2004) are equally plausible. Research in this area would therefore benefit from adopting experimental paradigms that specifically measure attention, such as Change Blindness tasks (see Gallace et al., 2006) or the Temporal Order Judgement tasks (see Zampini et al., 2007).

Until now, most studies investigating the effects of intentional attention to pain have used cueing paradigms. Van Damme et al. (2002) instructed healthy volunteers to detect pain and auditory stimuli. Each stimulus was preceded by a word that correctly (50% of trials) or incorrectly (50% of trials) cued the modality of the upcoming stimulus. It was found that stimulus detection was faster with a correct cue than with an incorrect cue. More importantly, reaction times were slowed when participants were cued for pain, but a tone target was presented, whereas this was not the case when participants were cued for the tone and a pain target was presented. This pattern of results indicates that the detection of pain targets had a higher goal priority than the detection of tone targets (see also Van Damme et al., 2004b, for a replication). Intriguingly, this effect was enhanced in participants with a high level of catastrophic thinking about pain, suggesting additional top-down regulation of attention. Again it should be noted that the effects in this study do not necessarily reflect perceptual changes but might also be explained by criterion shifting and response biases (Spence et al., 2004). In another study using a cueing paradigm, Spence et al. (2002) instructed healthy participants to make spatial discriminations of visual and pain stimuli presented on the left arm. Each stimulus was preceded by a symbolic cue correctly (67%) or incorrectly (33%) signalling the modality for the upcoming stimulus. As expected, participants responded more rapidly when the target was presented in the cued modality, confirming the effect of top-down processing. In contrast with the studies by Van Damme et al. (2002, 2004b) there was no difference between responses to pain targets and visual targets, suggesting that the goal to detect nociceptive input was not prioritized over the goal to detect visual input. However, this might be explained by the use of predictive cues in the study of Spence et al. (2002), resulting in a ceiling of the cueing effects and thereby leaving no further room for differences between pain trials and visual trials.

Other studies have looked at spatial attention. For instance, Dowman (2004) used a spatial cueing paradigm in which participants were instructed to rate pain stimuli presented at either the left or the right hand. Each stimulus was preceded by an arrow pointing left or right, and this correctly predicted which hand would be stimulated in 80% of the trials. It was found that participants needed less time to rate pain when the stimulated hand was attended than it was unattended. Recently, Van Damme et al. (2008c) also used a spatial cueing paradigm in which participants were instructed to detect pain stimuli or non-painful tactile stimuli at either the left or the right hand. Each stimulus was preceded by a visual signal presented at the stimulated hand or at the other hand. In line with Dowman (2004), reaction times were faster when the lateralized visual signal cued the stimulated hand than when it cued the non-stimulated hand. Particularly interesting was that the effect was more pronounced for painful somatic stimuli than for neutral somatic stimuli. This again suggests that goals are prioritized when they are related to pain (see also Bushnell et al., 1985). Note that also in these studies, effects might reflect criterion shifting or response bias rather than perceptual changes (Spence et al., 2004).

Using a different approach, neurophysiological and neuroimaging studies disclosed the spatio-temporal dynamics of goal-relevant selective processing of pain. In these studies, painful and non-painful (i.e., visual or auditory) stimuli were randomly delivered, and participants were instructed to focus their attention on one modality and to ignore stimuli from the other modality. Brain responses to nociceptive stimuli were compared when attention was directed to nociceptive stimuli and when attention was focused on another modality. Using electro-encephalography (EEG) and magneto-encephalography (MEG), several studies showed clear evoked responses indicating goal-directed attention (for a review see Lorenz & Garcia-Larrea, 2003). For instance, in the study of Legrain et al. (2002), nociceptive stimuli were randomly presented on both hands. The task was to focus attention on one hand in order to detect occasional targets (intensity increments or decrements) presented to that hand. Nociceptive stimuli induced larger evoked responses when the stimulated hand was task-relevant than when the other hand was task-relevant (see also Nakamura et al., 2002). The modulation was effective on the first scalp-recorded response, which is mainly generated in the secondary somatosensory cortex (Garcia-Larrea et al., 2003), but also in the primary somatosensory cortex (Ohara et al., 2004a,b; Nakata et al., 2008). Neuroimaging studies further confirmed attentional modulations in both primary and secondary somatosensory areas (Bushnell et al., 1999; Petrovic et al., 2000; Seminovicz et al., 2004). This suggests that nociceptive inputs can be modulated by cognitive factors from the very first cortical connections. In other words, the nociceptive system is “pre-activated” when pain is attended.

In all of these studies pain was primarily goal-relevant because participants had to perform a task related to the pain (detection, discrimination, evaluation). However, in real life or in the context of clinical pain, goals will be typically related to gaining control over the pain or finding a solution for the pain problem (Eccleston & Crombez, 2007).

### *4.3. Effects of “real-life” pain goals*

Bringing pain under control by means of adaptive action is commonly considered to be an important goal when one is confronted with bodily threat (Van Damme et al., 2008a). Behavioural control has been defined as the belief that one has a behavioural response available that can influence the aversiveness of an event (Thompson, 1981). Studies using the learned helplessness paradigm have taught us that an organism is advantaged when having control over aversive events compared with having no control (Abrahamson et al., 1978; Seligman, 1972). Evidence is accumulating that the (perceived) ability to control pain by behavioural responses results in less pain (e.g., Wiech et al., 2006) and decreased activation in neural areas usually linked with pain processing (anterior cingulate, insular, and secondary somatosensory cortices) (e.g., Salomons et al., 2004). Furthermore, several studies have identified the neurobiological basis for processes that are central in pain control such as cognitive reappraisal (Wiech et al., 2006) and motor preparation (Morrison et al., 2007).

Very few studies have investigated whether the goal of pain control increases attentional processing of pain-related information. Particularly important for answering this research question is the use of experimental paradigms in which the effects of attempting to control or avoid pain can be differentiated from the effects of actual pain stimulation. An elegant paradigm was used by Mobbs et al. (2007). Participants were pursued through a maze by a virtual predator that was able to chase and inflict pain (shocks). Results showed that participants were more efficient in movement planning and execution when the predator could inflict shocks of high compared to low intensity. This was accompanied by prefrontal activation, which might represent the selection of goal-directed behaviour in order to avoid pain. Prefrontal activation was more pronounced when self-reported dread was high, suggesting that effects were specifically related to the goal to avoid bodily threat. Crombez et al. (2008) used a paradigm in which the effects of the goal to control pain on attention are investigated more directly. In their study, participants performed a card sorting task which either allowed them to avoid pain stimuli or had no effect upon the administration of pain stimuli. They also had to perform a secondary tone detection task. When the card sorting task was related to pain control, performance on this task was better, whereas performance on the secondary tone detection task was worse. This indicates that the goal related to pain control was prioritized, as a result of which attention was preferentially allocated to pain-related information at the cost of other information. More research with this paradigm is needed in order to increase our knowledge about the precise processes underlying the prioritization of goals related to pain control.

### *4.4. Summary*

Both behavioural and neurobiological studies have provided evidence for the unintentional selection of nociceptive stimuli by the attention system, indicating that pain attracts attention even when it is irrelevant for a current task. Although it is known that the unintentional attentional capture by pain is modulated by cognitive engagement, more systematic research on the potential role of motivational aspects of the focal task in this modulation is recommended.

Research has also shown that attention to pain was enhanced when pain was relevant for a particular goal, and that this was associated with inhibited attentional processing of other information. However, less is known about the effects of real-life pain goals such as pain control on attentional processing of pain-related information. Although there are some indications in the literature, more work on this issue should be done using appropriate designs that allow measuring attentional deployment.

All the work reviewed above concerns fundamental research on (normal) attentional processing of pain in healthy persons. However, clinical models (Pincus & Morley, 2001; Vlaeyen et al., 1995) assume that patients suffering from chronic pain conditions are characterized by abnormal, excessive attentional processing of pain and pain-related information. In the next section, we review studies testing this assumption and discuss the findings within our motivational framework.

## 5. Do chronic pain patients show increased attentional processing of pain?

The majority of studies investigating this research question used paradigms in which pain was goal-irrelevant. Most frequently used are the modified Stroop paradigm and the Dot Probe paradigm, which were originally developed in the field of affective disorders, but later adopted by pain researchers to examine biases in attentional processing of pain. In a modified Stroop paradigm, pain-related words and neutral words are presented in different colours. Participants are instructed to name the colour of each word and response times are measured. It is assumed that the pain words automatically attract attention and therefore interfere with colour-naming, leading to slower responses to pain words relative to neutral words. Stroop interference is typically expected to be more pronounced in pain patients than in healthy persons (Roelofs et al., 2002). In the dot-probe paradigm, two words (a pain word and a neutral word) appear on a screen simultaneously. Next, one of these two words is replaced by a small dot. Participants are instructed to react to this dot by indicating the location in which it appeared. Response times are expected to be faster when the dot replaces a pain word relative to a neutral word and this effect is expected to be larger in pain patients compared to healthy controls (Asmundson et al., 2005). Also in this paradigm it is not clear whether reaction time effects reflect differences in perceptual processing or rather response biases. Overall, evidence for increased attentional processing of pain words in pain patients compared to healthy controls is far from convincing (for reviews, see Pincus & Morley, 2001; Van Damme et al., 2004c). This is somewhat surprising given the consistent findings of anxiety-related attentional biases obtained with the same paradigms in the context of affective disorders (see Bar-Haim et al., 2007).

A potential explanation for the inconsistent findings is that these studies typically use words. The use of pain-related words as valid and appropriate pain stimuli has been questioned, as these are only semantic representations of pain which are barely capable of activating bodily threat (Crombez et al., 2000). Therefore, the use of real somatic stimuli is recommended when studying attentional processing of pain information. This was done in studies using the primary task paradigm. When asked to perform a numerical interference task, those patients who were fearful about their pain showed most decrements in task performance as a result of pain (Crombez et al., 1999). Peters et al. (2002) instructed patients with chronic low back pain to perform an auditory reaction time task while ignoring low-intensity electrocutaneous stimuli on their back or arm. The results showed that task performance was most disrupted in patients with a high level of fear of pain. More recently, Vangronsveld et al. (2007) asked patients suffering from whiplash syndrome and healthy controls to perform an auditory discrimination task. During some of the blocks of this task, neck rotations or extensions were carried out by a physiotherapist. It was found that during these blocks, task performance dramatically decreased in the whiplash group but not in the healthy control group. Self-report ratings showed that the neck manipulations were perceived as highly threatening and painful by the whiplash patients but not by the healthy controls.

Very few studies have investigated attentional processing of goal-relevant pain in clinical samples. The study of Peters et al. (2000), who used a body scanning paradigm (see section 4.2), was also performed in a sample of patients with fibromyalgia. It was hypothesized that patients would be faster in the detection of electrical stimuli than healthy controls, but reaction time analyses could not confirm this. Perhaps because the pain-related goal in this study was induced by task instructions (rapid detection of electrical stimuli), this goal was equally strongly activated in the healthy control group as in the fibromyalgia sample, leading to similar attentional deployment in both groups. In order to detect differences in goal-relevant attention to pain-related information between patients and controls, we might need paradigms in which multiple goals are activated or goal conflicts are created. In such paradigms, patients might spontaneously prioritize pain-related goals more than healthy controls.

Overall, no consistent differences in attentional deployment between patients and controls have been found. Can we conclude then from the available research that there is no such thing as excessive attentional processing of pain-related information in chronic pain sufferers? We believe the answer is no… We argue that the inconsistent findings might be a consequence of the way in which hypervigilance was examined in these studies. Interpretation of the work that has been done so far is complicated by two factors. First, most studies investigating unintentional selection of goal-irrelevant pain-related information in patients versus healthy controls have used words as stimuli. In an experimental context, words might have insufficiently triggered the evolutionarily-driven interruption associated with bodily threat. Second, in the few studies that have investigated intentional selection of goal-relevant pain, the pain-related goal was induced by task instructions, such as detecting, discriminating, or evaluating a nociceptive stimulus. Studies using pain goals with greater ecological validity, such as controlling or avoiding nociceptive stimulation, would be welcome.

## 6. Implications for the effects of attention manipulations on pain perception

We have argued that the characteristics of a focal goal might influence attentional capture by goal-irrelevant pain. There is a strong theoretical basis for this idea, in the form of the mechanism of goal shielding. This mechanism is triggered when there is a goal conflict or multiple goals are activated, and refers to the finding that commitment to a focal goal inhibits the accessibility of distracting or goal-irrelevant information (Goschke & Dreisbach, 2008; Santangelo et al., 2007; Shah et al., 2002). Applied to pain, there is evidence that cognitive engagement to a primary task reduces attentional capture by pain (Bantick et al., 2002; Bingel et al., 2007; Legrain et al., 2005; Seminowicz & Davis, 2007b). However, it is unclear from this work whether cognitive engagement actually reduces the pain experience.

Studies investigating the idea of distraction might provide useful information on this issue. The underlying assumption of distraction is that when, during pain, attention is allocated to other demands, it cannot be applied to the pain and therefore diminishes the pain experience (McCaul & Malott, 1984; Van Damme et al., 2008b; Villemure & Bushnell, 2002). Despite its intuitive appeal, the effectiveness of distraction is debatable, and to date, results from clinical and experimental research remain inconclusive (Eccleston, 1995; Seminowicz & Davis, 2007a). However, note that the studies described in the literature typically report on the presumed consequences of attentional distraction, i.e., perceived pain intensity and pain-related distress. Most distraction studies assume that attention is directed away from pain and towards the distraction task, but fail to measure the actual focus of attention (Eccleston, 1995). This is a problem that makes comparison between the results of different studies unreliable. For instance, when in a particular study a distraction task has no effect upon self-reported pain, this does not allow us to conclude that distraction does not work. It might as well mean that the task demands were not sufficient to compete with the demand of pain, and that task-related and pain-related processes can be conducted in parallel without any interference from each other. Therefore it is important that the attentional focus during the distraction procedure is systematically checked. Consequently, more research is needed to identify the necessary characteristics of the focal task goal in order to effectively keep attention away from pain.

One important factor might be the perceptual load imposed by the focal task. Lavie (2005) argued that high perceptual load can eliminate the processing of task-irrelevant distractors. A number of pain studies relate to this point. For instance, McCaul et al. (1992), assuming that tasks that are more difficult will have a higher cognitive demand, investigated whether the difficulty of a task performed during pain mediated the effect of distraction. Participants were assigned to distraction tasks with different degrees of difficulty. Contrary to what was expected, the effects of distraction on the evaluation of pain were not modulated by task difficulty. Perhaps task difficulty alone is not sufficient to enhance cognitive engagement. Interesting in this context are studies using virtual reality as a way of distraction during pain. Hoffman et al. (2006), for instance, used a virtual environment called “snow world” during the administration of heat pain. Participants were assigned to a high-tech condition, in which the visual field was completely covered by the virtual word, or to a low-tech condition, in which the visual field was only partially covered by the virtual world. It was found that effects on self-reported pain were larger in the high-tech condition than in the low-tech condition. Self-report ratings suggested that differences in experienced “presence” in the virtual world might have been responsible for the larger distraction effect in the high-tech condition compared with the low-tech condition (see also Hoffman et al., 2004b). It would be interesting to examine whether increased presence in the virtual world is also accompanied by increased cognitive engagement. On a neurobiological level, virtual reality during pain has also been shown to significantly reduce pain-related brain activity in the anterior cingulate cortex, primary and secondary somatosensory cortex, insula, and thalamus (Hoffman et al., 2004a). Virtual reality distraction has also been successfully applied in the context of clinical and procedural pain (Patterson et al., 2004; Wismeijer & Vingerhoets, 2005).

The affective characteristics of the task goal might also be important. Since it is known that positive emotions have a beneficial effect on pain perception (Godinho et al., 2006; Kenntner-Mabiala et al., 2007; Prescott & Wilkie, 2006; Villemure et al., 2003), it could be argued that distraction with an emotional content might work better than a neutral distraction task (Leventhal, 1992). Note that in the study of Hoffman et al. (2006) participants in the high tech condition also reported having more “fun” in the virtual world compared with the low tech condition, suggesting that at least part of the distraction effect might have been due to positive affect experienced during the procedure. This is in line with several studies which have shown that viewing pleasant pictures during nociceptive stimulation increased pain tolerance (de Wied & Verbaten, 2001; Meagher et al., 2001) and reduced pain intensity (Rhudy et al., 2006). Similarly, it has been shown that listening to preferred music increased pain tolerance (Mitchell et al., 2006). Also in clinical situations distraction might be modulated by affective-motivational characteristics. For instance, a study in cancer patients showed that distractions were rated as more effective when they were interesting, important, and pleasant (Buck & Morley, 2006).

It can be concluded that in order for distraction to be effective, it is also important that people are sufficiently engaged into the distraction task. In other words, the task must have an affective-motivational value. Systematic research of this idea might prove a fruitful avenue for further research.

## 7. Conclusion: is motivation the missing piece?

In this review we have proposed that attentional processing of pain is not a static mechanism but a dynamic process that is modulated by current goal pursuit. From this perspective, research on attention to pain is incomplete in two ways.

First, it is typically reported that unintentional capture of attention by goal-irrelevant pain is determined by bottom-up characteristics of the pain (see Eccleston & Crombez, 1999). However, except studies that showed decreased orienting to pain in very demanding distracting task (Bingel et al., 2007; Legrain et al., 2005; Seminowicz & Davis, 2007b), there are few studies yet investigating the effects of competing goals on attentional processing of pain. It is possible that pain is less prioritized when competing demands are associated with important or highly valued goals.

Second, studies investigating the effects of real-life pain goals such as pain control on attentional processing of pain-related information are scarce. Until now, most studies investigating intentional selection of pain by attention have done this by means of task instructions such as detecting or evaluating pain stimuli. In future research it would be interesting to investigate how real-life adaptive goals such as attempting to control or avoid pain affect attentional processing of pain-related information. This might be particularly the case in patients suffering from chronic pain. These patients often have a narrow biomedical problem definition, and thus an unrealistic desired end state (complete pain removal). As a result, the goal is never fulfilled and therefore remains enduringly activated (cf. Förster et al., 2007; Moskowitz, 2002; Rothermund, 2003). Moreover, the goal of pain control might often be unconsciously activated in these patients (cf. Bargh & Williams, 2006; Shah, 2005) or might even have become a habit (cf. Wood & Neal, 2007). The consequences of such motivational mechanisms on attentional processing of pain and on pain perception are yet to be explored.

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