Psychological Bulletin
1999, Vol. 125, No. 3, 356–366

0033-2909/99/$3.00

Pain Demands Attention: A Cognitive–Affective Model of the Interruptive Function of Pain

Chris Eccleston
University of Bath

Geert Crombez
University of Ghent

Pain interrupts and demands attention. The authors review evidence for how and why this interruption of attention is achieved. The interruptive function of pain depends on the relationship between pain-related characteristics (e.g., the threat value of pain) and the characteristics of the environmental demands (e.g., emotional arousal). A model of the interruptive function of pain is developed that holds that pain is selected for action from within complex affective and motivational environments to urge escape. The implications of this model for research and therapy are outlined with an emphasis on the redefinition of chronic pain as chronic interruption.

> A faint tap *per se* is not an interesting sound; it may well escape being discriminated from the general rumor of the world. But when it is a signal, as that of a lover on the window-pane, hardly will it go unperceived. (James, 1892, p. 222)

William James, in contemplation of the imminent arrival of a lover, muses on how the fate of information is not solely dependent on its sensory characteristics. Equally important to how it achieves discrimination over competing demands within the "general rumor of the world" is a myriad of psychological variables. Pain is not usually as welcome as a lover, but its arrival is equally complex and as keenly felt.

A consensus has been reached in defining pain as "an unpleasant sensory and emotional experience associated with actual or potential tissue damage, or described in terms of such damage" (International Association for the Study of Pain Task Force on Taxonomy, 1994, p. 210). This definition recognizes three important qualities of the pain experience: (a) pain has unique sensory and perceptual characteristics; (b) there is no absolute correspondence between pain and tissue damage; and (c) pain is an unpleasant emotional experience. This definition is concerned with the experience of pain and its verbal communication (Merskey, 1994). Not stressed, however, are the affective–motivational effects of pain on an organism that behaves within and interacts with its natural environment: Specifically, pain interrupts attention and behavior and urges one to act (Chapman, 1995; Melzack & Casey, 1968; Price, 1988; Wall, 1994). These fundamental aspects of the pain experience are not unique to pain. We suggest, however, that the search for what is unique and unitary about pain has led to an undue focus on the sensory characteristics of the experience and a neglect of the central role of attentional and affective–motivational characteristics (see also Chapman, 1995; Rachlin, 1985). We argue for a focus on the fact that pain interrupts, distracts, and is difficult to disengage from.

In this article, we develop a model of the interruptive function of pain that accounts for how and why pain achieves salience in naturally complex environments of multiple and competing incentives. With this model, we stress the affective–motivational environment within which pain emerges or is selected for action. Model building is a notoriously precarious affair (Hunter, 1933; Novy, Nelson, Francis, & Turk, 1995). Rather than draft detailed blueprints, we offer three nascent guiding principles that account for the empirical evidence reviewed. Further research, it is hoped, will bear this model through infancy:

1. Attention is defined as selection for action. Intrinsic to the selection of pain is the urge to escape. The selection of pain for escape is ontogenetically and evolutionarily primitive.

2. The selection of pain interrupts attention, ruptures behavior, and imposes a new action priority to escape. The actions interrupted by pain also urge their own completion by the restoration or repair of the original actions.

3. Several variables moderate interruption by pain: specifically, factors primarily related to pain, such as intensity, novelty, predictability, and threat, and factors primarily related to the environment of pain, such as emotional arousal.

We begin by reviewing information-processing models of attention as a filter, as a resource, and as a mechanism for selection of action. Next, we review pain and attention from the perspective of pain as selection for escape. We then review in two parts the evidence for how and why pain achieves interruption. We consider (a) the pain-related characteristics that contribute to pain capturing and maintaining attention and (b) the environments in which pain emerges and is maintained. By way of summary and synthesis, we present a schematic model of the interruptive function of pain. We then outline future developments for research and therapy with a

Chris Eccleston, Department of Psychology, University of Bath, Bath, United Kingdom; Geert Crombez, Department of Psychology, University of Ghent, Ghent, Belgium.

We thank Frank Baeyens, Paul Eelen, Katrina Hinkley, Melissa Kuhajda, Stephen Morley, Beverly Thorn, Deb Vansteenwegen, Johan Vlaeyen, Pat Wall, Amanda de C. Williams, and Louise Yorke for commenting on earlier versions of this article and for ongoing discussion of these ideas.

Correspondence concerning this article should be addressed to Chris Eccleston, Department of Psychology, University of Bath, Bath, BA2 7AY, United Kingdom. Electronic mail may be sent to c.eccleston@bath.ac.uk.

particular focus on the redefinition of chronic pain as chronic interruption.

Models of Attention

In seeking to explain how and why some information is attended to and other information is ignored, models of attention have centered on the related observations that thought and behavior are limited, that some thought and behavior can be initiated and maintained automatically, and that multiple tasks are difficult to perform simultaneously. After extensive study of these effects in applied settings, Broadbent (1958) successfully introduced a language of control systems and information processing that is still prevalent in contemporary ideas about attention. In particular he modeled how noise and irrelevant information are filtered, denying them access to further processing. Modeling attention as a filter has provided a method for other researchers to develop in detail the idea of attention as a mechanism for the selection of information.

A second metaphor holds attention to be a capacity or a resource that can be allocated to the performance of tasks. Capacity models of attention have been particularly useful in guiding research into the study of divided or shared attention (Kahneman, 1973; Shiffrin, 1988). In its basic form, attention is understood as a common capacity or resource that can be divided between tasks. Thought and behavior slow, stop, or become flawed when the combined demands of tasks exceed the resource limit. Wickens (1989) has extended these ideas in postulating the existence of multiple resources specialized to general functions (e.g., perception and movement coordination).

Although attentional processes are recognized to be important in pain perception and pain behavior (Melzack, 1993; Price, 1988; Wall, 1994), a theory or model of how and why pain captures and maintains attention has not been developed. This lack of a model or theory does not mean that attention and pain are not discussed in the pain literature. There is a lively and extensive debate as to the clinical utility of distraction as a method to control pain (e.g., Devine & Spanos, 1990; Eccleston, 1995a; Farthing, Venturino, & Brown, 1984). Much of the research concerning the efficacy of distraction as a method of pain control uses methodological paradigms that assume pain has already captured or become the center of attention (Cioffi, 1991). How pain may be displaced from attention is an important concern. However, the successful answer to this question requires an answer to the logically precedent question that lies at the heart of this review: How and why does pain first capture attention?

Recent advances in the psychology of attention have attempted to answer the questions of how and why stimuli are selected over other stimuli, and for what purpose. These developments are in part a response to (a) the sustained criticism of the explanations for attentional effects that rely on the idea of resources (for detailed review and discussion, see Allport, 1987; Cheng, 1985; Logan, 1985; Navon, 1984; Neumann, 1987) and (b) conceptual advances in understanding vision (Allport, 1989), control processes (Norman & Shallice, 1986), artificial intelligence, and robotics (Brooks, 1991). These advances have all attempted to account for the fact that humans are situated and move within complex environments that cannot wholly be predetermined and are therefore unpredictable.

Attention as a Dynamic Mechanism of Selection for Action

Norman and Shallice (1986) developed the idea that the attentional system cannot be wholly resource bound. Instead, they proposed that much of behavior is automatically triggered environmentally in the pursuit of specific goals. These goals are maintained until they are fulfilled, stalled by incomplete information, or are interrupted by the imposition of a higher goal. Norman and Shallice recognized that there is also a need for a control system that acts to protect the organism from threat or that guides it in novel situations. This supervisory attentional system is called on when tasks involve planning, are novel or dangerous, or require one to overcome habitual behaviors or rescue failing automatic behaviors.

Norman and Shallice (1986) recognized that any successful attentional system must always be open to the possibility that at any time current engagement will be interrupted by the imposition of a new superordinate goal to protect an organism from danger or harm (see also Shallice & Burgess, 1993). Pain would seem to be an ideal candidate for interruption in imposing the superordinate goal of self-protection. The possibility of interruption, or priority reassignment, has not, to our knowledge, been developed for any bodily sensation, including pain. Allport (1989), interested in visual perception, has provided the most extensive account of attention and interruption. He argued that attentional systems are a reflection of the fact that humans are multifunctional and that behavior involves multiple bodily systems in particular environments. An attentional system must be able to cope with environments that are (a) partly or wholly unpredictable, (b) can change suddenly, and (c) offer multiple, competing, or contradictory goals. As Allport suggests,

> The primary *purpose* of an attentional system must be to ensure the *coherence* of behavior under these often conflicting constraints. Coherent, goal directed behavior requires processes of selective *priority assignment* and *coordination* at many different levels (motivational, cognitive, motor, sensory). Together this set of selective and coordinative processes can be said to make up the effective *attentional engagement* (or attentional *set*) of an organism at any moment. (1989, p. 652)

The problem then for any model of attention is that it must account for the two potentially contradictory requirements of an attentional mechanism: "the need for continuity of attentional engagement, against the need for its interruptibility" (Allport, 1989, p. 652). Being open to all environmental information leads to massive intrusion and chaotic behavior (Wegner & Pennebaker, 1993), whereas being uninterruptible is potentially hazardous and possibly fatal as demonstrated by the dramatic and life-threatening consequences of being insensitive to pain (Sternbach, 1963).

Pain as Interruption of Attention

Pain is the archetypal warning of danger to an organism: It interrupts, distracts, and demands attention (Öhman, 1979; Price, 1988). Theories and methods for investigating interruption have been developed in a number of areas of experimental psychology, including psychophysiology (Graham & Hackley, 1991), learning psychology (Siddle, 1991), and cognitive science (Gillie & Broadbent, 1989). These paradigms have been adopted and adapted for pain research (e.g., Crombez, Baeyens, & Eelen, 1994; Eccleston, 1994; Lorenz & Bromm, 1997). Factors implicated in moderating the interruptive function of pain are reviewed as those relating primarily to pain (e.g., intensity, novelty, predictability, and threat) and those relating primarily to other demands in the environment (e.g., task difficulty and emotional arousal). This distinction is made for narrative clarity, and we recognize that other distinctions are possible.

Factors Relating Primarily to Pain

Many experimental studies use a paradigm in which participants undergo a painful procedure such as placing a hand in cold water (e.g., Blitz & Dinnerstein, 1971). Participants are then instructed to engage in a mental task such as adding numbers (e.g., Barber & Cooper, 1972) or imagining the planning of a party (e.g., Grimm & Kanfer, 1976). The dependent variables are normally measures of pain threshold, pain tolerance, or self-report of pain intensity (for review see Eccleston, 1995a). Walker (1971) serendipitously introduced the possibility of measuring the impact of pain on the performance of the distraction task. She administered painful electrocutaneous stimuli to students and instructed them to perform an attentionally demanding motor task. Although there was no effect of the task on the students' pain tolerance, there was significant impairment of task performance during pain. We call focusing on the effect of pain on the task rather than the task as a distraction from pain the *primary-task paradigm.* The dependent variable is therefore a measure of performance of the primary task.

Using a primary task paradigm, one is able to focus on the direct and measurable effect of pain on attentional activity. This measure or index of pain interruption can then be studied experimentally. The first characteristic of pain to be studied with this paradigm was its presence. Pearce and Morley (1989) compared the performance of chronic-pain patients with pain-free controls on a common test of attentional interference (Stroop, 1992). Although the performance of the chronic-pain patients was slower than that of the control group on the most demanding task, that difference failed to reach significance on the standard color Stroop test. Eccleston (1994) investigated the characteristic of pain intensity. He classified chronic pain patients according to their self-reported pain as a high- or low-intensity group. All patients performed a simple, numerical, Stroop-like interference task (Windes, 1968). Pain, regardless of its intensity, did not disrupt performance on this simple interference task in comparison with a pain-free control group. In a second experiment, Eccleston made the task more attentionally demanding by manipulating the difficulty of the task (Morton, 1969). He achieved this manipulation by doubling the number of possible responses, thereby increasing the sources of interference. Those with high-intensity chronic pain showed marked and significant decrements in performance compared with those with low-intensity pain and pain-free controls. In a later study, identical in design, this finding was extended and replicated (Eccleston, 1995b). Importantly, these effects could not be explained by medication use or by affective status. Further, Kewman, Vaishampayan, Zald, and Han (1991), using a clinical battery of neuropsychological tests, showed that 32% of acute and chronic musculoskeletal pain patients had clinically significant impairments in attentional performance. The finding that pain intensity predicted impaired performance remained significant even after controlling for affective distress. Just as the loudness of the tap at William James's window might effect interruption, so also the intensity of the nociception may effect interruption. This cannot, however, be the whole story.

Learning theory teaches us that when a new stimulus is introduced into our environment, ongoing activity is inhibited, and attention is automatically drawn to it. This external inhibition of ongoing behavior is known to be a function of both the intensity of the stimulus and its novelty (Pavlov, 1927). Novelty means both unfamiliar and unexpected within a particular context (Öhman, 1979). In the context of silence, a tap on a window pane may easily gain attention. However, it is also true that in the context of general rumor or hubbub, silence may easily gain attention. According to Sokolov (1963), the onset and the offset of the stimulus are determining features of novelty. It is reasonable to hypothesize that novel painful stimuli will also elicit an attentional shift, particularly after pain onset. Crombez et al. (1994) instructed pain-free students to discriminate between noises of long (200 ms) and short (100 ms) duration and to ignore visual and thermal distractors. During the procedure, a painful heat stimulus of 46°C of 5 s in duration was administered. None of the participants had prior experience of the heat stimulus. This novel pain produced large interference on the primary task, despite the instructions to ignore it. Interference was most pronounced at the beginning of the pain stimulus compared with the end of the stimulus. More recently, Crombez, Eccleston, Baeyens, and Eelen (1996) replicated these findings. In this study, the authors refined the paradigm to investigate the temporal pattern of interruption in more detail. Participants were instructed to discriminate between high- and low-pitch tones while experiencing painful electrocutaneous stimuli. Patterns of interference can be analyzed at the onset of pain, further on during pain, and after the offset of pain. In comparison with a neutral visual stimulus (picture of a female face), greater interference was found immediately after pain onset. This finding was recently replicated and extended (Crombez, Eccleston, Baeyens, & Eelen, 1997). Of importance was the intriguing finding that task interference during pain diminished but did not disappear with repeated experience of the electrocutaneous pain stimulus. These studies support the idea that novel painful stimuli produce a shift in attention, as measured by the interference of pain on ongoing attentional engagement. Also demonstrated was the finding that attentional interruption by pain is peculiarly resistant to displacement and relegation.

If novelty is a primary characteristic of the disruptiveness of pain, it follows that manipulating one's prior experience of the pain and one's knowledge of its onset should affect its ability to interrupt current attentional engagement (Chapman, 1978). Although there is a cognate literature concerned with the effects of the predictability of pain on psychophysiological indexes of attention (e.g., Öhman, 1987), there are no experimental studies of the direct effects on behavioral measures of interruption due to these aspects of a novel pain stimulus. The one exception to this is the evidence for the claim that knowing when a noxious stimulus will be applied (in the context of the laboratory) leads to reduced task interference (Crombez et al., 1994; Dawson, Schell, Beers, & Kelly, 1982). Dawson et al. (1982), for example, found that task interference during a noxious electrocutaneous stimulus was reduced when its onset was cued or signalled. Knowing when a noxious stimulus will be delivered reduces interference.

The expectation of pain is rarely affectively neutral. Impending pain is often the source of distress and arousal and is often reported as a threatening experience (Eccleston, Williams, & Stainton Rogers, 1997). The threat of pain has widespread implications: Anticipating imminent pain will effect preparatory responses and increase access into awareness by assigning priority to stimuli that may signal the occurrence of the object of threat (Öhman, 1979). In line with this argument, Dawson et al. (1982) found larger task interference during a visual stimulus that signalled the occurrence of a noxious electrocutaneous stimulus than during a visual stimulus signalling the absence of a noxious electrocutaneous stimulus. Testing this hypothesis further, Crombez, Eccleston, Baeyens, and Eelen (1998a) adapted a primary-task paradigm. Using the same design as reported above, they instructed students to focus on the auditory discrimination task while being repeatedly exposed to low-intensity electrocutaneous stimuli. Prior to the procedure, half of the participants were threatened with the possibility that randomly throughout the procedure, highly intense painful stimuli would also be applied. Participants had no prior experience of such stimuli. The participants who were threatened with pain showed a larger disruption of task performance immediately after the onset of the low-intensity electrocutaneous stimulus compared with both the neutral visual stimulus and the participants who were not threatened with high-intensity pain. It would seem that increasing the threat value of a stimulus increases its access into focal attention.

One's cognitive pattern of further processing threatening information is also implicated in the prioritization of pain. For example, Heyneman, Fremouw, Gano, Kirkland, and Heiden (1990) investigated the effects of the style of thinking in which people anticipate that the outcome of an experience will be catastrophic or misinterpret events to have catastrophic consequences. They observed that this catastrophic thinking impaired students in their ability to distract attention from pain. Sullivan, Bishop, and Pivik (1995) found that those who engage repeatedly in catastrophic thinking about pain report great difficulty in suppressing or diverting attention away from pain-related thoughts. To experimentally address the impact of catastrophic thinking on attentional interruption, Crombez, Eccleston, Baeyens, and Eelen (1998b) classified students as either high- or low-pain catastrophizers by using the Pain Catastrophizing Scale (Sullivan et al., 1995). Crombez et al. (1998b) instructed students to perform a tone-discrimination task, and students were informed that they would experience high-intensity pain. The students experienced several short-duration, low-intensity electrocutaneous stimuli. The threat of intense pain was not honored. However, when this threat of intense pain was salient, the interruption of attention was inflated for those with high catastrophic thinking about pain. Attention was disrupted when pain threatened participants who anticipated that the outcome of an experience would be catastrophic or interpreted events as catastrophic.

High levels of fear and fear-related thinking are accompanied by a vigilance or increased awareness of the possible sources of threat (Eysenck, 1992). Vigilance can often be specific to a class of behaviors thought to initiate or exacerbate pain, such as back-stressing exercises in those with chronic low-back pain (Crombez, Vervaet, Lysens, Baeyens, & Eelen, 1998). It can, nevertheless, also generalize to other bodily sensations and beyond. Rollman and Lautenbacher (1993) have argued, for example, that in conditions of chronic widespread musculoskeletal pain, such as fibromyalgia, patients develop a vigilance not only to pain but also to other information, such as noise or imbalance. McDermid, Rollman, and McCain (1996) found that fibromyalgia patients do show an increased awareness of their bodies and report more somatic complaints than could be explained by the inclusive diagnostic criteria of fibromyalgia (Wolfe et al., 1990). The frequency and extent of the awareness of somatic information is also implicated in the selection and maintenance of pain into the focus of attention. Using a primary-task paradigm, Eccleston, Crombez, Aldrich, and Stannard (1997) compared the performance of chronic-pain patients with high and low somatic awareness. The authors classified patients as high or low in somatic awareness by using the Modified Somatic Perception Questionnaire (Main, 1983). High somatic awareness involves both a generalized awareness of bodily sensations and a high frequency in experiencing bodily sensations. Patients were also classified according to their self-reported pain as either a high- or low-intensity group. Only those with both high-intensity pain and high somatic awareness suffered significant impairment in attentional performance. Chronic pain in this patient group is best characterized by a strong and habitual bias toward processing pain information at the expense of the primary task. A general and frequent awareness of somatic information is not a sufficient condition for capturing attention. High somatic awareness increases the access of high-intensity pain into focal attention.

In summary, the selection of pain is disruptive of ongoing attentional engagement and behavior. By studying the interruptive effects of selection of pain, we can elucidate which factors predict the emergence of pain into focal attention. Reviewed so far are the factors relating primarily to pain. In chronic pain, self-reported high-intensity pain is more disruptive than self-reported low-intensity pain, even after controlling for affective distress. Novelty and unpredictability facilitate the emergence of pain and the disruption of attentional engagement. Threat mediates interruption by pain. The threat of pain alone will facilitate the emergence of pain-related stimuli. People who interpret pain-related stimuli as threatening and as highly likely to lead to catastrophe are particularly sensitive to the effect of threat of pain facilitating the emergence of pain. Finally, heightened awareness of somatic information increases the emergence of high-intensity pain into focal attention.

Factors Relating Primarily to the Environment of Pain

In natural settings, pain is only one among many incentives or urges to act, only one of many possible interruptions. To understand how pain emerges as the focus of attention and how it remains a priority, we need to consider the characteristics of other aspects of the environment in which pain achieves its salience. We know of little research that addresses the dynamic and complex environments within which pain emerges as the focus of attention. Relevant, however, is the research concerning the efficacy of distraction as a technique for altering pain perception (Fernandez & Turk, 1989). McCaul and Malott (1984), interested in why and when distraction could be effective as a method of pain control, presented an explicit and detailed account of pain as a strong demand for attentional resources. In particular, they proposed that the intensity of the pain stimulus above other stimulus attributes together with the attentional requirements of the distraction task (e.g., task difficulty) could explain the growing number of puzzling and contradictory findings regarding the efficacy of distraction. McCaul and Mallott concluded that distraction can be efficacious when pain is of low intensity but not when the pain is of high intensity. Further, they also concluded that the success of a distraction technique is dependent on the task being sufficiently difficult to consume resources otherwise allocated for pain processing.

Two well-executed studies did not find the predicted results that difficult distraction tasks were more successful in altering pain perception. Hodes, Howland, Lightfoot, and Cleeland (1990) subjected participants to a cold-pressor task. All participants reported pain ratings at regular intervals, and tolerance to the pain stimulus was also measured. The participants were assigned to one of three conditions: a high-difficulty distraction-task condition involving the performance of a difficult and complex arithmetic task, a low-difficulty distraction-task condition involving the performance of a relatively simple recognition arithmetic task, and a no-distraction condition. Hodes et al. (1990) concluded that "Contrary to our hypothesis the high and low distraction conditions did not differ on either pain ratings or pain tolerance" (p. 113). McCaul, Monson, and Maki (1992), in a series of four experiments, explored the hypothesis that tasks requiring a greater degree of attention for their successful performance would provide greater distraction from cold-pressor pain. Three variants of a digit-recognition task were defined as to their relative difficulty according to resource theory. Counter to their hypothesis, they did not find evidence for this hypothesis with physiological, self-report, and behavioral measures of pain.

The experimental series reported by Johnson, Breakwell, Douglas, and Humphries (1998) is also noteworthy in its attempt to define why a particular distraction task might be expected to displace pain from attention. Johnson et al. (1998) argued that the efficacy of distraction depends not only on the difficulty of the distractor but also on the similarity between the distractor and pain. In developing these ideas, Johnson et al. applied Wickens' (1989) model of multiple resources in which only those tasks similar in their processing characteristics share common resources. It follows that only those distraction tasks that share similar characteristics to pain will succeed in reducing pain. Testing this hypothesis, Johnson et al. compared the distractiveness of two tasks on pain threshold. The first task was similar to an electrocutaneous pain stimulus as it involved attending toward somatic information (nonnoxious heat). The second task was dissimilar to pain as it involved attending toward visual information (nonnoxious light). Contrary to the prediction of the multiple-resource model, both tasks were equally successful in raising the pain threshold.

Leventhal (1992), in a provocative editorial preceding the McCaul, Monson, and Maki (1992) study, argued that the most important aspect of the environment of pain is the emotional significance of the task offered as a distraction of attention from pain. He suggested that researchers should account for the emotional involvement of participants when considering attention and distraction phenomena. Indeed, there is preliminary evidence that distraction with emotional content is successful in altering pain perception. Stevens, Heise, and Pfost (1989), for example, randomly assigned student participants to four experimental conditions that they described as high pleasure (e.g., images or thoughts of making love), low pleasure (e.g., images or thoughts of a cool breeze), high anger (e.g., images or thoughts of familial conflict), and low anger (e.g., images or thoughts of receiving a parking ticket). All students then underwent a pressure-pain procedure. The results of tolerance to pressure pain demonstrated a main effect of the emotional content: Pleasant cognitions or images produced a significant increase in tolerance compared with anger-based cognitions or images.

It is unclear how distraction with an emotional theme alters pain perception, but at least two processes may be involved. First, affective responses congruent with the current emotional state are facilitated, whereas affective responses incongruent with the emotional state are inhibited. For example, it has been demonstrated that a defensive startle reflex is potentiated during the imagination of an aversive state but is inhibited during the imagination of pleasant scenes (Vrana & Lang, 1990). Second, emotions are also powerful demands for attention that may displace pain from attention (Mandler, 1964). Bradley, Bruce, and Lang (1996) demonstrated that highly arousing stimuli with both a positive and a negative valence interfere with the performance of tasks.

Perhaps the most powerful examples of the importance of the emotional environment within which pain is relegated comes from animal research of stress-induced analgesia (Bolles & Fanselow, 1980). Rats, for example, when confronted with a rival or predator, become less sensitive to pain (Fanselow, 1985; Lester & Fanselow, 1985). Often-cited examples in humans are the reports of reduced complaint of pain and reduced request for analgesia where extensive war-related injury is present (Beecher, 1956). Beecher explained this analgesic effect by recourse to the meaning of pain, stressing that in this environment pain and injury meant escape from threat to life in battle. However, only in exceptional situations, such as a threat to life, does pain lose its demanding character. (For a recent discussion of this topic, see Janssen & Arntz, 1997.)

Thankfully, for many people threat to life is not an everyday occurrence. The environments within which pain emerges offer many possible demands and multiple interruptions. The interruption of the coherence of an action sequence by pain also produces a salient urge to complete the original interrupted sequence of actions (Allport, 1987; Gillie & Broadbent, 1989; Mandler, 1984; Zeigarnik, 1927/1939). In an environment of multiple demands, the urge to escape from pain will often invoke the urge to repair or restore the coherence of the preceding action sequence. When pain interrupts, one therefore often attempts to continue with the original task. The response to environments of multiple demand is to switch continuously between the source of the interruption and the original task (Jersild, 1927; Morton, 1969; Windes, 1968). Eccleston (1995b) designed a series of experiments to operationalize this switching function of attention in an environment of pain. Using an altered version of the primary-task paradigm (Allport, Styles, & Hsieh, 1994), Eccleston instructed chronic pain patients to perform an ongoing complex task. The successful performance of this task requires the rapid switching between different environmental information without external cues. Chronic-pain patients reporting high-intensity pain suffer performance errors in switching between different environmental demands. In this situation, where pain is inescapable and participants are directed to perform a complex task that requires attentional switching, pain is another demand for attention and will therefore interrupt when switching occurs. Coping with pain in this environment may be characterized as an attempt at the maintenance of coherent behavior by the intentional and effortful switching between pain and the primary task.

In summary, pain emerges as the focus of attention and the most salient priority for action within environments of multiple demands. Therefore, one must account for the environment in which pain emerges. The factor relating primarily to environment most often researched is the nature of a distraction task placed experimentally in competition with pain. It is as yet unclear as to the exact contribution of structural factors such as the difficulty of the task. Relatively unexplored is the role of the affective–motivational significance of the environment within which pain may emerge. Evidence suggests, for example, that positive affect or extreme arousal can take priority over pain and escape. Selection of pain for escape within environments of multiple demands involves switching between the demands of pain and the demands of the interrupted behavior.

A Functional Model of the Interruption of Pain and Attention

By way of summary and synthesis, Figure 1 illustrates the attentional system before interruption by pain, and Figure 2 illustrates the attentional system during interruption by pain. These are static illustrations of an essentially dynamic system. The three guiding principles introduced at the beginning of the article provide the foundations of this model. First, attention is a mechanism of selection for action where pain is selected for escape. Second, in the natural environment of multiple demands, pain is ontogenetically and evolutionarily disposed to interrupt attention. In turn the actions interrupted by pain also urge completion by the restoration or repair of the original actions. Third, a number of variables moderate the interruption of pain into awareness.

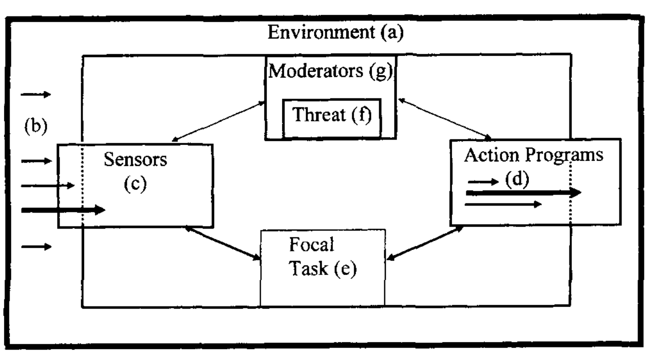

Figure 1. The attentional system before the interruption by pain. The environment (a) contains multiple demands (b), many of which impact on the sensory system (c). One of these demands, listening to an interesting story, is the focal task that engages current attention (e). The bidirectional arrows indicate the paths of influence of both control and feedback between sensory units and action programs (d). The strength of influence is represented by the thickness of the arrows. Where there is no noxious stimulation, the effects of threat are silent (f, g).

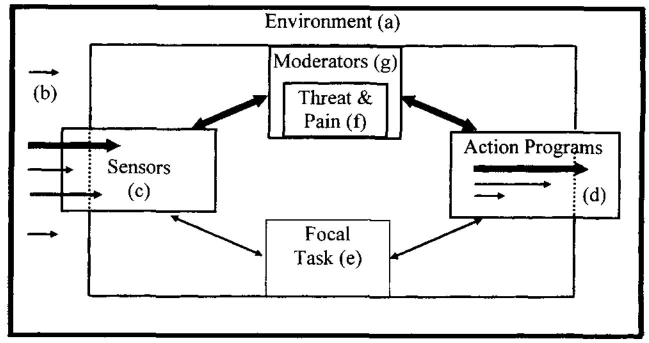

Figure 2. The attentional system during interruption by pain. The environment (a) contains multiple demands (b). One of these demands (a burning tongue) is noxious and is sensed (c). This painful stimulus is threatening (f) and interrupts the focal task (e). Escape is urged and action programs initiated (d). The efficiency and coherence of the selection of pain for escape is dependent on moderating variables (g). The bidirectional arrows indicate the paths of influence of both control and feedback between sensory units and action programs. The strength of influence is represented by the thickness of the arrows. When pain dissipates, the current engagement in the focal task is restored. Switching is the rapid alternation over time of the input or output weights of the focal task and painful experience of a burning mouth.

Seven interrelating components make up the model: (a) environment, (b) multiple demands arising from the environment, (c) sensory system, (d) action programs, (e) focal task, (f) threat mediation, and (g) moderating factors. For clarity we have isolated one focal task: listening to an interesting story. In Figure 1, the focal task is the current engagement of attention. In Figure 2, the focal task is interrupted by pain, which becomes the current engagement.

Figure 1 shows an environment of multiple demands. None of these demands are noxious. For example, imagine you are at a party listening to an interesting story being told by a friend. Some of the demands arising from the environment will simply never impinge on your sensors, such as conversations too far away to be heard or the smell of food from the stove behind the closed kitchen door. Other demands will be sensed but will not take up current attentional engagement, such as respiration and the effects of gravity on muscles and tendons. Current engagement is taken up with the meanings arising from the demands of speech impinging on auditory and visual sensors, that is, the story. Although there are many other demands for attention, a coherence of engagement in the story is maintained. Some action proceeds without mediation by current engagement, such as remaining balanced and upright, redistributing weight between muscle groups (shuffling), eating, etc. Certain action programs concerned with listening to the story are prioritized. Coherence of action is achieved by the control and feedback of both sensory inputs and action programs. Interruption by threat is dormant but remains possible.

Figure 2 shows an environment presenting multiple demands, one of which is noxious. To extend our example, imagine again that while you have been listening to the fascinating story, you eat hot food. Suddenly, the current attentional engagement with the story is interrupted as your burnt tongue produces pain. Also interrupted are other ongoing actions: For example, you make a sharp intake of breath as regular respiration is interrupted. Action programs that enable a focus on the story are halted, and new action programs are prioritized aimed at escaping from the noxious input. Current engagement switches to the pain and its threat value: Escape is urged. The selection of the noxious input to enable escape is mediated by its threat value and is moderated by a range of pain-related variables, such as novelty, unpredictability, the extent of your catastrophic thinking about pain, and your general awareness of somatic information. Coherence of escape behavior is achieved by the control and feedback of both sensory inputs and by action programs. As the demand of the interrupted story continues, the environment now has two salient demands: the ongoing story and your burning mouth. Responding to both demands is best resolved by the dynamic switching between pain and the focal task.

Attention is illustrated here as functioning within a simplified environment where pain and a focal task are dominant. Nevertheless, we recognize that attention is a general system that functions within all environments of multiple emotional and motivational demands (Frijda, 1986; Lang, Bradley, & Cuthbert, 1992; Mandler, 1984; Öhman, 1987). In emphasizing the similarities between pain and these other demands, we argue that pain should be modeled as more than a sensory and perceptual experience. Pain is part of a complex and hierarchichal system of motivations to act (Bolles & Fanselow, 1980; Konorski, 1967). It imposes a high and overriding priority on an action-oriented attentional system because it is both culturally and biologically hardwired to signal harm and urge escape (Morris, 1991; Sokolov, 1963). Pain is selected for escape within an ontogenetically and evolutionarily primitive defensive system that functions to limit the impact of aversive events (Crombez, Baeyens, Vansteenwegen, & Eelen, 1997; Sokolov, 1963).

Future Directions

If our model of pain and attention is to survive infancy, it must facilitate a change in the conceptualization of pain. Changing the ways in which we conceptualize pain should stimulate new directions of research and enable innovation in the treatment and management of pain. Three areas of research require development: (a) the selection of pain over competing demands, (b) the deselection or replacement of pain by other demands, and (c) the implications for chronic pain.

The Selection of Pain Over Competing Demands

The first area for research development relates to the unique characteristic of pain as a noxious sensory input that is inherently threatening. The few attempts made to dissociate pain and its threat value with human participants have relied on the use of a habituation procedure. Unlike other demands on attention, pain cannot easily be deselected, and pain does not readily lose its interruptive function (Crombez, Eccleston, et al., 1997). In addition, defence or escape responding cannot easily be extinguished (Sokolov, 1963). For example, Hardy, Wolff, and Goodell (1967) demonstrated that the electrodermal response to painful heat disappeared only after repeated exposure to pain during a period of up to 100 days. This habituation effect was hard-won but then proved to be fragile: The response to pain was reinstated immediately after the experience of any unrelated stressor or when pain became unpredictable. Largely unexplored with humans is a counterconditioning procedure in which a pain stimulus is systematically coupled with a positive event (Dickenson & Pearce, 1977). Although animal research suggests that defensive responses to pain diminish or disappear after counterconditioning, it remains to be investigated whether counterconditioned pain can be produced in humans, and if so whether this will be stable across situations and time (Brooks, Hale, Nelson, & Bouton, 1995). To our knowledge, there are no reports of counterconditioned pain in humans.

Although pain and threat cannot easily be dissociated, interruption by pain can be successfully moderated. Several variables that moderate interruption have been reviewed; others still deserve investigation. For example, no study has yet manipulated experimentally the intensity of pain and measured its effects on task performance. In addition, it is not known how these moderating variables are structurally related to each other and to the threat value of pain. Understanding the structural relationships between moderating variables will critically depend on a clarity of definition of general psychological concepts when applied to pain. For example, key affective concepts, such as somatic awareness (Main, 1983), negative affectivity (Watson & Pennebaker, 1989), and anxiety sensitivity (Asmundson, Norton, & Norton, in press) will need to be specified in more detail. We predict, for example, that fear of pain and catastrophic thinking about pain will produce the priming of escape behavior and a general hypervigilance for pain.

The Deselection or Replacement of Pain by Other Demands

Pain is selected for escape over other competing demands for attention. It remains possible within this model that other attentional demands may inhibit interruption by pain and possibly displace pain from current engagement. Studies of distraction as a clinical tool will need to be improved by defining more clearly the exact properties of any demand for attention placed in competition with the noxious stimulus. For example, an important distinction should be drawn between the difficulty and complexity of the chosen distraction task (Graydon & Eysenck, 1989). Also important will be to develop further research into the emotional content of any source of distraction. Tasks need to be designed that vary the emotional significance and the personal relevance of any demand for attention (Berlyne, 1960; Maltzman, 1988).

Perhaps of more central importance to the study of distraction will be the development of new methodologies and experimental paradigms that allow pain to emerge against a background of other demands and allow other demands to emerge against a background of pain. Because interruption by pain is an inescapable fact of life, the dynamic switching between pain and other demands is a more realistic model of distraction. Coping with pain in this model means the efficient recovery from interruption by pain by the fast switching of attention away from pain and back to the interrupted task. To study this recovery, an enriched environment is needed into which is incorporated the dynamic interplay between competing attempts at attentional prioritization. We need an analogue of a natural environment in which pain emerges rather than is delivered. In such an environment, pain will achieve urgency at the expense of other behavioral engagements. To our knowledge, no study has attempted to simultaneously manipulate the priority of pain and the priority of other competing engagements.

Implications for Chronic Pain

Chronic pain is an environment where the source of pain cannot be removed and escape from pain is not possible. One might expect that if the repeated selection of pain does not lead to escape that the selection of pain will stop. However, clinical observation and the preceding analysis demonstrate that the selection of pain persists: Chronic pain means chronic interruption of current attentional engagement. According to the model, this chronic interruption is the normal process of selection of pain for escape and is not the development of a pathological pattern of responding. The consequences of chronic interruption for many people with chronic pain is the development of a clinical pattern of high symptom reporting (Bacon et al., 1994), depression (Turk, Okifuji, & Scharff, 1995), widespread avoidance of pain and movement (Asmundson, Kuperos, & Norton, 1997; Crombez, Vervaet, et al., 1998; Vlaeyen, Kole-Snijders, Boeren, & Van Eek, 1995), and withdrawal from social contact (Asmundson, Norton, & Jacobson, 1996). The consequence of this clinical pattern is that chronic-pain patients inhabit an impoverished and restricted environment that is dominated by pain, disability, and the fear of more pain and more disability.

In such an impoverished environment of chronic interruption by pain, it is possible for signals of pain themselves to become threatening (Vansteenwegen, Crombez, Baeyens, & Eelen, in press), capture attention (Dawson et al., 1982), and instigate avoidance behavior (Crombez, Vervaet, Lysens, Eelen, & Baeyens, 1996). In addition to interruption by pain, the fear of pain may also become disruptive. Indeed, fear of pain may be more disabling than the pain itself (Crombez, Vlaeyen, Heuts, & Lysens, 1999; Waddell, Newton, Henderson, Somerville, & Main, 1993). For people without pain who are distressed and disabled by a generalized fear or specific phobia, gradually exposing them to the signals of threat has proven to be an effective treatment component (Davey, 1997). Although avoidance behavior is a common treatment target of many cognitive behavioral interventions for chronic pain, we know of no research reports of treatment programs that have incorporated graded exposure to the threatening signals of pain (Morley, Eccleston, & Williams, 1999). Unlike the treatment of specific fears and phobias, chronic pain is an environment that provides many threatening signals. Of critical importance to the success of exposure with chronic-pain patients will be the identification of the exact threatening signals of pain for each individual. Specific examples for chronic low-back-pain patients might be the thought of being in a crowd of people or bicycling on a bumpy road. Because of the large number of possible signals of threat and the importance of specifying the signals of threat for each individual, the challenge to clinical researchers will be to develop optimal treatment methods that allow generalization of the effects across situations and time (Bouton & Swartzentruber, 1991).

The consequences of a chronic environment of interruption by pain and the fear of pain is that for many chronic-pain patients, threat-related rumination about pain, disability, and its consequences flourish. We propose that this rumination leads chronic-pain patients to repeatedly focus problem-solving attempts at the removal of the source of pain. Persistent failure to solve the problem of chronic pain does not, however, promote new or creative methods of problem solving. Paradoxically, patients perseverate in misdirected attempts at solving the insoluble problem of chronic pain (Aldrich, Eccleston, & Crombez, in press). Patients remain stuck in defining all problems as pain problems. Such rigidity in problem definition may lead to yet more problems of distress and disability. Redefining the problem set with disability and distress as the focus involves an acceptance of pain as an insoluble problem (McCracken, 1998) and a focus away from pain as the only cause of disability and distress. There is currently no consensus on how such an acceptance is reached or therapeutically achieved for people with chronic pain. Innovation in the treatment and management of pain will be enabled by the development of an explicit clinical model of acceptance and problem solving.

Conclusion

Pain interrupts ongoing thought and behavior from within affective–motivational environments. We reviewed how and why the selection of pain over other demands for attention is achieved by focusing on the dynamic interplay between the characteristics related to pain and to the environment in which pain emerges. As interruption by pain is mediated by its inherent threat value, many of the variables that moderate the selection of pain are threat-related. The pain-related characteristics implicated in interruption are the intensity, novelty, and predictability of a threatening pain stimulus and whether the person catastrophizes about pain and has a high somatic awareness. Also implicated in interruption are several characteristics related to the environment, such as the difficulty and complexity of tasks used as distraction from pain and their emotional content and arousal properties. However, further research regarding these key environmental characteristics is required to define their precise role in moderating interruption of attention by pain.

Our analysis suggests that interruption by pain is an inescapable fact of life: Pain will emerge over other demands for attention. The implication of this view is that recovery from interruption by pain emerges as an important area for future investigation. In addition, chronic pain can usefully be redefined as chronic interruption by pain. Coping with chronic pain can be understood as the ongoing attempt to recover from chronic interruption by repeatedly switching between pain and other demands in the environment.

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Received July 24, 1997
Revision received September 23, 1998
Accepted October 3, 1998 ■