Comprehensive Review

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Towards a new model of attentional biases in the development, maintenance, and management of pain

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Abstract

Individuals with chronic pain demonstrate attentional biases (ABs) towards pain-related stimuli. However, the clinical importance of these biases is yet to be determined and a sound theoretical model for explaining the role of ABs in the development and maintenance of pain is lacking. Within this article, we (1) systematically review prospective and experimental research exploring ABs and pain outcomes in light of current theoretical models and (2) propose a theoretical framework for understanding AB in pain. Across prospective research, an attentional pattern of vigilance–avoidance was observed. Interventions targeting ABs were less consistent; however, there were promising findings among studies that found attentional training effects, particularly for laboratory research. The proposed *Threat Interpretation Model* suggests a relationship between threat, interpretation, and stimuli in determining attentional processes, which while tentative generates important testable predictions regarding the role of attention in pain and builds on previous theoretical and empirical work in this area.

Keywords: Attentional bias, Hypervigilance, Chronic pain, Acute pain, Aystematic review, Theory

1. Introduction

There are numerous models of the development and/or maintenance of chronic pain that suggest that attentional biases (ABs) are important in chronic pain.[1,7,11,12,41] Although these models attribute slightly different roles to attentional processes, the broad assumption is that when people are in pain and are highly fearful or threatened by the pain, they overattend to pain-related stimuli. Pain is known to capture attention, which interferes with activity, leads to avoidance of the pain-provoking activity, and consequently is associated with processes that exacerbate disability.[7,41]

There is also a large and growing body of research exploring the relationship between attentional processes and pain. Two recent meta-analyses have summarised this research. Schoth et al.[30] found evidence of ABs in those with chronic pain compared with healthy controls ($g = 0.45$). Results differed with the time at which biases were assessed with differences in ABs being greater with longer presentation times (eg, >1000 milliseconds) than at shorter durations (eg, 500 msec). Another recent meta-analysis conducted by Crombez et al.[8] confirmed that ABs were present in chronic pain groups ($d = 0.13$). However, only ABs towards sensory pain words were unique to patients with chronic pain compared with healthy controls. Crombez et al.[8] also found that ABs towards signals of impending pain were present in healthy participants ($d = 0.68$).

Despite confirmation of the presence of ABs once someone has developed chronic pain, the mere presence of ABs is not sufficient to confirm that they actually *influence* pain.[20] Theories typically assign a potentially causal role to ABs, such that those who overattend to pain are more likely to subsequently avoid activity and become more disabled, creating a vicious cycle of chronicity.[41] However, the specific role of attentional processes in the development of chronic pain remains poorly understood. For example, in their meta-analysis, Crombez et al.[8] found that in cross-sectional studies, ABs were neither consistently associated with important theoretical constructs, such as fear of pain, state and trait anxiety, or depressive mood, nor were they associated with pain outcomes.

To date, no systematic reviews have focussed on the types of studies that can be used to test the causal nature of ABs in chronic pain: prospective studies and experimental studies. Prospective studies can determine whether ABs present before the development of pain actually precedes and predict subsequent pain outcomes, which are necessary but not sufficient conditions to establish causation. Experimental studies that manipulate attention and then assess pain outcomes can directly test whether attentional processes have a causal role in people's response to pain. This study therefore sought to systematically review the available prospective and experimental studies concerning ABs and chronic pain, as well as develop a hypothesis-generating model, which can be used to direct future research into ABs in pain.

2. Systematic review methodology

The search was conducted in November 2014. Suitable studies were identified through a search of MEDLINE, PsycINFO, and

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Cumulative Index to Nursing and Allied Health (CINAHL) databases. A broad range of search terms were used to obtain titles and abstracts relevant to both AB and pain. The search was restricted to human studies published since January 2001 to cover the period since Pincus and Morley's[27] review, which did not identify any studies that met the current inclusion criteria. A sample of articles were independently screened at the title, and abstract stage and full-text articles were determined by 2 authors. For search terms and an example of the full database search, see Supplemental Digital Content 1 (available online at http://links.lww.com/PAIN/A94). The following journals were also manually searched: *European Journal of Pain, Pain, Cognitive Behaviour Therapy, British Journal of Health Psychology, The Clinical Journal of Pain, Pain Medicine,* and *The Journal of Pain*. In addition, reference lists from relevant reviews and articles were searched, using the ancestry method for additional articles, and key authors were contacted to provide in press and recently accepted publications. These strategies were used to reduce the risk of bias across studies.

For the initial search, 1941 titles and abstracts were screened and 187 full-text articles were retrieved for further screening. A sample of 100 titles and abstracts were independently screened by 2 authors with good interrater reliability (κ = 0.76). The remaining full-text articles were screened and resulted in a consensus between 2 authors that 11 studies were eligible for inclusion in the current systematic review and an additional article was identified through searching relevant journals. The study selection flow diagram is outlined in **Figure 1**.

Studies were eligible for inclusion in this systematic review if they assessed AB to pain using standard experimental paradigms including the modified Stroop task, the dot-probe paradigm, Posner's visual cueing task or an adapted spatial cueing task, or an attentional eyeblink task. Prospective and predictive studies were required to assess ABs using one of these standard paradigms and examine their predictive relationship with at least 1 measure or rating of subsequent pain. We included, therefore, studies that assessed pain after the assessment of ABs but not in the same session as we considered these as cross-sectional studies. Experimental studies were included if the outcome of an intervention, which specifically targeted attention, was reported in comparison with a control intervention. Clinical and laboratory studies of pain and pain-free samples were included, as long as a measure of pain was included in the outcomes reported. Only controlled studies were included to maintain a higher quality of research. Where available, pre–postintervention AB and pain change scores were extracted, as were other pain-related secondary outcomes (such as disability and fear of pain), although these outcomes were not the main focus of the review.

The 3 types of intervention that were included were (1) attentional bias modification (ABM), (2) Wells' attention retraining, and (3) mindfulness. Although other forms of attention training exist in the literature, only studies using these interventions met the inclusion criteria. In ABM paradigms, the dot-probe task is used to implicitly train participants to either attend towards or away from pain-related stimuli. Participants are presented with 2 stimuli (either words or pictures/faces), one that is pain related and one that serves as a control. One of these stimuli is then followed by a probe, which the individual has to respond to. In ABM, the probe either consistently follows the pain stimuli

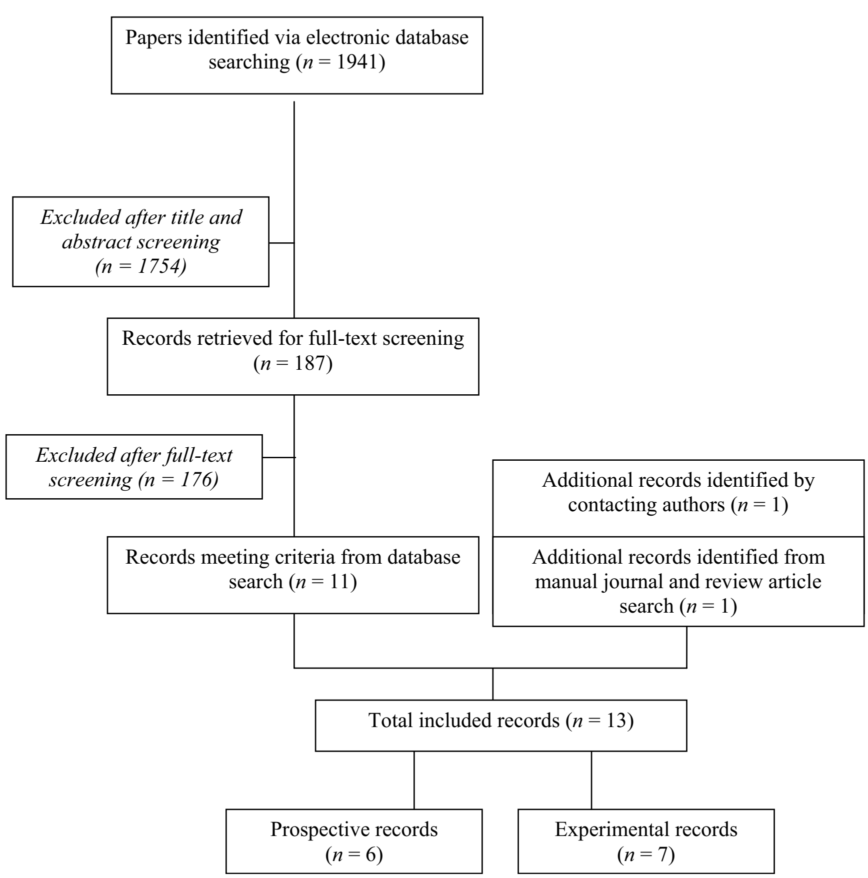

Figure 1. Flowchart outlining the screening and study selection process.

(training toward) or the control stimuli (training away). Change in ABs is the primary target of the intervention, and for this reason, all studies that used the dot-probe as a training paradigm were included regardless of whether ABs were assessed at pre- and posttraining.

Wells' attention retraining was originally designed for use in the treatment of panic disorder.[42] This paradigm involves deliberately training people to have more control over the direction of their attention and to subsequently use this control to attend away from threatening pain-related information. Although this intervention is focused primarily on attention, the mechanisms behind Wells' attention retraining have not been investigated, and it is possible that this paradigm works to target aspects of the pain experience other than attention. Therefore, to be included, in addition to pain outcomes, studies needed to measure AB outcomes.

Unlike Wells' attention training and ABM, mindfulness does not focus on drawing attention away from pain but on enabling focused attention to bodily sensations while at the same time reducing judgment and catastrophic interpretations of these sensations. Although attention is a core component of mindfulness, other mechanisms are thought to also be important, and therefore AB outcomes and pain outcomes were necessary for mindfulness interventions to be included in this review.

Two authors independently performed a quality assessment of each study included in the systematic review (**Tables 1–4**) using the criteria specified by Schoth et al.[30] in their meta-analysis of the dot-probe task investigating ABs in pain. This was adapted from the criteria used by Roelofs et al.[29] in their earlier meta-analysis. Additional criteria were adapted from the EPHPP Quality Assessment Tool for Quantitative Studies.[26] Interrater reliability for each individual criterion for the quality assessment was acceptable ($\kappa = 0.60$), and discrepancies were resolved through discussion. For quality assessment criteria and results, see Supplemental Digital Content 2 (available online at http://links.lww.com/PAIN/A95).

Effect sizes were included to explore the magnitude of significant results. For predictive studies, correlations were used as the primary effect size, except in the case where the outcome measure was categorical, in which case odds ratio was used, or in the case where the predictor was categorical, in which case Cohen's *d* was used as an indicator of effect size. For experimental studies, Cohen's *d* was used as the primary effect size. Effect size categories (small, medium, and large) were determined based on recommendations in the literature.[6] Effect size confidence intervals were calculated by the authors, where available. Researchers were contacted to provide further information where effect sizes were not present or able to be calculated from the text.

Importantly, effect sizes were not combined into a meta-analysis for 3 key reasons. First, the primary and a priori goal of the review was to descriptively summarise studies to understand patterns in the available data. Second, as argued in previous literature,[13] the current literature is marked by considerable heterogeneity, and it is not meaningful to create an aggregate of studies in this situation. Third, the small number of studies available meant that there was insufficient information for the necessary moderator analyses to be used for meta-analysis.

3. Results

3.1. Do attentional biases predict subsequent pain?

Regarding whether ABs predict subsequent pain, only 6 articles reporting 5 prospective studies were identified that met the inclusion criteria.[17–19,25,31,38] Two articles reported on the same study with an overlapping sample, although the follow-up outcome length differed.[18,19] Of the 5 studies, 3 investigated individuals who were awaiting an acute medical procedure likely to cause pain, namely, minor gynaecological surgery, cancer surgery, or correction of chest malfunction, whereas 1 tested individuals with acute and subacute low back pain and 1 tested individuals with chronic pain. Three of the studies used the dot-probe, 1 used the Stroop, and 1 used a modified spatial cueing task. In the 3 studies of individuals awaiting surgery, a measure of AB was taken before surgery. Across the 6 articles, outcomes were assessed immediately postsurgery ($n = 3$), 2 days later ($n = 1$), or 3 and 6 months later ($n = 2$). **Tables 1–4** provide a summary of the descriptive variables and results of prospective studies reviewed. Overall quality of the articles was good, indicating low risk of bias.

All 6 articles included an assessment of pain, which was the primary outcome, and the pain was measured either as pain intensity or the presence or absence of chronicity or clinically meaningful pain. In 4 of the 6 articles, some aspect of AB directly predicted pain, although effect sizes ranged from negligible to small, with the exception of a medium effect size for the 1 study that reported a categorical pain outcome (high vs low pain intensity). Munafò and Stevenson[25] were the only ones to find, as predicted, that a bias towards pain-related words predicted future pain. They showed that those with greater ABs reported

Table 1

Summary of prospective research descriptive variables and quality ratings.

	Population	N	Task	Word stimuli used	Stimuli presentation time, ms	Quality assessment rating/10
Lautenbacher et al[17]	Undergoing surgery, primarily for cancer	58	Dot-probe	Affective pain, affective positive, social threat	500	7
Lautenbacher et al[18]	Undergoing corrective surgery for chest malformation	54	Dot-probe	Affective pain, affective positive, social threat	500	7
Lautenbacher et al[19]	Undergoing corrective surgery for chest malformation	84	Dot-probe	Affective pain, affective positive, social threat	500	8
Munafo and Stevenson[25]	Undergoing gynaecological surgery	47	Dot-probe	Physical threat, social threat	100	8
Sharpe et al[31]	Individuals with acute/subacute lower back pain	100	Stroop	Sensory pain, affective pain, disability pain, threat pain	500	9
Van Ryckegham et al[38]	Individuals with chronic pain	69	Modified spatial cueing task	NA	200	10

AB, attentional bias; NA, not available.

Table 2

Summary of prospective research with attentional bias predicting pain outcomes.

Article	Outcome; follow-up length	Attentional bias stimuli				Direction of bias; notes	Effect size			
		Pain	Disability	Social threat	Positive		Value	Size*	95% CI	
									Lower	Upper
Lautenbacher et al[17]	Postoperative pain intensity (11-point NRS); <1 d	NS	—	NS	NS					
Lautenbacher et al[18]	Postoperative pain intensity (11-point NRS); 1 wk	Y	—	NS	NS	Away from general pain	$r = -0.292$	Small	−0.519	−0.026
Lautenbacher et al[19]	Postoperative pain intensity (11-point NRS); 3 mo	NS	—	NS	NS		$d = 0.507$	Medium	0.003	1.008
	Postoperative pain intensity (11-point NRS); 6 mo	NS	—	NS	Y	Towards affective bias	$d = 0.648$	Medium	−0.001	1.293
Munafo and Stevenson[25]	Pain intensity (SF-MPQ); <1 d	Y	—	—	—	Towards physical threat	$r = -0.251$	Small	−0.502	0.039
Sharpe et al[31]	Chronicity (dichotomous); 3 mo	Y	NS	NS	—	Away from affective pain	OR = 0.98	Negligible	0.97	1.00
	Chronicity (dichotomous); 6 mo	Y	NS	NS	—	Away from affective pain	OR = 0.98	Negligible	0.95	1.00
Van Ryckegham et al[38]	Pain severity (MPI); 2 wk	Y/NS	—	—	—	NS when other measures controlled for				

* Descriptor based on Cohen's[6] classifications of effect sizes.

AB, attentional bias; MPI, multidimensional pain inventory; NRS, numerical rating scale; NS, not significant; OR, odds ratio; SF-MPQ, Short-Form McGill Pain Questionnaire; Y, significant.

greater postoperative pain. In their version of the modified Stroop, physical pain words were presented at 100 milliseconds with masked presentation, and hence this finding indicates that biases in initial orientation of attention to pain-related words predicted future pain.

Van Ryckeghem et al.[38] conducted the only study in which the modified spatial cueing task was used. At stimuli presentation times of 200 milliseconds, ABs predicted average pain severity recorded over a 2-week period; however, when prior pain levels and demographic variables were controlled for, this association was no longer significant.

The 4 remaining articles that used the dot-probe to assess ABs all used longer presentation durations (500 milliseconds), but there were different patterns of findings. In a group of patients awaiting surgery for the correction of a chest malfunction, Lautenbacher et al.[18] found that biases away from pain words were the strongest predictors of postoperative pain, whereas positive and social threat words did not predict pain outcomes. In the same sample, Lautenbacher et al.[19] found that ABs did not predict pain outcomes at the 3-month follow-up. However, AB towards positive (nonpain) stimuli predicted whether patients had clinically meaningful pain 6 months later, whereas there was no effect found for pain-related words or social threat words. At face value, these findings seem conflicting, and it is difficult to determine which mechanisms and factors might be contributing to these mixed findings. However, it might be that biases towards positive stimuli and away from salient negative stimuli are different facets of the same process. Biases away from pain stimuli may, for example, signify avoidance of pain and, in an effort to increase distraction away from pain, a bias towards positive stimuli may be observed. Indeed, this is not a new idea and has been argued previously by Lautenbacher et al.[19] based on the findings of several studies.[18,19] Although this is a potentially contentious claim, if one makes this assumption, then the study by Sharpe et al.[31] is no longer inconsistent with Lautenbacher's claim. That is, Sharpe et al. found that biases away from affective pain words predicted chronicity of pain in acute and subacute low back pain patients, whereas biases towards sensory, disability, and threat words were not significant predictors of chronicity. Finally, in an independent sample of cancer patients awaiting surgery,

Table 3

Summary of predictive research with attentional bias predicting disability.

Article	Outcome; Follow-up length	Attentional bias stimuli				Direction of bias; notes	Effect size			
		Pain	Disability	Social threat	Positive		Value	Size*	95% CI	
									Lower	Upper
Lautenbacher et al[19]	Disability; 3 mo	NS	—	NS	NS					
	Disability; 6 mo	NS	—	NS	NS					
Sharpe et al[31]	Disability; 3 mo	Y/NS	NS	NS	—	Away from affective pain; NS when other measures controlled for	$r = 0.177$	Small	−0.021	0.362
	Disability; 6 mo	Y/NS	NS	NS	—	Away from affective pain; NS when other measures controlled for	$r = 0.217$	Small	0.020	0.397
						Towards sensory pain; NS when other measures controlled for	$r = 0.210$	Small	0.013	0.391
Van Ryckegham et al[38]	Disability; 2 wk	NS	—	—	—	NS; but AB significant moderator of pain/disability	$r = 0.18$	Small	−0.051	0.392

* Descriptor based on Cohen's[6] classifications of effect sizes.

AB, attentional bias; NS, not significant; Y, significant.

Table 4

Summary of predictive research with other outcomes, by attentional bias stimuli.

Article	Outcome	Attentional bias stimuli				Direction of bias; notes	Effect size			
		Pain	Disability	Social threat	Affective positive		Value	Size*	95% CI Lower	95% CI Upper
Lautenbacher et al[17]	Analgesics; 2 d	N	—	Y	NS	Away	$r = -0.389$	Medium	−0.610	−0.111
Lautenbacher et al[18]	Analgesics; 1 wk	Y	—	NS	NS	Away	$r = -0.157$	Small	−0.408	0.116
Sharpe et al[31]	D/A/S; 3 mo	NS	NS	NS	—					
	D/A/S; 3 mo	NS	NS	NS	—					
Van Ryckegham et al[38]	Avoidance behavior; 2 wk	NS	—	—	—					
	Distractibility; 2 wk	NS	—	—	—	NS; but AB significant moderator of pain/distractibility	$r = 0.17$	Small	−0.061	0.444

* Descriptor based on Cohen's[6] classifications of effect sizes.
Analgesics, amount of requested analgesics; AB, attentional bias; D/A/S, DASS depression anxiety stress scale; NS, not significant; Y, significant.

Lautenbacher et al.[17] found that ABs to pain, social threat, and positive words did not predict acute postoperative pain in a sample of patients undergoing surgery for cancer. However, it was notable that a bias away from pain words did predict analgesic use, which may partly explain the lack of relationship between biases and pain.

3.1.1. Disability as an outcome

In addition to pain, 3 articles measured disability as an outcome. In 2 of these studies, disability was significantly predicted, although effect sizes were again small. Sharpe et al.[31] found that affective pain word biases measured using the dot-probe were negatively associated with disability both 3 and 6 months later; however, this relationship was no longer significant when other variables were controlled for in a regression analysis. Sensory pain, disability, and threat word biases did not predict disability at either time point. Similarly, Lautenbacher et al.[19] found that dot-probe ABs towards pain, social threat, and positive words did not predict disability 3 and 6 months after surgery. In contrast, Van Ryckeghem et al.[38] found that although a conditioned AB was not a direct predictor of disability 2 weeks later, the pain severity–AB interaction was a significant predictor of disability. When taken together, these findings suggest that ABs alone may not account for pain-related disability but rather that for individuals who have high levels of AB, the experience of pain may be more likely to lead to disability.

3.1.2. Other outcome measures

Two studies measured the amount of postoperative analgesia used as an outcome. Lautenbacher et al.[18] found that biases away from pain words were the strongest predictors of analgesia used in the 2 days postoperatively, whereas pain and positive word biases were not predictive. In an independent sample, Lautenbacher et al.[17] found that ABs towards pain words were a significant predictor of postoperatively requested analgesia 1-week postsurgery, whereas social threat and positive word biases were not predictive.

Other outcome measures were only measured in single studies. For example, Sharpe et al.[31] did not find ABs predictive of depression, anxiety, or stress scores at 3 or 6 months. Finally, although Van Ryckeghem et al.[38] did not find ABs directly predictive of pain avoidance behavior or distractibility, there was a significant interaction between pain severity and ABs that predicted distractibility, such that for those with greater ABs, pain was a stronger predictor of distractibility.

3.1.3. Presence of attentional biases

When the presence of AB was measured, it was included in the secondary analyses, although biases may not necessarily be directly observable in healthy samples. Munafò and Stevenson[25] conducted the only study in which the Stroop task was used. Under masked presentation at 100 milliseconds, hypervigilance

Table 5

Summary of experimental research descriptive variables and quality ratings.

	Population	N	Biases measured pre/posttreatment	Nature of training	Training compared with	Quality assessment rating/10
Carleton et al[4]	Fibromyalgia patients	17	No	Dot-probe ABM	Dot-probe placebo	7
McGowan et al[23]	University students	104	Yes	Dot-probe ABM	Trained away from pain stimuli	8
Sharpe et al[32]—Study 1	Individuals with acute pain	54	Yes	Dot-probe ABM	Dot-probe placebo	10
Sharpe et al[32]—Study 2	Individuals with chronic pain	34	Yes	Dot-probe ABM	Dot-probe placebo	10
Sharpe et al[33]	University students	128	Yes	Dot-probe ABM	Trained away from pain stimuli	9
Sharpe et al[34]	University students	103	Yes	Wells' attention training	Progressive muscle relaxation	8
Sharpe et al[35]	University students	140	Yes	Mindfulness	Progressive muscle relaxation	8

ABM, attentional bias modification.

Table 6

Summary of experimental research—clinical pain outcomes.

Article	Effects on AB	Direction of effect	Outcome; follow-up length	Effects on pain	Direction of effect	Effect sizes			
						Value	Size	95% CI	
								Lower	Upper
Carleton et al[4]	NA	Not measured	Pain severity	NS					
Sharpe et al[32]–Study 1	NS		Pain severity; Post	NS					
			Pain severity; 3 mo	Y	Improvements in ABM group vs placebo	$d = -0.602$	Large	−1.461	−0.342
			Average pain severity; 3 mo	Y	Improvements in ABM group vs placebo	$d = -0.926$	Large	−1.487	−0.365
			Number of days in pain; 3 mo	Y	Improvements in ABM group vs placebo	$d = -0.070$	Negligible	−0.603	0.464
Sharpe et al[32]–Study 2	NS		Pain severity; Post	NS					
			Pain severity; 6 mo	NS					

AB, attentional biases; ABM, attentional bias modification; NA, not available; NS, not significant; Y, significant.

was found such that ABs towards physical pain words were observed within a healthy sample. However, ABs were neither found with other stimuli presentations, such as neutral, positive, and social threat words, nor for unmasked presentations of any stimuli. In the remaining 5 articles using the modified spatial cueing task[38] and the dot-probe task,[17–19,31] ABs were not found to be significantly different from zero. However, in the only dot-probe task study to use a sample that was already in pain, Sharpe et al.[31] found a significant difference in affective biases between the chronic pain group and the comparison group 3 months later, with greater avoidance of affective pain words for those with chronic pain compared with those in the comparison group.

3.2. Can modifying attentional biases impact the experience of pain?

Regarding AB modification and the impact on pain, 6 articles reporting 7 studies that met criteria were identified.[4,23,32–35] Most studies tested ABM through the modified dot-probe task ($n = 5$), whereas 1 study used Wells' attention training task (ATT) and another used mindfulness. Six of the 7 studies assessed ABs before and after the treatment. Four studies applied interventions in the laboratory on pain-free individuals and assessed the effect of these interventions on the cold pressor task (an acute experimental pain paradigm). The remaining 3 studies investigated the efficacy of the interventions on patients with fibromyalgia ($n = 1$), chronic pain patients ($n = 1$), or acute pain patients ($n = 1$). Of the 5 dot-probe ABM studies, 3 studies compared ABM with placebo and 2 compared ABM with a paradigm that trained participants towards pain-related stimuli. One dot-probe ABM study evaluated its efficacy as an adjunct to cognitive behavioural therapy for chronic pain. Both the mindfulness and the ATT studies compared the tasks with a progressive muscle relaxation task. **Tables 5–8** provide a summary of the descriptive variables and main findings of these studies. The overall quality of the articles was good, indicating low risk of bias.

3.2.1. Effects of attention training on clinical pain outcomes

In the clinical samples, only 1 of 3 studies found evidence of an effect on pain outcomes. In an acute pain sample, Sharpe et al.[32] found positive benefits of a single session of ABM. Compared with the placebo group, the ABM group reported less current and average pain (large effect sizes) and fewer days in pain 3 months later. This study differed from the other 2 studies in that it used acute pain patients and pain was one of the nominated primary outcomes. In contrast, the other 2 studies used chronic pain samples and did not find an effect on pain using ABM training,[4,32] although Carleton et al.[4] found a trend-approaching significance ($P = 0.06$). They both, however, found an effect on other measures of anxiety sensitivity, and Sharpe et al.[32] also found effects on disability.

Importantly, despite these clinical outcomes, none of the studies were able to document a training effect (although Carleton et al.[4] did not assess biases before and after treatment), and only in the acute pain sample[32] was the change in bias correlated with pain outcomes. Hence, the mechanism of treatment is unclear.

3.2.2. Effects of attention training on laboratory pain outcomes

In the laboratory, all 4 studies assessed biases before and after treatment and used 3 measures from a cold pressor task: threshold (time to register pain), tolerance (length of time of pain tolerance), and pain intensity (at threshold, 30 seconds, and/or tolerance). Regarding intervention effects on attention, 3 of the 4 studies demonstrated the predicted training effects after treatment, such that the 2 ABM studies both found changes in ABs, and the ATT study found reductions in hypervigilance towards pain-related stimuli. The fourth study of mindfulness did not produce changes in AB when compared with relaxation and also did not produce changes in any of the pain outcomes.[35] Effect sizes ranged from negligible to medium but were generally small.

For the 3 studies that did show evidence of changes in attentional processes,[23,33,34] all 3 found that after the attention training, participants took longer to register pain compared with the control condition. Only 1 of the 3 studies showed an impact of ABM on pain intensity, and none showed an impact of attentional training on tolerance. Hence, it seems that treatments that are able to successfully change attentional processes seem to influence how quickly participants identify pain, which is arguably a behavioural indicator of hypervigilance to pain-related sensations. Although changes in pain threshold were consistently found in studies where attentional processes changed, which shows greater confidence in the proposed mechanism than is available in clinical studies, it remains the case that only McGowan et al.[23] found associations between changes in ABs and pain outcomes.

Table 7

Summary of experimental research—laboratory pain outcomes.

Article	Effects on AB	Description	Pain outcome	Effects on pain	Description	Effect sizes			
						Value	Size	95% CI	
								Lower	Upper
McGowan et al[23]	NS		CP threshold	Y	Training towards pain stimuli reduced threshold compared with neutral training	−0.393	Small	−0.781	−0.005
			CP 30s pain	Y	Training towards pain stimuli increased pain compared with neutral training	0.417	Small	0.029	0.806
			CP tolerance	NS					
			CP tolerance pain	NS					
Sharpe et al[34]	Y	Hypervigilance: 3 way (group, time, stimuli) interaction: ATT reduced hypervigilance towards sensory pain words over time, whereas relaxation group became more hypervigilant to sensory pain words. No changes for affective words. Disengagement: no effects	CP threshold	Y	ATT group slower to register pain than relaxation group	0.427	Small	0.038	0.816
			CP 30s pain	NS					
			CP tolerance	NS					
			CP tolerance pain	NS					
Sharpe et al[35]	Y	3 way (threat, time, group) interaction: increased bias towards painful words for relaxation high-threat group, and for those in mindfulness low threat group. No change over time for relaxation high threat or mindfulness low threat	CP threshold	NS					
			CP tolerance	NS					
			CP average pain rating	NS					
Sharpe et al[33]	Y	*Pain stimuli:* 2 way (time, group) interaction: increased bias towards pain stimuli when trained towards; increased bias away from pain stimuli when trained away. *Happy stimuli:* no effects	CP threshold	Y	Improvements in ABM training away from vs training towards pain	Pain faces: $d = -0.001$	Negligible	−0.516	0.514
						Pain words $d = -0.787$	Medium	−1.339	−0.222
			CP tolerance	NS					
			CP average pain rating	NS					

AB, attentional biases; ABM, attentional bias modification; ATT, Wells' attention training; CP, cold pressor; NS, not significant; Y, significant.

Table 8

Summary of experimental research—other outcomes.

Article	Effects on AB	Description	Pain outcome	Effects on pain	Description	Effect sizes			
						Value	Descriptor	95% CI	
								Lower	Upper
Carleton et al[4]	NA	Not measured	Fear of pain	Y	Significant fear of pain reductions for experimental group; no changes in control group (groups not compared directly)	$d = 0.262$	Small	−0.775	1.299
			Anxiety sensitivity	Y	Significant anxiety sensitivity reductions for experimental group; no changes in control group (groups not compared directly)	$d = 0.202$	Small	−0.833	1.238
			Injury sensitivity	NS					
			Pain anxiety	NS					
Sharpe et al[32]–Study 2	NS		Disability (post)	Y	Significant improvements in disability for experimental group compared with control group	$d = 0.45$	Small	0.26	1.42
			Anxiety sensitivity (post)	NS					
			Fear of pain (post)	NS					
			Mood (post)	NS					
			Disability (6 mo)	Y	Significant improvements in disability for experimental compared with control group	$d = 0.55$	Medium	0.33	1.35
			Anxiety sensitivity (6 mo)	Y	Significant improvements in anxiety sensitivity for experimental compared with control group	$d = 0.75$	Medium	0.05	1.66
			Fear of pain (6 mo)	NS					
			Fear of movement (6 mo)	Y	Significant reductions in fear of movement for experimental compared with control group	$d = 0.65$	Medium	0.28	1.4
			Mood (6 mo)	NS					

AB, attentional biases; NA, not available; NS, not significant; Y, significant.

3.2.3. Effects of attention training on secondary outcomes

Two experimental studies included secondary outcome measures in addition to pain outcomes. Carleton et al.[4] measured fear of pain, anxiety sensitivity, injury sensitivity, and pain anxiety and found significant reductions in fear of pain and anxiety sensitivity in the ABM experimental group, with small effect sizes. However, these findings must be interpreted with caution as the ABM group was not directly compared with the control group, a 1-tailed test was used and the sample size was small ($n = 8$ for each group). The second study by Sharpe et al.[32] included a range of secondary outcomes including disability, anxiety sensitivity, fear of pain, and mood that were measured both immediately after and 6 months after ABM training. Postintervention, significant improvements in disability in the ABM group in comparison with the control group were observed. These improvements in disability were maintained at 6-month follow-up. Furthermore, at 6 months, significant improvements in anxiety sensitivity and fear of movement were also observed. These effects ranged from small to medium in size.

3.3. Summary of results

Overall, the prospective studies were mostly consistent in finding that some aspect of AB predicted pain outcomes; however, the pattern of findings differed across studies. One possible explanation for this pattern of results is the vigilance–avoidance hypothesis for which there is mounting evidence in the anxiety disorders.[24] According to the vigilance–avoidance hypothesis, anxious individuals under high threat show immediate vigilance towards threat, which is supported in the only study that assessed early attentional processes.[25] This initial vigilance is then followed by an avoidance of threat; an avoidance of negative (or focus on positive) stimuli was identified in the remaining studies, although the precise stimuli to which biases were observed differed between studies. Although speculative, if the premise of Lautenbacher et al.[19] that biases towards positive stimuli is another facet of biases away from pain stimuli is accepted, the vigilance–avoidance hypothesis seems to fit the available data. Preoperative biases consistently predict pain in some instances up to 6 months after surgery,[17,19] suggesting that ABs have an important role in the development of pain. However, further research is warranted to determine the mechanisms behind these effects.

The attentional modification literature shows some promise, particularly in laboratory settings. These studies have shown that interventions that change attentional processes are generally effective, particularly in changing pain threshold (ie, how quickly a person recognises pain). Although the clinical applications have been promising, it is premature to conclude that ABM is consistently efficacious. All 3 clinical studies reported effects on at least 1 outcome. However, given the variety of populations, measures, stimuli, and parameters, if one looks at individual outcomes (eg, pain), the data are less compelling. Similarly, the lack of a plausible mechanism is problematic. This is particularly the case, because if the process that is identified in prospective studies is vigilance–avoidance, then it is unclear that the training away paradigms used in ABM studies to date should be efficacious. The reliability of measurement tasks such as the dot-probe has also been questioned,[10] and more direct

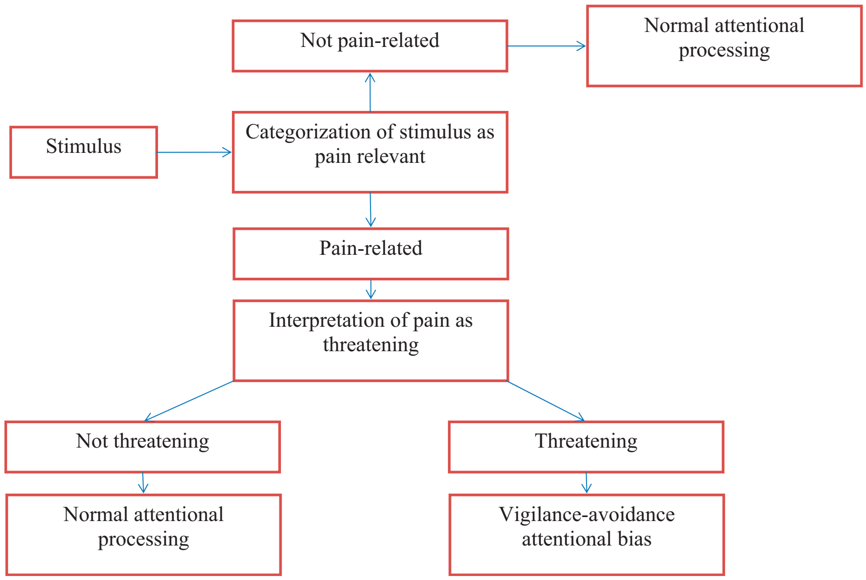

Figure 2. An integrated *Threat Interpretation Model* of attentional biases to pain.

measurement of AB (such as eye tracking) may help to elucidate the mechanisms of change. Researchers have called for further exploration and improvement of AB modification procedures until these procedures can consistently modify biases.[5] Measuring cognitive change through pre–post AB assessments (which was present in most studies reviewed) and systematically manipulating task parameters have also been recommended to better understand and improve modification procedures.[22]

4. Discussion

4.1. The proposed threat interpretation model

Although previous theories have all highlighted an important role for ABs in pain, theories to date have not considered the exact nature of attentional processes and the way in which they may contribute to the experience of pain. The aim of the *Threat Interpretation Model* (**Figure 2**) proposed here is to provide, on the basis of available evidence, a hypothesis-generating model that can guide and be evaluated in future AB research.

In cross-sectional studies, it is the spatial cueing task that has found the most robust ABs towards pain-related stimuli.[8] This is perhaps unsurprising, because the bias tested here is in response to somatosensory stimuli, which is most ecologically valid in terms of the pain experience.[36] In contrast, the most widely used tasks to assess AB have been the dot-probe and Stroop tasks using word stimuli. These tasks arguably measure a bias towards words that represent aspects of the pain. For participants to be able to respond to these words as pain related, they first have to categorize these stimuli as pain related. That is, these paradigms rely on the interpretation of sometimes ambiguous word stimuli (eg, sharp, boring) as pain related. Hence, in understanding the available literature, one would assume that interpretation biases that favour pain-related interpretations are necessary, although not sufficient, for ABs to pain-related word stimuli to be observed. This interpretation bias may be less relevant for other types of stimuli (eg, faces[15,16] or pictures[9]), although may be present to varying degrees.

Once the stimuli are categorized as pain related, the degree to which someone will demonstrate a bias towards that stimulus is likely to depend on the salience of that stimulus to the individual. Most theories of pain suggest that the salience is determined by the degree to which participants find the pain experience threatening or fearful (eg, Refs. 11 and 41). Hence, we would anticipate that it is not the experience of pain alone that necessarily influences ABs but the degree to which the pain is interpreted as threatening.

There is now good meta-analytic evidence that there are biases towards sensory pain stimuli on reaction time tasks in chronic pain patients and healthy controls, although this is marginally greater for chronic pain patients.[8] The meta-analytic findings give only a snapshot of where attention is placed at the time of the assessment and therefore eye-tracking studies can help to disentangle the processes more clearly. Recent eye-tracking studies have found an engagement bias and a pattern of initial vigilance to pain-related words even in healthy participants.[28,43] Interestingly, both studies found that this initial vigilance was followed by faster disengagement from pain-related stimuli than other neutral stimuli (ie, avoidance). The authors of these studies argued that there may be benefit to immediate orientation towards pain-related stimuli and, when that stimulus has no threat value, to disengage from it quickly to maintain positive mood.[28] Other studies investigating the time course of attentional processes have also found similar patterns of speeded orientation followed by avoidance.[2] This pattern of vigilance–avoidance in healthy participants seems consistent with the previous interpretation of prospective studies, such that initial vigilance and then subsequent avoidance of salient negative information (or focus on positive) was associated with a range of outcomes across studies. It therefore seems that vigilance and avoidance could potentially indicate a *vulnerability* to the experience of subsequent pain (and associated disability). What is particularly interesting is that previous meta-analytic research[30] suggests that, for the *maintenance* of chronic pain, difficulty disengaging may be a more relevant attentional process. Although the pattern proposed here would need to be further investigated and remains preliminary, when taken together with the meta-analytic findings, it seems that different patterns of attentional processes may be important at different stages of the development and maintenance of chronic pain.

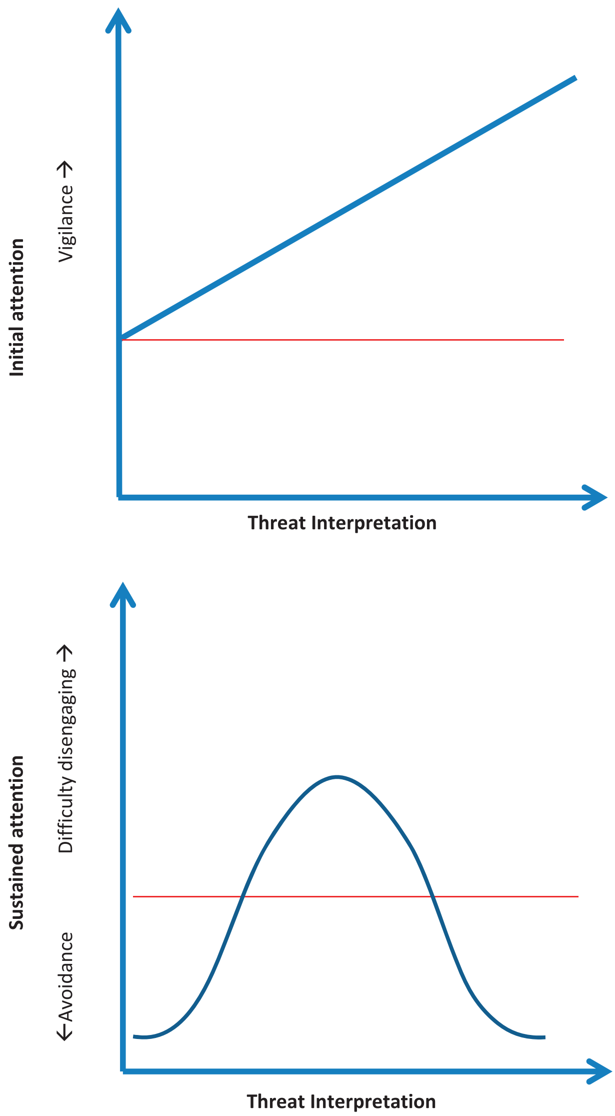

Figure 3. The vigilance–avoidance hypothesis within the *Threat Interpretation Model*. Note: Red lines indicate no bias to pain-related stimuli compared to neutral stimuli.

Previous theoretical models are consistent with the vigilance–avoidance hypothesis. For example, within the fear of a (re)injury model[41] and its successor the fear avoidance model,[7] It is proposed that pain-related fear leads to hypervigilance towards pain, as well as an avoidance of further pain and injury. However, the time course of these processes is not specified, and nor is the role of attention and interpretation made explicit. One advantage of the *Threat Interpretation Model* is that it generates testable predictions, particularly about the role that these attentional processes play and how these attentional processes are influenced by interpretation.

In addition to looking at the pattern of attention over time and the role of interpretation, it is important to determine in what way high levels of threat might impact this vigilance–avoidance pattern. Threat is not a new construct in the pain literature and has been incorporated into previous theoretical models such as the cognitive affective model of attention and pain.[11] The cognitive affective model suggests that although it is usual for pain to capture attention, individuals have difficulty disengaging from pain stimuli under conditions of threat. The failure to disengage effectively from painful stimuli is thought to interfere with efforts to engage in appropriate goal-directed function, which contributes to the risk of increasing disability. The *Threat Interpretation Model* differs in that it proposes that avoidance rather than difficulty disengaging is important in high-threat environments. Other researchers have also indicated the importance of threat,[37] particularly explaining how AB influences pain through threat mechanisms rather than attentional deficits. However, to date, the *Threat Interpretation Model* is the first to explicitly outline this relationship and propose that the mechanism underlying the influence of threat on attention is interpretation. Furthermore, the model proposes that different levels of threat may influence attentional processes differently.

Evidence from a number of sources suggests that, under high levels of threat, initial orientation or vigilance continues to increase as the level of threat increases, at least to sensory pain words. In available eye-tracking studies comparing chronic pain to healthy controls, greater vigilance has been demonstrated to pain stimuli.[21,43] This is also the case for those studies that have compared high vs low fear of pain in both chronic pain[43] and healthy participants.[44] Furthermore, in the only prospective study, to date, examining orientation biases (masked presentation at 100 milliseconds), Munafo and Stevenson[25] confirmed that biases towards pain stimuli were associated with future pain. Furthermore, this is potentially consistent with the meta-analytic data.[8,30] Hence, there seems to be relatively strong evidence from a variety of sources indicating that orientation biases increase under conditions of threat, at least for sensory aspects of pain.

What is less clear is the nature of biases of sustained attention that are relevant to the development or maintenance of pain. This is where the cross-sectional and prospective data are conflicting. That is, cross-sectional data indicate larger ABs at longer presentation intervals, which has been interpreted as difficultly disengaging, whereas it has been the avoidance of pain-related and other salient negative information (or a focus on positive), that has predicted future pain in prospective studies. Eye-tracking literature has not only found biases in orientation indicating vigilance but also found earlier disengagement from pain words among chronic pain patients compared with controls indicative of avoidance.[43] Although Liossi et al.[21] did not find this effect, there was also a trend towards avoidance in their study. Yang et al.[44] found the same pattern for high fear of pain participants in another study, as did Vervoort[39,40] with parents of children with pain who were high in catastrophizing. Indeed, avoidance increased as the severity of the pain faces increased (ie, increasing threat of the stimuli). Thus, there is increasing evidence to suggest that when threat is sufficiently high, the ABs towards threat switch to a mechanism of avoidance (**Figure 3**). The primary predictions from the *Threat Interpretation Model* are further outlined in **Table 9**.

Although this potentially links prospective and experimental studies, what remains unclear is why then would modifying ABs by training people away from pain-related stimuli lead to improved pain, if avoidance is the putative mechanism through which ABs result in poorer outcomes. One possibility is that it may be the stimuli that are important. In the seminal paper of Pincus and Morley,[27] they differentiated between sensory and affective components of pain and argued that sensory aspects of pain would be preferentially attended to by all pain patients, whereas only those who are depressed would attend towards affective pain words. Although that prediction has not been borne out, there is evidence that affective and sensory pain words play different roles. For example, Sharpe et al.[31] found that acute pain patients did demonstrate a bias towards sensory pain words, as

Table 9

Hypotheses arising from the *Threat Interpretation Model*.

Impact of threat and interpretation	
Interpretation biases	As threat increases, interpretation biases increase (ie, more likely to interpret pain stimuli as threatening)
Initial vigilance	As threat interpretation increases, initial vigilance towards pain-related stimuli will increase
Sustained attention	The relationship between threat and sustained attention will be nonlinear (see below)
Sustained attention and threat	
Low threat	Participants will disengage easily from threat (ie, low levels of attentional bias)
Moderate threat	Participants will have difficulty disengaging from threat (ie, high levels of AB)
High threat	Participants will avoid threatening stimuli (ie, negative levels of AB)
Relationship between interpretation bias and attentional bias	
Interpretation biases will be associated with attentional biases to ambiguous stimuli (eg, pain-related words)	
The relationship between threat and attentional biases should be mediated by interpretation biases	
The relationship between interpretation biases and AB will be higher under conditions of high threat	
The relationship between interpretation biases and pain outcomes should be mediated by attentional biases	

previously demonstrated,[14] but that avoidance of affective pain words predicted subsequent chronicity. In the laboratory, it has also been shown that threat can influence training effects. Boston and Sharpe[3] found that attending to sensory aspects of pain was helpful under condition of low threat, relative to affective pain, whereas the opposite was true under high threat. Therefore, it may be that different stimuli produce a different pattern of attentional processes. To date, the majority of ABM studies have trained towards either all pain words (eg, sensory pain, affective pain, threat, disability) or sensory pain words only. It seems that it is avoidance, particularly of the affective components of pain, that might be important. Therefore, it is possible that ABM protocols are effective by training only 1 aspect of attention (eg, reduced vigilance) or from changes in biases towards some stimuli but not others.

5. Recommendations and conclusions

Given that the literature reviewed is widely varied and still emerging, any conclusions that are drawn from the *Threat Interpretation Model* generated remain tentative. In addition, the small number of studies and variations in training paradigms, stimuli, samples, and outcomes mean that conclusions drawn from this research remain preliminary and require further testing. Nonetheless, the prospective literature seems to generally fit a pattern of vigilance followed by avoidance, and the proposed *Threat Interpretation Model*, although preliminary, generates testable hypotheses about attentional processes. For example, interpretation biases should be associated with ABs, particularly to words on the dot-probe paradigm. In addition, under conditions of threat, a pattern of increasing vigilance is likely to be observed. Finally, although avoidance may be helpful under conditions of low threat as the individual can disengage to carry out other tasks, avoidance under high threat may be detrimental and contribute to poor pain outcomes. These predictions should be tested, and, if found to hold, could be used to build theory-based interventions. Intervention tools may integrate ABM strategies, cognitive behavioural approaches, and other strategies that target not only attention but also threat and interpretation, which would be in keeping with recent recommendations in the literature.[38]

To summarize, the aim of this article was to answer the question recently posed about ABs: do they matter[20]? On the basis of available evidence, it seems that ABs do matter but are the product of a complex relationship between the nature of the pain, threat interpretation and other individual factors, and characteristics of the task used to assess the ABs. The primary pattern of biases that predicted pain under conditions of high threat was initial vigilance, followed by avoidance of negative stimuli (or a focus on positive stimuli). Furthermore, manipulating biases through ABM showed some promise in the management of pain in a range of settings in which it has been trialled, although these changes did not consistently map changes in ABs. For this reason, Clarke et al.[5] have made a call for better training paradigms that can reliably change ABs. The use of different stimuli, different directions of training, and eye-tracking technology could help to disentangle the processes involved and thereby maximize the efficacy of ABM protocols.

Conflict of interest statement

The authors have no conflicts of interest to declare.

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Appendix A. Supplemental Digital Content

Supplemental Digital Content associated with this article can be found online at http://links.lww.com/PAIN/A94, http://links.lww.com/PAIN/A95.

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References

[1] Aldrich S, Eccleston C, Crombez G. Worrying about chronic pain: vigilance to threat and misdirected problem solving. Behav Res Ther 2000;38:457–70.

[2] Baum C, Schneider R, Keogh E, Lautenbacher S. Different stages in attentional processing of facial expressions of pain: a dot-probe task modification. J Pain 2013;14:223–32.

[3] Boston A, Sharpe L. The role of threat-expectancy in acute pain: effects on attentional bias, coping strategy effectiveness and response to pain. PAIN 2005;119:168–75.
[4] Carleton RN, Richter AA, Asmundson GJG. Attention modification in persons with fibromyalgia: a double blind, randomized clinical trial. Cogn Behav Ther 2011;40:279–90.
[5] Clarke PJ, Notebaert L, MacLeod C. Absence of evidence or evidence of absence: reflecting on therapeutic implementations of attentional bias modification. BMC Psychiatry 2014;14:8.
[6] Cohen J. A power primer. Psychol Bull 1992;112:155.
[7] Crombez G, Eccleston C, Van Damme S, Vlaeyen JW, Karoly P. Fear-avoidance model of chronic pain: the next generation. Clin J Pain 2012; 28:475–83.
[8] Crombez G, Van Ryckeghem D, Eccleston C, Van Damme S. Attentional bias to pain-related information: a meta-analysis. PAIN 2013;154:497–510.
[9] Dear BF, Sharpe L, Nicholas MK, Refshauge K. Pain-related attentional biases: the importance of the personal relevance and ecological validity of stimuli. J Pain 2011;12:625–32.
[10] Dear BF, Sharpe L, Nicholas MK, Refshauge K. The psychometric properties of the dot-probe paradigm when used in pain-related attentional bias research. J Pain 2011;12:1247–54.
[11] Eccleston C, Crombez G. Pain demands attention: a cognitive-affective model of the interruptive function of pain. Psychol Bull 1999;125:356–66.
[12] Eccleston C, Crombez G. Worry and chronic pain: a misdirected problem solving model. PAIN 2007;132:233–6.
[13] Garg AX, Hackam D, Tonelli M. Systematic review and meta-analysis: when one study is just not enough. Clin J Am Soc Nephrol 2008;3:253–60.
[14] Haggman SP, Sharpe LA, Nicholas MK, Refshauge KM. Attentional biases toward sensory pain words in acute and chronic pain patients. J Pain 2010;11:1136–45.
[15] Khatibi A, Schrooten M, Vancleef LM, Vlaeyen JW. An experimental examination of catastrophizing-related interpretation bias for ambiguous facial expressions of pain using an incidental learning task. Front Psychol 2014;5:1002.
[16] Khatibi A, Sharpe L, Jafari H, Gholami S, Dehghani M. Interpretation biases in chronic pain patients: an incidental learning task. Eur J Pain. In Press.
[17] Lautenbacher S, Huber C, Baum C, Rossaint R, Hochrein S, Heesen M. Attentional avoidance of negative experiences as predictor of postoperative pain ratings and consumption of analgesics: comparison with other psychological predictors. Pain Med 2011;12:645–53.
[18] Lautenbacher S, Huber C, Kunz M, Parthum A, Weber PG, Griessinger N, Sittl R. Hypervigilance as predictor of postoperative acute pain: its predictive potency compared with experimental pain sensitivity, cortisol reactivity, and affective state. Clin J Pain 2009;25:92–100.
[19] Lautenbacher S, Huber C, Schöfer D, Kunz M, Parthum A, Weber PG, Roman C, Griessinger N, Sittl R. Attentional and emotional mechanisms related to pain as predictors of chronic postoperative pain: a comparison with other psychological and physiological predictors. PAIN 2010;151:722–31.
[20] Liossi C. Attentional biases in chronic pain: do they exist and does it really matter? PAIN 2012;153:9–10.
[21] Liossi C, Schoth DE, Godwin HJ, Liversedge SP. Using eye movements to investigate selective attention in chronic daily headache. PAIN 2014; 155:503–10.
[22] MacLeod C, Koster EH, Fox E. Whither cognitive bias modification research? Commentary on the special section articles. J Abnorm Psychol 2009;118:89–99.
[23] McGowan N, Sharpe L, Refshauge K, Nicholas MK. The effect of attentional re-training and threat expectancy in response to acute pain. PAIN 2009;142:101–7.
[24] Mogg K, Bradley B, Miles F, Dixon R. Time course of attentional bias for threat scenes: testing the vigilance-avoidance hypothesis. Cogn Emot 2004;18:689–700.
[25] Munafò MR, Stevenson J. Selective processing of threat-related cues in day surgery patients and prediction of post-operative pain. Br J Health Psychol 2003;8:439–49.
[26] National Collaborating Centre for Methods and Tools. Quality assessment tool for quantitative studies (Updated 13 April, 2010). Hamilton: McMaster University, 2008.
[27] Pincus T, Morley S. Cognitive-processing bias in chronic pain: a review and integration. Psychol Bull 2001;127:599–617.
[28] Priebe JA, Messingschlager M, Lautenbacher S. Gaze behaviour when monitoring pain faces: an eye-tracking study. Eur J Pain 2015;19: 817–25.
[29] Roelofs J, Peters ML, Zeegers MP, Vlaeyen JW. The modified Stroop paradigm as a measure of selective attention towards pain-related stimuli among chronic pain patients: a meta-analysis. Eur J Pain 2002;6:273–81.
[30] Schoth DE, Nunes VD, Liossi C. Attentional bias towards pain-related information in chronic pain: a meta-analysis of visual-probe investigations. Clin Psychol Rev 2012;32:13–25.
[31] Sharpe L, Haggman S, Nicholas MK, Dear B, Refshauge K. Avoidance of affective pain stimuli predicts chronicity in acute low back pain patients. PAIN 2014;155:45–52.
[32] Sharpe L, Ianiello M, Dear BF, Nicholson Perry K, Refshauge K, Nicholas MK. Is there a potential role for attention bias modification in pain patients? Results of 2 randomised, controlled trials. PAIN 2012; 153:722–31.
[33] Sharpe L, Johnson A, Dear B. Attention bias modification and its impact on experimental pain outcomes: comparison of training with words versus faces in pain. Eur J Pain. In Press.
[34] Sharpe L, Nicholson Perry K, Rogers P, Dear BF, Nicholas MK, Refshauge K. A comparison of the effect of attention training and relaxation on responses to pain. PAIN 2010;150:469–76.
[35] Sharpe L, Nicholson Perry K, Rogers P, Refshauge K, Nicholas MK. A comparison of the effect of mindfulness and relaxation on responses to acute experimental pain. Eur J Pain 2013;17:742–52.
[36] Van Damme S, Crombez G, Eccleston C, Koster EH. Hypervigilance to learned pain signals: a componential analysis. J Pain 2006;7:346–57.
[37] Van Ryckeghem D, Crombez G. Attentional bias and chronic pain: where to go from here? PAIN 2014;155:6–7.
[38] Van Ryckeghem DM, Crombez G, Goubert L, De Houwer J, Onraedt T, Van Damme S. The predictive value of attentional bias towards pain-related information in chronic pain patients: a diary study. PAIN 2013;154: 468–75.
[39] Vervoort T, Trost Z, Prkachin KM, Mueller SC. Attentional processing of other's facial display of pain: an eye tracking study. PAIN 2013;154:836–44.
[40] Vervoort T, Trost Z, Van Ryckeghem DML. Children's selective attention to pain and avoidance behaviour: the role of child and parental catastrophizing about pain. PAIN 2013;154:1979–88.
[41] Vlaeyen JWS, Linton SJ. Fear-avoidance and its consequences in chronic musculoskeletal pain: a state of the art. PAIN 2000;85:317–32.
[42] Wells A. Panic disorder in association with relaxation induced anxiety: an attentional training approach to treatment. Behav Ther 1990;21:273–80.
[43] Yang Z, Jackson T, Chen H. Effects of chronic pain and pain-related fear on orienting and maintenance of attention: an eye movement study. J Pain 2013;14:1148–57.
[44] Yang Z, Jackson T, Gao X, Chen H. Identifying selective visual attention biases related to fear of pain by tracking eye movements within a dot-probe paradigm. PAIN 2012;153:1742–8.