Do individuals with Chronic Pain show attentional bias to pain-related information? An early stage systematic review of the eye-tracking evidence.

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Introduction

Selective attention to pain-related information has been highlighted as a contributing factor to the aetiology and maintenance of chronic pain (Schoth, Nunes & Liossi, 2012). This attentional bias (AB) increases the preferential allocation of attentional resources to pain-related information, resulting in faster detection of threat (Liossi, Schoth, Godwin & Liversedge, 2014), greater difficulty disengaging from threat (Brookes, Sharpe & Dear, 2017) and/or avoidance of threat (Van Damme, Crombez & Eccleston, 2004). Attentional biases have been consistently observed in many forms of psychopathology (e.g., anxiety and depression), but the evidence for them among chronic pain populations has been mixed (Crombez, Heathcote & Fox, 2015).

AB has commonly been measured using experimental paradigms such as the emotional-Stroop task, the visual-probe task (VPT), the spatial cueing task and the visual search task (see Maratos & Sharpe, 2018 for review). Considering chronic pain, the most commonly used paradigm is the VPT, which simultaneously presents a pair of task-irrelevant stimuli (one pain-related and one neutral) that compete for attentional resources. After a fixed exposure period (e.g, 500ms/1250ms), a visual probe (e.g., "X") replaces one of the former stimuli. Participants have to identify the position of the probe as quickly and accurately as possible. If the probe replaces the pain-related image, faster response times are treated as indicating vigilance to threat, and slower response times avoidance or difficulty disengaging from threat (Schmukle, 2005).

Despite its frequent use, studies employing this methodology have failed to provide convincing evidence that patients with chronic pain selectively attend to pain-related information compared with healthy controls (e.g. Liossi, Schoth, Bradley & Mogg, 2009). Although in a recent meta-analysis of VPT investigations Schoth, Nunes and Liossi (2012) found significant biases during *later* stages of attentional processing. That is, in studies where a stimulus presentation time of 1250ms was used, chronic pain patients consistently showed greater biases towards pain-related information than healthy controls. However, researchers have questioned the ecological validity of the VPT because it cannot fully capture the dynamic nature of attention (Waechter, Nelson, Wright, Hyatt & Oakman, 2014).

Additionally, reaction time, which is the primary outcome measure of the VPT, assumes that gaze location corresponds to motor (usually manual) responses, which is not always the case (Fashler & Katz, 2014). These limitations also apply to the emotional-Stroop task, spatial cueing task and visual search task (Algom, Chajut & Lev, 2004; Lavie, 2005) and, as such, eye-tracking technology has recently become the gold-standard for measuring attentional biases related to chronic pain, given it provides a direct measure of overt attentional deployment (Schoth, Godwin, Liversedge & Liossi, 2015).

Adding to this, in recent years, a new theoretical framework has been established to guide AB research in chronic pain. The Threat Interpretation Model (TIM, Todd, Sharpe, Johnson, Perry, Colagiuri & Dear, 2015) – developed from a systematic review examining the causal nature of attentional biases in chronic pain - proposes a relationship between threat and interpretation in determining biases at different stages of the attentional process. This model asserts that the interpretation of stimuli as pain- and threat-relevant will lead to a vigilance-avoidance pattern of attentional processing. At the initial stages of attentional processing, this interpretation bias increases initial vigilance towards pain-related stimuli. However, at later stages of attentional processing, and under conditions of sustained attention, significant attentional biases are predicted depending on the perceived threat value of the stimulus. To expand, low threat should lead to easy disengagement of attention; moderate threat to more difficulty disengaging attention; and high threat to attentional avoidance. Because eye-tracking provides better insights into early versus late stage attentional biases, a systematic review of the available eye-tracking evidence of pain-related bias can test aspects of the TIM by assessing biases at earlier versus later stages of attentional processing.

Hence, a systematic review evaluating the available eye-tracking evidence of pain-related bias may not only prove useful in clarifying whether chronic pain patients show AB to pain-related information, but also whether this bias occurs in the earlier or later stages of attentional processing, thus enabling evaluation of the TIM.

Thus, the aim of this review was to systematically examine studies using eye-tracking technology in the area of pain to determine the time-frame within which individuals with chronic pain show evidence of attentional biases towards pain-related information. Based on the TIM, we predicted that participants would exhibit vigilance to threat during the early stages of attention and either rapid disengagement, difficulty disengaging, or avoidance of threat during the late stages of attention.

Systematic review methods

To be included in the review, studies had to:

i. Be available in the English Language.

ii. Include samples of adults (≥ 18 years old) with chronic pain - defined as pain that has persisted for a minimum of three months as well as a sample of healthy, pain-free, control participants.

iii. Use an eye-tracking task with stimuli related to the sensory and/or affective dimensions of pain.

iv. Explore attentional biases in relation to the initial orienting of attention and/or maintenance of attention.

Studies were excluded if they examined attentional biases in the context of an intervention.

Studies were identified by searches of: PsycINFO, PsycArticles, Medline, Google Scholar, The Cochrane Library and PROSPERO. Search terms included "atten*" or "attentional bias" or "vigilance" or "avoidance" or "engagement" or "disengagement" AND "eye tracker" or "eye tracking" or "eye movement measures" or "attention tracking", intersected with the term "pain*" (TX All Text). All results ranged from January 1986 to July 2018. The searches were conducted in November 2017 and updated in June/July 2018. An examination of the reference lists of relevant articles was also conducted. Additionally, to avoid publication bias, key researchers in the area were contacted to request any unpublished work or *in press* work that could be included.

Search Results

The database searches produced a total of 720 articles published between 1986 and 2018 (excluding 11 duplicates). Of the 720 articles, 692 records were excluded due to not meeting inclusion criteria. This left 28 full-text articles to be assessed for eligibility. Of these, 25 were excluded due to: not employing a chronic pain and/or healthy control group (12); no use of eye-tracking technology (6); or stimuli related to the affective/sensory dimensions of pain (4); incorrect study design (2); and duplication of participants from other included studies (1). Consequently, 3 studies were included in this review.

Data were extracted using a modified extraction sheet obtained from the Cochrane Collaboration. Data were extracted independently by the lead author (DG). The included studies reported similar aims, outcome measures and research designs. All three studies included eye-tracking indices related to the initial orienting and/or maintenance of attention. Characteristics of each eye-tracking study included in this review are outlined in Table 1.

Table 1: Characteristics of each included study in this mini-systematic review

Study	Country	Sample size (Pain/Control)	Type of pain	Duration of pain	Cognitive paradigm used	Eye-tracking indices	Stimulus type
A. Fashler & Katz (2014)	Canada	51/62	Neck and/or back pain, headache/migraine pain, ankle and/or knee pain, shoulder pain, stomach pain, hip pain, arm pain, eye pain, jaw pain.	3-6 months (13.7%), 6-12 months (9.8%), 12 months+ (76.5%).	Visual-probe task	Number of fixations/visits, average fixation duration, average visit duration	Words (pain-related; sensory and neutral)
B. Liossi et al. (2014)	UK	23/23	Chronic headache	18.8 years (Mean)	Visual-Scanning Task	Number of initial fixations, mean initial fixation duration, mean visits/fixation duration per image category	Images (Pain, Angry, Happy and Neutral)
C. Yang et al. (2013)	China	24/24	Abdominal pain, headache, back pain, orofacial pain, shoulder pain, neck pain, chest pain.	3.21 years (Mean)	Visual-probe task	First fixation direction bias, first fixation latency bias, first fixation duration bias, overall gaze duration bias	Words (pain-related; sensory, health-catastrophe and neutral)

Review findings

Participants

Study *B* utilised a clinical population of patients suffering from chronic headache and studies *A* and *C* utilised participants suffering from various forms of chronic pain. The age of participants ranged from 18–69. Studies were conducted in the United Kingdom (*B*), Canada (*A*) and China (*C*). The prevalence of male participants ranged from 17–43%. Two studies reported that participants had lived with chronic pain for a mean duration of 18.8 and 3.22 years respectively (*B*, *C*). One study did not report the mean duration of pain but noted that 76.5% of participants had reported experiencing pain for 12 months or longer (*A*). No studies reported any baseline imbalances among chronic pain (n = 98) and pain-free control (n = 109) groups.

Study Design

All of the studies included here used an experimental design. Collectively the three studies included 207 participants, with 98 suffering from chronic pain. One study recruited participants via press announcements (*B*), one recruited participants through an Undergraduate Research Participant pool (*A*) and another recruited participants advertising via a campus electronic bulletin board (*C*).

Two studies combined eye-tracking technology with VPT methodology (*A*, *C*). Both studies used a single stimulus presentation time of 2000ms, to capture early and late AB processes. Study B used visual-scanning methodology, measuring early and late AB processes according to one stimulus presentation time of 4000ms (*B*).

Stimuli

All of the studies used stimuli related to the sensory and/or affective dimensions of pain. Two studies included word stimuli related to the sensory dimensions of pain (*A*, *C*). For each of these studies, other word stimuli (e.g., Neutral/Control) were matched for length and frequency. One study included painful facial expressions, which were matched to other facial expressions (i.e., angry, happy, neutral) on low-level visual features such as luminance, colour, contrast and complexity (*B*).

Aims

Each of the included studies outlined their aims and objectives. These were to track participants' eye movements during a VPT to evaluate AB to sensory pain-related words in individuals reporting chronic pain (*A*); expand on previous work on the time-course and specificity of bias attention in chronic pain (*B*); and to evaluate ABs in chronic pain and pain-free groups by tracking eye-movements within a dot-probe paradigm (*C*). Two studies predicted that participants in the chronic pain group would attend to pain-related stimuli more quickly and/or frequently compared to their pain-free, healthy counterparts during the early stages of attentional processing (i.e. an early enhanced AB to pain-related information) (*A*, *C*). One study predicted that chronic pain participants would show biases during the initial orienting of attention and during maintained attention (i.e. later stages of processing) (*B*).

Quality Assessment of Included Studies

A number of methodological factors were assessed for quality. The quality of included studies was very good. Details of the inclusion/exclusion criteria, testing environment and matching of stimuli were all clearly reported in each study. However, none of the included studies matched control and pain participants. Study *B* lost a point for failing to assess participants' levels of pain-related fear, while study *A* lost a point for not assessing participants levels of depression. Nevertheless, all studies were sufficiently reported to enable replication.

Quantitative Analysis

The studies used similar statistical methods to assess the research questions, specifically Independent/ Mixed Measures ANOVAs and t-tests, which were appropriate for the study designs employed.

Initial Orienting Bias

Study *A* calculated the total fixation duration for three different periods of stimulus presentation: "early-phase total fixation duration" (0–500 ms); "middle-phase total fixation duration" (500–1,000 ms); and "late-phase total fixation duration" (1,000–2,000 ms) to investigate whether gaze patterns varied during different stages of visual processing/attention. For early-phase 'total fixation duration' only the main effect of word type was significant. This suggests that chronic pain participants were no more likely than healthy control participants to display an AB during early stages of attentional processing. Studies *B* and *C* measured indices of orienting with stimulus durations of 4000ms and 2000ms respectively. Study *C* found no evidence of AB during the early stages of attentional processing, as indicated by null effects for ‘first fixation bias scores’ and ‘first fixation latencies’ for sensory pain words. In contrast, study *B*, which used visual-scanning methodology, found that when participants were simultaneously presented with 4 images, one for each facial expression per scene (i.e., pain, angry, happy, neutral), participants were more likely to orient their attention towards the pain-related images (i.e. proportion of initial fixation locations), suggesting that their attention was captured by the presence of pain faces in their periphery. Moreover, probability scores showed that bias towards pain images was significantly greater than chance, indicating participants were more likely to orient their attention to the pain-related images.

Maintained Attentional Bias

Studies *A* and *C* found evidence to suggest that participants with chronic pain displayed AB to pain-related information during maintained attention. Study *A* found that for late-phase ‘total fixation duration’ (1,000 – 2,000 ms), participants with chronic pain fixated significantly longer on sensory pain words relative to neutral words. Further, for ‘average visit duration’, it was found that participants with chronic pain were significantly more likely to visit sensory pain words for longer than neutral words, supporting the notion that patients with chronic pain display an AB to pain-related information during maintained attention. Study *C* found that while participants with chronic pain did not show a bias towards sensory pain words, they did show significantly shorter fixation durations for health-catastrophe words which reflected potential causes (e.g., injury) or consequences (e.g., disabled) of pain. By contrast, study *B*, using visual-scanning methodology, found no evidence of bias during maintained attention via the absence of significant effects for mean initial fixation duration, mean number of visits per image category and mean fixation duration per image category.

Implications of Results

Study *B* concluded that findings were consistent with a pain-related bias that operated in the initial orienting of attention, suggesting that such an AB is observable even in the presence of other competing stimuli (e.g., happy images). In contrast, studies *A* and *C* each concluded that chronic pain patients only showed evidence of AB during the later stages of attentional processing.

Discussion

The aim of this systematic review was to determine whether individuals with chronic pain show AB to pain-related information during early and/or later stages of attentional processing using eye-tracking technology and to evaluate such findings in the context of the recently proposed TIM. The findings of this review provide some evidence to support the presence of an initial orienting bias (1 of 3 studies), while slightly stronger evidence to support the presence of an AB during attentional maintenance (2 of 3 studies).

Considering the TIM, the findings of this review can be argued to fail to provide support for the model's claim that as interpretation bias increases, initial vigilance towards pain-related stimuli also increases linearly. This is evidenced by a lack of significant findings observed in studies *A* and *C* in relation to a variety of early attentional processing eye-tracking indices, including early-phase total fixation duration, first fixation bias scores and first fixation latencies. Nonetheless, it is important to note that Study *B* did provide evidence to support an initial orienting bias. However, it is unclear whether this bias is more likely to have been detected due to the use of pictorial stimuli, as word stimuli have been argued to require a higher level of cognitive processing and hence be limited in threat value (Dear, Sharpe, Nicholas & Refshauge, 2011). Thus, it could be argued that the findings of studies *A* and *C* are consistent with a key claim of the TIM, that if stimuli are interpreted to possess a low threat value normal attentional processing will occur.

Despite the limited evidence for an initial orienting bias, studies *A* and *C* provide convincing evidence to suggest that under conditions of sustained attention, participants with chronic pain do show an AB to pain-related information. Although it could be argued that the presentation of word stimuli for longer stimulus durations of 1250ms-2000ms instead reflects an explicit cognitive bias, which only becomes apparent once the pain-related words have been interpreted and their meaning and relevance understood. This would accord with the TIM. For example, study A found that participants with chronic pain fixated significantly longer on sensory pain words relative to neutral words. This suggests that patients with chronic pain interpreted the pain-related words to pose a moderate level of threat as evidenced by their difficulty disengaging from the pain-related stimuli. Moreover, the findings of study C provide further support for the TIM, evidenced by shorter fixation durations for health-catastrophe words. As patients with chronic pain have been found to be vulnerable to ruminating or worrying over pain-related information (Crombez, Eccleston, Van Damme, Vlaeyen & Karoly, 2012), the presence of health-catastrophe words, reflecting the potential causes or consequences of pain, may have been interpreted as highly threatening by participants, as evidenced by their avoidance of such stimuli.

Nevertheless, it is important to recognise that study B found no evidence to suggest that chronic pain patients did show a bias towards pain-related facial images during maintained attention. Although such findings may be the result of the presence of other stimuli competing for attentional resources, as participants did show an initial orienting bias towards the pain-related images, but then avoidance – i.e. opting to view pleasant (i.e., happy) images to potentially reduce their level of threat. These findings would not be observable in studies A and C owing to the constraints of the visual probe tasks utilised. As such, it would be advantageous for future VPT research to build on this existing knowledge by incorporating trials which present pain-related pictures (cf. words) with stimuli of differing emotions (e.g., happy, angry). This would clarify whether biases in maintained attention reflect cognitive processes associated with pain-related stimuli per se, or simply pain-related word stimuli. Moreover, additional studies employing visual-scanning methodology are also needed to confirm the presence of an initial orienting bias.

Limitations

One limitation of the current review was the inability to accurately assess the presence of attrition bias due to the incomplete outcome data provided in multiple studies. Another limitation relates to the potential incomplete retrieval of grey literature. While key researchers were contacted, response rates were low. Thus, it remains unclear whether grey literature, which may have been eligible for inclusion in this review, has been missed. However, the main limitation is that only three eligible studies were identified, highlighting what an early stage review this is, and how further research is needed.

Conclusion

Eye-tracking technology is a superior measure of AB than traditional reaction time indices, offering a continuous measure that allows researchers to directly examine eye-gaze parameters. The findings of this review indicate that patients with chronic pain do show AB towards pain-related information, with two out of three studies indicating this bias to only occur during later stages of attentional processing. This partially supports the TIM. However, to clarify that such findings are not limited to studies using the VPT, further research using visual-scanning methodology is needed. Additionally, future VPT studies should include trials where pain-related pictorial stimuli (cf. words) are paired with happy/angry images. This would help to confirm whether biases in maintained attention reflect attentional processes associated with pain-related stimuli per se, or simply pain-related word stimuli.

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