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Do people with acute low back pain have an attentional bias to threat-related words?

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Abstract

Objectives: It has been hypothesised that attentional bias to environmental threats can contribute to persistent pain. It is unclear whether people with acute low back pain (LBP) have an attentional bias to environmental threats. We investigated if attentional bias of threat related words is different in people with acute LBP and pain-free controls.

Methods: People with acute LBP and pain-free people completed a free viewing eye tracking task. Participants were simultaneously presented with two words, a threat related word and a neutral control word. Threat related words were general threat, affective pain and sensory pain. We conducted linear mixed models to detect differences between acute LBP and pain-free participants on five eye tracking outcome measures (dwell time, first fixation, latency to first fixation, first run dwell time and number of fixations). We calculated absolute reliability, (standard error of measure), and relative reliability (intraclass correlation coefficients [ICC 2,1]) for each eye tracking outcome measures.

Results: We recruited 65 people with acute LBP and 65 pain-free controls. Participants with acute LBP had a higher proportion of fixations towards the affective pain words (M=0.5009, 95% CI=0.4941, 0.5076) than the pain-free controls had (M=0.4908, 95% CI=0.4836, 0.4979), mean between group difference = −0.0101, 95% CI [−0.0198, −0.0004], p=0.0422. There was no difference between acute LBP and pain-free controls for the remaining eye tracking outcome measures (all p>0.05). The only outcome measure that had an ICC of more than 0.7 was the latency to first fixation (affective pain words ICC=0.73, general threat words ICC=0.72).

Conclusions: When compared with pain-free controls, people with acute LBP looked more often at affective pain words relative to neutral control words. This may indicate a form of engagement bias for people with acute LBP. Attentional bias was not consistent across outcome measures or word groups. Further research is needed to investigate the potential role of attentional bias in the development of persistent pain.

Keywords: attention; attentional bias; back pain; eye tracking; pain; reliability.

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Introduction

Low back pain (LBP) is global health problem; in most countries of the world it is the leading cause of years lived with disability [1]. One factor contributing to the burden of

LBP is that most interventions have been shown to be only moderately effective [2–5]. A more complete understanding of the factors associated with LBP, and of the mechanisms that contribute to the development of chronic LBP (LBP that lasts longer than 3 months), may lead to the design of more effective interventions to reduce the burden of LBP [6, 7].

Attentional bias, a measurable systematic preference for types of sensory information [8], has been hypothesised to contribute to the development and maintenance of chronic pain [9, 10]. The findings from studies that have investigated the role of attentional bias in people with pain are mixed [8–11]. Results are dependent on the location of pain (e.g. LBP or headache), the duration of pain (acute or chronic), the method used to assess attentional bias (eye tracking or reaction time tasks), the instructions for the task (e.g. dot probe or free viewing), and the outcome measure used to assess attentional bias (e.g. initial orientating or attentional engagement) [8, 10–12].

Individual studies have reported people with chronic LBP have a faster fixation time to threat information compared to pain-free controls [13] and that people with chronic pain have more fixations on sensory pain words compared to pain-free controls [14]. Meta-analyses that have included non-eye tracking outcome measures have reported that people with chronic pain have an attentional bias towards sensory pain words compared to healthy controls. Two recent reviews, that included only eye tracking studies, reported that there were no consistent differences in attentional bias outcome measures between people with and without chronic pain [11, 15].

In people with acute LBP, attentional bias has been investigated by visually presenting different types of threatening words [9, 16]. Types of threatening words presented to participants include sensory pain words (e.g. sharp, burning), affective pain words (e.g. punishing, irritating) and general threat words (e.g. danger, harmful) [8, 12, 17]. Haggman [16] reported that compared to healthy controls, people with acute LBP had an attentional bias towards sensory pain words, but not towards affective pain words. Sharpe [9] reported that compared to healthy people, people with acute LBP had a visual attentional bias towards sensory pain words, and that avoidance of affective pain words was associated with the development of chronic LBP [9]. It is unknown how reliable the findings from these studies are as they used the dot probe task to assess attentional bias [9, 16]. The dot-probe task is known to have poor reliability [18–21] which can lead to decreased statistical power [22, 23], reduced magnitude of most statistics [24], inflated Type I and Type II errors [24, 25] and decreased probability of replicating effects [25, 26]. Recently, researchers have focused on eye tracking methods to assess attentional bias [27] as there is evidence that outcomes from this task are reliable [28] and the different components of attentional bias can more readily be assessed.

The aim of this study was to investigate whether people with acute LBP have an attentional bias to threatening information. Our objective was to test whether, compared to people without LBP, people with acute LBP have an attentional bias to threatening words when assessed using a free viewing eye tracking task. Our null hypothesis was that there would be no difference in attentional bias outcome measures between people with acute LBP and people without acute LBP.

Methods

Study design

We used a cross-sectional design to investigate whether people with acute LBP have an attentional bias when viewing pain-related words that is different from that of pain-free participants. We used a test-retest design to determine if previously established eye tracking outcome measures were reliable in people with acute LBP.

We published our statistical analysis plan with the Open Science Framework-OSF.IO/XHGQ8 [29]. Deviations from this plan are noted.

Participants

All participants in the study met the following inclusion criteria: 18–75 years old, good level of English proficiency and normal or corrected normal vision.

People with LBP were included if they fulfilled the following criteria: current LBP with or without leg pain, pain duration less than six weeks with at least a one month pain-free period prior to the current episode, self-reported average pain intensity over the past week of more than one out of 10 on a numeric rating scale (NRS), no suspected serious pathology or had been diagnosed with nerve root pain.

People were included as control participants in the study if they fulfilled the following criteria: 18–75 years old, no current pain, no history of a persistent pain condition (pain of more than one out of 10 on a pain intensity NRS on most days lasting more than three months), no pain in the past three months that had lasted for more than 72 h and was rated more than one out of 10 on an NRS.

Participants with acute LBP were recruited from primary care clinics in the Sydney metropolitan area, from the local community and from participants recruited to a randomised control trial of patient education for acute LBP [30], prior to randomisation. Pain-free participants were recruited from the local community; advertisements were placed on community notice boards and emailed to the local university community (UNSW).

Materials

Eye movements were recorded from the right eye at 500 Hz using an Eyelink 1000 eye tracker, (V4.56; SR Research; Ontario, Canada) with

remote camera upgrade, desktop mount, 16 mm lens and target sticker. Stimuli were displayed on a HP Compaq LA2205 wide LCD monitor with a 1680 × 1050 resolution, 32 bits per pixel, and a refresh rate of 60 Hz. The free viewing task was programmed with Experiment Builder (V1.10.1241; SR-Research; Ontario, Canada). We used a 5-point calibration procedure and accepted the calibration when the average error was less than 1° of visual angle [31]. All stimuli were presented in white on a black background. Testing took place in a purpose-built laboratory at Neuroscience Research Australia, Sydney, Australia. Lighting and temperature (23 °C) were standardised.

Questionnaires

We administered questionnaires on the day of testing. The questionnaire included demographic questions (age, gender, highest level of education), the Depression Anxiety and Stress Scales (DASS-21) [32], the Pain Catastrophising Scale (PCS) [33], the Back Beliefs Questionnaire (BBQ) [34], the Anxiety Sensitivity Index (ASI) [35] and the Pain Anxiety Symptoms Scale-20 (PASS-20) [36]. Acute LBP participants rated their average pain intensity over the past week using an 11 point NRS, anchored at left with '0 no pain' and at right with '10 pain as bad as it could be' [37]. Acute LBP participants also completed the Roland Morris Disability Questionnaire (RMDQ) [38] and the Pain Self-Efficacy Questionnaire (PSEQ) [39].

Eye tracking task

The free viewing task consisted of eight practice trials and 48 active trials. Each trial consisted of three sequential still screens (Figure 1). The first screen displayed a fixation cross (font: Times New Roman, normal; size: 90; location: x=840, y=525 [centre of screen]). Participants were instructed to fix their gaze on the centre of the cross. A researcher monitored the participants gaze from an adjacent room via real time output. Upon stable fixation on the cross for 2,000 ms, the researcher manually progressed the trial to the next screen. The second screen displayed two words (the stimuli), presented on the left and right sides of the screen for 4,000 ms (font: Tahoma normal; size: 30). One of the words was a 'threat word' and the other a 'neutral (control) word'. Participants were instructed to read both words on the screen and keep reading the words for as long as they remained on the screen. In order to maintain participant blinding to the real purpose of the task, they were instructed to read both words. The third screen, a blank screen, was automatically displayed for 1,000 ms. A drift check

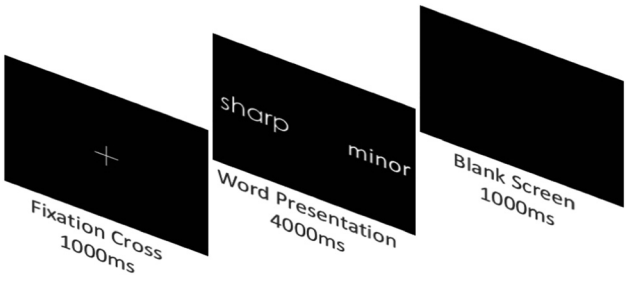

Figure 1: Three sequential screens presented as a free viewing to participants.

was performed prior to each trial. A calibration was performed when there was an error of more than 1° of visual angle.

To avoid participant fatigue, trials were arranged into three equal blocks of 16 trials. After each block, participants were given a self-timed break of at least 30 s. The threat words in each block of trials were from three categories (1) 'sensory pain', (2) 'affective pain' or (3) 'general threat'. Each block contained words from one threat category. The eight words from each threat category (target) were presented with a 'neutral' (control) word, matched to the threat word for length and frequency of use in everyday language, using an English control word search engine (Table 1) [40]. Word pairs were presented twice within each block, with each word presented once on the left and once on the right. Word pairs were randomised within each block and were not presented in consecutive order. The order of blocks was randomised.

Procedure

Referred participants were screened for eligibility by telephone. The true purpose of the study was not disclosed to the participants until after the testing. Participants were initially informed that the study aimed to investigate pupil dilation in response to words. On the day of testing, participants signed an informed consent form and then completed the eye tracking task. On completion of the task, all participants completed a battery of questionnaires. To enable assessment of reliability within the clinical population, LBP participants were invited to complete the eye tracking task a second time after they completed the task for the first time. Participants were debriefed as to the true purpose of the study after they completed the eye tracking task(s).

Data pre-processing

Data extraction: Raw gaze data were parsed into sequences of saccades and fixations, which were then extracted to SR Research Eye Link® Dataviewer (V2.3.22; Ontario, Canada). A 100-pixel interest area was set around each word. Fixations were trimmed, so that only fixations that occurred during the specified interest period were included. A 100 ms minimum fixation duration was applied. No other filters (for example merge of fixations or blink correction) were applied to the data.

Data reduction

Invalid trials were removed according to the following criteria:

(1) A fixation was not made to both interest areas. No detection of a fixation to both interest areas implies the eye tracker may have lost view of the eye and not regained the view of the eye, or the participant did not read both words [41].
(2) The first fixation latency to either interest area was less than 80 ms.
(3) Fewer than 3,000 ms (75%) of fixations were captured in the interest period [14].

If more than 25% of a participant's trials were excluded (<36 trials remained), the remainder of that participant's trials were also excluded [42].

Table 1: Threat and neutral words presented to participants.

Sensory pain		Affective pain		General threat	
Threat	**Control**	**Threat**	**Control**	**Threat**	**Control**
Sharp	Minor	Tiring	Orient	Crushing	Footpath
Ache	Eats	Unbearable	Delicately	Frightful	Stonework
Throbbing	Visionary	Punishing	Polishing	Terrifying	Theatrical
Cramping	Allusive	Exhausting	Decisively	Threat	Sounds
Burning	Samples	Annoying	Marketed	Scared	Drives
Dull	Maps	Troublesome	Nutritional	Danger	Fields
Shooting	Entering	Irritating	Installing	Harmful	Drifted
Pain	Hill	Nagging	Planner	Suffocating	Interviewee

Analysis plan

General principles: The statistical analysis was completed in STATA (v13.1; StataCorp, Texas, USA). Statistical tests were two-tailed with alpha set at p≤0.05. There was no correction for multiple testing.

Sample size

G*Power 3 was used to calculate the required sample size [43]. We required a sample of 64 participants per group for a *t*-test with a two-sided significance level ($p<0.05$) to detect an effect size of 0.5 with 80% power. We selected a medium effect size based on the results of Fashler et al. [14] who reported a medium effect size in an eye tracking study that compared the number of fixations to threat words in people with chronic pain compared to pain-free controls.

Outcome measures

Pre-planned primary outcome measure: Our primary outcome measure was the dwell time towards affective pain words within a 0–4,000 ms epoch (dwell time). To calculate the dwell time we subtracted the dwell time towards the neutral word from the dwell time towards the threat-related word for each trial.

Additional outcome measures

To compare our results to previous studies and inform current theories of attention bias in pain, we investigated additional outcome measures that were not part of our pre planned analysis. The additional outcome measures were:

(1) The proportion of first fixations towards the threat word (first fixation)
(2) The latency of the first fixation towards the threat word (latency to first fixation)
(3) The dwell time of the first run of fixations on the threat word (first run dwell time)
(4) The number of runs of fixations towards the threat word (number of fixations)

The proportion of first fixations towards the threat word indicates how likely the participant was to first look at the threat word compared to the neutral word. To calculate the first fixation, we coded each trial with a "1" when the first fixation was towards a threat word, or a "0" if the first fixation was towards the neutral word.

The latency of the first fixation toward the threat words indicates the delay for the first fixation to the threat word. To calculate the latency to first fixation, we used the time in milliseconds of the first fixation towards the threat word of the pre-specified outcome measure from the Dataviewer software "first_fixation_time".

The dwell time of the first run of fixations on the threat word indicates how long a participant spent looking at the threat word the first time they looked at the threat word. To calculate the first run dwell time, we divided the first run of the dwell time towards the threat word by the total first run dwell time to both words.

The total number of runs towards the threat word indicates the number of unique times the participant looked at the threat word compared to the neutral word. To calculate the number of fixations, we divided the number of runs in the interest area of the threat word by the total number of runs of both interest areas.

Attentional bias analysis

We conducted linear mixed models to investigate whether people with acute LBP have an attentional bias. Independent models were required to account for correlations between repeated measurements of the different word groups for the same participant [44–46]. We tested five models, one for each outcome measure (dwell time, first fixation, latency to first fixation, first run dwell time, number of fixations). In each model the outcome measure was the dependent variable. In all models the *participant group* (acute LBP, pain-free control) and *word group* (affective pain, general threat, sensory pain) were considered fixed main effects. The interaction between *participant group* and *word group* was included in each model. Participants were considered as random effects.

To investigate the difference between participants with and without acute LBP, we conducted independent *t*-tests when the p value was less than 0.5 for each of the linear mixed models. When a linear mixed model demonstrated a significant difference ($p<0.5$) we conducted an independent *t*-test for each word group. In each *t*-test we compared acute LBP participants and pain-free controls, the dependent variable was the relevant outcome measure from the linear mixed model.

Reliability analysis

We calculated the absolute and relative reliability for each of the five outcome measures to investigate whether previously reported eye

tracking outcome measures in pain-free participants are also reliable in people with acute LBP [28]. As reliability is a population specific construct, when comparing two participant groups reliability should be known for both groups. Additional variance in a pathological population may increase or decrease the absolute or relative reliability.

We used variance scores to calculate absolute and relative reliability. To assess absolute reliability, we calculated the standard error of measurement (SEM) using the formula: $SEM_{agreement} = \sqrt{\sigma^2_{retest} + \sigma^2_{residual}}$ [37]. To assess relative reliability, we calculated an ICC for dwell time outcome measure and word group using a two-way random effects model, with absolute agreement (ICC 2,1), using the formula: $ICC_{agreement} = \frac{\sigma^2_p}{\sigma^2_p+\sigma^2_{pt}+\sigma^2_{residual}}$ [47]. ICC values of more than 0.7 were classified as adequate [48, 49].

Protocol deviations

We planned to only calculate and report outcome measures and word types that have previously demonstrated adequate reliability [28]. In a deviation to our protocol we decided, based on reviewer feedback and in considering previous literature, to include outcomes measures and word types that did not meet the threshold for adequate reliability but that would allow our research to be compared to previous work and integrate with current proposed models of attentional bias. We conducted an unplanned analysis to include the effect of participant psychological factors on each eye tracking outcome measure. We conducted five linear mixed models, one for each eye tracking outcome measure (dwell time, first fixation, latency to first fixation, first run dwell time and number of fixations). In each model the eye tracking outcome measure was the dependent variable. In all models the *participant group* (acute LBP, pain-free control) and *word group* (affective pain, general threat, sensory pain) were considered fixed main effects. The interaction between *participant group* and *word group* was included in each model. The answers to the following questionnaires were included as independent variables: depression from the DASS-21 depression items, anxiety (state) from the DASS-21 anxiety items, stress from the DASS-21 stress items, catastrophising from the PCS, back beliefs from the BBQ, anxiety (trait) from the ASI and pain anxiety from the PASS-20. Participants were considered as random effects.

Results

Participants

We recruited 65 pain-free participants and 65 acute LBP participants. Of the LBP participants, 21 were recruited directly from primary care clinicians, 11 were recruited from the local community via email to the local university community and notices placed on notice boards and 33 were recruited as part of a randomised control trial of patient education [30, 50]. LBP participants were recruited between February 2015 and November 2016. Pain-free participants were recruited between August 2015 and August 2016. Characteristics of the sample are provided in Table 2. Severity of depression, anxiety, stress and pain catastrophising were significantly different between the acute LBP participants and pain-free participants.

Eye tracking data reduction

We excluded 7.4% (461 of 6,240) of trials because they were classified as invalid according to our *a priori* criteria. The number of trials excluded for each reason were: 65 trials because of no fixation to both interest areas, 78 trials because of a first fixation latency of less than 80 ms, and 166 trials because less than 75% (3000 ms) of fixations were captured during the interest period. As a result of the data reduction, three pain-free controls and two acute LBP

Table 2: Characteristics of non-pain controls and acute low back pain participants.

	Pain-free n=65		Acute LBP n=65					
	M	SD	*M*	SD	Difference	95% CI		p
Age	34.5	16.4	37.0	10.9	−2.4	−7.3	2.4	0.3215
Gender (N Female)	38 (58%)		37 (57%)					0.859
Education (Bachelor's degree)	42 (65%)		37 (57%)					0.369
Depression (State)	1.3	1.7	3.6	3.7	−2.3	−3.3	−1.3	0.0000
Anxiety (State)	1.2	1.5	2.6	2.8	−1.4	−2.2	−0.6	0.0006
Stress (State)	2.9	2.5	5.6	3.4	−2.7	−3.7	−1.7	0.0000
Catastrophizing	8.5	9.8	14.9	10.2	−6.4	−9.9	−2.9	0.0004
Anxiety (trait)	17.2	9.9	18.5	10.7	−1.6	−5.2	1.9	0.365
Pain anxiety	32.2	21.6	36.8	16.5	−4.6	−11.3	2.1	0.422
Back beliefs	24.0	6.2	25.9	5.7	−1.9	−4.0	0.1	0.066

Depression (State) = DASS-21 (Depression items); Anxiety (State) = DASS-21 (Anxiety items); Stress (State) = DASS-21 (Stress items); Catastrophising = PCS; Anxiety (Trait) = ASI; Pain Anxiety = PASS-20; Back Beliefs = BBQ.

participants had more than 25% of trials excluded. These participants were therefore excluded from the analysis.

Attentional bias

The results of the linear mixed models are reported in Table 3. There was no difference between acute LBP participants and pain-free participants for the primary outcome measure of dwell time. For the secondary outcome measures there was a group effect for the number of fixations. That is, compared to the pain-free controls, LBP participants looked more often at the threat words relative to the neutral words. There was no effect for the remaining secondary outcome measures (first fixation, latency to first fixation, first run dwell time).

To determine in which word group(s) acute LBP participants looked more often at the threat words, we conducted three independent *t*-tests, one for each of the word groups. In each *t*-test we compared acute LBP participants and pain-free controls, the dependent variable was the number of fixations. The acute LBP participants looked more often at the affective pain words (M=0.5009, 95% CI 0.4941, 0.5076) compared to the pain-free controls, (M=0.4908, 95% CI 0.4836, 0.4979), mean between group difference = −0.0101, 95% CI [−0.0101, −0.0004], p=0.0422.

Table 3: Linear mixed models comparing ALBP and pain-free participants attentional bias when viewing threat words.

Outcome measure	Coefficient	*b*	95% CI		p-Value
Total dwell time	47	−96	−55	150	0.366
Proportion of first fixations	−0.009	0.510	−0.027	0.0083	0.305
Latency to first fixation	38	564	−13	89	0.150
First fixation dwell time	−0.0004	0.493	−0.014	0.014	0.958
Number of fixations	0.01009	0.491	0.001	0.019	0.021

b, unstandardized.

For the number of fixations, there was no difference between people with acute LBP and pain-free controls for the general threat words or the sensory threat words (Table 4).

The results from the analysis that included the participant psychological variables are included in the Supplementary Material.

Reliability of eye tracking outcome measures in acute LBP participants

The average age of the 18 acute LBP participants who completed the eye tracking task twice was 46.4 (SD 15.9, Range = 20−75, seven females). The ICC(2,1) (relative reliability) and standard error of measurement (absolute reliability) results for each outcome measure and word category are reported in Table 5. The only outcome measure that had an ICC of more than 0.7 was the latency to first fixation (affective pain words ICC = 0.73, general threat words ICC = 0.72).

Table 5: Reliability of eye tracking outcome measures in acute low back pain participants.

Outcome measure	Word category	ICC (2,1)	95% CI		SEM
Dwell time	Affective	0.63	0.23	0.85	308
	General threat	0.48	0.04	0.77	242
	Sensory	0.24	−0.23	0.62	361
First fixation	Affective	−0.40	−0.78	0.10	0.05
	General threat	−0.02	−0.36	0.40	0.06
	Sensory	−0.08	−0.52	0.40	0.05
Latency to first fixation	Affective	0.73	0.41	0.89	79
	General threat	0.72	0.36	0.89	88
	Sensory	0.53	0.11	0.79	104
First run dwell time	Affective	0.13	−0.35	0.56	0.05
	General threat	0.52	0.10	0.79	0.03
	Sensory	−0.02	−0.50	0.45	0.05
Number of fixations	Affective	0.21	−0.29	0.61	0.03
	General threat	0.40	−0.09	0.73	0.02
	Sensory	0.45	0.00	0.75	0.02

SEM, standard error of measurement.

Table 4: Between group *t*-test for the proportion of the number of fixations towards the threat word for each word group.

Word group	Group	Mean	Mean 95% CI		Between group difference	95% CI of between group difference		p-Value
Affective	ALBP	0.5009	0.4941	0.5076	−0.0101	−0.0198	−0.0004	0.0422
	Pain-free	0.4908	0.4836	0.4979				
General threat	ALBP	0.5013	0.4956	0.5071	-0.0076	-0.0165	0.0014	0.0959
	Pain-free	0.4937	0.4868	0.5007				
Sensory	ALBP	0.4983	0.4931	0.5035	−0.0013	−0.0085	0.0059	0.7204
	Pain-free	0.4970	0.4919	0.5020				

Discussion

Our aim was to investigate whether people with acute LBP have an attentional bias to threatening information. We found no difference between people with acute LBP and pain-free controls in our primary outcome measure of dwell time when viewing threat related words. That is, there was no difference in how long people with acute LBP looked at threat-related words, when compared to people who are pain-free. In addition, there was no difference between the groups for the proportion of first fixations to the threat word, the latency of the first fixation to the threat word, or the dwell time of the first run of fixations to the threat word. The results did reveal that, when presented with an affective pain word and a neutral word, the degree to which people with acute LBP look more often at the affective pain than the neutral word, was greater than it was in people who are pain-free.

In contrast to reliability data from healthy controls [28], our results indicate that absolute reliability and relative reliability for dwell time was not adequate when acute LBP participants viewed general threat words or sensory pain words, but adequate for the affective pain-related words. There was only adequate reliability for the latency to first fixation for affective and general threat words. The inconsistent results from the reliability analysis suggest that researchers need to be cautious when interpreting results of eye tracking studies using threat words [24, 25] and that replication of results is required to confirm findings [25, 26].

To interpret our results, we adopted the recently proposed eye tracking categories of initial orientating, attentional engagement and attentional maintenance [11]. We found no evidence of a bias for initial orientating (proportion of first fixations, latency to first fixation) or attentional maintenance (dwell time). We did find evidence of attentional engagement towards threat information as indicated by the number of visits to the threat word interest area. At first these results may seem counterintuitive. People with acute LBP looked more often at a threat stimulus but not for a longer duration. It has been suggested that attentional engagement reflects a pattern of disengagement followed by re-engagement [11]. From an evolutionary perspective it is advantageous that once a potential threat is identified, that we are on the lookout for further evidence of the potential threat [51]. It may be that the affective pain words were processed as potentially threatening and therefore participants looked at them more often, however it was not salient enough to warrant continual distribution of resources in the form of attentional maintenance (dwell time).

We hypothesise that attentional engagement was only observed for affective pain words as a bias towards the affective component of pain may require an initial unpleasant experience in the form of acute clinical pain. There was no difference in attentional engagement for sensory pain words and general threat words as potentially both groups of participants are equally likely to scan their environment for general threats and specific sensory threats. The affective component of pain is potentially the most dominant construct for influencing attentional processes in a clinical pain experience. When acute clinical pain is experienced, subsequent affective stimuli is likely to demand additional attentional resources. In a clinical sense this may mean people with acute pain are more likely to be influenced by emotionally salient information.

The findings from the current study should be treated with caution. We would not consider the results from the current study as strong evidence that attentional bias is a widespread and easily detectable phenomena in people with acute LBP. The number of fixations was analysed post-hoc and not included in our original analysis plan. The results from this study should be replicated to confirm the above theories.

In contrast with our findings, previous research has found that people with acute LBP have an attentional bias for sensory pain-related words but not affective pain-related words [9, 16]. These previous studies have used a dot probe task, assessing attentional processes at a single point in time. Dot probe tasks are limited in their ability to untangle the various components of attentional bias. In addition, there is a potential limitation with using sensory related threat words in reaction time tasks, as people in pain may be primed to attend towards sensory related threat words, particularly within the context of a pain experiment. It is estimated that 96% of people in pain use sensory pain-related words to describe their pain (e.g. sharp, achy), whereas 31% use affective pain-related words (e.g. annoying, nagging) [17]. One might expect then that sensory words are more likely to be vulnerable to priming effects, thus perhaps explaining why previous studies reported an attentional bias towards sensory words but not affective pain words [9, 16, 52]. Eye tracking tasks may be less vulnerable to these priming effects as different components of attentional bias can be investigated. Another reason for the contrasting results is that the sensory pain words in the current study demonstrated overall lower levels of reliability compared to the affective pain words and general threat words. Therefore, while previous studies have found that people in pain are more likely to attend towards sensory pain stimulus, we would caution the use of using sensory pain stimulus in reaction time tasks unless more reliable techniques are established to investigate sensory pain words [8, 12, 52].

Previous research indicates there is no evidence that people with chronic pain have an attentional engagement bias [14, 53]. This is not surprising as chronic pain is a complex experience and attentional processes in people with chronic pain are likely different to those in people with acute pain. Neither of the previous studies that investigated engagement bias in people with chronic pain explicitly tested an affective pain stimulus. Liossi [49] did use angry and happy faces as stimuli but this may not have effectively reflected the affective component of pain.

An important outstanding question from the current study is whether or not the pattern of attentional engagement observed in people with acute LBP is associated with the development of chronic LBP. Perhaps attentional bias in people with acute LBP plays a role in the development of persistent pain, or pain-related disability, or both. The vigilance-avoidance model proposes that a pattern of initial orientating followed by avoidance of threatening stimuli, in situations of high threat, predicts ongoing pain [10]. While the results of the current study do not support the vigilance-avoidance model, it remains possible that such a pattern may be evident in a longitudinal study design. The single previous study that investigated the role of attentional bias in the development of chronic pain used a dot probe task and as such evidence for attentional engagement or the vigilance-avoidance model cannot be determined [9]. Testing for evidence of the vigilance-avoidance model, or an engagement bias using reliable measures and prospective cohort designs seems to be an important future research direction.

We acknowledge the following limitations of the current study. We did not apply a blink correction or test the implications of additional filtering on the data. There are many filtering options available when investigating eye tracking data. We applied as few filters as necessary to allow as much of the raw data to be analysed as possible. Testing the effect of additional filters inflates the chance of a type I errors and potentially decreases the reproducibility of our findings. There are also strengths of the current work with regards to transparency of reporting and methodological rigour. That is, we lodged our protocol and statistical analysis plan on OSF, determined sample size according to an *a priori* power calculation, fully evaluated the reliability of our measures, and reported all deviations from our original protocol. These measures are now recommended practice in the pain field [54]. We did not collect data on how many participants were excluded or for what reasons limiting the ability to comment on the generalisability of the results. Finally, the study is likely underpowered. The power analysis was based on the effect size from a single study [14]. Meta-analysis findings report smaller effect sizes than the ones used to calculate the sample size in the current study [52].

The aim of the current study was to investigate whether people with acute LBP have an attentional bias to threatening information. We used threat related words as a proxy for threatening information. There are justifiable concerns with this approach. Words may not be ecologically valid and may not be a true representations of the categories from which the words are drawn. For example we used affective pain words such as exhausting to represent pain that is described as exhausting. There is currently no method to measure attentional bias directly and it should be acknowledged that measuring how long a person looks at a particular type of word is a proxy measure and may be influenced by many other factors that are currently not completely understood. A potentially more valid method would be to measure attention towards clinical pain itself or threat of future harm in people with acute LBP [55, 56].

In conclusion, our results suggest that there is evidence of attentional bias to threats in acute LBP participants compared to pain-free participants. We only found evidence of an engagement bias and no evidence for initial orientating or attentional maintenance. Furthermore, attentional bias was not consistent across word groups. We only found an engagement bias for the affective pain words. While we endeavoured to use reliable outcome measures, we found inconsistent reliability results in the current study for acute LBP participants. Future investigations of attentional bias should include a reliability analysis in the target population and with the specific eye tracking task used. Finally, future research should investigate prospective cohort studies using reliable measures to test whether attentional bias in people with acute LBP plays a causal role in the development of persistent pain, persistent pain causes an attentional bias, neither or both.

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Informed consent: Informed consent has been obtained from all individuals included in this study.

Ethical approval: The research related to human use complies with all the relevant national regulations, institutional policies and was performed in accordance with the tenets of the Helsinki Declaration, and has been approved by the authors' institutional review board or equivalent committee.

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