Attentional bias malleability as a predictor of daily pain interference

Research Paper

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Attentional bias malleability as a predictor of daily pain interference

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Abstract

Despite a preponderance of pain-related attentional bias research, little is known about how these biases arise and change over time. We tested whether the degree of attentional bias *malleability*, that is, ability to acquire and relinquish patterns of selective attention towards pain information, predicts daily pain interference. Individuals with chronic pain (N = 66) completed a novel attentional bias malleability procedure based on a modified dot-probe paradigm. Participants received a contingency that encouraged an attentional preference toward and away from pain words across 2 counterbalanced blocks, and attentional bias was assessed before and after each contingency block. Participants then completed a daily diary for 7 days, including the Patient-Reported Outcomes Measurement Information System-29 pain severity and interference. Multilevel modelling was conducted to predict daily pain interference from attentional bias malleability constructs, controlling for pain severity and demographic factors. Greater attentional bias ($F_{1,391} = 3.97$, $P = 0.047$), greater readiness to acquire an attentional bias ($F_{1,389} = 4.92$, $P = 0.027$), and less readiness to lose an acquired attentional bias toward pain ($F_{1,354} = 5.18$, $P = 0.024$) all predicted less pain interference. There was also an interaction between pain severity and overall attentional bias malleability ($F_{1,62} = 5.48$, $P = 0.023$), such that as pain severity increased, those who showed greater attentional bias malleability showed less corresponding increase in their pain interference than those who showed less attentional bias malleability. This study adds new thinking to the dynamic nature of attentional bias and how such biases might arise and influence pain outcomes.

Keywords: Attentional bias, Chronic pain, Attentional malleability

1. Introduction

For more than 2 decades, preferential attention to pain (and pain-related information) has been theoretically considered an important factor in the maintenance of pain and associated disability.[32] Research has rapidly expanded in this area, with 2 meta-analyses finding small differences in attentional bias to pain information between individuals with and without chronic pain.[8,26] However, despite a sound theoretical basis, research generally fails to find an association between attentional bias and pain-related antecedents, consequences, or, indeed, degree of pain itself.[8] This is particularly evident in trials attempting to modify attentional bias, where it has been difficult to establish whether a reduction in attentional bias forms the mechanism of change for improved pain outcomes.[22,23,27] What has not been considered is the degree to which an individual can adapt their attentional preference in response to changing environmental conditions that render a particular pattern more or less adaptive. Individual differences in the ability to acquire and relinquish patterns of selective attention, here termed "attentional bias malleability," may influence the degree to which the presence of pain interferes with functioning.

Research has found relationships between attentional bias malleability and anxiety responsiveness. In particular, malleability of attention *toward* anxiety-related information has been shown to predict increased trait anxiety in response to stress,[5] better adjustment to the transition from primary to secondary school[15] and a greater reduction in anxiety after a cognitive-behavioural intervention.[4] However, malleability of attention *away* from anxiety-related information did not predict anxiety-related outcomes in response to changes in environmental stressors.[5,15] No studies to date have assessed the relationship between malleability towards vs away from pain information and the relative impact on pain outcomes.

Here, we test whether attentional bias malleability predicts pain outcomes (ie, pain severity and pain interference, as measured on the Patient-Reported Outcomes Measurement Information System-29 [PROMIS-29]).[3] Furthermore, given past findings showing that the interaction between attentional bias and pain severity predicts daily pain interference[20] and consistent with models of pain (interference) such as the misdirected problem solving model,[9] we evaluated the hypothesis that greater

Sponsorships or competing interests that may be relevant to content are disclosed at the end of this article.

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Supplemental digital content is available for this article. Direct URL citations appear in the printed text and are provided in the HTML and PDF versions of this article on the journal's Web site (www.painjournalonline.com).

PAIN 164 (2023) 598–604

http://dx.doi.org/10.1097/j.pain.0000000000002744

attentional bias malleability would predict less pain interference, controlling for pain intensity.

Using a standard dot-probe–based attentional bias modification procedure, participants were delivered alternate contingencies that favoured attention towards *and* away from pain information across sequential blocks. Changes in attentional bias across these blocks were assessed as predictors of subsequent pain outcomes, measured using ecological momentary assessment.

2. Method

This study was preregistered (https://osf.io/edr6k/) and approved by the University of Sydney's Human Research Ethics Committee.

2.1. Participants and sampling procedures

Participants were undergraduate students recruited across 2 large Australian universities, who participated in exchange for course credit. These students could choose to complete a battery of screening questionnaires, which enabled studies to be offered to individuals based on their screening results. Only individuals who had indicated that they were aged between 18 and 60 years, were experiencing persistent or chronic pain that had lasted for at least 3 months, and were able to see and sign up for this study were included. Participants were also required to be fluent in English, have normal (or corrected to normal) vision, and no history of head injury. To use the electronic diary, participants also needed to have a smartphone. The target sample size for this study was 60 participants, based on similar diary-based studies in this area.[20] To allow for 20% dropout and 20% exclusion, we aimed to recruit 100 participants. A total of 104 participants signed up for the study.

2.2. Survey materials

The PROMIS-29[3,7] is a measure of general physical and mental well-being over the past 7 days. It includes 4 questions across each of the following 7 domains: pain interference, anxiety, depression, physical functioning, sleep difficulties, fatigue, and ability to participate in social roles and activities. These items are rated on a 5-point Likert scale. The PROMIS-29 also includes a single item on pain severity, which is rated on an 11-point Likert scale from 0 (no pain) to 10 (worst pain imaginable). Although the whole scale was used, only the pain interference and pain severity items are reported here because they are most pertinent to the prespecified study aims. The PROMIS was used at baseline as described and was also adapted for daily use in the diary by reducing the reference time to the previous 24 hours. Other studies have demonstrated validity of adapting PROMIS questionnaires in this way for daily diary use.[20]

The study included demographic questions assessing age, gender, and ethnicity, as well as items assessing pain experience, including years lived with pain, and current pain intensity.

2.3. Malleability task

The malleability task is based on the paradigm as used in other studies.[4,5,15] The malleability paradigm consisted of 5 blocks of trials using the dot-probe task: 3 attentional bias assessment blocks where no contingency existed between pain and neutral stimuli and 2 contingency blocks where the contingency favoured selective attention towards either the pain or the neutral stimulus. In one contingency block, the contingency favoured attention towards pain stimuli, and in the other block, the contingency favoured selective attention away from pain stimuli, with the order counterbalanced. **Figure 1** provides a visual representation of the malleability paradigm.

Across all trials of the malleability assessment task, the basic trial structure was the same. Each trial commenced with a fixation cross in the middle of the screen. This cross then disappeared and was replaced by a word pair (1 pain-related and 1 neutral), appearing above and below the fixation cross (3 cm apart). The location of the pain-related word was counterbalanced across trials. After 500 milliseconds, the word pair disappeared and was replaced by a probe, either "<" or ">," occurring in either the same location as the pain-related word (pain congruent trials) or the same location as the neutral word (pain incongruent trials). Participants responded to the probe as quickly and accurately as possible by pressing a button on their keyboard corresponding to the type of probe presented. The next trial only commenced once a response has been made. To increase accuracy, if a participant pressed an incorrect button on the keyboard, an "incorrect" message was displayed for 3 seconds, before the next trial could be commenced.

For each *assessment block*, participants were presented with 96 trials in a random order, in which the probe was equally likely to follow the pain word or neutral word. Faster responses to probes after pain words compared with probes after neutral words are taken to indicate an attentional bias towards pain information. The *contingency blocks* each consisted of 288 trials. In one block, probes consistently followed the pain word (contingency favouring attention towards pain information, ie, pain congruent block), whereas in the other block, the probes consistently followed the neutral word (contingency favouring attention away from pain information, ie, pain incongruent block). Each participant completed one of each block, with the order counterbalanced across participants.

Across assessment and contingency blocks, stimuli were pain and neutral words, matched for number of letters and syllables. See Supplementary File 1 for the list of words used (available at http://links.lww.com/PAIN/B691). A total of 72 pain words and 72 neutral words were used across the study, divided into 3 lists of 24 words, presented 4 times for assessment blocks and 12 times for training blocks. To not influence attentional bias assessment by word familiarity, the first word list was used for the first assessment and first training blocks, the second word list was used for the second assessment and second training blocks, and the third word list was used for the final assessment block. The presentation order of the word lists was counterbalanced across participants.

An *attentional bias index* was calculated for each of the 3 attentional bias assessment blocks (*AB1, AB2,* and *AB3*), as per the traditional attentional bias index. To calculate this index, average response time latencies for pain congruent trials were subtracted from average response time latencies for pain incongruent trials. The first attentional bias index (*AB1*) was used as a measure of baseline attentional bias. To assess attentional bias malleability, 3 indices were extracted from the attentional bias assessment blocks. A measure of attentional bias malleability towards pain (*AMtowards*) was calculated as the difference between attentional bias after a pain congruent block and attentional bias before a pain congruent block. Higher values on this index indicate greater readiness to acquire an attentional bias towards pain in response to the pain congruent block. An attentional bias malleability away from pain (*AMaway*) was similarly calculated as the difference between attentional bias

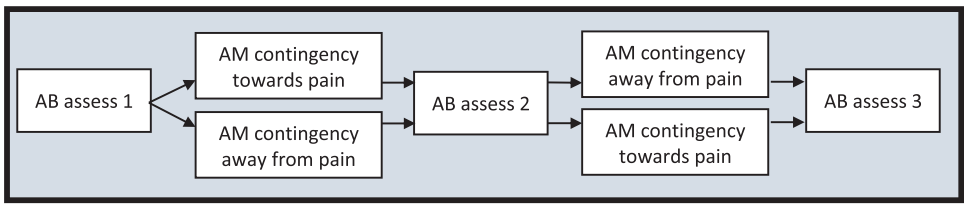

Figure 1. Attentional bias malleability procedure. Participants complete 2 cue-probe contingency blocks (one where contingency favoured selective attention toward pain stimuli and one where contingency favoured selective attention away from pain stimuli, with the order counterbalanced across participants), separated by attentional bias assessment blocks. AB, attentional bias; AM, attentional bias malleability.

after a pain incongruent block and attentional bias before a pain incongruent block. Higher values on this index indicate greater readiness to acquire an attentional bias away from pain. Finally, an overall attentional bias malleability (*AMoverall*) index was calculated as the total extent to which attention changed in line with each contingency block across the malleability procedure. This was calculated as the sum of the absolute changes across each block: $|AB2 - AB1| + |AB3 - AB2|$.

2.4. Procedure

This study consisted of 2 parts: a baseline assessment session and a week-long daily diary. The baseline session was conducted online through Millisecond Inquisit Web[14] and took approximately 45 minutes. After obtaining informed consent, participants completed a screen calibration procedure to ensure consistency in presentation across different screens before completing demographic items and questionnaires. They then completed the malleability paradigm as described.

After completing the baseline session, participants were emailed instructions for the diary component of the study, which they commenced the following evening. This was completed through the SEMA3 App, an ecological momentary assessment (EMA) app developed at the University of Melbourne for EMA research. At 7 PM each night for 7 nights, participants received a push notification inviting them to complete that day's pain diary. Participants were given 3 hours in which to complete the diary for that day. The diary consisted of the PROMIS-29 questions adapted to refer to outcomes over the past 24 hours. The diary took approximately 2 minutes per day to complete.

2.5. Data cleaning and analysis

Given that chance accuracy on the task was 50% and in line with a similar exclusion criterion adopted in past studies,[11,16,25] any participant falling below 75% accuracy on any of the attentional bias blocks was excluded. In addition, if any participants indicated at the time of testing that they had not experienced chronic pain for >3 months, their data were also excluded from analysis. Finally, as a quality criterion, data from participants who did not complete at least 4 of the 7 pain diaries, or who did not complete all study questionnaires and tasks, were excluded. This is consistent with previous diary-based research.[18,20]

The reaction time data from dot-probe assessment blocks were cleaned by first removing incorrect trials and trials with <150 milliseconds or >2000 milliseconds response times (3.2%-5.3% of trials across blocks). Then, trials with a median absolute deviation of >2.5 were removed (5.8%-7.7% of trials across blocks). Data were cleaned and sorted in RStudio.[19] Baseline data analysis was conducted in IBM SPSS.[13] Multilevel data analysis was conducted in jamovi,[24] using the general analyses for linear models (GAMLj) module.[10] Fixed effects were used for repeated measures indicators, and random effects were used for subject-level factors. The Satterthwaite method was used for calculating degrees of freedom. Effect sizes (η_p^2) were calculated in RStudio using the "effectsize" package, providing the proportion of variance explained by each predictor. As a rough indicator, effect size values of 0.01, 0.06, and 0.14 were taken to represent small, medium, and large effect sizes, respectively[6]; although as these guidelines were developed for η^2, they should not be over-interpreted.

3. Results

3.1. Descriptive statistics

Of the 104 participants who signed up to the study, 4 participants withdrew due to technical difficulties (n = 2), lack of time (n = 1), or did not specify a reason (n = 1). An additional 19 participants did not complete all parts of the study (n = 5 completed part 1 but not part 2; n = 14 completed <4 diaries). Of the 81 participants who did complete the study, 15 participants were excluded at the data cleaning stage (n = 8 reported not experiencing chronic pain at the time of testing, n = 6 did not complete the attentional bias assessment with sufficient accuracy, and n = 1 had incomplete data). The final sample was 66 participants who were included in all analyses.

Of the final sample, 55 identified as female, 10 identified as male, and 1 identified as nonbinary. Where gender was included as a covariate, the nonbinary participant's data were combined with female participants' data to create a dummy-coded categorical variable (ie, male vs female/nonbinary). The sample ranged in age from 18 to 56 years, with a mean of 23.83 years (SD = 8.91). Participants mostly identified as Australian or Aboriginal Australian (68%), although there was diversity in the remaining ethnicities (11% Asian, 6% Caucasian/British, 6% European, 6% Middle Eastern, 1.5% African, and 1.5% Russian). All participants were university students.

To be eligible for this study, participants needed to have experienced persistent pain for at least 3 months. Years lived with pain varied widely between <1 year and 20 years (M = 4.48 years, SD = 4.76), with 78.8% of the sample having lived with chronic pain for longer than 1 year. At the time of baseline testing, on average, participants reported a pain severity level of 3.83 of 10 (SD = 1.88).

3.2. Baseline correlations between attentional bias and Patient-Reported Outcomes Measurement Information System pain outcomes

Baseline correlations between attentional bias variables and PROMIS pain variables are presented in **Table 1**. *AMtowards* was

negatively associated with baseline pain severity ($r = -0.269$, $P = 0.029$), such that those with greater pain severity showed less attention bias malleability towards pain. Post hoc analyses revealed that the association between *AMtowards* and pain severity was no longer significant ($r = -0.088$, $P = 0.417$) when controlling for baseline attentional bias through partial correlations. There were no other significant correlations between baseline attentional bias or attentional bias malleability indices and baseline PROMIS pain scores.

3.3. Attentional bias malleability predicting daily pain severity

First, multilevel analyses were conducted to predict daily pain severity from malleability constructs, as shown in **Table 2**. Gender, age, malleability block presentation order (away-towards vs towards-away), and baseline attentional bias were included as covariates, and the 3 malleability indices (*AMoverall*, *AMtowards*, and *AMaway*) were included as predictors of daily pain severity. In this analysis, no covariates were significant predictors of daily pain severity. Baseline attentional bias, *AMtowards*, and *AMaway* were also not significant predictors of daily pain severity. However, *AMoverall* significantly negatively predicted pain severity, such that those with greater attentional bias malleability reported less daily pain severity ($F_{1,58.2} = 4.09$, $P = 0.048$, $\eta_p^2 = 0.07$), representing a moderate effect size.

3.4. Attentional bias malleability predicting daily pain interference

Next, multilevel analyses were conducted to predict daily pain interference from malleability constructs. Gender, age, malleability block presentation order (away-towards vs towards-away), baseline attentional bias, and daily pain severity were included as covariates, and the 3 malleability indices (*AMoverall*, *AMtowards*, and *AMaway*), as well as their interaction with daily pain severity, were included as predictors of daily pain interference.

Results indicate that gender, age, and daily pain severity were significant predictors of daily pain interference (**Table 3**). That is, those who identified as female/nonbinary, were older, or reported greater daily pain severity also had greater daily pain interference. Controlling for these constructs (and block order, which was not significant), there were main effects for baseline attentional bias ($F_{1,391} = 3.97$, $P = 0.047$, $\eta_p^2 = 0.01$), such that those with higher baseline attentional bias to pain showed greater pain interference. Although there was not a main effect of *AMoverall*, both *AMtowards* ($F_{1,389} = 4.92$, $P = 0.027$, $\eta_p^2 = 0.01$) and *AMaway* ($F_{1,354} = 5.18$, $P = 0.024$, $\eta_p^2 = 0.01$) were associated with pain interference with a small effect size, such that greater readiness to acquire an attentional bias towards pain predicted greater pain interference and greater readiness to lose an attentional bias toward pain predicted less pain interference, respectively.

There was also an interaction effect between daily pain severity and *AMoverall* ($F_{1,62} = 5.48$, $P = 0.023$, $\eta_p^2 = 0.08$), such that as daily pain severity increased, those who showed greater overall malleability in their attentional bias showed less increase in their daily pain interference than those who showed less attentional bias malleability. This interaction effect was of a moderate effect size and is illustrated in **Figure 2**.

4. Discussion

The aim of this study was to determine the extent to which attentional bias malleability predicted daily pain interference in people with chronic pain. We tested whether degree of attentional malleability, and in particular, greater malleability in directing attention towards and away from pain information, predicted pain interference over the subsequent week. We found that greater attentional bias to pain information, less malleability in attention away from pain information, and greater malleability in attention towards pain information predicted greater pain interference. Furthermore, consistent with predictions, we found an interaction between overall attentional bias malleability and pain severity, such that with increasing pain severity, greater malleability served to buffer against the impacts of pain severity, resulting in lesser increases in pain interference.

Attentional bias towards pain information predicted daily pain interference above the effects of pain severity. This is consistent with previous research showing that people with chronic pain display an attentional bias towards pain information,[8,26] although an *association* between attentional bias and pain-related outcomes has not been consistently established.[8] Surprisingly, little research tests the association between attentional bias and pain outcomes prospectively,[27] yet such research is important to establish attentional bias as a predictor, rather than an epiphenomenon, of pain experience. Given no baseline associations between attentional bias and pain were found, but attentional bias predicted daily pain interference, above pain severity, our findings tentatively indicate that attentional bias could precede pain interference, rather than being a product of pain itself. Theoretical models suggest a causal role of attentional bias in pain,[31,32] although evidence from longitudinal and interventional studies with clinical samples is less clear.[27] Further investigation of the potential causal role of attentional bias and attentional bias malleability through experimental manipulation is required, particularly before or during the development of chronic pain.

The direction of malleability in attentional bias was found to predict pain interference, controlling for pain severity. That is, individuals who displayed greater propensity to adapt their pattern

Table 1

Correlations between baseline measures of attentional bias, attentional bias malleability, and Patient-Reported Outcomes Measurement Information System pain measures.

	ABpre	AMoverall	AMtowards	AMaway	Mean	SD
Pain interference	−0.009	−0.196	−0.079	0.135	10.91	4.20
Pain severity	0.104	−0.058	−0.269*	0.063	4.74	1.73
Mean	0.11	51.11	−0.10	0.13		
SD	21.77	32.98	32.07	34.27		

*$P < 0.05$, **$P < 0.01$.

AB, attentional bias; ABpre, baseline attentional bias index; AMaway, change in attentional bias during training away from a pain block (more negative numbers signify a greater decrease in attentional bias); AMoverall, absolute change in attentional bias across the 3 bias assessment blocks; AMtowards, change in attentional bias during training toward a pain block (more positive numbers signify a greater increase in attentional bias).

Table 2

Attentional bias constructs predicting daily pain severity.

Variables	Estimate	SE	df	T	*P*	η_p^2
Intercept	3.449	0.330	58.0	10.440	<0.001	0.65
Gender	−0.571	0.663	58.1	−0.860	0.393	0.01
Age	−0.042	0.027	57.9	−1.569	0.122	0.04
Block order	−0.117	0.475	58.0	−0.246	0.807	0.001
ABpre	−0.015	0.016	58.0	−0.946	0.348	0.02
AMoverall	−0.015	0.007	58.2	−2.023	0.048	0.07
AMtowards	−0.005	0.012	58.4	−0.413	0.681	0.003
AMaway	−0.009	0.011	58.7	−0.804	0.424	0.01

η_p^2, partial eta squared; ABpre, baseline attentional bias index; AMaway, attentional bias malleability away, ie, change in attentional bias during training away from a pain block (more negative numbers signify a greater decrease in attentional bias); AMoverall, attentional bias malleability, ie, absolute change in attentional bias across the 3 bias assessment blocks; AMtowards, attentional bias malleability toward, ie, change in attentional bias during training toward a pain block (more positive numbers signify a greater increase in attentional bias).

of attention bias towards pain showed greater pain interference, and reciprocally, those who displayed a greater propensity to adapt their pattern of attention bias away from pain showed less pain interference. This pattern suggests that greater malleability to acquire an attentional bias, and more difficulty or resistance to decreasing an attentional bias, may lead to greater vulnerability to pain interference. This is consistent with the finding that those who had already acquired an attentional bias to pain information at baseline showed greater pain interference, while also potentially explaining how this attentional bias may arise. One previous study found a similar pattern in anxiety, in which people who showed greater readiness to acquire a threat-related attentional bias were more likely to subsequently show an increase in anxiety symptoms over time in response to sustained stress.[5] However, greater readiness to acquire an attentional bias has also shown benefits such as predicting a better treatment response to cognitive behavioural therapy for social anxiety[4] and a greater reduction in anxiety symptoms in the adjustment from primary school to secondary school.[15] In some circumstances, acquiring an attentional bias could be helpful in managing a current threat, whereas for chronic pain where pain no longer signals physical damage, acquiring an attentional bias may be less adaptive. Circumstances (eg, acute pain) in which acquiring an attentional bias towards pain may be adaptive should be investigated.

Table 3

Attentional bias constructs predicting daily pain interference, controlling for pain severity.

Variables	Estimate	SE	df	T	*P*	η_p^2
Intercept	2.375	0.136	298.1	17.504	<0.001	0.51
Gender	−0.922	0.275	285.1	−3.351	<0.001	0.04
Age	0.024	0.010	376.6	2.498	0.013	0.02
Block order	0.054	0.183	360.7	0.293	0.770	0.002
Pain	0.880	0.057	56.7	15.337	<0.001	0.81
ABpre	0.012	0.006	390.7	1.993	0.047	0.01
AMoverall	−0.002	0.003	374.5	−0.745	0.457	0.001
AMtowards	0.010	0.004	388.9	2.217	0.027	0.01
AMaway	0.010	0.004	354	2.275	0.024	0.01
Pain × AMoverall	−0.004	0.002	61.9	−2.340	0.023	0.08
Pain × AMtowards	0.000	0.002	74.2	−0.212	0.833	0.001
Pain × AMaway	0.001	0.002	70.7	0.505	0.615	0.004

ABpre, baseline attentional bias index; AMaway, attentional bias malleability away, ie, change in attentional bias during training away from a pain block (more negative numbers signify a greater decrease in attentional bias); AMoverall, attentional bias malleability, ie, absolute change in attentional bias across the 3 bias assessment blocks; AMtoward, attentional bias malleability toward, ie, change in attentional bias during training toward a pain block (more positive numbers signify a greater increase in attentional bias); Pain, daily pain severity.

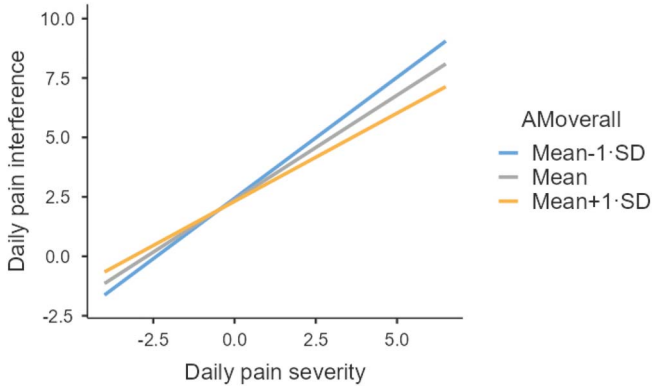

Figure 2. Interaction between attentional bias malleability and daily pain severity, predicting daily pain interference. Graph represents interaction, controlling for all other variables in the modelling, and therefore, values represent adjusted scores rather than observed scores. Pain severity and pain interference originally measured on 0 to 10 numeric rating scales, with higher numbers indicating higher pain severity and pain interference. AMoverall, attentional bias malleability overall.

This study also explicitly tested the malleability of attention by exposing participants to contingencies favouring attention both towards and away from pain information. The degree to which attention was malleable overall did not predict pain interference on its own but did interact with pain severity, such that attentional bias malleability served as a buffer against increasing pain severity. That is, with greater attentional bias malleability, pain severity and interference were aligned at lower levels of pain, but with increasing pain severity, interference increased less than would be expected, given higher levels of pain. Taken together, these findings indicate that although attentional bias is problematic in potentially contributing to increased pain interference, greater malleability in attention can help to buffer against the impacts of pain at least at higher levels of pain.

This may have implications for attentional bias modification techniques in identifying who may benefit most, and respond best, to such interventions. Furthermore, the repeated delivery of cognitive bias modification strategies may in fact increase attentional bias malleability. This increase in malleability may help an individual to adapt their attention as needed, creating a buffer against pain-related interference. Individual differences in attentional bias malleability may help to explain why attentional bias modification techniques are generally effective, but effects remain small and are not consistent across individuals.[27] Furthermore, some attentional bias modification trials have found that the control group (in which trials towards and away from concern-relevant stimuli were equally presented) shows improvements in outcomes.[1,21] This control procedure may train individuals to attend toward and away from pain more flexibly, although a more explicit test of this hypothesis is needed.

There is growing recognition that, rather than biased attention to threat or pain content being "good" or "bad," at times attention needs to be directed towards real threats to avoid legitimate danger, whereas other times attentional bias is less useful, particularly when the potential threat does not require action or is not in fact dangerous.[17] As such, whether heightened attention to certain visual

information is helpful or not needs to be assessed within the context in which it occurs.[21] The ability to direct attention toward or away from certain information in response to changing situational demands may in fact be more important than an average propensity to attend to one type of stimulus. Attentional bias malleability may draw on cognitive processes, such as attentional control,[2] or cognitive flexibility more broadly. In light of this study, further research to identify the cognitive factors underpinning attentional malleability could test whether aspects of attentional control such as attention switching, cognitive flexibility, or other cognitive biases, such as interpretation bias, can account for the present findings in pain. These findings would have implications for treatment targets. For example, if attentional bias malleability is an aspect of cognitive flexibility, then treatments such as acceptance and commitment therapy (ACT), which target psychological flexibility, could potentially produce benefits by facilitating adaptive changes in attention bias malleability. Although there is promise for the benefits of ACT for pain,[12,30] the underlying cognitive mechanisms that facilitate adaptive changes from ACT have not been thoroughly described, and it is possible that attentional bias malleability could represent one such candidate process.

It is worth noting that although attentional bias malleability as conceptualised in this study is entirely new, the techniques used to assess malleability constructs were not. This study relied on the dot-probe and adapted attentional bias modification paradigms, and therefore, limitations of reaction time–based assessments of attentional bias to pain-related information apply here. Further investigation of these processes with other attentional assessment methods, such as eye tracking, or other pain-related stimuli, such as conditioned pain cues, would help us to establish how robust the present findings are across these different assessment methods. It is also worth noting that we found gender differences in pain interference, which we controlled for. However, our sample was heavily skewed towards women, with a small male sample, and only 1 person identifying as non-binary, which limited our ability to test whether our hypotheses applied equally across different genders. Further research with robust sample sizes and a more balanced gender representation would allow for better delineation of gender effects. Furthermore, our sample all experienced persistent pain (>3 months), yet they were drawn from a university sample and were not necessarily treatment seeking. Although the findings have potential clinical implications because the study did not explicitly seek to recruit a clinical treatment-seeking sample, it will be critical for future research to replicate and extend these findings with a clinical treatment-seeking pain sample. Finally, our study was conducted entirely online, which was necessary given the impacts of the COVID-19 pandemic, to enable people with chronic pain to safely participate. Nonetheless, our data indicate high engagement with the study and its tasks, with high accuracy on the dot-probe task, and high levels of diary completion.

This is the first study to investigate individual differences in malleability of attention bias toward (and away from) pain information as a predictor of (fluctuations in) daily pain outcomes and reflects current trends to consider attentional bias as a dynamic, context-dependent construct. Going beyond cross-sectional methods, this study used a 7-day pain diary, providing real-world ecological momentary assessment data on pain experiences that are less prone to recall bias, allowing more sensitive mapping of pain severity and pain interference over time.

5. Conclusions

This study is the first to test whether attentional bias malleability predicts daily pain interference above pain severity. Alongside the traditional attentional bias index, being more ready to acquire (rather than lose) an attentional bias and showing less malleability in attention were important in explaining subsequent pain interference. This study used a novel, ecologically valid, daily pain diary to better capture pain outcomes. This study adds new thinking to the dynamic nature of attentional bias, and in particular, how attentional bias malleability might buffer against the impacts of pain interference. With further research, these findings may help to improve the efficacy of current attentional bias modification techniques, enabling more targeted approaches based on individual differences in attentional bias malleability, to improve current pain prevention and management strategies.

Conflict of interest statement

The authors have no conflicts of interest to declare.

Acknowledgements

A.M. Hughes is supported by funding from the National Institute for Health Research (NIHR) Biomedical Research Centre at South London and Maudsley NHS Foundation Trust. D. van Ryckeghem is supported by funding from FNR Core Junior programme (Painflex; Nr. 12671141). J. Todd and D. van Ryckeghem are investigators on ARC Discovery Project DP210101827. No other authors have funding sources to declare.

Appendix A. Supplemental digital content

Supplemental digital content associated with this article can be found online at http://links.lww.com/PAIN/B691.

Article history:
Received 12 April 2022
Received in revised form 28 June 2022
Accepted 21 July 2022
Available online 9 August 2022

References

[1] Badura-Brack AS, Naim R, Ryan TJ, Levy O, Abend R, Khanna MM, McDermott TJ, Pine DS, Bar-Haim Y. Effect of attention training on attention bias variability and PTSD symptoms: randomized controlled trials in Israeli and U.S. Combat Veterans. Am J Psychiatry 2015;172:1233–41.
[2] Basanovic J, Notebaert L, Grafton B, Hirsch CR, Clarke PJF. Attentional control predicts change in bias in response to attentional bias modification. Behav Res Ther 2017;99:47–56.
[3] Cella D, Riley W, Stone A, Rothrock N, Reeve B, Yount S, Amtmann D, Bode R, Buysse D, Choi S, Cook K, Devellis R, Dewalt D, Fries JF, Gershon R, Hahn EA, Lai JS, Pilkonis P, Revicki D, Rose M, Weinfurt K, Hays R; PROMIS Cooperative Group. The patient-reported outcomes measurement information system (PROMIS) developed and tested its first wave of adult self-reported health outcome item banks: 2005-2008. J Clin Epidemiol 2010;63:1179–94.
[4] Clarke PJF, Chen NTM, Guastella AJ. Prepared for the best: readiness to modify attentional processing and reduction in anxiety vulnerability in response to therapy. Emotion 2012;12:487–94.
[5] Clarke P, MacLeod C, Shirazee N. Prepared for the worst: readiness to acquire threat bias and susceptibility to elevate trait anxiety. Emotion 2008;8:47–57.
[6] Cohen J. Statistical power analysis for the behavioral sciences. New York: Routledge, 1988.
[7] Craig BM, Reeve BB, Brown PM, Cella D, Hays RD, Lipscomb J, Simon Pickard A, Revicki DA. US valuation of health outcomes measured using the PROMIS-29. Value Health 2014;17:846–53.
[8] Crombez G, Van Ryckeghem DML, Eccleston C, Van Damme S. Attentional bias to pain-related information: a meta-analysis. PAIN 2013;154:497–510.
[9] Eccleston C, Crombez G. Worry and chronic pain: a misdirected problem solving model. PAIN 2007;132:233–6.

[10] Gallucci M. GAMLj: general analyses for linear models, 2019. Available at: https://gamlj.github.io/.
[11] Georgiades J, Cusworth K, MacLeod C, Notebaert L. The relationship between worry and attentional bias to threat cues signalling controllable and uncontrollable dangers. PLoS One 2021;16:e0251350.
[12] Hughes LS, Clark J, Colclough JA, Dale E, McMillan D. Acceptance and commitment therapy (ACT) for chronic pain: a systematic review and meta-analyses. Clin J Pain 2017;33:552–68.
[13] IBM Corp. IBM SPSS statistics for windows, 2020.
[14] Inquisit 4.0.8. Millisecond Software LLC [computer software], 2015. Available at: https://www.millisecond.com.
[15] Lester KJ, Lisk SC, Carr E, Patrick F, Eley TC. Associations between attentional bias and interpretation bias and change in school concerns and anxiety symptoms during the transition from primary to secondary school. J Abnorm Child Psychol 2019;47:1521–32.
[16] Liu Y, Roefs A, Nederkoorn C. Fluctuations in attentional bias for food and the role of executive control. Appetite 2022;168:105761.
[17] Notebaert L, Georgiades JV, Herbert M, Grafton B, Parsons S, Fox E, MacLeod C. Trait anxiety and the alignment of attentional bias with controllability of danger. Psychol Res 2020;84:743–56.
[18] Rost S, Van Ryckeghem DML, Koval P, Sutterlin S, Vogele C, Crombez G. Affective instability in patients with chronic pain: a diary approach. PAIN 2016;157:1783–90.
[19] RStudio team. RStudio: integrated development for R, 2020. Available at: http://www.rstudio.com/.
[20] Schneider S, Choi SW, Junghaenel DU, Schwartz JE, Stone AA. Psychometric characteristics of daily diaries for the patient-reported outcomes measurement information system (PROMIS®): a preliminary investigation. Qual Life Res 2013;22:1859–69.
[21] Schoorl M, Putman P, Van Der Does W. Attentional bias modification in posttraumatic stress disorder: a randomized controlled trial. Psychother Psychosom 2013;82:99–105.
[22] Schoth DE, Georgallis T, Liossi C. Attentional bias modification in people with chronic pain: a proof of concept study. Cogn Behav Ther 2013;42:233–43.
[23] Sharpe L, Ianiello M, Dear BF, Perry KN, 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.
[24] The jamovi project. jamovi. 2021. Available at: https://www.jamovi.org.
[25] Todd J, Rudaizky D, Clarke PJF, Sharpe L. Cognitive biases in type 2 diabetes and chronic pain. J Pain 2022;23:112–22.
[26] Todd J, van Ryckeghem DML, Sharpe L, Crombez G. Attentional bias to pain-related information: a meta-analysis of dot-probe studies. Health Psychol Rev 2018;12:419–36.
[27] Todd J, Sharpe L, Johnson A, Nicholson Perry K, Colagiuri B, Dear BF. Towards a new model of attentional biases in the development, maintenance, and management of pain. PAIN 2015;156:1589–600.
[28] Van Ryckeghem DML, 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.
[29] Van Ryckeghem DML, Noel M, Sharpe L, Pincus T, van Damme S. Cognitive biases in pain: an integrated functional-contextual framework. PAIN 2019;160:1489–93.
[30] Veehof MM, Trompetter HR, Bohlmeijer ET, Schreurs KMG. Acceptance- and mindfulness-based interventions for the treatment of chronic pain: a meta-analytic review. Cogn Behav Ther 2016;45:5–31.
[31] Vlaeyen JWS, Crombez G, Linton SJ. The fear-avoidance model of pain. PAIN 2016;157:1588–9.
[32] Vlaeyen JWS, Linton SJ. Fear-avoidance and its consequences in chronic musculoskeletal pain: a state of the art. PAIN 2000;85:317–32.