Implicit evaluations and physiological threat responses in people with persistent low back pain and fear of bending

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Pages (including figures): 31

Figures: 4

Tables: 1

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Research funding: *JP Caneiro* is supported by an Australian Postgraduate Award (APA) and Curtin University Postgraduate (CUPS) Scholarships. *G. Lorimer Moseley* is supported by a Principal Research Fellowship from the National Health & Medical Research Council of Australia.

Conflict of interest: *Peter O'Sullivan* receives speaker fees for workshops on pain management. *G. Lorimer Moseley* has received support from: Pfizer Australia, Kaiser Permanente, Results Physiotherapy, Agile Physiotherapy, Workers' Compensation Boards in Australia, Europe and North America, the International Olympic Committee and Port Adelaide Football Club. He receives speaker fees for lectures on pain and rehabilitation. He receives royalties for books on pain and rehabilitation. *All the other authors* declare no conflicts of interest.

ABSTRACT

Background and aims: Pain and protective behavior are dependent on implicit evaluations of danger to the body. However, current assessment of perceived danger relies on self-report, on information of which the person is aware and willing to disclose. To overcome this limitation, attempts have been made to investigate implicit evaluation of movement-related threatening images in people with persistent low back pain (PLBP) and pain-related fear. Lack of specificity of the sample and stimuli limited those explorations. This study investigated implicit evaluations and physiological responses to images of tasks commonly reported as threatening by people with PLBP: bending and lifting. We hypothesized that people who differ in self-reported fear of bending with a flexed lumbar spine (*fear of bending*) would also differ in implicit evaluations and physiological responses.

Methods: This study used a convenience sample of 44 people (54% female) with PLBP, who differed in self-reported *fear of bending*. Participants completed a picture-viewing paradigm with pleasant, neutral and unpleasant images, and images of people bending and lifting with a flexed lumbar spine ('round-back') to assess physiological responses (eye-blink startle modulation, skin conductance). They also completed an implicit association test (IAT) and an affective priming task (APT). Both assessed implicit associations between (i) images of people bending/lifting with a flexed lumbar spine posture ('round-back' posture) or bending/lifting with a straight lumbar spine posture ('straight-back' posture), and (ii) perceived threat (safe vs dangerous).

Results: An implicit association between 'danger' and 'round-back' bending/lifting was evident in all participants (IAT (0.5, CI [.3;.6]; p< 0.001) and APT (24.2, CI [4.2;44.3]; p= 0.019)), and unrelated to self-reported fear of bending (IAT (r= -.24, 95% CI [-.5, .04], p= 0.117) and APT (r= -.00, 95% CI [-.3, .3], p= 0.985)). Levels of self-reported fear of bending

were not associated with eye-blink startle (F (3,114) =0.7, p=0.548) or skin conductance responses (F (3,126) =0.4, p=0.780) to pictures of bending/lifting.

Conclusions: Contrary to our expectation, self-reported fear of bending was not related to physiological startle response or implicit measures. People with PLBP as a group (irrespective of fear levels) showed an implicit association between images of a round-back bending/lifting posture and danger, but did not display elevated physiological responses to these images. These results provide insight to the understanding of the relationship between pain and fear of movement.

Implications: The potential clinical implications of our findings are twofold. First, these results indicate that self-report measures do not always reflect implicit associations between particular movements and threat. Implicit association tasks may help overcome this limitation. Second, a lack of the predicted physiological and behavioural responses may reflect that the visualization of a threatening task by people in pain does not elicit the same physiological defensive responses measured in people with fear of specific objects. It may be necessary to expose the person to the actual movement to elicit threat-responses. Together, these results are consistent with current views of the role of 'fear' in the fear-avoidance model, in which a fear response may only be elicited when the threat is unavoidable.

Key-words: Persistent back pain; lifting back posture; fear of movement; beliefs; implicit bias; threat-response

Word count: 479

1. Introduction

Modern understanding of the relationship between pain and fear poses that both can be considered emergent protective feelings[1, 2], broadly captured by the idea that pain emerges when the organism concludes that a body part needs protecting and fear emerges when the organism concludes that the entire body needs protecting[3-5]. Within this conceptualization, pain and fear are dependent on implicit evaluations of danger to the body[3-5]. However, current assessment of perceived danger to the body relies solely on explicit, or self-report, measures[6-8], which require conscious reflection, only accessing information of which a person is aware and which they are willing to disclose[1, 9-11]. To overcome this limitation, attempts have been made to investigate implicit evaluation of movement-related threatening images in people with persistent low back pain (PLBP) and pain-related fear[12,1, 2].

Explorations of implicit attitudes of people with PLBP found no implicit association between 'danger words' and movement-related threatening images, despite participants explicitly evaluating the stimuli as aversive[1, 2]. A common limitation of these studies[12,1, 2] was the use of a wide range of threatening images (e.g. driving, hanging a coat, digging, running)[1, 2] and words (e.g. warning, AIDS, fatal)[1, 2]. Those stimuli lack threat-specificity, which is an important aspect of fear/danger assessment[13,14].

Investigations of physiological threat-responses in people with PLBP and pain-related fear[12,13,14] report mixed results[14]. One study found that people with high fear display enhanced autonomic arousal (indexed by skin conductance) in anticipation of performing a task they perceived as harmful[15]. Different from autonomic arousal measures, eye-blink startle modulation enables assessment of the emotional valence of stimuli[16-18]. Thus far, only one study recorded eye-blink startle as a measure of threat-responses in people with PLBP[12], and found no difference between those reporting high and low fear beliefs[12] when presented with pictures of back pain-related movements (e.g. bending and rotation). Although a pilot

sample determined the images were sufficiently aversive, participants did not report feeling 'fearful' of performing the depicted tasks[12]. That study may have been limited by a non-specific sample, based on a generic fear-avoidance beliefs questionnaire[12], and by not using task-specific or personally-threatening stimuli .

Considering that threat-specificity is critical for evaluating perceived danger to the body, the current study selected a group of people with PLBP reporting different levels of explicit fear of bending with a flexed lumbar spine (*fear of bending*). This movement was chosen because bending and lifting are one of the most feared tasks for people with and without LBP, holding a high threat-value in western society[19-23]. To investigate implicit evaluations of danger, we employed implicit measures of attitude, (affective priming task - APT[28], and implicit association test - IAT[19]), and physiological responses (eye-blink startle modulation[16-18], and skin conductance[15, 18]) to images of people bending and lifting with a flexed lumbar spine ('round-back' posture). We hypothesized that: 1) Higher levels of explicit *fear of bending* would be positively associated with higher levels of implicit association between round-back bending/lifting and danger. 2) Physiological threat-responses to pictures of round-back bending/lifting would be enhanced in people with higher self-reported *fear of bending*.

2. Materials & Methods

This section and Table-1 report only key aspects of the methodology. Full detailed methods are provided in the *Appendix*.

2.1. Study Design

Exploratory cross-sectional experimental study.

2.2. Participants and recruitment

Participants were sequentially recruited from a cohort who had indicated willingness to participate in future studies[24], and via physiotherapists and general practitioners. Adults aged 18 years and older with dominant axial low back pain (LBP), greater than 6 months duration, and average pain in the past week ≥3/10 on the Numerical Rating Scale (NRS: 0-10 - *Appendix*), were included in the study. Participants who reported red flags, dominant leg pain, radicular pain with nerve compression, uncorrected hearing impairment (restriction for the acoustic stimulus during the eye-blink startle), pregnancy, taking opioids, or were unable to read English were excluded. Long-term analgesics or medications for other co-morbidities were allowed, however participants were asked not to take non-prescribed analgesics on experiment day.

To ensure balanced sequential recruitment of equal numbers of participants with and without fear of bending, potential participants were screened over the phone with the question: "Are *you fearful of reaching to the floor without bending your knees? Yes or No"*. Recruitment continued until a minimum of 20 participants in both groups was reached.

The study was approved by the Human Research Ethics Committee of the Faculty of Health Sciences-Curtin University (HR157/2015). All participants provided informed consent.

2.3. Outcome measures

This study involved three computer-based tasks measuring implicit attitudes (IAT, APT) and psychophysiology (eye-blink startle modulation and skin conductance response) related to bending and lifting back posture and perceived threat to the spine.

2.3.1. Beliefs

2.3.1.2. Explicit measures

To minimize potential influence of self-report assessments on results, the following questionnaires were completed online a week prior data collection: fear of bending (FearBend), pain-related fear (TSK)[8], pain-anxiety (PASS-20)[7], disability (RMDQ)[25], and pain in the past week.

2.3.1.2.1. Fear of bending

To assess fear of bending with a flexed lumbar spine (herewith called *fear of bending*), participants were presented with a side view picture of a person bending forward with a flexed lumbar spine, straight knees and fingers touching the floor, followed by the question:" How *fearful are you of reaching to the floor without bending your knees?"* (NRS anchored on "0: No fear of bending", and "10: Maximum fear of bending"). This measure (FearBend) ensured specificity of the fear-provoking task[6].

The FearBend question was adapted from the item "reaching to the floor" from the Fear of Daily Activities Questionnaire[26], which has sound psychometric properties and adequate reliability in determining fear of specific activities[26].

2.3.1.2.2. Pain-related fear, anxiety and disability

These measures were taken for sample descriptive purposes. Pain-related fear beliefs were assessed with the *Tampa Scale of Kinesiophobia-TSK*[8, 27]. Pain-related anxiety symptoms were assessed with the *Pain Anxiety Symptoms Scale-PASS-20*[7]. TSK and PASS-20 were taken as secondary measures for sample descriptive purposes only. Pain-related disability was assessed with the *Roland Morris Disability Questionnaire-RMDQ*[25, 28]. Psychometric properties and descriptions of scoring ranges for these well-established questionnaires are detailed in *Appendix*.

2.3.1.2.3. Demographic data

A questionnaire including age, LBP duration and pain intensity (NRS: 0= 'no pain' and 10= 'worst pain' - *Appendix*) was completed on experiment day.

2.3.1.3. Implicit measures

The IAT[11] and the APT[29] are well-established measures, which were adapted for this study to assess associations between bending/lifting posture and risk (Table-1). In the **IAT**, five stimuli representing each target ("Round-back" and "Straight-back") and attribute category ("Safe" and "Danger") were presented. Participants had to assign a single stimulus displayed in the center of the screen to its proper category (displayed at the upper corners of the screen), by pressing the left or right "Shift" key as fast as possible while avoiding mistakes. A bias score ($IAT_{D\text{-}score}$) was calculated using the improved scoring algorithm recommended by Greenwald et al (2003)[74] with an error penalty of 2 standard deviations. (see *Appendix* for details). The IAT exhibits adequate reliability and, internal, construct and predictive validity[11, 30].

In the **APT**, a series of positive and negative target words was presented (for 10s or until a response was made), which had to be evaluated as either "safe" or "dangerous" by pressing the right or left "Shift" key, respectively. Each target word was preceded by a prime picture of person standing or bending/lifting with a round-back (for 200ms) - see *Appendix* for APT priming score calculation. The APT presents adequate predictive validity[10] and sensitivity[31].

The category "Danger" was represented by six words (selected from interviews with people with PLBP and high-fear[32, 33]) frequently used to describe danger associated with movement. Words matching in length, frequency, and emotionality represented the category "Safe"[34]. Twelve side view images of males and females standing, bending and lifting with a straight ("Straight-back") and flexed lumbar spine ("Round-back"), were developed for this experiment after piloting with people with PLBP to confirm their suitability (Table-1).

2.3.1.4. Physiological measures

Using a picture-viewing paradigm, participants' eye-blink startle reflex and skin conductance were assessed in response to four categories of foreground stimulus: *neutral*; *pleasant*; *unpleasant*; and *bending/lifting*, represented by six images each. Pictures in the first three categories were selected from the International Affective Picture System (IAPS[35]). Bending/lifting images (persons bending/lifting with a flexed lumbar spine) were selected from PHODA-SeV (Photographs of Daily Activities-Short electronic version - a valid and reliable measure of perceived harmfulness of activities)[6] (Table-1). During the presentation of bending/lifting images, participants were instructed to imagine themselves performing the action displayed.

The primary outcomes for startle blink reflex were eye-blink EMG magnitude and response latency (*Appendix*). The startle probe used to elicit a response was a 105dBA burst of white

noise with instantaneous rise time, generated with a custom-built noise generator and presented to both ears for 50ms through Sennheiser headphones (HD 25-1; 70Ω). Orbicularis oculi electromyographic activity (EMG) was measured using two 4mm Ag/AgCl electrodes placed underneath the participant's left eye (1cm apart), and a ground electrode placed on the centre of the forehead. All electrodes were connected to a BIOPAC EMG amplifier (amplification: 5000; filters: low pass of 500Hz and high pass of 10 Hz). Skin conductance response (SCR) was recorded with two pre-gelled Ag/AgCl electrodes attached to the thenar and hypothenar eminences of the participant's non-dominant hand. Electrodes were connected to BIOPAC SCR amplifier with a gain of 2 μS/V. The primary outcome for SCR was the magnitude of the increase in skin conductance (*Appendix*).

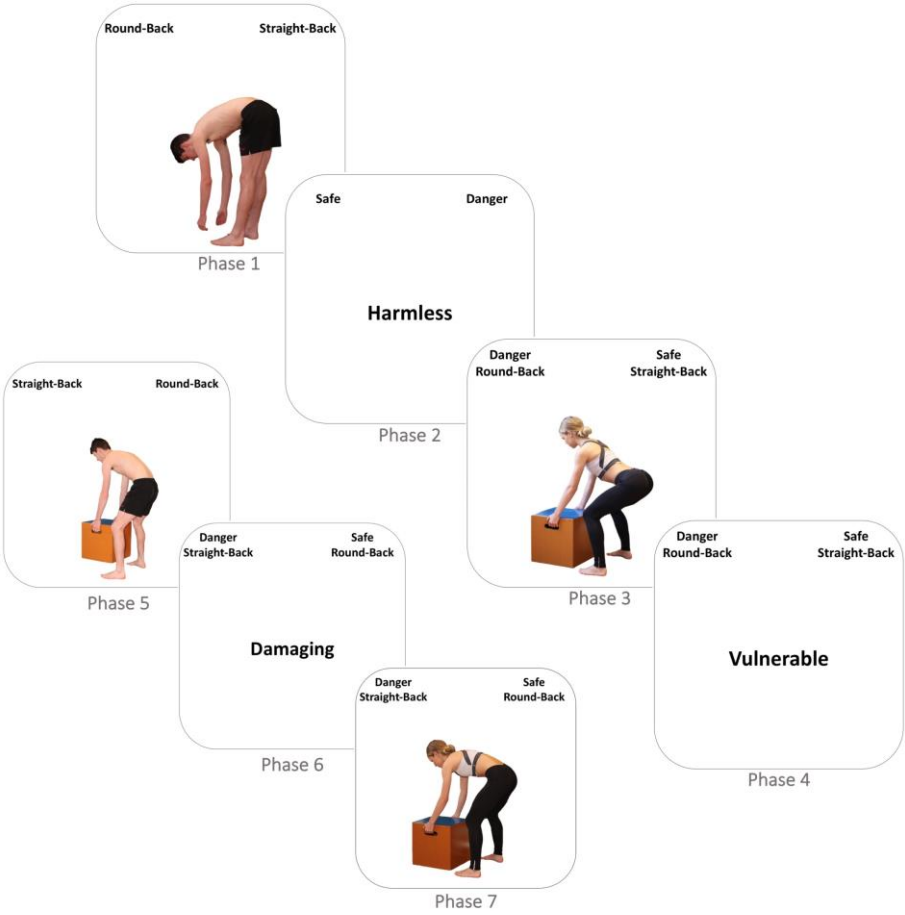
Picture rating: At the end of this task, each picture was rated on dimensions of pleasantness and arousal, using a 9-point scale ('1': unpleasant/low arousal; '9': pleasant/high arousal). The keyboard keys 1–9 were used to record the values for each image (Full protocol in *Appendix*).

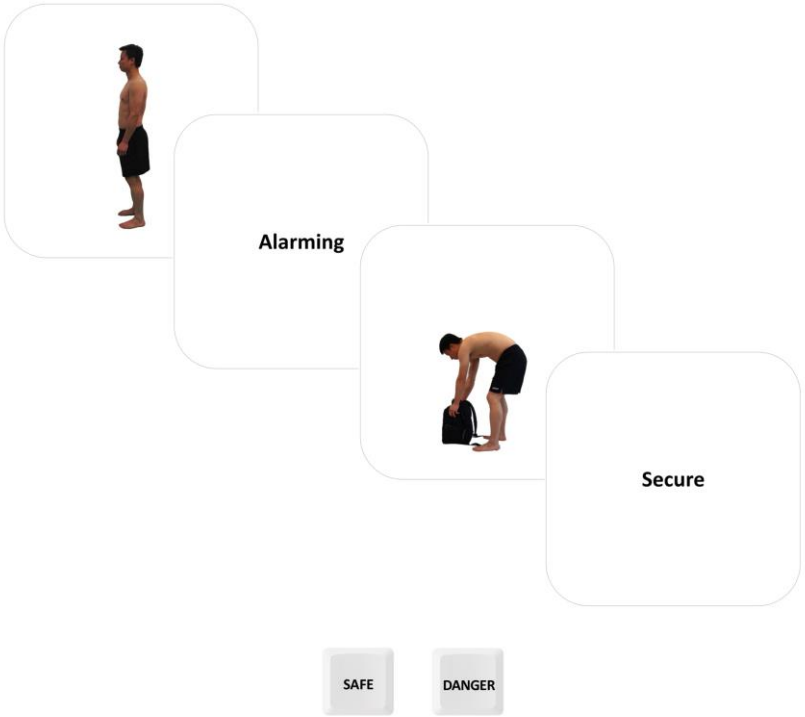
2.4. Experimental procedure

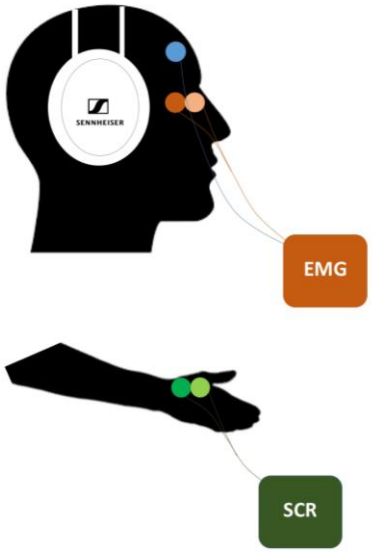
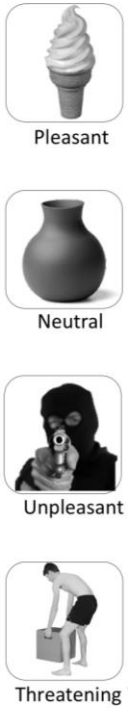
All data collection was undertaken in the Emotion, Learning and Psychophysiology Laboratory, School of Psychology & Speech Pathology, Curtin University, Western Australia, and lasted approximately 80 minutes. Participants were told the experiment related to measuring their body's reaction and automatic thinking processes while looking at words and images representing daily activities. To minimize potential for task interference, assessment of physiological response was performed first. The order in which the implicit tasks were performed was counterbalanced using a Latin-square design.

Data processing, scoring and response definition followed standard procedure for each task (details in *Appendix*).

Table-1. Summary description of the implicit and physiology measures.

MEASURE	STIMULUS		PROCEDURE	SCHEMATIC REPRESENTATION
IAT	**Target:** back posture (*round-back* and *straight-back*) Pictures of a person bending and lifting objects with a flexed lumbar spine ("Round-back"), and with a straight spine ("Straight-back")	**Attribute:** perceived risk to the spine (*Safe* and *Danger*) Words[^32, 33]: "Danger": *damaging, vulnerable, threatening, alarming, risky, unpredictable* "Safe": *harmless, confident, secure, protecting, certainty, reliable*	**The IAT consisted of 7 phases:** **Phase1** (target-discrimination): 20 trials **Phase 2** (*attribute*-discrimination): 20 trials **Phases 3-4** (*combined*-discrimination): 30 and 40 trials/each **Phase 5** (*target*-discrimination): 20 trials **Phases 6-7** (*combined*-discrimination): 40 trials/each Each trial started with the display of a fixation cross for 1000ms followed by a word or image for 1000ms and an intertrial interval of 1000ms. To sort the stimuli, participants pressed the left "Shift" key for categories displayed in the left upper corner of the screen, and the right "Shift" key for categories displayed in the right upper corner of the screen. On each trial the participant was given feedback (''correct'' or ''wrong''). Categories remained on screen throughout an entire phase.	

APT	**Target:** Words[^32, 33] related to safe and danger. "Danger": *damaging, vulnerable, threatening, alarming, risky, unpredictable* "Safe": *harmless, confident, secure, protecting, certainty, reliable*	**Prime:** images of a person standing adopting a flexed lumbar spine posture while bending or lifting	The APT consisted of 8 blocks of 12 trials involving the presentation of a negative or positive word that was preceded by one of the prime pictures. Each block consisted of 6 affectively congruent (straight–safe, bending–dangerous) and 6 affectively incongruent image-word pairs (straight– dangerous, bending–safe). Each trial began with the presentation of two white fixation crosses in the center of a black screen for 200ms, a picture for 200ms, a black screen for 100ms, and a word for 1 s or until the participant responded by pressing either button. The intertrial interval was 1s. A series of positive and negative *target* words was presented. Participants were instructed to decide whether the word represented the category "Safe" or "Danger", by pressing left "Shift" key for ''Safe", and the right "Shift" key for " Danger". Each target was preceded by a *prime* picture.	

PICTURE VIEWING	**Four categories of pictures (*neutral, pleasant, unpleasant and bending/lifting*) were represented by six images each.**				
	Pictures in the first three categories were selected from the IAPS[+35]: *neutral:* rolling pin (7000), towel (7002), mug (7009), wooden stool (70025), lamp (7175), clock (7211); *pleasant:* wedding (4626), children (2347), ice cream (7330), fireworks (5480), beach (5833), man and woman kissing (4660); *unpleasant:* snake (1050), spider (1201), shark (1930), baby with eye lesion (3170), aimed gun (6230), attack (3530)	*The bending and lifting-related pictures were selected from* PHODA-SeV [*6] and round-back lifting from IAT (as per example depicted here). *Bending/lifting*: shovelling (2), lifting a pot plant (4), 20 (lifting a heavy crate out of car), 27 (unloading dishwasher), 29 (vacuuming), 33 (mopping the floor), 83 (picking up a toddler).	Participants looked at the blank computer screen for 3 minutes, while baseline data were collected. After baseline, the picture-viewing task was initiated. Three startle probes were administered to reduce the novelty of the startle probe and the 24 pictures were presented pseudo randomly such that no more than two pictures from the same category were presented in a row. Four picture sequences were predetermined and counterbalanced across participants. Probes were presented at 3.5 s or 4.5 s after picture onset during four of the six pictures per category as well as during one third of the inter-picture intervals. Participants were asked to relate to the bending and lifting pictures by imagining they were performing the action displayed.		

^ Words selected from interviews with people with PLBP and high pain-related fear[32, 33]. + IAPS – International Affective Pictorial System[35]. * PHODA-SeV – Photographs of Daily Living Activities-Short Electronic Version[6].

2.5. Statistical analysis

Descriptive statistics were used to describe participants' characteristics and scores on the self-reported questionnaires. Pearson's correlations between self-reported measures (TSK, PASS-20), and fear of bending (FearBend) were calculated.

One-sample t-tests were used to evaluate the size (and 95% confidence intervals) and significance of the sample mean deviation from zero, which indicates the direction of the implicit bias. A positive score indicates an implicit bias to associate "round-back" and "danger". Pearson's correlation was used to evaluate associations between the magnitude of implicit bias (i.e. IAT_{D_score} and APT_{Diff_score}) and fear of bending (FearBend).

To test differences in eye-blink latency, eye-blink magnitude, SCR magnitude and ratings across each picture conditions (pleasant, unpleasant, neutral and bending/lifting) a mixed model ANOVA (RM ANOVA) with FearBend as a covariate was used. A picture condition*fear of bending interaction was evaluated to test whether the pattern of responses differed according to the degree of FearBend. The effect size measure η_p^2 is reported for significant effects. For interpretative purposes only, graphical results are provided for the interaction test of picture condition*fear of bending by splitting the sample into groups based on fear of bending level. A score of > 5 indicates high *fear of bending* (23 participants; 52.3%), while ≤5 indicates low *fear of bending* (21 participants; 47.7%).

Greenhouse-Geisser corrections were applied when the assumption of sphericity was violated. Corrected degrees of freedom and corrected p-values are reported together with ε. All statistical analyses were run using IBM SPSS Statistics 24.

2.5.1. Power analysis

An a priori power calculation indicated a sample of 40 participants would provide 80% power to detect small to moderate effect size of η_p^2 = .05 to .08 for condition*fear

interactions, at α=.05 and assuming a conservative intra-subject correlation of 0.3 between conditions (GPower Version 3.1.9).

3. Results

3.1. Demographics

Forty-four people with PLBP (54% female) participated in the study. The mean (SD) age was 50 years (14; range 24-72), pain duration was 16 years (13; range 1-50), pain intensity in the week prior to the experiment was 4.8 (2.3), and pain on the day was 3.7 (1.9). The mean disability index on RMDQ was 8.2 (34%) (SD= 5).

3.2. Beliefs

3.2.1. Explicit measures

The mean level of self-reported specific fear of bending (FearBend) was **4.4 (SD= 3.3; range 0-10)**. The mean level of pain-related fear (TSK) was **41.0 (SD= 9.0; range 22-59)**, and pain-anxiety (PASS-20) **37.5 (SD= 21.8; range 2-89)**.

There were high correlations between self-reported FearBend and TSK **(r= 0.68, 95% CI [.51, .81], p<0.001)**, between FearBend and PASS-20 **(r= 0.62, 95% CI [.40, .81], p<0.001)**; and between TSK and PASS-20 **(r= 0.66, 95% CI [.45, .82], p<0.001)**.

3.2.2. Implicit measures

The mean IAT_{D_score} (**Mean= 0.46, 95% CI [. 30, .61]**) was significantly larger than zero (t (43) = 5.8, **p< 0.001**), which indicates an implicit bias towards the association between pictures of bending/lifting with a 'round-back' and 'danger' words. There was no correlation between FearBend and the IAT_{D_score} (**r= -.24, 95% CI [-.50, .044], p= 0.117)**.

APT data from six participants were invalid due to response times larger than 1000ms, which suggests a lack of automatic target evaluation. The mean APT_{Diff_score} (**N= 38, Mean= 24.2, 95%CI [4.2, 44.3]**) was also significantly larger than zero (t (37) = 2.4, **p= 0.019**), which

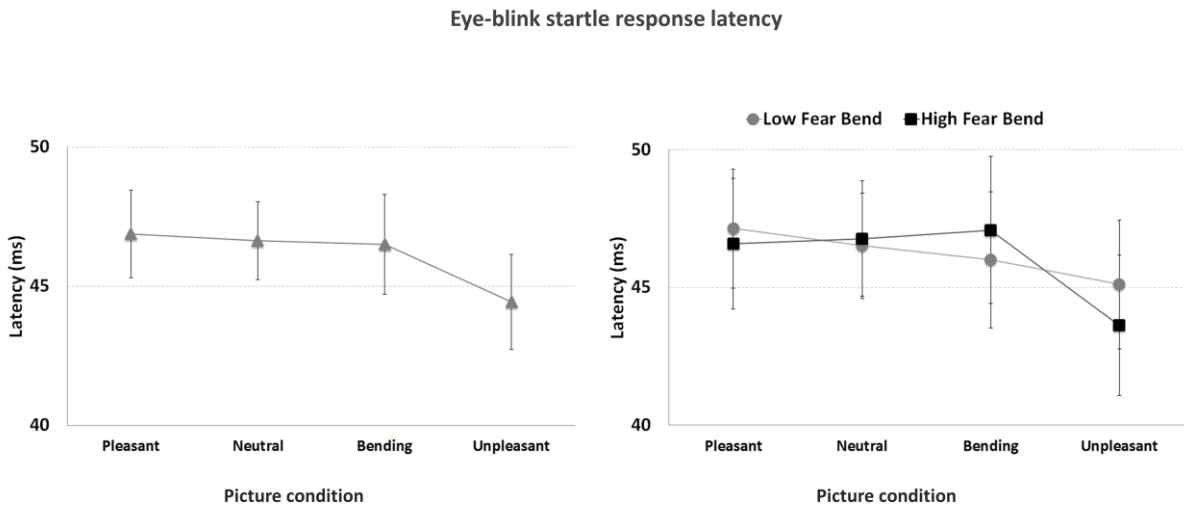
indicates an association between pictures of bending/lifting and 'round-back' and 'danger' words. There was no correlation between FearBend and the APT_{Diff_score} (**r= -.00, 95% CI [-.30, .30], p= 0.985)**.

3.3. Physiological measures

3.3.1. Eye-blink response latency

Eye-blink response latency did not differ across picture conditions, (**F (2.5, 81.8) =0.2, p=0.878**). Similarly, eye-blink latency across picture conditions did not differ according to self-reported level of fear of bending (FearBend) (picture condition* fear of bending interaction **F (2.5, 81.8) =0.6, p=0.614**) (Figure 1).

Figure 1 – Estimated means of eye-blink response latency across picture conditions. Bars indicate Standard Error (SE). Participants grouped by high (>5) and low (≤5) levels of *fear of bending*.

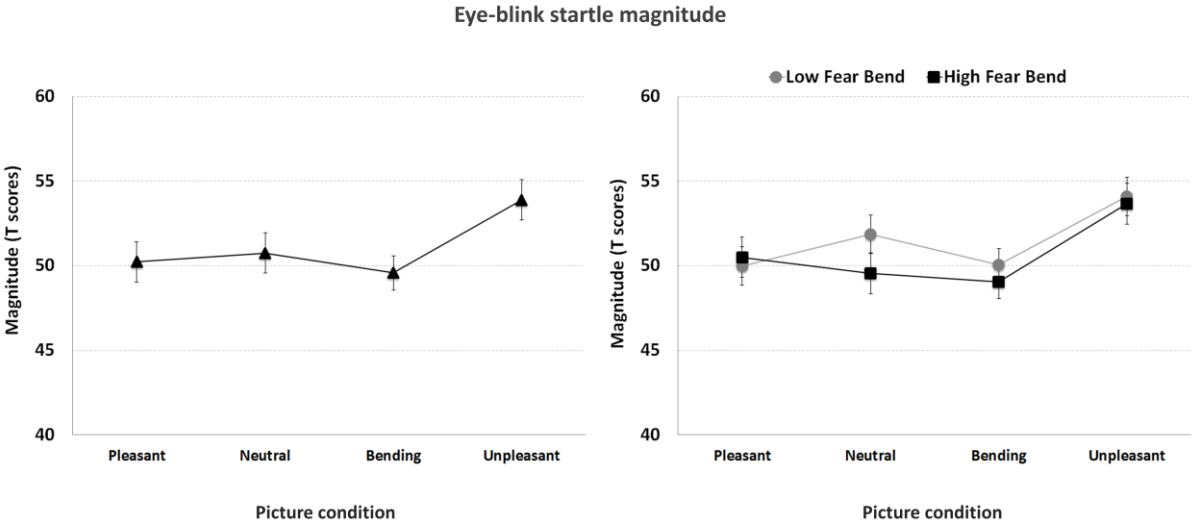


3.3.2. Eye-blink magnitude

As shown in Figure 2, the eye-blink magnitude differed across picture conditions (**F (3, 114) =4.7, p=0.04, ε=. 938, η_p^2= .109)**. Contrasts indicated larger eye-blink magnitude to probes during unpleasant pictures than during pleasant (**F (1, 38) =8.2, p=.007, η_p^2= .177**), neutral

(**F (1, 38) =5.7, p=.022, η_p^2= .131**) and bending/lifting pictures (**F (1, 38) =12.3, p=.001, η_p^2= .245**). The eye-blink magnitude across picture conditions did not differ according to level of fear of bending (FearBend) (picture condition* fear of bending interaction **F (3, 114) =0.7, p=0.548**).

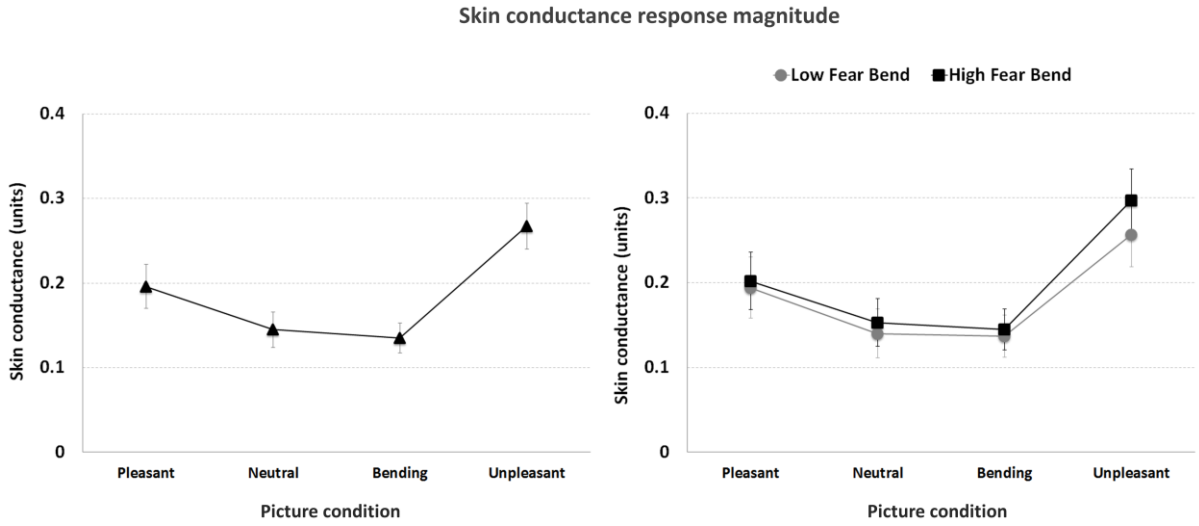
Figure 2 – Estimated means of eye-blink magnitude across picture conditions. Bars indicate Standard Error (SE). Participants grouped by high (>5) and low (≤5) levels of *fear of bending*.



3.4. Skin conductance response

Participant's SCR differed according to the type of picture viewed **(F (3, 126) =3.2, p=0.026, ε=. 903, η_p^2= .070)**. As displayed in Figure 3, the SCRs to unpleasant pictures were significantly larger than to bending/lifting pictures (**F (1, 42) =7.4, p=0.009, ε=. 903, η_p^2= .150**). However, there was no difference in emotional arousal across picture conditions according to level of fear of bending (FearBend) (picture condition* fear of bending interaction **F (3, 126) =0.4, p=0.780**).

Figure 3 – Estimate means of skin conductance magnitude across picture conditions. Bars indicate Standard Error (SE). Participants grouped by high (>5) and low (≤5) levels of *fear of bending*.

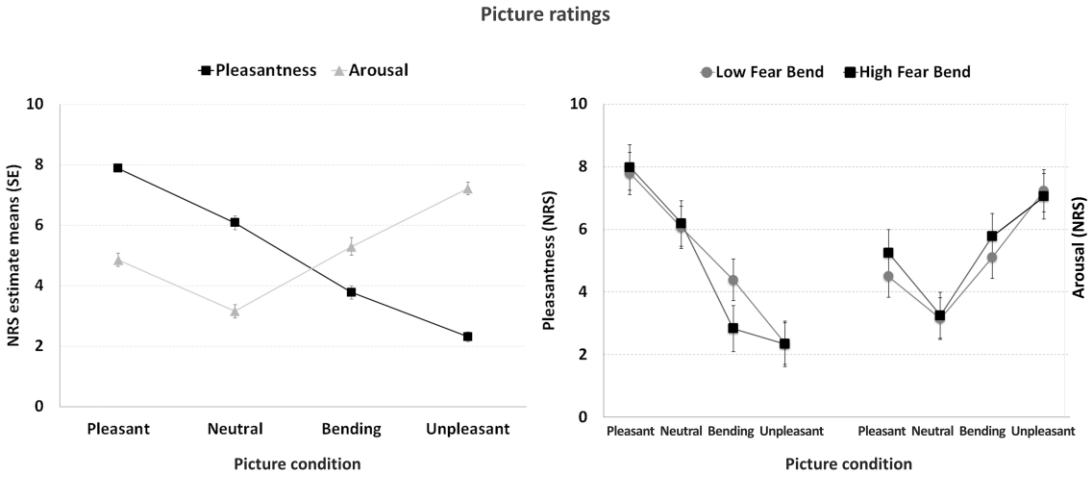


3.4.1. Subjective evaluation of picture conditions

Pleasantness (**F (2.5, 99.8) =56.2, p<0.001, ε=. 831, η_p^2=.584**) and arousal ratings (**F (2.3, 96.0) =21.0, p<0.001, ε=. 781, η_p^2=.339**) differed across picture conditions (Figure 4). Contrasts indicated that bending/lifting pictures were rated as less pleasant than neutral (**F (1, 40) =45.5, p<0.001, η_p^2=.532**) and pleasant (**F (1, 40) =205.0, p<0.001, η_p^2= .837**) pictures, but more pleasant than unpleasant pictures (**F (1, 40) =30.5, p<0.001, η_p^2= .433**). Bending/lifting pictures were rated as more arousing than pleasant (**F (1, 41) =26.75, p<0.001, η_p^2=.395**) and neutral pictures (**F (1, 41) =62.945, p<0.001, η_p^2=.606**), but less arousing than unpleasant pictures (**F (1, 41) =28.3, p<0.001, η_p^2=.408**).

There was an interaction between FearBend and picture condition for pleasantness ratings **F (2.5, 99.7) =6.7, p=0.001, η_p^2= .144**. As shown in Figure 4, participants with higher FearBend rated the bending/lifting pictures as less pleasant **F (1, 40) =12.4, p=0.01, η_p^2= .236**. In contrast, there was no interaction for arousal ratings. **F (2.3, 96.1) =1.2, p=0.319**.

Figure 4 – Estimated means of picture ratings across picture conditions. Bars indicate Standard Error (SE). Participants grouped by high (>5) and low (≤5) levels of *fear of bending*.



4.Discussion

This study investigated implicit evaluations and physiological responses to images of bending and lifting in people with PLBP, who differed in self-reported fear of bending with a flexed lumbar spine (*fear of bending*). Contrary to our hypotheses, *fear of bending* was not associated with implicit evaluations or physiological responses to viewing images of people bending and lifting with a flexed lumbar spine ('round-back' posture). Participants were faster to associate images of bending/lifting with a 'round-back' with words representing 'danger' rather than with words representing 'safety'. This indicates that people with PLBP display an implicit 'danger bias' towards bending and lifting with a flexed lumbar spine. Critically, that bias is unrelated to their self-reported fear of bending.

Previous explorations that investigated people with and without PLBP and high fear of movement have not found evidence of implicit association between a wide range of back-related movements and danger in PLBP[1, 2]. In contrast, the current study used images of bending and lifting for the implicit tasks, because these have been reported to be the two most commonly feared and pain-provoking movements for people with and without LBP[36-39]. Specifically, we used images of bending/lifting in two distinct postures that are often advocated as ergonomically safe ('straight-back') and dangerous ('round-back')[40, 41]. In addition, the words representing 'danger' in our study are highly relevant for this population, as they were selected from interviews with people with PLBP and high pain-related fear[32, 33]. Interestingly, despite this enhanced level of stimulus specificity, there was no association between higher self-reported fear and an implicit 'danger bias' to bending/lifting with a 'round-back'. These findings suggest that people with PLBP have discordant explicit beliefs but share concordant implicit beliefs about bending and lifting back posture, and danger.

In terms of physiology, participants' responses across the picture conditions was not associated with self-reported fear level. Blink startle potentiation and skin conductance responses were higher during unpleasant pictures than during other picture categories, confirming the sensitivity of the picture-viewing paradigm[42]. However, despite the personally-relevant nature of the stimuli and irrespective of self-reported fear, participants did not present a typical physiological threat response pattern to images of threatening bending/lifting tasks. Such response would be typically represented by enhanced eye-blink magnitude and skin conductance responses, similar to or higher than those during unpleasant images [16, 18].

These findings are at odds with previous work in specific fears/phobias in which a defensive response is activated even by the symbolic representation of the feared object (e.g. spiders)[43, 44]. Nevertheless, this result is in line with other studies that investigated threat responses to images of threatening tasks in people with PLBP using eye-blink startle[12], heart rate and back muscle activity[13] and fMRI[14]. Only one study has found physiological response differences between people with high and low fear, and notably, this was when participants with PLBP were led to believe they had to actually perform the lifting task that they reported to be harmful[15]. While recent fMRI studies have demonstrated that viewing movement-related threatening images[45] and imagining performing these movements[46] was sufficient to activate brain regions associated with threat-processing, the findings in this study confirm previous results using eye-blink startle modulation[12]. That is, simply viewing and imagining performing a threatening task seems insufficient to activate a defensive response in persons with PLBP, even when confronted with personally-relevant stimuli. It appears that visual images of spiders still hold immediate protection value, but visual images of other people performing a task do not. In order to induce a physiological response a person may need to be confronted with the task[15, 47].

Contemporary understanding of threat-processing proposes fear as an intertwined cognitive-emotional process, in which the amygdala plays an important role[48, 49]. In the presence of a stimulus, a fundamental function of the amygdala, is related to determining "what is it?", and also "what needs to be done?", thus guiding decision-making[48]. In this study, it is plausible to speculate that while the stimuli were implicitly detected, and likely identified as threatening, there was no imminent threat to the person and no protective action required. That is, in this context the conclusion may have been that "nothing needed to be done", resulting in no physiological response. While the results of the current study contradict our initial predictions, they lend support to more recent views of the role of 'fear' in the fear-avoidance model, in which defensive responses (physiology and behavior) vary according to context and motivation[50, 51], and are most prominent when the threat is unavoidable[15, 50, 52].

According to the common sense model of self-regulation,[53] when a person experiences pain, their behavioral response is influenced by their pre-existing *schema*, which is informed by media, healthcare providers, family, friends, their own experience and that of others[33]. Considering the general belief that the back is vulnerable[22, 23, 54, 55], it is plausible to infer that a person's schema includes information that is congruent with the idea that bending and lifting with a round-back represents danger to their back or to their goals. Experimental studies, investigating how movements of the back are perceived by asymptomatic subjects,[2, 45, 56] suggest that '*the back is vulnerable to bending and lifting*' may in fact be a *common schema*.

Modern conceptualization of pain would support that an implicit association between danger and forward bending with a flexed spine could potentially influence both pain and behavioral responses to the 'dangerous' task[3-5]. In the context of our results, we speculate that once pain is felt during bending or lifting, it provides a salient learning experience[33, 50, 57] in which a *'protect the back' schema* may be activated. In line with this thinking, experimental studies

have reported pain reduction during forward bending following interventions that aim to de-threaten bending via pain education[58], the use of visual observation of the spine during the movement[59], or providing cognitive and functional control during behavioral exposure[60]. Together, our results provide support for the argument that self-reported pain-related fear may be more cognitively-driven, in which an unhelpful schema may influence avoidance behavior, and a physiological threat-response may only occur when the person is exposed to the task itself[15, 61].

A potential weakness of this study is the use of visual stimuli only, rather than inducing participants to believe they would be required to actually perform the tasks. Although the eye-blink startle has been successfully used previously to assess physiological responses in threat-specific picture-viewing paradigms[43, 44], people with PLBP may need to be exposed to the task itself to elicit these responses. Future studies may benefit from investigating physiological startle response in anticipation of and during performance of back-related threatening tasks. Another limitation is the lack of a pain-free group, which could have informed whether these findings are unique to people with PLBP, although we were interested in how people with similar pain but different self-reported fear of bending compare, not in how people with and without pain compare. A unique aspect of this study was the use of combined implicit and physiology measures to compare people with PLBP with high or low fear of tasks relevant to PLBP (bending and lifting), using stimuli specific to these tasks and that holds a societal threat-value.

5. Conclusion

Contrary to our expectation, self-reported fear of bending was not related to physiological startle responses or implicit measures. People with PLBP as a group showed an implicit association between images of a round-back bending/lifting posture and danger, but did not display elevated physiological responses to these images. These results provide insight to the understanding of the relationship between pain and fear of movement.

6. Implications

The findings of this study suggest that independent of explicitly reported fear levels, people with PLBP implicitly associate bending and lifting with a flexed spine with danger, but this is not accompanied by enhanced physiological threat-related responses. The potential clinical implications of our findings are twofold. First, these results indicate that self-report measures do not always reflect implicit associations between particular movements and threat. Implicit association tasks may help overcome this limitation. Second, a lack of the predicted physiological and behavioural responses may reflect that the visualization of a threatening task by people in pain does not elicit the same physiological defensive responses measured in people with fear of specific objects. It may be necessary to expose the person to the actual movement to elicit threat-responses. Together, these results are consistent with current views of the role of 'fear' in the fear-avoidance model, in which a fear response may only be elicited when the threat is unavoidable.

Ethical issues

The study was approved by the Human Research Ethics Committee of the Faculty of Health Sciences-Curtin University (HR157/2015). All participants provided informed consent.

Acknowledgements

Funding acknowledgements:

JP Caneiro is supported by an Australian Postgraduate Award (APA) and Curtin University Postgraduate (CUPS) Scholarships.

G. Lorimer Moseley is supported by a Principal Research Fellowship from the National Health & Medical Research Council of Australia.

Technical acknowledgements:

The authors thank the participants for sparing the time out of their busy schedule to take part in this study. To Dr Leo Ng, our appreciation for the valuable assistance with the images developed for this project. To Dr Camila Luck for assistance provided in the laboratory.

Conflicts of interest:

Peter O'Sullivan receives speaker fees for workshops on pain management. G. Lorimer Moseley has received support from Pfizer, Kaiser Permanente, USA; Workers' Compensation Boards in Australia, North America, and Europe; Agile Physiotherapy, USA; Results Physiotherapy, USA; the International Olympic Committee and the Port Adelaide Football Club, Australia. He receives royalties for books on pain and rehabilitation, including two books that are cited in this article. He receives speaker fees for lectures on pain and rehabilitation.

All the other authors declare no conflict of interest.

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Figure captions

Table 1. Summary description of the implicit and physiology measures.

Figure 1 – Estimated means of eye-blink response latency across picture conditions. Bars indicate Standard Error (SE). Participants grouped by high (>5) and low (≤5) levels of *fear of bending*.

Figure 2 – Estimated means of eye-blink magnitude across picture conditions. Bars indicate Standard Error (SE). Participants grouped by high (>5) and low (≤5) levels of *fear of bending*.

Figure 3 – Estimated means of skin conductance magnitude across picture conditions. Bars indicate Standard Error (SE). Participants grouped by high (>5) and low (≤5) levels of *fear of bending*.

Figure 4 – Estimated means of picture ratings across picture conditions. Bars indicate Standard Error (SE). Participants grouped by high (>5) and low (≤5) levels of *fear of bending*.

APPENDIX

Methods - complementary details

Explicit measures

Pain in the past week

The question "*How would you rate the pain you have had on average during the past week*?" on a Numerical Rating Scale anchored on: 0= "no pain", 10= "worst pain"

Pain today

The question "*How would you rate the pain you have today*?" on a Numerical Rating Scale anchored on: 0= "no pain", 10= "worst pain"

Tampa Scale of Kinesiophobia - TSK

The TSK is a widely-used measure of pain-related fear beliefs[8, 28]. Scores range from 17 to 68, with higher scores indicating higher levels of fear of movement and a cut-off of 40 is typically used to define a high degree of pain-related fear[37,38].

Pain Anxiety Symptoms Scale - PASS-20

The PASS-20[7] was used to assess cognitive anxiety symptoms, escape and avoidance responses, fearful appraisals of pain and physiological anxiety symptoms associated with pain. The participant makes a frequency rating for each item (where 0 = never and 5 = always). The PASS-20 has acceptable psychometric properties[7]. Scores range from zero to 100, with higher score indicating higher levels of pain-anxiety.

Roland Morris Disability Questionnaire - RMDQ

The RMDQ measures effects of LBP on physical activities and activities of daily living. It is valid, reliable, and responsive to change[26, 29]. Scores range from zero to 24, with higher scores indicating higher levels of disability.

Implicit measures

Apparatus and stimulus material: The stimuli used in all tasks followed a theme: forward bending and lifting, representing a highly socially and clinically significant activity for people with PLBP[41, 42, 43].

The category "Danger" was represented by the following six words: *damaging, vulnerable, threatening, alarming, risky, unpredictable*. The category "Safe" was represented by the following six words: *harmless, confident, secure, protecting, certainty, reliable*. All words were used in the affective priming task (APT), whereas only the first five of each category were used in the implicit association test (IAT).

Presentation of the tasks and reaction time recording was controlled by DMDX[62]. The words were presented in bold, 20-point Arial font in white lower case on a black background. The images were presented embedded in a white square image of 800 x 800 pixels on a black background.

Implicit Association Test

Procedure: Following well-established guidelines[11], the bending-IAT comprised seven phases separated by a pause for instructions. In the **first phase** (20 trials), participants sorted each of the 10 images twice, into the categories "Round-back" and "Straight-back". In the **second phase** (20 trials), participants sorted the 10 words twice into the categories "Safe" and "Danger". In **phases, three and four** (30 and 40 trials each) participants sorted words and images into the combined categories (e.g., *Danger* / *Round-back* and *Safe* / *Straight-back* or *Danger* / *Straight-back* and *Safe* / *Round-back*). In **phase five** (20 trials) participants sorted images with the location of the categories switched. **Phases six and seven** (40 trials each) reversed category combinations of phases three and four (e.g., *Danger* / *Straight-back* and *Safe* / *Round-back* or *Danger* / *Round-back* and *Safe* / *Straight-back)*. The sequence of

congruent and incongruent matches during phases three and four and six and seven were counterbalanced across participants.

On each trial the participant was given feedback (‘‘correct’’ or ‘‘wrong’’). Categories remained on screen throughout an entire phase. Each trial started with the display of a fixation cross for 1000ms followed by a word or image for 1000ms and an intertrial interval of 1000ms.

Affective Priming Task

Procedure: Participants were informed that the task was to categorize words. The APT consisted of 8 blocks of 12 trials involving the presentation of a negative or positive word that was preceded by one of the prime pictures. Each block consisted of 6 affectively congruent (straight–safe, bending–dangerous) and 6 affectively incongruent image-word pairs (straight– dangerous, bending– safe).

Each trial began with the presentation of two white fixation crosses in the center of a black screen for 200ms, a picture for 200ms, a black screen for 100ms, and a word for 10s or until the participant responded by pressing either button. The intertrial interval was 1s.

In order to validate the APT in this sample, each participant also performed a standard animal-APT using pleasant and unpleasant animal pictures as primes (snakes, spiders, fish and birds) selected from the International Affective Picture System (IAPS[36]). Both APT and animal-APT were performed consecutively; the order however was counterbalanced.

Physiological measures

Apparatus and stimulus material: Four categories of pictures (neutral, pleasant, unpleasant and bending/lifting) were represented by six images each. Pictures in the first three categories were selected from the (IAPS[36]) (*neutral:* rolling pin - 7000, towel - 7002, mug - 7009, wooden stool - 70025, lamp – 7175, clock - 7211; *pleasant:* wedding - 4626, children - 2347,

ice cream - 7330, fireworks - 5480, beach - 5833, man and woman kissing - 4660; *unpleasant:* snake - 1050, spider - 1201, shark - 1930, baby with eye lesion - 3170, aimed gun - 6230, attack - 3530). The bending and lifting-related images selected from PHODA-SeV (Photographs of Daily Activities-Short electronic version[6]) were images number: 2, 4, 20, 27, 29, 33, 83. The presentation of these stimuli was also controlled by DMDX[62].

Orbicularis occuli electromyographic activity (EMG): The first electrode was placed on the skin directly underneath the participant's left eye. The second electrode was placed approximately 1 cm to the left below the corner of the participant's left eye. A ground electrode was placed on the centre of the forehead. All electrodes were connected to a BIOPAC EMG 100 C amplifier (amplification: 5000; filters: low pass of 500Hz and high pass of 10 Hz).

Skin conductance (SCR): The electrodes were attached to the thenar and hypothenar eminences of the participant's non-dominant hand and connected to a BIOPAC SCR 100 C amplifier with a gain of 2 μS/V.

Procedure: Participants washed their face and hands with non-allergic soap and water prior to the task to remove skin residue, minimizing skin impedance in the areas where the electrodes would be attached[44]. Electrode gel was applied under the participant's left eye and on the centre of the forehead to facilitate conductivity. The gel was allowed time to absorb into the skin and any excess was wiped off. A respiration belt was fitted over the participant's thorax. The participant was then asked to sit comfortably on an adjustable chair and the electrodes were attached.

Once the set up was ready, the participant was left alone in the room, while the researcher (JPC) controlled the experiment and monitored the participants through a CCTV system from the adjacent room. Participants looked at the blank computer screen for 3 minutes, while

baseline data were collected. After baseline, the picture-viewing task was initiated. Three startle probes were administered to reduce the novelty of the startle probe and the 24 pictures were presented pseudo randomly such that no more than two pictures from the same category were presented in a row. Four picture sequences were predetermined and counterbalanced across participants. Probes were presented at 3.5 s or 4.5 s after picture onset during four of the six pictures per category as well as during one third of the inter-picture intervals.

Data processing, scoring and response definition

Implicit assessment data

For each participant, two measures of implicit attitude were obtained, one for the IAT ($IAT_{D\text{-}score}$) and one for the APT ($APT_{Diff\text{-}score}$). For both measures, response time was defined as the time elapsed from the presentation of the stimulus (word or picture) to when the shift key was pressed. This time was recorded and incorrect responses, responses shorter than 100 ms or longer than 1000ms, and trials on which the participant had pressed the incorrect button were considered as errors.

IAT

An IAT bias score ($IAT_{D\text{-}score}$) was calculated using the improved scoring algorithm recommended by Greenwald et al (2003)[63] with an error penalty of 2 standard deviations. This algorithm has been thoroughly tested and shown to outperform conventional scoring algorithms, providing valid measures of implicit associations[63]. A positive score indicates an implicit bias to associate "round-back" and "danger".

APT

Preparation of the affective priming data began with the removal of errors (as above) and outliers, which were defined as response times deviating by more than three standard deviations from the mean of the individual. Response times were sorted into 4 variables

based on prime (standing and bending) and target (safe or danger word). A priming score ($APT_{Diff\text{-}score}$) was calculated as the difference in response time between incongruent (Round-back/Safe + Straight/Danger) and congruent (Round-back/Danger + Straight/Safe) trials. ($APT_{Diff\text{-}score} = RT_{incongruent} - RT_{congruent}$). A positive score indicates a bias to associate "round-back" and "danger".

Physiological measures

Eye-blink startle reflex

EMG data were recorded using a hardware bandpass 10-500 Hz filter, and processed with a software 50 Hz notch filter, followed by 30-500Hz bandpass filter. Baseline eye-blink activity was the average magnitude of EMG recorded during the period of 50 ms prior to the startle stimulus. Response latency was determined as the interval between the beginning of the startle stimulus and the onset of EMG activity, visually-detected within 20-70 ms after startle stimulus onset. Blink magnitude was defined as the peak of the rectified and smoothed (moving average across three consecutive values) orbicularis oculi EMG activity occurring within 20-120 ms after startle stimulus onset.

A trial was scored as missing if the EMG signal was unstable due to noise, movement artifacts or if a spontaneous or voluntary blink occurred within the latency response window (20-70 ms after startle onset), or if the response lasted longer than 100 ms. Baseline EMG (within 50 ms prior to startle stimulus onset) was inspected to determine whether it was stable[64]. If visual inspection of the waveform failed to identify a response onset, then the trial was classified as a nonresponse trial and a magnitude of zero was recorded[44].

Given the interest in intra-individual rather than inter-individual differences in response amplitude, startle responses were standardized within each individual to T-scores with a mean of 50 and SD of 10[44].

Skin conductance

Using visual inspection, the SCR data were scored with consideration of the respiration trace, where SCRs associated with atypical respiration were removed. A SCR was considered stimulus-elicited if it began within 1-4 s of picture onset. Zero responses were scored if no response was observed within that window.

Data processing followed standard procedure, which involved square root transformation and range correction of SCRs to approximate to a normal distribution[18]. The average response of all pictures (six) per condition was calculated and analysed.

Picture ratings

Measures of pleasantness and arousal for each of the four conditions (neutral, pleasant, bending/lifting and unpleasant) were analysed for all participants.

References are listed at the end of the manuscript's reference list.