Walsh, Joe, Eccleston, C and Keogh, E (2014) Pain communication through body posture: the development and validation of a stimulus set. PAIN, 155 (11). pp. 2282-2290.

Pain communication through body posture: The development and validation of a stimulus set

Joseph Walsh , Christopher Eccleston, Edmund Keogh
Centre for Pain Research, University of Bath, Bath, UK

Abstract

Pain can be communicated nonverbally through facial expressions, vocalisations, and bodily movements. Most studies have focussed on the facial display of pain, whereas there is little research on postural display. Stimulus sets for facial and vocal expressions of pain have been developed, but there is no equivalent for body-based expressions. Reported here is the development of a new stimulus set of dynamic body postures that communicate pain and basic emotions. This stimulus set is designed to facilitate research into the bodily communication of pain. We report a 3-phase development and validation study. First 16 actors performed affective body postures for pain, as well as happiness, sadness, fear, disgust, surprise, anger, and neutral expressions. Second, 20 observers independently selected the best image stimuli based on the accuracy of emotion identification and valence/arousal ratings. Third, to establish reliability, this accuracy and valence rating procedure was repeated with a second independent group of 40 participants. A final set of 144 images with good reliability was established and is made available. Results demonstrate that pain, along with basic emotions, can be communicated through body posture. Cluster analysis demonstrates that pain and emotion are recognised with a high degree of specificity. In addition, pain was rated as the most unpleasant (negative valence) of the expressions, and was associated with a high level of arousal. For the first time, specific postures communicating pain are described. The stimulus set is provided as a tool to facilitate the study of nonverbal pain communication, and its possible uses are discussed.

Keywords: Pain; Communication; Body posture; Nonverbal behaviour

1. Introduction

Pain is not only a sensory and emotional experience, but also a social-communicative event [13,14,31]. Being able to accurately communicate one's internal state is essential to survival [52]. Accordingly, humans must be able to encode, transmit, and decode affective information, including pain. Multiple channels are available for use, including aspects of voice, face, and bodily posture [26]. However, this is not straightforward, as information loss and interference in the encoding/decoding process can occur through a variety of sources, including context, individual characteristics of observers and communicators, and communication clarity.

Nonverbal pain communication has attracted significant clinical attention, especially around accurate observer ratings in assessment and treatment of pain in the preverbal [25,37] or no-longer verbal [17,44]. The success of nonverbal communication is governed by standard features including cue intensity, valence, salience, and context [7,34]. Observers' judgements of pain are differentially influenced by verbal and nonverbal communication, with nonverbal expression often perceived as more reflexive and honest, free of the influences of artefact or experience that affect verbal pain representations [12,14].

Experimental work has also played a role in shaping our understanding of pain communication, with most focusing on facial expressions. The introduction in 1976 [19] of the first widely used affective picture set for use in experimental studies (Pictures of Facial Affect [POFA]) provided a springboard for research into the facial communication of emotion, and later of pain [6,9,12, 32,33,35,38,40,43]. Pain communication through facial expression is well established, and a prototypical facial expression has been described and validated [14,30,49]. Research has also established that humans can be trained to differentiate between spontaneous and acted pain facial expressions, with mixed success [3]. Although arguably not an emotion, pain also appears to have a unique communication signature that is well identified and replicated.

Pain can be expressed through other channels, including the body. Although Ekman's 6 basic emotions (anger, happiness, fear, disgust, surprise, and sadness) have been considered in posture research [11,18,48], and judgements of pain on walking have been investigated [8,27,28], most studies focus on clinical observational tools [25,37]. This dearth of research is surprising, given the wider range of methods that could be used, as well as evidence that body posture may be more indicative of pain than facial expressions [2]. For example, although some have considered the potential communicative effect of body posture, such as work by Sullivan et al. [45], little research has used specific, isolated, body posture stimuli for the examination of the communicative function of postural changes.

This lack of research may be due to the scarcity of evidence suggesting a communicative function of pain body posture, as well as the absence of a psychometrically sound set of stimuli. Creation of such stimuli will facilitate the examination of pain communication through body posture, and what influences this communication. This study aims to investigate the extent to which postural pain behaviours serve a communicative function, while also creating and validating a set of dynamic body posture stimuli.

2 Methods and results

2.1 Phase 1: stimulus creation and posture definition

The study was conducted in 3 phases. In phase 1, potential stimuli were created. In phase 2, the stimuli were presented to participants who rated them for affective content to reduce the images to a core set. In phase 3, a replication was undertaken, using only the core set of stimuli for further validation. Ethical approval for the whole study, including all 3 phases, was granted by the University of Bath Department of Psychology and Department for Health.

For the purposes of the research that we present here, ''body posture'' is defined as the position of the body, or parts of the body [26]. This includes the position of body parts in relation to each other at any given time, but does not include movements. ''Communicative body posture'' is defined as any body posture that communicates information to an observer, whether intentionally or unintentionally.

2.1.1 Participants

Nineteen amateur actors and dancers (10 male; age range 20–26; average age, 23.68 years; standard deviation [SD] = 2.62) were recruited. All were performers drawn from the amateur dance and dramatics societies at the University of Bath. Each actor provided informed consent and agreed to the use of their image in the stimulus set. Participants were reimbursed for their participation. All were required to be pain free, and free also of prescribed medication, and were to have not ingested alcohol for 24 hours before filming. All 19 met these criteria.

2.1.2 Stimulus creation

All filming took place in a television studio at the University of Bath. Lighting in the studio was kept constant throughout filming. Each actor performed in front of a plain white backdrop curtain, and wore plain black clothing (T-shirt and trousers). A Sony HDR PJ250E video camera, mounted on a Sony VCT-R640 Tripod, was used. The position and angle of the camera were fixed throughout filming. For each participant, different levels of zoom were used to ensure that they occupied the same screen space, regardless of individual height and weight.

Each actor stood at the same location in the studio in front of the plain white backdrop, facing 45° away from head-on to the camera, facing to the left of camera (their right). A frontal view (as opposed to a view based on a view of the actor's back) was chosen because previous research has demonstrated that emotions are optimally judged from such angles [11]. Fig. 1 presents an example of the final layout of the stimuli in 25-frame increments.

Fig. 1. An example of a directed pain stimulus, with images taken every 25 frames (running from left to right, starting at frame 1).

During filming, each actor first adopted a neutral posture, with back straight, head aligned to the body, arms by the sides, and feet approximately shoulder-width apart (termed the anatomic standard position). From this neutral position, they moved to the communicative posture and held it until directed to stop; this allowed researchers to edit the stimuli for length without losing any affective content.

Actors were directed in the final posture that they would adopt for each core emotion (happiness, sadness, fear, anger, disgust, and surprise) by the researchers. Postures for the basic emotions were directed based on previous research regarding emotion communication [1,11,48], which has found specific actions and exemplar body posture configurations that communicate each emotion. Pain postures were directed based on previous evidence examining pain behaviours [29,39]. Researchers chose to direct postures (see below) to ensure that final stimuli conformed to a uniform set of general rules, such as length of stimulus, distance moved by actors, and restrictions on actions. Furthermore, their movements were directed by the researchers for speed and fluency. The exact movement and timing of each posture other than those directed were left to the actors themselves, to ensure that movement sequence was natural both to the actors and to any audience.

Previous research [3,42] has established that there are potential limitations to the use of posed nonverbal expressions for both emotions and pain over spontaneous, natural expressions, and in creating the stimuli presented here we were aware of these limitations. However, in the interests of maintaining a high level of control over the stimuli created, and ensuring consistent dimensions for presentation, it was decided that directing and tightly control- ling the stimuli created afforded the researchers the best opportunity to examine pain and emotion expressions in body postures.

Alternative strategies for examining pain communications may have been through the use of an observational design, examining real-life spontaneous pain expressions. Although this would have been a valid method for examining how the body communicates pain, this would not have afforded the researchers the same level of control and utility in the final stimulus set. It would also have been difficult to ensure that we gained the full range of emotional expressions, alongside pain, within the same patient. In using this approach, we are also able to isolate and specifically focus on potential communicative behaviours. From this, we believe that we are better able to examine the specific characteristics of pain body postures that are communicative.

2.1.3 Pain postures

For pain, actors performed 2 different types of posture. First, each actor performed a directed pain posture, in which the actor was instructed to adopt a prespecified movement/posture configuration, in the same way as for the basic emotions. The configuration of this pain posture was based on previous research that has found that certain types of behaviour are consistently observed as being strongly associated with pain. For example, in an early study that examined nonverbal pain behaviours, Keefe and Block [29] describe guarding, bracing, and rubbing as postural pain behaviours. Subsequent research [2,39,50] corroborated these findings with regard to body posture, and further emphasised the role of guarding, along with hand touches to pain sites, as an important predictor of pain-related disability. Muscle tension has also been proposed as an important postural pain behaviour, and is used in multiple clinical scales as a measure of pain intensity [5,38]. Based on this research, the directed pain posture used in the present study was an angular posture, which suggests muscle tensions, and facilitated hand action towards a potential injury site in the lower abdominal area and a forward upper body lean that resulted in a diminished overall posture.

In addition to this directed posture, actors performed undirected postures in which they spontaneously adopted a posture with little direction from the researchers, except to start with the anatomic standard position. The purpose of using undirected postures was 2-fold: We were aware that a lack of previous evidence, combined with the low likelihood of there being a single, prototypical pain posture, meant that we needed to include a variety of potential pain postures, which could then be examined both for their communicative efficacy and shared characteristics. The result was a varied collection of pain postures, ranging from specific injury site based pain postures (eg, clutching a leg or arms), to more chronic pain postures (for example, back pain portrayed through stiff or awkward movement and guarding-type behaviours). Accordingly, for the purpose of analysis, pain postures were separated into directed and undirected categories to account for the differences in the creation process of these 2 subtypes of pain posture. For the directed postures, each actor performed each of the 6 basic emotions and the directed pain posture twice to ensure that at least 1 example of sufficient quality to take into the validation phases was produced. For the undirected pain postures, actors produced as many postures as they were able to, with limited constraint except for the length of the stimulus and the extent to which they were able to move away from the starting location. The number of postures was decided by the actors, based on how they believed pain could be best communicated through body posture. Accordingly, each actor produced between 5 and 10 postures, which were not directed as stringently as the other stimuli produced through this process. For the purposes of differentiation in analysis and subsequent conclusions, these postures were termed ‘‘undirected pain’’ postures.

In total, 374 video clips were produced (2 per actor for directed pain, anger, happiness, fear, disgust, surprise, and sadness, 5 to 10 for undirected pain, per actor).

Once all of the clips had been filmed, they were edited for length using Adobe Premiere Elements. Each final stimulus was 50 frames in length, lasting 2 seconds at 25 frames per second. Actors’ faces were digitally masked using the same software package to ensure that when the stimuli were observed any communicative function could be attributed solely to the movement and position of the body and not the face. In addition, the sound was removed from each stimulus.

2.2. Phase 2: initial validation and stimulus selection

2.2.1. Participants

A new group of 20 healthy adult participants (10 male and 10 female; average age 26.4 years, SD = 3.85 years), was recruited opportunistically from the University of Bath campus. Each had normal or corrected to normal vision, and was free of any pain or chronic health condition. Each provided fully informed consent and completed a demographic information form. None had any formal training in pain diagnosis or assessment.

2.2.2. Task

Participants sat approximately 30 cm away from a Hans-G monitor and were presented with the 374 stimuli created in phase 1, which was controlled using e-prime software. Stimuli were presented in a quasi-random order, in which no 2 stimuli communicating the same emotion could be presented in sequence. Each stimulus was presented only once.

During the task, participants were instructed that they would be taking part in an expression recognition task, in which they would be presented with a series of short videos of people. They were informed that the faces of actors would be masked. They were asked to identify what was being communicated through the posture, using the forced choice discrimination paradigm in which they were presented with 8 options, 1 for each possible target expression, and a ''no emotion'' option.

After a focus interval, participants were presented with a single body posture stimulus. They were then asked to identify which target expression was present in the clip in a forced choice discrimination task in which 8 potential choices were presented (sadness, happiness, pain, fear, disgust, surprise, anger, no emotion).

Next, participants were required to rate the clip for valence, giving a score between 1 and 9, where '1' was 'very unpleasant' and '9' was 'very pleasant'. They were then required to rate the clip for level of arousal, again on a scale of 1 to 9, in which '1' was 'very relaxed' and '9' was 'highly aroused'. In both instances '5' could be used as a 'neither/nor' neutral option. Measures of valence and arousal were taken to investigate how participants viewed simple, isolated, exemplar-type body postures, and also to compare perceptions of different affective states, as has been done in previous research [46]. Any subsequent differences in valence or arousal ratings would help to elucidate differences between affective states considered in the research by enabling the direct comparison of states.

Finally, a 1-second interstimulus interval occurred before the presentation of the next trial. The same process was repeated for each of the 374 clips. Participants were not limited in the time that they took to respond, and completed the task in approximately 40 minutes. Participants had regular breaks at evenly spaced intervals throughout the task to minimise fatigue.

2.3. Data analyses

2.3.1. Stimulus selection and recognition accuracy

Average recognition accuracy ratings for each stimulus were gathered based on the data collected in the forced choice discrimination task. Based on these recognition rates, one stimulus in each category was selected from each of the 16 most consistently accurately recognised actors. This gave a final stimulus set of 144 videos; 6 emotions, 2 pain types, plus a neutral stimulus for each of the 16 actors, which was then used in all subsequent analyses.

For recognition accuracy analysis, each rater was given a score out of 16 for each target expression based on the number of stimuli that they had correctly categorised, as each expression was viewed 16 times (once per actor) by all raters. A mixed-model analysis of variance (ANOVA) of 8 (body posture expression) × 2 (actor sex) × 2 (participant sex, between-groups factor) was then carried out on these recognition scores.

2.3.2. Valence and arousal

To investigate the main effects of expression and sex variables on valence and arousal ratings, two 8 (body posture expression) × 2 (actor sex) × 2 (participant sex, between-groups factor) mixed-model ANOVAs were conducted, one using valence ratings data and one using arousal ratings data.

2.3.3. Body Action Posture Coding System

Once the data had been analysed and the most communicative clips had been defined, the Body Action Posture Coding System (BAP) [15] was used to code which specific actions were consistently present for each expression. The BAP is a comprehensive coding system designed to emulate the utility of the Facial Action Coding System [20] but tailored for use with body postures. As a research tool, it allows body postures and actions to be objectively described through the use of standardised, consistent descriptors. This would enable the researchers to define objectively specific body postural cues that communicate each target affect.

BAP codes describe postures and actions on 2 integrated levels; anatomical articulation (the body part which is actually moving) and forms of movement (how the body part is moving), while also describing movements on a functional level as emblems, illustrators, and manipulators as first described by Ekman and Freisen [21]. For the present study, a simplified version of the BAP was used; the original 141 codes were included, but we did not code postures according to functional units, that is, how pronounced movements and changes were. This was due to the relatively simple nature of the stimuli, in which movements were generally very pronounced, as they were designed to be exemplar-type expressions that communicated information clearly. In addition, a temporal proviso is placed on functional units, in which increased duration is associated with higher pronouncement. This was not appropriate for the current stimuli, as all actions were controlled to the same length, and no posture lasted more than 2 seconds.

Two independent coders evaluated each of the 144 stimuli included in the final set. Each coder was presented with the edited stimuli (no sounds or facial expressions) and was asked to code the body posture that they presented. Each rater coded the stimuli separately. Codes were then used to calculate interrater reliability, using Cohen's κ [23]. For calculation of Cohen's κ, the coding for each stimulus was taken as either a value of '1' (present in the stimulus) or '0' (not present in the stimulus) for each of the 141 codes of the BAP. Cohen's κ was then calculated for each stimulus individually. Finally, to provide a reliability rating for each expression, a mean average κ value was calculated for each stimulus type.

2.4. Phase 2 results

Table 1 summarises descriptive statistics for recognition accuracy, valence, and arousal ratings for each expression.

Table 1 Mean recognition accuracy, valence, and arousal for emotions, and standard deviations.

Expression	Recognition accuracy (as %)	Recognition accuracy (total)	Arousal ratings	Valence ratings
Directed pain	61.00	9.72 (1.83)	7.35 (1.61)	2.29 (1.56)
Undirected pain	90.62	14.60 (1.60)	7.32 (1.54)	1.95 (2.21)
Anger	93.75	15.05 (1.15)	9.64 (1.45)	2.80 (1.77)
Disgust	64.69	11.67 (2.04)	6.95 (1.65)	2.42 (1.45)
Fear	90.00	14.40 (2.30)	6.81 (1.73)	2.64 (1.48)
Happiness	92.19	14.80 (1.77)	6.60 (2.18)	7.29 (2.06)
Sadness	92.19	15.44 (.69)	5.27 (2.51)	2.42 (1.43)
Surprise	79.06	12.70 (3.10)	7.32 (1.57)	3.59 (1.68)

2.4.1. Recognition accuracy

A significant main effect of body posture expression was found ($F_{3.89,126} = 20.41$, $P < .01$), with no significant main effect of actor sex or participant sex, and no significant interactions among any of the independent variables.

To examine specific differences between target expression, post hoc pairwise comparisons using a Bonferroni correction were conducted. The Bonferroni method was selected based on previous literature that suggests using a more conservative significance value when performing a large number of pairwise comparisons. Applying this correction, a significant value of $P < .0018$ was used throughout analyses. The results are reported below; to aid clarity, here and in subsequent analyses, where a significant effect is found, we report the difference between total scores for each expression (ie, of 16). Where a negative figure is presented, recognition accuracy for the first expression was significantly lower than the comparison expression. Where a positive difference is presented, the opposite is true.

No significant difference in body posture recognition accuracy was found between undirected pain postures and anger, fear, happiness, sadness, or surprise. Undirected pain was recognised with a significantly greater accuracy than directed pain (difference = 4.88, $P < .0018$). This demonstrates that for undirected pain postures, recognition accuracy was as high or higher than for all other expressions considered.

Analysis also revealed that there were significant differences in recognition accuracy between directed pain and anger (difference = − 5.33, $P < .0018$), directed pain and fear (difference = − 4.68, $P < .0018$), directed pain and happiness (difference = − 5.08, $P < .0018$), directed pain and sadness (difference = − 5.72, $P < .0018$), and directed pain and surprise (difference = − 2.98, $P < .0018$). No significant difference was found between directed pain and disgust (difference = − 1.95, $P > .0018$). In addition, significant differences in recognition accuracy were found between disgust and anger (difference = − 3.38, $P < .0018$), disgust and fear (difference = − 2.73, $P < .0018$), disgust and happiness (difference = − 3.13, $P < .0018$), and disgust and sadness (difference = − 3.77, $P < .0018$). Finally, a significant difference was observed between surprise and sadness (difference = −2.74, $P < .0018$).

2.4.2. Valence

For valence ratings, a significant main effect of body posture expression was found ($F_{3.89,126} = 43.9$, $P < .05$). No significant main effect was found for sex of actor or sex of observer, and no significant interaction between any of these variables. Post hoc pairwise comparisons using a Bonferroni correction revealed significant differences between directed pain and happiness (difference = − 5.00, $P < .0018$) and directed pain and surprise (difference = − 1.30, $P < .0018$). In addition, significant differences were observed between undirected pain and happiness (difference = − 5.34,

$P < .0018$) and between undirected pain and surprise (difference = − 1.64, $P < .0018$).

In addition to pain variables, differences were also observed between anger and disgust (difference = 3.09, $P < .0018$), anger and fear (difference = 2.86, $P < .0018$), and anger and sadness (difference = 3.09, $P < .0018$), as well as between fear and happiness (difference = −4.65, $P < .0018$).

2.4.3. Arousal

For arousal ratings, a significant main effect of body posture expression was found ($F_{3.89,126} = 16.12$, $P < .01$). Again, no significant main effect of either sex variable was found, and no significant interactions were found between independent variables. Post hoc pairwise comparisons, as before, revealed significant differences between directed pain and sadness (difference = 2.05, $P < .0018$), as well as between undirected pain and sadness (difference = 2.02, $P < .0018$). No other significant differences were found between pain and any other target expression.

Further significant differences were also found between anger and fear (difference = 0.932, $P < .0018$), anger and happiness (difference = 1.14, $P < .0018$), and anger and sadness (difference = 2.47, $P < .0018$). This shows that both directed and undirected pain, alongside anger, were rated as being the highest arousal expressions compared to the others considered.

2.4.4. BAP coding

Two raters viewed each stimulus and used the BAP codes to objectively describe the communicative actions in them. Mean interrater reliability ratings for each target emotion and pain are presented in Table 2, alongside specific posture codes defined by raters as best describing the stimuli within each target expression. Overall, the κ value for all expressions was above the 0.75 threshold defined by Fleiss [23] as ‘excellent’, demonstrating good agreement between the raters on codes describing the communicative postures.

Focusing on the pain ratings, BAP analysis demonstrated that consistent actions were present in pain body postures with high recognition accuracy rates, considering both directed and undirected postures. Specifically, high-intensity rapid movements enabling hand contact to pain sites were observed. Lower back movements leading to torso displacement were also consistently observed in the undirected pain postures. Trunk orientation was generally towards the forward position, with some undirected postures demonstrating averted trunk postures, generally associated with hand interaction with upper body areas such as the head and shoulder. Knee bending was consistently observed throughout directed and undirected pain body postures.

Table 2 Body Action Posture Coding System (BAP) [8] codes for each expression category, including interrater reliability calculations.

Expression	Key BAP components	Mean Cohen's κ
Directed pain	Head averted, gaze downward, forward body lean, trunk facing, elbows bent, arms site, hands manipulate injury site, knees bent	0.953
Undirected Pain	Head averted, trunk averted, left and right hands touch to various sites, knee bend, shoulder to front	0.974
Anger	Head facing, gaze toward, whole body forward lean, trunk facing, left and right arms front, elbows bent, hands clenched, left and right knees bent	0.936
Disgust	Head averted, gaze toward, trunk averted, left and right arms front, palms facing, legs straight	0.874
Fear	Head facing, gaze downward, no body lean, trunk facing, knees bent elbows bend, palms facing, knees bent	0.914
Happiness	Head facing, gaze upward, no body lean, arms vertical, elbows and knees straight	0.981
Sadness	Head facing, gaze downward, forward body lean, left and right arms side, knees bent	0.922
Surprise	Head facing, gaze toward, backwards body lean, trunk averted, arms vertical, elbows bent, knees straight	0.861

2.5. Phase 3: further validation

2.5.1. Participants

In phase 3, a new group of 40 healthy adult participants who were free of any pain or chronic health conditions were recruited from the University of Bath (20 male; average age 22.03 years, standard deviation [SD] = 2.96). Each participant gave fully informed consent and had normal or corrected-to-normal vision. None had any formal training in pain diagnosis or assessment.

2.5.2. Procedure

All procedural details relating to recognition accuracy were identical to those in phase 2. Participants were asked to perform a similar rating task as described in phase 2 with the principal difference being the number of items to be rated, in that only the final set of 144 stimulus clips selected in phase 2 were presented. Stimuli were selected for inclusion in the final set based on recognition accuracy rates found in phase 2. Stimuli were eliminated based on an above-chance cut-off of 60% recognition accuracy. A 60% point was used to ensure that the stimuli included in the final set would have high recognition accuracy, and was preferred over the chance rate of 12.5% as this would reflect a very high degree of inaccuracy in recognition (87.5% incorrect selection). Once these had been removed, 8 male and 8 female actors who presented complete video sets were included. If more than 8 actors met these removal criteria, the 8 actors with the highest recognition accuracy rates across all expression categories were included in the final stimulus set. This ensured that the actors with the most communicative postures were included in the final set. In addition, for each actor, the undirected pain posture with the highest recognition accuracy rate was included. In total, each actor provided 9 stimuli to the final set (neutral, happy, sad, fear, anger, disgust, surprise, directed pain, and undirected pain).

Participants were asked to rate each of the stimuli for the intensity of each expression that they contained, regardless of the target expression. For example, participants were asked to rate how much fear, happiness, sadness, anger, disgust, surprise, and pain were present in each pain target stimulus. From these ratings, hit rates were calculated that would provide a second measure of recognition accuracy for each stimulus within each target expression condition. This would provide the researchers with a second measure of recognition accuracy. Previous research [42] has criticised the use of forced-choice–type tasks as creating artificially high recognition rates by providing participants with only a limited selection of response options. In using a second recognition accuracy measure, we hoped to control this effect.

Furthermore, in using hit rates, we enabled the further validation of results previously reported. This also allowed an examination of participants' ability to discriminate between specific expressions and identify any ambiguities in the stimuli through the use of a cluster analysis.

2.5.3. Data analysis

Recognition accuracy, valence, and arousal analyses were repeated from phase 2. Participant's ratings of intensity across expressions were used to compute hit rates for each emotion. A hit was defined as an instance in which the participant rated the target expression as the highest intensity present. This method provides a second measure of recognition accuracy, alongside the forced choice discrimination task. Hit rates were calculated using the formula from Simon et al. [43].

In addition, a cluster analysis was conducted, which establishes whether clear boundaries existed between the different expression categories (Euclidean distances, Ward method) [46]. Separation of the results into distinct clusters defined according to target expression would demonstrate minimal confusion in participants between the target expression and establish a level of specificity in the stimuli defined for each expression.

2.6. Phase 3 results

Recognition accuracy, valence, and arousal scores are presented in Table 3.

Table 3 Recognition accuracy rates, valence, and arousal from phase 3 data.

Expression	Recognition accuracy (%)	Recognition accuracy, raw score (total)	Arousal ratings	Valence ratings
Directed pain	56.03	8.95 (2.16)	7.02 (0.98)	1.94 (0.69)
Undirected pain	90.00	14.30 (1.14)	6.56 (1.34)	1.73 (0.57)
Anger	91.59	14.33 (2.85)	7.50 (1.04)	2.63 (1.19)
Disgust	66.70	9.75 (4.13)	6.28 (1.15)	2.32 (1.06)
Fear	90.83	14.45 (1.66)	6.59 (1.34)	2.56 (0.96)
Happiness	91.16	14.28 (2.05)	6.07 (1.52)	7.47 (0.88)
Sadness	94.40	14.95 (2.11)	4.60 (4.45)	2.09 (0.91)
Surprise	76.46	12.53 (2.67)	7.28 (0.91)	4.16 (0.96)

2.6.1. Recognition accuracy

Similar to phase 2, a significant main effect of body posture expression was found ($F_{3.48,266} = 32.63$, $P < .05$), with no significant main effect of actor sex or participant sex, and no significant interactions among any of the independent variables. Post hoc pairwise comparisons using a Bonferroni correction again revealed significant differences in recognition accuracy between undirected pain and directed pain (difference = 5.35, $P < .0018$) and undirected pain and disgust (difference = 4.55, $P < .0018$). No other significant differences in recognition accuracy were found for undirected pain. This again shows that participants were able to recognise undirected pain postures with a degree of accuracy as good as, or better than, any other expression presented.

Significant differences in recognition accuracy were observed between directed pain and anger (difference = − 5.38, $P < .0018$), directed pain and fear (difference = − 5.5, $P < .0018$), directed pain and happiness (difference = − 5.33, $P < .0018$), directed pain and sadness (difference = − 6.0, $P < .0018$), and directed pain and surprise (difference = − 3.58,

$P < .0018$). Significant differences in recognition accuracy were found between disgust and anger (difference = − 4.58, $P < .0018$), disgust and fear (difference = 4.70, $P < .0018$), disgust and happiness (difference = 4.53, $P < .0018$), and disgust and sadness (difference = 5.20, <.0018). Finally, a significant difference was observed between surprise and sadness (mean difference = 2.42, $P < .0018$). No other significant differences were found. These results closely mirror phase 2 (above).

2.6.2. Valence and arousal

As in phase 2, a significant main effect of body posture expression was found for both valence ($F_{3.48,266} = 249$, $P < .05$) and arousal ($F_{3.48,266} = 40.92$, $P < .01$) ratings. No significant influence of either sex of the actor, or the observer, or an interaction between the 2 was found for either outcome. Post hoc pairwise comparisons using a Bonferroni correction for both valence and arousal matched well with the results from phase 2.

For valence, results showed significant differences between directed pain and anger (difference = − 0.7, $P < .0018$), directed pain and happiness (difference = −5.52, $P < .0018$), and directed pain and surprise (difference = −2.29, $P < .0018$). Significant differences were observed between undirected pain and anger (difference = −0.88, $P < .0018$), undirected pain and fear (difference = −0.79, $P < .0018$), undirected pain and happiness (difference = −5.70, $P < .0018$), and undirected pain and surprise (difference = −2.47, $P < .0018$). Away from pain stimuli, significant differences were also found between anger and happiness (difference = −4.82, $P < .0018$) and anger and surprise (difference = −1.59, $P < .0018$), as well as between fear and happiness (difference = −4.92, $P < .0018$) and fear and surprise (difference = −1.68, $P < .0018$).

For arousal ratings, analysis found significant differences between directed pain and disgust (difference = 0.71, $P < .0018$) and directed pain and sadness (difference = 2.43, $P < .0018$), as well as between undirected pain and sadness (difference = 2.01, $P < .0018$), and undirected pain and surprise (difference = −0.80, $P < .0018$). Significant differences were once again found between anger and disgust (difference = 1.25, $P < .0018$), anger and fear (difference = 0.88, $P < .0018$), anger and happiness (difference = 1.27, $P < .0018$), and anger and sadness (difference = 2.97, $P < .0018$).

2.6.3. Hit rate and discrimination

In addition to the forced choice discrimination paradigm results, the intensity ratings allowed a further calculation of recognition accuracy hit rates. Hit rate was calculated as an overall percentage, based on the number of hits and the number of observations in total. Hit rate scores are detailed in Table 4, and show high recognition rates for most of the expressions considered, with the exception of directed pain postures and disgust. This further supports the findings from the previous recognition accuracy measures.

The cluster analysis grouped ratings of expression intensity into 8 distinct clusters corresponding to the target expressions (including the neutral category), with directed and undirected pain forming a single cluster. All clips were adequately assigned to the target expression category (meaning the distance between stimuli of the same target expression was smaller than the distance between stimuli of difference target expression). Second-order combinations were observed between fear and directed pain. There was also minor proximity between anger and directed pain.

Table 4 Hit rate and discrimination data for phase 3.

Expression	Hit rate (%)	Expression perceived (based on mean intensity ratings)						
		Pain	Anger	Disgust	Fear	Happiness	Sadness	Surprise
Directed pain	86	5.60 (2.09)	2.48 (0.99)	2.68 (0.26)	4.27 (1.37)	1.29 (0.22)	2.78 (0.56)	2.95 (0.59)
Undirected pain	100	7.30 (0.88)	2.04 (0.27)	2.37 (0.39)	2.93 (0.61)	1.26 (0.14)	2.95 (0.58)	2.54 (0.64)
Anger	100	1.71 (0.22)	7.01 (0.51)	3.56 (0.43)	2.21 (0.38)	1.43 (0.20)	1.62 (0.13)	2.23 (0.36)
Disgust	66	1.69 (0.23)	2.30 (0.30)	5.52 (0.66)	4.62 (0.54)	1.29 (0.14)	1.88 (0.18)	3.64 (0.78)
Fear	100	2.18 (0.28)	1.89 (0.20)	3.04 (0.37)	6.84 (0.50)	1.33 (0.20)	2.49 (0.31)	3.33 (0.72)
Happiness	100	1.19 (0.08)	1.30 (0.15)	1.19 (0.09)	1.20 (0.09)	7.24 (1.23)	1.20 (0.14)	3.73 (0.57)
Sadness	96	2.53 (0.29)	1.58 (0.19)	2.00 (0.18)	1.87 (0.32)	1.22 (0.12)	6.79 (0.59)	1.64 (0.25)
Surprise	100	1.54 (0.13)	1.70 (0.28)	2.45 (0.37)	3.79 (0.69)	1.92 (0.55)	1.52 (0.18)	7.02 (0.85)

2.7. Final Bath Emotion and Pain Posture Stimuli (BEPPS)

The final stimulus set of 144 postures grouped into 16 clips for each of the 9 affect states (2 pain, fear, happiness, sadness, anger, disgust, surprise, and neutral) and BAP descriptions are made available for research purposes via the Bath Centre for Pain Research Web site (http://www.bath.ac.uk/pain/assessment-tools/).

3 Discussion

In this article, we present a stimulus set for use in pain communication research. We demonstrate that pain behaviours serve a communicative function. Naive observers accurately recognised and categorised pain behaviours at rates that compare favourably to those for emotions. Pain was rated overall among the most unpleasant expressions, and was rated among the highest for arousal. This finding is consistent with previous research on facial expressions [43], and suggests that pain is afforded high significance in social perception.

Results from the BAP demonstrate that specific postural cues and actions are identified as pain-communicative, in particular hand movements towards specific body parts. Knee bending was consistently found in pain body postures. This is most likely to be indicative of an attempt to protect, but may also serve an additional communicative function to diminish the overall profile of the posture and to appear less threatening to potential noxious stimulus sources. Consistency in observed postures suggests at least some level of prototypical movement, although a single unifying posture was not found.

Information about one's private experience of pain is transmitted through body posture, and is reliably identified by observers. These findings add to and extend those with facial expressions [12,37,40,43], and vocalisations [4]. Pain can be communicated through each key nonverbal channel [26]. Posture clearly holds information that can be used by observers, and could usefully be thought of as one of the nonverbal channels used in the social communication of private experience, regardless of intention.

Although above the chance rate, the recognition accuracy of the directed pain postures was relatively low, failing to support our concept of a prototypical pain posture. Although other postures can be considered and examined, it may be that pain is better communicated through postural cues rather than through a single posture. This would be in keeping with the findings that we present here, which suggest that a certain, limited field of postural cues are associated with pain, rather than a single, uniform posture. This is perhaps to be expected, considering the breadth of the pain experience; different pain types and locations are likely to differentially influence body posture. However, the findings that we present here suggest that across all potential variations in pain experience, the presence of certain pain behaviours, well documented in previous research, could serve a communicative function. This may be due to pain being better communicated not through a single posture but rather through select, indicative postural actions that are consistently produced in pain experiences. Actions such as arm movement towards injury sites and increases in muscle tension can potentially serve multiple purposes in isolation, but when combined with contextual cues to pain may become pain communicative. Replication and extension of these findings in other laboratories is necessary.

One application of this research will be to consider the role that body posture communication plays in eliciting help. Pain communication is intrinsically social: overt pain display serves a number of important functions, including warning others of danger, and provoking succour, assistance, or repair. In real-world settings, body posture and actions are the first visual cue to bystanders that help is required. This is important in crowds, where posture must be quickly and accurately recognised to maximise the chances of receiving aid. Models of bystander behaviour have highlighted the need for clarity in communication channels when attempting to acquire help from others [16]. In this research, we have demonstrated that pain body postures are accurately identified when in isolation, providing a first step towards understanding how we attempt to encourage helping behaviour. The next step is to consider the role of additional contextual factors such as social crowding, attention to threat, and goal-specific movement behaviour. What must also be considered is the dichotomous role of pain communication; we express pain to encourage others to help, but observers can use this communication as a cue to be self-protective. Further research is needed to establish reasons for helping behaviour selection, and to examine whether the dual role of pain behaviours, that is, as both communicators and self-protective actions, plays a role in the reactionary behaviours of others. Individual differences communicators and observers are also likely to play a role: principal candidates are gender [10,22,30], previous pain experiences [41], and state and trait affect [24].

Another key aspect of pain communication is the role multiple nonverbal channels play in recognition. Previous research has already demonstrated that presenting information in multiple channels can have a significant effect on observers' recognition and interpretation of cues that are individually seen with high recognition accuracy. Vroomen and de Gelder [51] found that facial emotion recognition could be biased by the simultaneous presentation of auditory stimuli, leading participants to rate faces as more expressive. Similar findings are presented by Aviezer et al. [2], who found greater accuracy of recognition for affective valence for body postures compared with facial expressions for a number of target expressions, including pain. This finding supports the assertion that facial expressions and body postures may hold different roles in communication [45]. Similar findings regarding multi-modal communication have been described by other researchers [9,10], and it is clear that a combination of channels can be used to change how we perceive affect. The stimuli created in this study should help to facilitate further investigation of how cross-modal pain communication influences our ability to recognise and react to pain.

Considering clinical applications for this research tool, the role that training and expertise may play in patients' pain body posture has yet to be adequately considered. Although overall pain posture recognition in a normal population has been demonstrated to be good, expertise may enable greater accuracy or allow observers to garner more information from communicators. Previous research has shown that body actions are important in clinical pain diagnostics. Tsai et al. [49] found that pain body postures such as guarding were strong predictors of verbally reported pain levels, and a number of scales have aimed to use nonverbal behaviour to interpret pain. The Toddler-Preschooler Postoperative Pain Scale (PTTS) [47] is an observational assessment tool that measures postoperative pain in young children based on a 7-point rating scale in 3 categories, relating to the channels of nonverbal behaviour. Although the scale demonstrates high interrater reliability, specific body posture cues that indicate pain are marginalised in favour of facial expression and vocalisation information. Similar issues arise with scales used to diagnose adult pain. With the application of the present research, a more specific set of body posture cues to children's pain may be developed, thus further enhancing the utility of scales such as the PTTS and others [25,27,28]. Applying this objectively gathered data to clinical populations will facilitate more accurate and faster diagnosis of pain-related problems.

This study is limited currently to the study of healthy adults enacting movements being observed by participants without specific knowledge about pain behaviour. A significant body of literature has developed regarding the use of actors, well summarised by Russell [42], and although this has focussed on facial expressions, the same issues may arise when considering body postures. Considering the aims of the present research, the use of actors was justified through a number of issues that arise in emotion perception research (issues of emotion induction) and pain (issues of how influential pain is on movement and of requiring pain patients to perform complex movements). Future research may wish to consider clinical or real-world pain populations and their communicative body postures. Also, directed pain postures were recognised with significantly lower accuracy rates than undirected postures. This is likely due to a limitation in the directed posture, such as inconsistent or unclear hand contact with injury sites due to the crouching nature of the posture. It may also be that this posture was more similar to other expression types considered, most likely fear and anger postures that were associated with similarly crouched and angular postures. Despite this, recognition accuracy remained above the 60% inclusion rate required, and so directed and undirected postures are included in the final stimulus set and analysis.

In addition, there is an element of preconception in the stimuli created; actors were instructed to adopt postures in this study. Although instruction was informed by previous research, such instructions and the postures created through them are contingent on the social conventions of the director and actor. This would perhaps be more in keeping with emblematic, premeditated behaviours, which may not reflect the more spontaneous behavioural responses to pain that might be expected. Previous research has established that facial expression use and recognition can be subjective and culturally bound [33,36], and a logical assumption is that the same applies to body postures. Similarly, research has found that there can be significant differences in recognition between voluntary and posed emotion expressions, and although research considering this effect in pain is still limited, research by Bartlett et al [3] has found that observers can be trained to identify deceptive pain expressions, suggesting there are detectable difference between the 2. Despite of this, high recognition rates by naive observers presented here suggest an element of universality that would not be possible if pain communication were totally individual.

Individual differences in postures created by actors, either in directed or undirected posture categories, may point toward a lack of agreement regarding what actions communicate pain. However, although overall pain postures varied significantly, shared characteristics across the stimuli that characterised pain communication were found. This suggests that common pain actions are present and shared, despite overall differences in type of posture observed. Certainly, an important future direction for research will be to further validate the postures that we have created here against spontaneous pain expressions, to further identify these common features. We suggest that pain communication is accurate despite individual differences, and that perhaps social convention enables high recognition rates. Future research may wish to expand this consideration.

3.1 Conclusion

In conclusion, we offer (free for use) a validated set of affective body posture stimuli that includes communicative pain body postures alongside postures for the 6 basic emotions, as well as neutral postures. These stimuli are reliably recognised as communicating their target expressions by normal individuals. We report specific postures and actions that communicate pain consistently to observers. This set of body posture stimuli can be widely used in a range of studies to further investigate how we communicate pain nonverbally.

Acknowledgements

This research was funded by a Graduate School Scholarship provided by the University of Bath. The authors thank Emma Fisher of the University of Bath for acting as the second coder for the Body Action Posture Coding System (BAP)

results.

References

[1] Atkinson A, Dittrich W, Gemmell A, Young A. Emotion perception from dynamic and static body expressions in point-light and full-light displays. Perception 2004;33:717–46.
[2] Aviezer H, Trope Y, Todorov A. Body cues, not facial expressions, discriminate between intense positive and negative emotions. Science 2012;338:1225–9.
[3] Bartlett Marian S, Littlewort Gwen C, Frank Mark G, Lee K. Automatic decoding of facial movements reveals deceptive pain expressions. Curr Biol 2014;24:738–43.
[4] Belin P, Fillion-Bilodeau S, Gosselin F. The Montreal Affective Voices: a validated set of nonverbal affect bursts for research on auditory affective processing. Behav Res Methods 2008;40:531–9.
[5] Berman D, Duncan A, Zeltzer L. The evaluation and management of pain in the infant and young child with cancer. Br J Cancer 1992;18:S84–91.
[6] Boucher J, Carlson G. Recognition of facial expression in three cultures. J Cross Cult Psychol 1980;11:263–80.
[7] Burgoon J, Bonito J, Ramirez Jr A, Dunbar N, Kam K, Fischer J. Testing the interactivity principle: effects of mediation, propinquity, and verbal and nonverbal modalities in interpersonal interaction. J Commun 2002;52:657–77.
[8] Clarke J, Eccleston C. Assessing the quality of walking in adults with chronic pain: the development and preliminary psychometric evaluation of the Bath Assessment of Walking Inventory. Eur J Pain 2009;13:305–11.
[9] Collignon O, Girard S, Gosselin F, Roy S, Saint-Amour D, Lassonde M, Lepore F. Audio-visual integration of emotion expression. Brain Res 2008;1242:126–35.
[10] Collignon O, Girard S, Gosselin F, Saint-Amour D, Lepore F, Lassonde M. Women process multisensory emotion expressions more efficiently than men. Neuropsychologia 2010;48:220–5.
[11] Coulson M. Attributing emotion to static body postures: recognition accuracy, confusions, and viewpoint dependence. J Nonverbal Behav 2004;28:117–39.
[12] Craig K. The facial expression of pain: better than a thousand words? APS J 1992;1:153–62.
[13] Craig K. The social communication model of pain. Can Psychol 2009;50:22–32.
[14] Craig K, Versloot J, Goubert L, Vervoort T, Crombez G. Perceiving pain in others: automatic and controlled mechanisms. J Pain 2010;11:101–8.
[15] Dael N, Mortillaro M, Scherer K. The Body Action and Posture Coding System (BAP): development and reliability. J Nonverbal Behav 2012;36:97–121.
[16] Darley J, Latane B. Bystander intervention in emergencies: diffusion of responsibility. J Pers Soc Psychol 1968;8:377–83.
[17] Dethier M, Blairy S, Rosenberg H, McDonald S. Spontaneous and posed emotional facial expressions following severe traumatic brain injury. J Clin Exp Neuropsychiatry 2012;34:936–47.
[18] Ekman P. Differential communication of affect by head and body cues. J Pers Soc Psychol 1965;2:726–35.
[19] Ekman P, Friesen W. Picture of facial affect. Palo Alto, CA: Consulting Psychology Press; 1976.
[20] Ekman P, Friesen W, Hager J. Facial Action Coding System (FACS). Salt Lake City: A Human Face; 2002.
[21] Ekman P, Friesen W. Head and body cues in judgement of emotion—a reformulation. Percept Mot Skill 1967;24: 711–24.
[22] Fillingim R, Maixner W. Gender differences in the responses to noxious stimuli. Pain Forum 1995;4:209–21.
[23] Fleiss J. Statistical methods for rates and proportions. Hoboken, NJ: Wiley; 2004.
[24] Geisser M, Robinson M, Keefe F, Weiner M. Catastrophizing, depression and the sensory, affective and evaluative aspects of chronic pain. PAIN® 1994;59:79–83.
[25] Hand I, Noble L, Geiss D, Wozniak L, Hall C. COVERS neonatal pain scale: development and validation. Int J Pediatr 2010;2010:1–5.
[26] Harrigan J, Rosenthal R, Scherer K. The new handbook of methods in nonverbal behavior research. New York: Oxford University Press; 2005.
[27] Jensen M, Turner J, Romano J, Fisher L. Comparative reliability and validity of chronic pain intensity measures. PAIN® 1999;83:157–62.
[28] Jensen M, Turner L, Turner J, Romano J. The use of multiple-item scales for pain intensity measurement in chronic pain patients. PAIN® 1996;67:35–40.
[29] Keefe F, Block A. Development of an observation method for assessing pain behavior in chronic low back pain patients. Behav Ther 1982;13:363–75.
[30] Keogh E. Gender differences in the nonverbal communication of pain: A new direction for sex, gender, and pain research? PAIN® 2014;155:1927–31.
[31] Krahé C, Springer A, Weinman J, Fotopoulou A. The social modulation of pain: others as predictive signals of salience—a systematic review. Front Hum Neurosci 2013;7:386–407.
[32] Kret M, Pichon S, Grezes J, de Gelder B. Similarities and differences in perceiving threat from dynamic faces and bodies. An fMRI study. NeuroImage 2011;54:1755–62.
[33] LaFrance M, Mayo C. Cultural aspects of nonverbal communication. Int J Intercult Relat 1978;2:71–89.
[34] LaGuardia R. The effect of the social setting on nonverbal exchange behaviors: a functional approach. Lincoln: University of Nebraska; 1982.
[35] Lang P, Greenwald M, Bradley M, Hamm A. Looking at pictures: affective, facial, visceral, and behavioral reactions.

Psychophysiology 1993;30:261–73.
[36] Matsumoto D. Cultural similarities and differences in display rules. Motiv Emot 1990;14:195–214.
[37] McGrath P, Johnson G, Goodman J, Schillinger J, Dunn J, Chapman J. CHEOPS—a behavioral-scale for rating postoperative pain in children. Adv Pain Res Ther 1985;9:395–402.
[38] Prkachin K. The consistency of facial expressions of pain: a comparison across modalities. PAIN® 1992;51:297–306.
[39] Prkachin K, Schultz I, Hughes E. Pain behavior and the development of pain-related disability: the importance of guarding. Clin J Pain 2007;23:270–7.
[40] Prkachin K, Solomon P. The structure, reliability and validity of pain expression: evidence from patients with shoulder pain. PAIN® 2008;139:267–74.
[41] Riedl V, Valet M, Wöller A, Sorg C, Vogel D, Sprenger T, Boecker H, Wohlschläger AM, Tölle TR. Repeated pain induces adaptations of intrinsic brain activity to reflect past and predict future pain. NeuroImage 2011;57:206–13.
[42] Russell J. Is there universal recognition of emotion from facial expression - review of the cross-cultural studies. Psychol Bull 1994;115:102–41.
[43] Simon D, Craig K, Gosselin F, Belin P, Rainville P. Recognition and discrimination of prototypical dynamic expressions of pain and emotions. PAIN® 2008;135:55–64.
[44] Spell L, Frank E. Recognition of nonverbal communication of affect following traumatic brain injury. J Nonverbal Behav 2000;24:285–300.
[45] Sullivan M, Adams H, Sullivan M. Communicative dimensions of pain catastrophizing: social cueing effects on pain behaviour and coping. PAIN® 2004;107:220–6.
[46] Tabachnick B, Fidell L. Using multivariate statistics. 7th ed. Boston MA: Pearson Education Inc; 2007.
[47] Tarbell S, Thomas Cohen I, Marsh J. The Toddler-Preschooler Postoperative Pain Scale: an observational scale measuring postoperative pain in children aged 1–5. Preliminary report. PAIN® 1992;50:273–80.
[48] Troje N. Decomposing biological motion: a framework for analysis and synthesis of human gait patterns. J Vis 2002;2:371–87.
[49] Tsai P, Kuo Y, Beck C, Richards K, Means K, Pate B, Keefe F. Non-verbal cues to osteoarthritic knee and/or hip pain in elders. Res Nurs Health 2011;34:218–27.
[50] von Baeyer C, Spagrud L. Systematic review of observational (behavioral) measures of pain for children and adolescents aged 3 to 18 years. PAIN® 2007;127:140–50.
[51] Vroomen J, de Gelder B. Sound enhances visual perception: cross-modal effects of auditory organization on vision. J Exp Psychol Hum Percept Perform 2000;26:1583–90.
[52] Williams A. Facial expression of pain: an evolutionary account. Behav Brain Sci 2002;25:439–88.