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**Creating a better picture of chronic pain: Improving pain pictogram designs through systematic evaluation of user responses.**

Journal:	<i>British Journal of Pain</i>
Manuscript ID	BJP-15-0033.R1
Manuscript Type:	Original Manuscript
Keywords:	Pain, pain assessment, pain quality, pictograms, graphic design, user testing
Abstract:	<p>Abstract: This paper discusses the challenges of visually representing pain qualities in pictogram design. An existing set of 12 pictograms designed for people with literacy problems was evaluated to understand more about misunderstandings of pictogram interpretation. Two sets of university students from different disciplines were asked to interpret the pictograms and a novel classification system was developed to categorise answer types, as 'location', 'affective', temporal' or 'literal'. Several design recommendations are made as a result that will help improve the design of pain pictograms as a whole as well as guide designers of related pictogram work. We demonstrate how, through the robust classification of incorrect responses, it is possible to extract useful comprehension error patterns to inform future design.</p>

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Short title: Pain pictogram designs

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(main paper 4,729 words; abstract 119 words)

## Introduction

Chronic pain is common and a recent review reported global prevalence rates for chronic pain at approximately 30%. (1) It affects approximately 14 million adults in England. (2)

Diagnosing the causes of pain requires its quality to be fully understood by the clinician. Where the person in pain is unable to describe it verbally (for instance due to poor English, a learning disability or cognitive impairment) diagnosis can be particularly problematic. Whilst the clinician may observe non-verbal communication (such as gestures) to aid diagnosis there is increasing interest in the role that pictures and in particular, pictograms (simplified icon-based pictures) can play in representing pain.

This paper discusses the challenges of visually representing pain qualities in pictogram design. It reports on the first evaluation phase of on-going research that involves designing and animating pain quality pictograms. The main impetus of this research is, in the first instance, to identify good and poor practice in the visual design of static pictograms for the representation of pain qualities. The first phase consisted of the evaluation of a set of existing still-image pictograms with literate users. We use the term 'literate' to refer to those who can read, write, and use numbers effectively in English (3).

This paper's main contribution is its novel classification method for user responses. This newly developed Pain Pictogram Evaluation System (PPES) could be used more widely by designers of pain-related pictograms. User responses to pain pictograms could be classified in future work, enabling more precise identification of design errors types. We demonstrate how, through

the robust classification of incorrect responses, we were able to extract useful comprehension error patterns to inform future design.

The images examined in this paper depict qualities of both neuropathic and non-neuropathic pain. The former is due to nerve disease or damage and requires specialised treatment and is found in 8–18% of the general population (4). A recent review (5) summarised the words used to describe key sensations caused by the two main types of pain in 13 existing pain quality assessment scales. Neuropathic pain tended to be: burning, tingling, numb, sensitive, electrical or cold. In contrast non-neuropathic pain tended to be: sharp, pressure-like, sore, shooting, achy, throbbing or dull. Patients whose pain has mixed aetiology may experience sensations from both groups. The treatment for these two kinds of pain differs, so it is essential that the clinician is able to recognise the presence of nociceptive and/or neuropathic pain before deciding on treatment. How we may improve the visual representation of the two pain types, as a possible method of communication between patient and clinician, is this paper's focus.

**Pictorial Systems for Communication in Health**

Pictures are commonly used in health communication to aid attention, comprehension and recall, and promote adherence. Studies in health-based picture comprehension have previously been oriented towards user understanding of medical instructions or warnings (6;7;8;9;10), particularly in terms of pictogram designs. However pictograms may also prove useful in assessing pain, particularly with children (11). Using pictures to aid people in pain to express the pain quality they experience is a relatively new area and shifts the research agenda from pictures that *instruct* or *inform* to those that facilitate *expression*. This requires a tight mapping

of pain qualities onto visual representations that are easy to understand both for clinicians and people in pain and it requires a set of representations that cross cultural borders and work for a range of literacy levels. This is particularly challenging given that people are likely to picture their own pain in many different ways (12; 13).

Pictorial interpretation is bound by semiotics. As Stephenson and Linfoot (14) stated, the resemblance between the object and its picture is a characteristic determined by the observer. It is vital therefore that extensive user testing is carried out on existing visual tools to understand how audiences comprehend pictograms. If these evaluations prove unsatisfactory then redesigns are required using a range of methodologies, including co-design methods with patients.

Using a broader theoretical approach, Pierce's three sign modes (of symbol, icon and index) enables the classification of a pictogram's system for meaning (15). Previously Pierce's classification system has been convincingly used to analyse user interface icons (16) and it can also, we believe, be applied usefully to health pictograms. In the classification system, the word 'symbol' is used to describe an arbitrary mode of communication which must be learned and does not visually resemble the referent. An example of an arbitrary sign might be a triangular shaped border around a road sign connoting warning for British drivers. Conversely, an 'icon' visually resembles the referent, for example a traffic congestion sign featuring cars waiting behind each other. An 'index' is not arbitrarily assigned but has some link to the referent, which may also need learning. An 'index' example may be related to the cause or trigger of the referent such as a 'high winds' road sign represented by a blowing windsock. Since wind is invisible, the resultant effect of high winds is pictured instead. Since pain is internal and invisible it has a limited visual referent (except external bodily gestures) and therefore a symbol and

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index-led approach may be more commonly used as sign modes when visualising pain. Using a symbol may be problematic, since it has to be learned and is arbitrary in form. Preferably any health tool should allow immediate recognition and it cannot be assumed that the patient (in this case the person in pain) will encounter the tool more than once. Applying Pierce's (15) typology to pain pictograms would suggest that an indexical approach would be more suited to pain representation - a trigger/cause of the pain (such as an object) may be more appropriate. This is evident for instance in Padfield's work (17) where photographic visual analogy is used. For instance, to depict a particularly debilitating and restricting pain, Padfield (together with the participant in pain), visualised the pain as a photograph of a specially constructed concrete suit jacket. This is not a direct representation of the pain but rather what pain could feel *like*.

Despite the challenges of representing pain, a small number of picture-based tools have recently been developed for use with adults and children. Each of these tools has a slightly different purpose and intended user. 'A better picture of chronic pain', is intended to assess the qualities of neuropathic pain in people with diabetes, and was developed by McAuley (18). One part of this tool comprises 12 images representing six nociceptive and six neuropathic pain qualities. Although reported as easy to use and effective by a small group of health care professionals, it appears not to have undergone formal testing with patients and so its validity is unknown.

More recently, Laloo and colleagues devised the Iconic Pain Assessment Tool, IPAT2 (19,20), which was intended to assess the location, quality, and intensity of arthritis pain, using ten icons to represent pain quality, e.g. an ice cube to represent freezing. A sample of 30 adults and adolescents found it easy and quick to use and potentially valuable for communication. Difficulties in icon interpretation (e.g. an archery type target for 'aching') were encountered.

Padfield (12) developed and tested a set of 64 photographic montage representations of pain in 54 patients with chronic pain and 52 clinicians, and showed that the images were of particular benefit in communicating the affective components of pain. However, the extent to which the images could differentiate between nociceptive and neuropathic pain was not reported.

A visual tool was designed for Brazilian children (11) and featured 18 pain qualities. The 50 children used in the evaluation were divided into three groups by age and were shown the complete set of images. Images were classified as sensory, affective or miscellaneous. Results indicate that the child's age impacts on which depictions they can understand; e.g. pre-school age children had particular difficulty recognising the images. However within the paper no design guidelines were discussed to improve comprehension rates.

There appear to be several key issues that arise from existing work in this area. There is a current lack of standardisation when choosing which pain qualities, and how many, to depict (the total ranges from 10 to 54). The current literature does not reflect on why certain depictions fail to represent pain qualities. For instance Rossato & Magaldi (11) reported that three depictions failed to be recognised by any of their 50 participants but did not reflect on the reason for this failure to avoid repeated design mistakes. There is great variety to the depiction approach - from including the whole body (11) to more abstract photographic approaches (12). This suggests that there is much work to be done to understand more about the comprehension of pain quality pictograms. This study aims to test the comprehension of one set of pictograms to understand more about miscomprehension of pain pictograms, and to identify pain qualities that were difficult to interpret through static images alone.



**Method**

The McAuley (18) set of 12 pictograms (see Figure 1), was selected for investigation since it is a) psychometrically untested and b) employs a mixed system of symbols, icons and index-led approaches.

The pictograms were presented to 63 UK university students (25 nursing students and 38 first year design students) as a PowerPoint presentation. By choosing specialist students we wanted to understand how a literate audience, in terms of health or design literacy, as well as English literacy would receive the images, before undertaking future studies with audiences who show low literacy skills in terms of English use or cognitive ability. A literate audience's comprehension problems would need addressing first to reduce the number of pictograms that are particularly difficult.

The study had been approved by the Ethics Committee at the host institution and the students volunteered to take part and gave written consent for their responses to be used in research. All responses were anonymised. The pictograms were presented one at a time and in the same order for each group. No information about how they had been developed or tested was made available. As part of the exercise each student was asked to complete a form on which, for each pictogram, they provided the words describing the quality of pain they thought was being communicated by that pictogram. They were asked to provide as many or as few answers as occurred to them, and to record them in the same order as they occurred. The form comprised of one open question per pictogram. One set of instructions was written at the top of the form: "Please describe what kind of pain the pictogram represents to you. You may list as many meanings as you wish. Please list them in the order you think of them."

The method of analysis comprised both quantitative and qualitative approaches. Firstly, the number of correct first responses was calculated, compared and analysed to identify the most and least frequently correctly identified pictograms. In addition, a simple scoring system was devised, whereby if the first word in a participant's response (or set of responses) was correct it was scored as 1. If the participant gave the correct word (or a close derivative, e.g. burning, burn, burned) on their second or subsequent response, it was scored as 0.5. Answers were classified as correct / incorrect and scored by three independent coders, with differences resolved through consensus when required. Semiotic analysis was carried out on the most (4) and the least (5) successful pictograms to rationalise their particular successes or failures. This involved describing an image and discussing how it may relate to broader systems of meaning and its wider symbolic associations.

Secondly, all responses, including incorrect responses, were analysed and categorised according to a new Pain Pictogram Evaluation System (PPES). This was developed using thematic analysis in which data were inspected and classified based on observation of seven emergent codes. It was noted that participant responses often represented non-sensory aspects of pain, such as severity, temporality, location or emotional impact. Where interpretation of the icon, symbol or index system failed and a literal response was made that described the pictogram's contents, the code 'literal' was used. The 'other' category was used when the response did not fit into any category or was used when the response related to another disease/condition. Classification was performed by two coders with over 95% concurrence.

## Results and Discussion

First Responses

The percentage of correct first responses is shown in Figure 2 (presented in order of correct responses rather than display order). The mean ‘scored’ results for all correct responses, regardless of first, second or subsequent responses is shown in Figure 3.

There were similar results found for both student groups, with little variation in the success rate of most of the pictograms. The images varied enormously, however, in their ability to convey meaning accurately. ‘Burning’, ‘stabbing’ and ‘cold’ were the pain qualities most often scored correctly. At the other end of the spectrum ‘dull/numb’ was interpreted correctly by only five of the 63 respondents on their first attempt.

Semiotic analysis aids our understanding of the more successful pictograms. Semiotic analysis was performed by a design academic based upon Pierce’s principles outlined above. ‘Burning’ and ‘cold’ were two of the four most correctly interpreted pictograms. ‘Cold’ and ‘burning’ relate to conventional signage seen in physical reality and thus may have a degree of familiarity; for example, household appliances or foods feature snowflake icons, while flames are used on flammable material warnings. Context is vital here and the familiarity of the pictogram has to be coupled with an understanding of pain - in this example a flame indicates a burning feeling, rather than indicating that our bodies are dangerously flammable. ‘Cold’ and ‘burning’ are also good examples of Pierce’s indexical signs. Since the participants appear to understand that flames cause burning and snowflakes are caused by something being very cold, this enabled them to identify the pictogram correctly. It would appear that a combination of these two justifications – familiarity and index-like qualities - may enhance the likelihood of recognition.

The type of pain also may be familiar to most participants and this is also an important aspect of recognising the pictogram that is needed to be taken into account.

The other two most correctly interpreted pictograms were 'stabbing' and 'tightening/squeezing'. Stabbing as a word has a strong association with one object – the knife. Since most people have never been stabbed they rely on representations in the media and in fictional settings, in much the same way as leaning on conventional signage in the case of 'burning' and 'cold'. Similarly our understanding of 'tightening/squeezing' comes from a specific, un-lived and imagined experience. The function of rope is often to constrain and this particular pictogram successfully shows the results of the squeeze as edges bulge. The experience is exaggerated, as is often the case in fictional representations. Exaggeration lessens the scope for ambiguity – rope here is not for tying objects together but for squeezing. We suggest therefore that unambiguous indexical pictures that have a degree of familiarity (either mediated or lived), suitable for the context of use, are desirable qualities for a pain pictogram.

The incorrect responses given by participants were of as much, if not more interest than the correct ones. The lowest comprehension rates were for pictograms that employed two symbols, one icon and three index-led approaches - 'dull/numb', 'throbbing', 'aching', 'crawling' and 'shock-like'. Again, using a semiotic approach to analyse the incorrect responses, it appears that symbol approaches are indeed problematic. Using essentially abstract shapes – that is, dotted lines or repeated circles that have little causal relationship or visual relationship to the pain - may have resulted in incorrect interpretations. Inconsistent use of abstract shapes is also problematic: four circles are used to present the temporal quality of a throbbing pain and three circles are used to present various aching limbs. 'Dull/numb', 'aching' and 'throbbing' lack visual triggers and thus index-led approaches are difficult. Where index-based systems are used in the

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‘shock-like’ and ‘crawling’ pictograms, picture elements perhaps lack the familiarity of those that were more correctly identified.

In order to gain greater understanding of how and where misinterpretations occurred, responses were categorised according to the PPES as outlined earlier (see Table 1, which displays the number of every individual’s responses in relation to each category).

In total there were 1,763 responses (including repeated phrases across all participants). The analysis phase focused on the non-sensory qualities of incorrect responses – that is, those that referred to another aspect of the pain itself such as severity, location, affect, temporality and literalness.

Severity was a quality mentioned most often with respect to ‘burning’ and ‘stabbing’. 9% of all responses for ‘burning’ referred to some aspect of severity including phrases such as ‘intense’ and ‘severe’. This may cause particular problems for people with mild pain symptoms but sharing the same overall sensory qualities of the pain itself. Severity may also be indicated by exaggerated triggers which earlier were recommended positively in terms of making a pictogram less ambiguous. Clearly there is further work needed to understand how an exaggerated form reflects further meanings. For instance, in the case of ‘burning’, severity may have been indicated by the size of the flame, though no interpretations of severity for ‘cold’ occurred despite the pictogram element being of similar scale.

Responses that referred to localized body areas were categorised under the ‘location’ heading. Examples of responses categorised by ‘location’ include ‘stomach ache’, ‘pain in one place’,

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9 'stomach' and 'chest pain'. The percentages of responses to each pictogram by location are  
10 shown in Figure 4 and as can be seen, location was a particular problem for interpretation of the  
11 'aching' pictogram, where responses such as 'shin splints', 'foot pain' and 'sore shoulder' were  
12 given. Almost a third of responses for 'aching' were incorrect by making reference to a specific  
13 body part. 'Dull/numb' also scored relatively highly with incorrect responses including 'all over  
14 the body', 'complete body pain', 'skin pain' and 'skin irritation'. Therefore it seems important to  
15 avoid overuse of different specific body parts in the pictograms. This may involve depicting skin  
16 or a body area without distinctive shape, accompanied by a simple visual or verbal instruction  
17 explaining that the pictogram represents any part of the body.  
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27 The affective category deals with the emotional qualities of pain (see Figure 5). 20 (9%) of  
28 responses for the 'burning' pictogram referred to emotional qualities such as 'angry', 'sad' and  
29 'scary'. 15% of responses for 'dull/numb' were classified as affective including 'sad',  
30 'loneliness' and 'detached'. Whilst the emotional impact of pain is important it does not aid  
31 diagnosis. If pictograms are to be used to support clinical diagnosis it is important to focus on  
32 the sensory element within the image. One of the key reasons for the affective responses is  
33 likely to be the presence of facial expression. McCauley's (18) pictograms feature sad faces and  
34 even tearful faces (in 'dull/numb') that can sway the interpretation away from the pain quality  
35 itself. It is therefore suggested that facial expression, in this instance, is extraneous and should  
36 be removed.  
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47 The temporal category refers to the duration of the pain, for which results are shown in Figure 6.  
48 Whilst duration is an important aspect for some pain types, particularly 'throbbing' and  
49 'shooting', it is less so for others. For instance some of the responses for 'pins and needles'  
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referred to temporal qualities such as ‘quick’ or ‘small constant pain’ that doesn’t clearly represent the quality of pins and needles. In the case of ‘throbbing’, including a clearer temporal descriptor device such as a frame may have aided interpretation. Bespoke discussion would be required between the designer and clinician in order to agree on whether a temporal interpretation is a positive or negative outcome of viewing any particular pain pictogram.

The literal category, shown in Figure 7, was that most frequently used for incorrect responses with 263 words or phrases in total. The results of the literal answers for ‘pins and needles’ include ‘drop’, ‘wet interior’, ‘red circle’ and ‘man is trapped in circle’. This highlights the biggest concern resulting from the study, as it signifies a lack of participant interpretation related to pain. This may be caused by the context of the study – i.e. not carried out in a medical setting and the respondents were unlikely to be in pain. In addition participants failed to recognise what the marks even depicted. Literal interpretations were particularly high for ‘shooting’ with almost a quarter of answers failing to recognise what the pictogram depicted. Responses include ‘pencils’, ‘shooting pencil lead’, ‘shooting pencils’, ‘veins’, ‘earthquake’, ‘heavy blades’, ‘roots’ and ‘cracks’. This reiterates the point made earlier about the need for familiarity and a lack of ambiguity within the pictogram’s elements. There is also reason to suggest that the visual pain triggers such as ants, flames and pins and needles need to be underplayed. 27 responses for ‘tingling/crawling’ referred to the ants themselves rather than the skin sensation. Literal responses for ‘squeezing’ included ‘locked in’, ‘tied down’, ‘knots’, ‘tied up’, ‘hanging’, ‘knotted’ which again, shows emphasis on the varying functions of rope rather than a sensation.

Nursing students were less likely to write literal answers. Perhaps due to their greater knowledge of pain qualities resulting from their training, they were able to 'see through' the literal depiction to map it more tightly to existing knowledge.

Recommendations from an analysis of the results of the 'literal' category include ensuring that all trigger elements are recognisable and placing more design focus on the skin or body sensation rather than the trigger element itself.

### Conclusions and Further Work

This study has shown that there is much redesign work required on this particular set of pain pictograms before they can be evaluated with less literate users. Given the lack of discussion in published research about why certain designs have failed, we believe the work presented here is crucial to increase the quality of pictograms. The PPES was useful in providing a robust means of response categorisation. This systematic classification of error types can provide designers with a checklist of elements to 'underplay' in their designs. Many of the coding categories used in the PPES were found to be non-sensory pain qualities already assessed in existing non-visual questionnaires (such the McGill Pain Questionnaire - 21). We urge designers and health communicators to inspect existing medical assessment tools in their own areas as they design pictograms for health-related diagnosis purposes. This will enable them to form their own PPES-style approaches to guide the design and to evaluate responses to their own pictograms.

Based on the results of this study, we propose three key principles that support the removal of particular extraneous elements.



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- Firstly, specific body parts should be avoided where possible, with clear guidance given about the generality of the pictograms regarding pain location.
- Secondly, emotional faces or gestures should be avoided.
- Finally only easily recognisable objects should be depicted as pain triggers and these should be scaled down to emphasise the pain sensations themselves.

Semiotic analysis based on correct response results also suggests the use of familiar and unambiguous index-led pictogram systems for pain representation rather than symbol or icon-based pictograms. The index-led approach however, again, has to be recognisable and ideally very familiar to the viewer.

In terms of the latter results, the findings suggest a need for greater testing with a wider variety of participants as well as participatory or co-design tasks. For instance, asking people themselves to draw their interpretation may empower participants and allow for a greater understanding of the elements they already find ‘familiar’.

The distinctive nature of the ‘temporal’ category, as a category which can aid identification given its role in certain pain sensations (such as ‘throbbing’ or ‘shooting’) helped provide further direction for the project. Further potential developments include moving from the restrictions of the still image to a more multimodal approach using animation and sound.

Since university student participants were used in the study, the likely generalisability of the findings is small. In particular the sample mostly comprised persons aged under 21 and so their experience of pain is likely to be limited. This may have hindered their ability to interpret pain types. Further work will be required, still employing the PPES, to compare the results from a more varied set of literate users before redesigning and evaluating pictograms with low literate

users. Testing will also take place in a more realistic environment (8) with someone who is required to use the pictograms to express their own pain type. This existing work does however highlight some valid problems with the pictogram set as it is and offers a new method to aid knowledge of pictogram comprehension.

The frequent instances of literal interpretation of the images were particularly concerning in this sample of literate users. It is likely that there is an even higher risk of literal interpretations when future evaluation is undertaken with less literate users, such as those with learning disabilities. They may be less likely to perform higher cognitive processes (22) such as interpreting indexical images and relating them to their personal experiences. This contrasts somewhat with the index-led approach where relatively complex cognitive processes are required to interpret the relationship between the depiction and the referent. Much more work is needed to make these pictograms, and other sets, comprehensible to a range of people with language and learning difficulties. The guidelines and evaluation system suggested here may take us one step forward towards this goal.

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## Figures

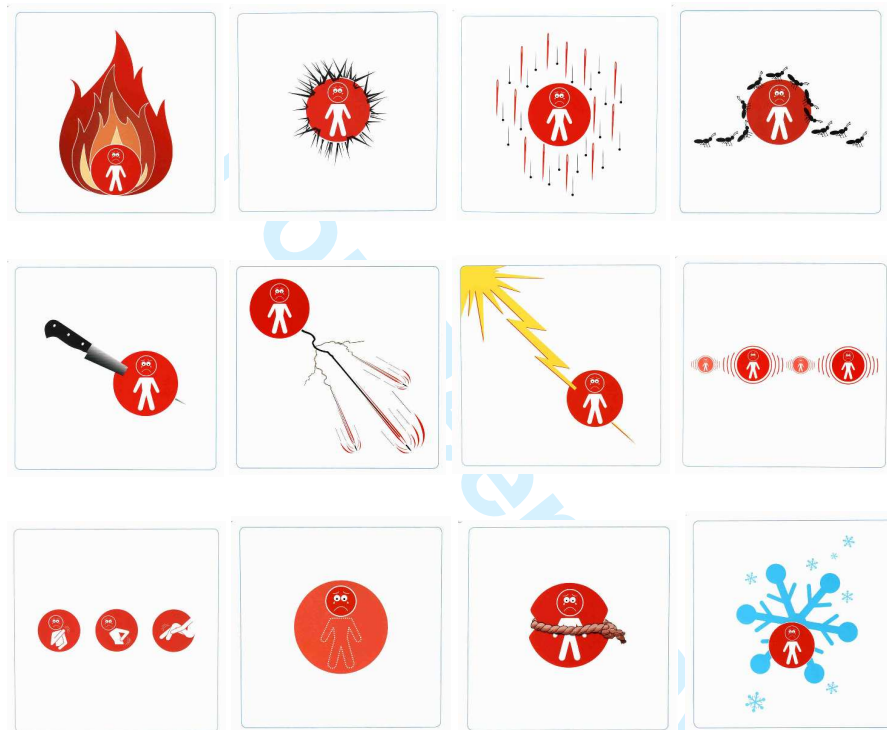


Figure 1: McAuley (2009) set of 12 pictograms

[Key: Top row, L-R: burning; prickly; pins and needles; skin tingling / crawling; stabbing; shooting; shock-like. Bottom row, L\_R: throbbing; aching; dull / numb; tightening / squeezing; cold.]

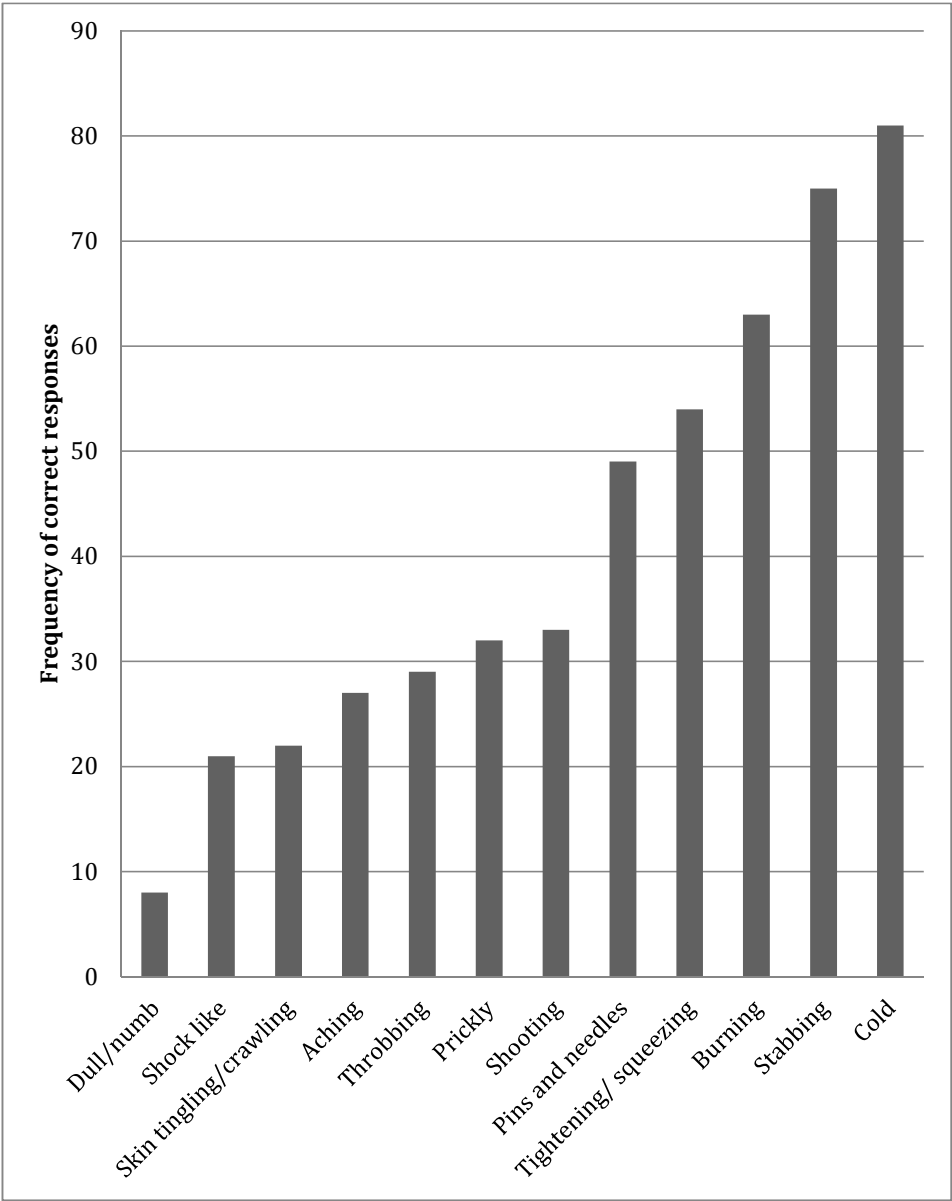


Figure 2: Percentage of students who gave the correct first response for each of the 12 pictograms.

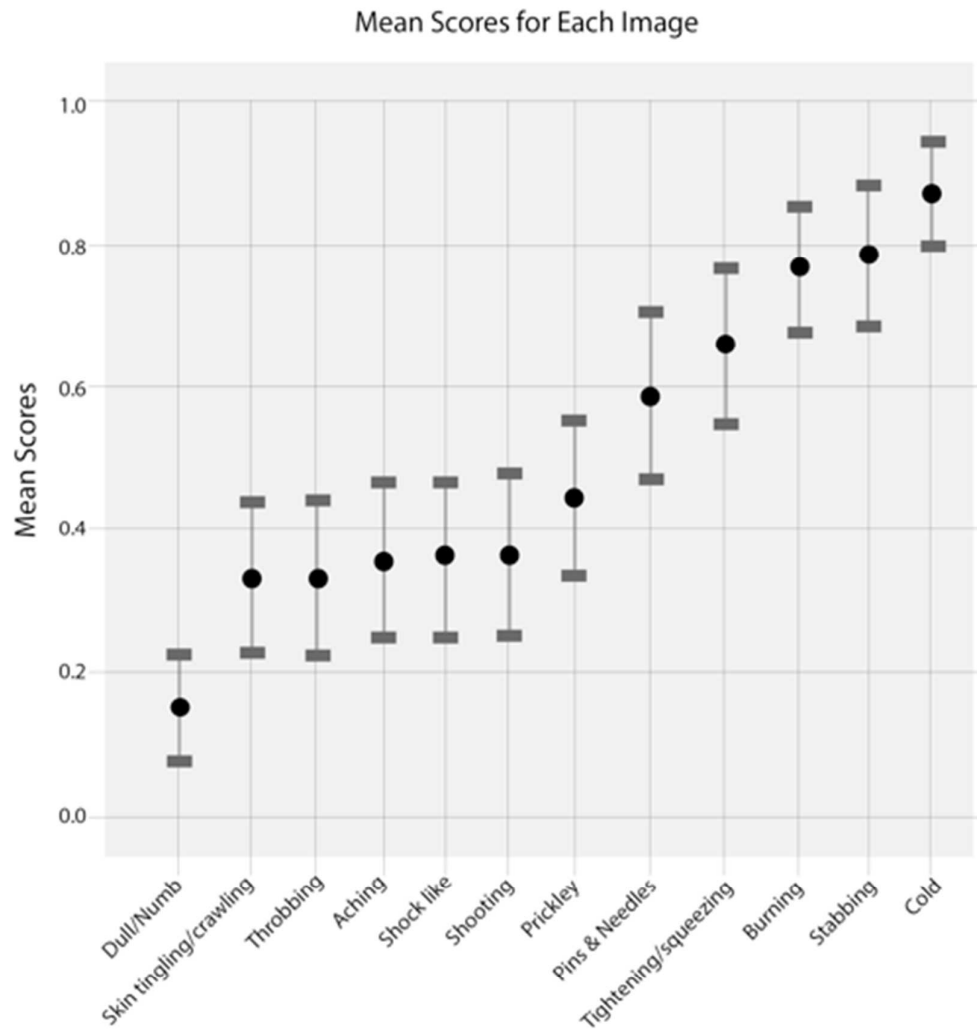


Figure 3: Students' mean scores (n =63) for each pictogram image . (Pictograms are not shown in order of presentation. Vertical bars indicate the 95% Confidence Interval around the mean)



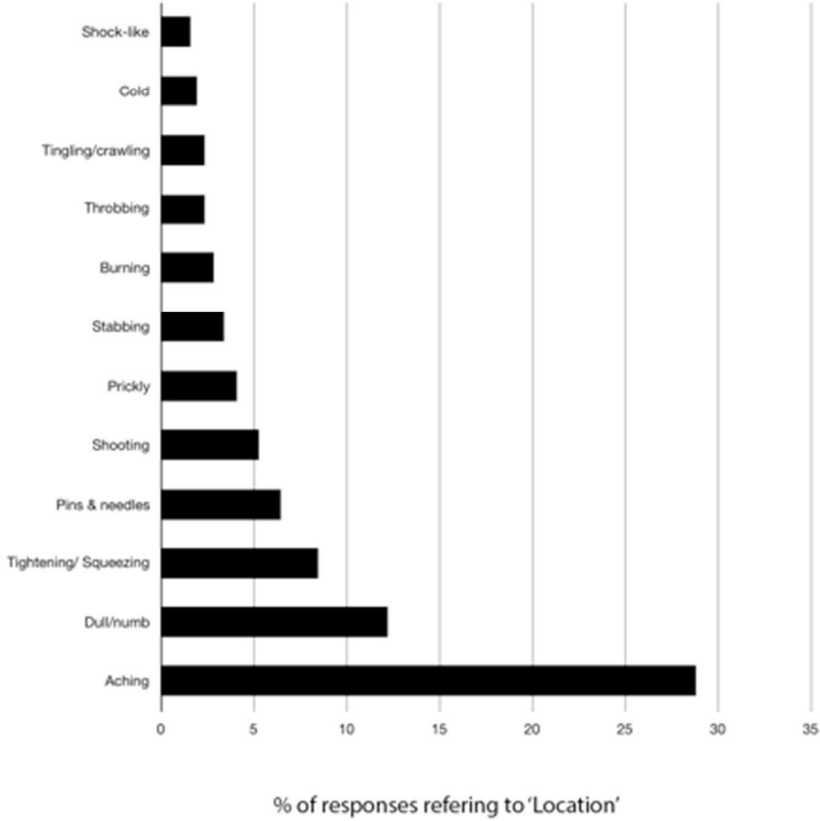


Figure 4: Percentage of responses that included 'location' reference, for each pictogram.

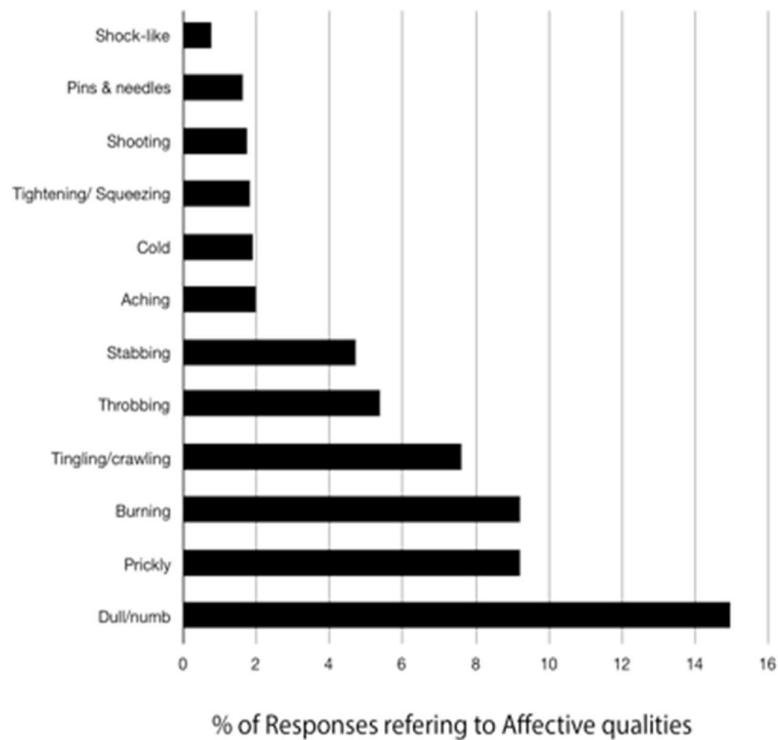


Figure 5: Percentage of responses that included 'affective' reference, for each pictogram.

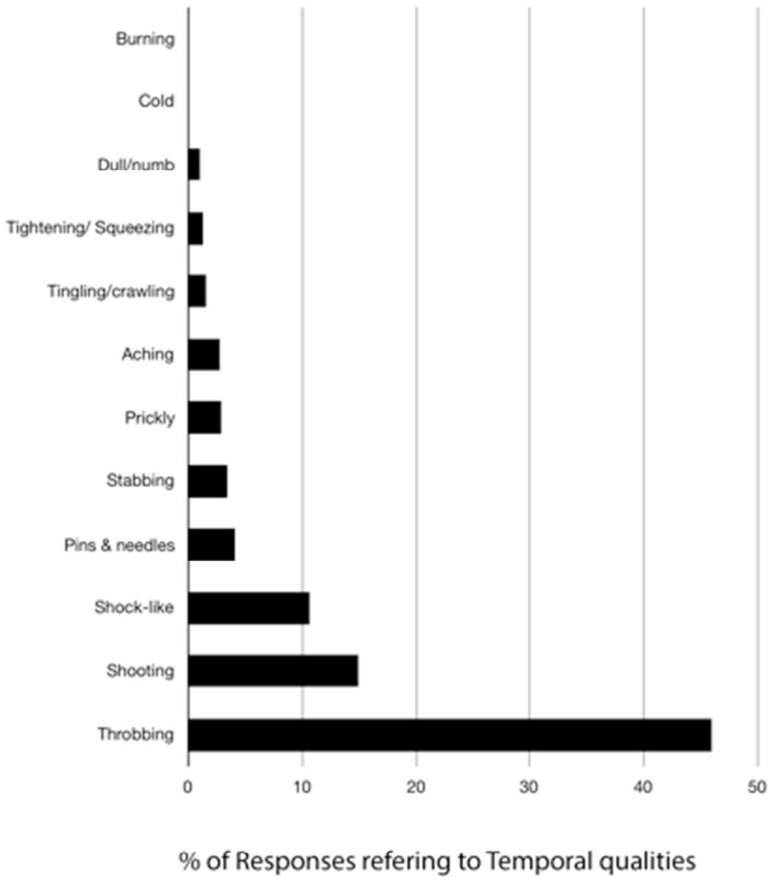


Figure 6: Percentage of responses that included 'temporal' reference for each of the 12 pictograms.

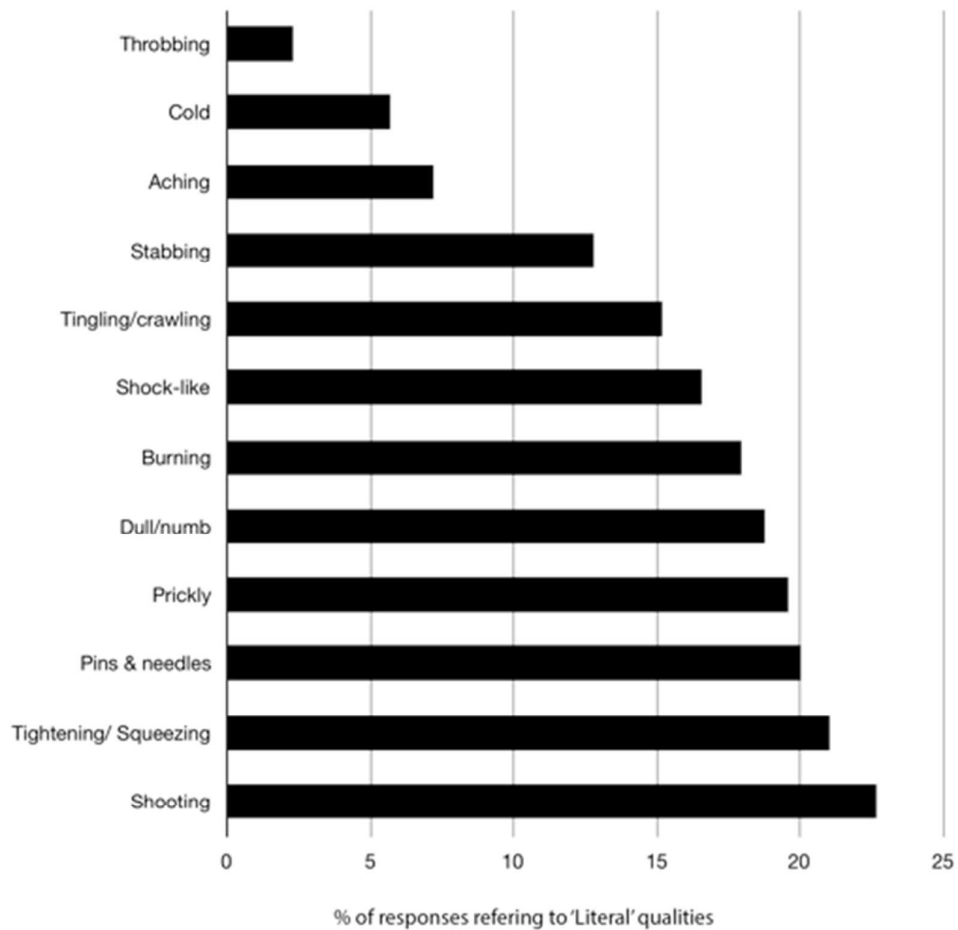


Figure 7: Percentage of responses that included 'literal' reference for each of the 12 pictograms.

Image	Severity	Location	Sensory	Affective	Temporal	Literal	Other condition	Total no. of words/phrases
Burning	19	6	106	20	0	39	28	218
Prickly	0	7	107	16	5	34	5	174
Pins & needles	0	8	76	2	5	25	9	125
Tingling/crawling	0	3	80	10	2	20	17	132
Stabbing	10	5	98	7	5	19	5	149
Shooting	2	6	43	2	17	26	19	115
Shock-like	6	2	77	1	14	22	11	133
Throbbing	0	3	29	7	60	3	29	131
Aching	1	44	68	3	4	11	22	153
Dull/numb	6	13	27	16	1	20	24	107
Tightening/Squeezing	0	14	86	3	2	35	27	167
Cold	0	3	126	3	0	9	18	159

Table 1: Classification of all responses according to the Pain Pictogram Evaluation System (PPES)