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Multidimensional quantitative semantics of pain: A nomothetic-idiographic approach through functional measurement

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Under the unifying leverage of Melzack's theory, and resting on several streams of clinical and multivariate statistical evidence, pain has come to be increasingly recognized as multidimensional in character (Gracely & Naliboff, 1996; Melzack, 1975; Melzack & Casey, 1968; Melzack & Katz, 2001; Melzack & Wall, 1965). The most general form of such recognition is the separation of pain into the sensory and affective dimensions (Fernandez & Turk, 1992). As the emotional component of pain was recognized, pain assessment instruments were met with the challenge of moving from a unitary focus on intensity toward the evaluation of the affective and sensory factors (Gracely, 1979; Tursky, Jamner, & Friedman, 1982).

While the idea of separability of pain in sensation and affect has wide consensus, despite some criticism (Turk, Rudy, & Salovey, 1985; Morley, 1989), little is known about how these dimensions combine to produce the overall experience of pain (Fernandez & Turk, 1992). This ignorance is not only a theoretical downside of present understanding of pain but also is a limiting factor to multidimensional assessment. The problem is most obvious for measurement instruments that seek to provide overall pain scores from the sampling of pain components, as in the *McGill Pain Questionnaire* (Melzack, 1975). The issue of dimensions of pain is implicitly addressed in scoring procedures and is commonly solved using arbitrary additive combination rules (Melzack, 1975; Melzack & Katz, 2001). Other evaluation tools that expand on one-dimensional psychophysics evade the quandary by having affect and sensation separately scaled without any concern for the overall measure of pain as, for example, in the *Descriptor Differential Scale of Pain* that provides one scale component for intensity and one for affect (Gracely & Kwilosz, 1988). However, the problem surfaces each time substantive issues concerning the relative importance or the comparative range of dimensions come about (Gracely, MacGrath, & Dubner, 1978; Tursky et

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al., 1982; Fernandez & Turk, 1992; Wijk & Hoogstraten, 2004). Adequate answers to this problem cannot actually dispense with a model for the integration of pain components (Anderson, 1981, 1982, 1996).

A further problem is the extent to which multidimensional pain evaluation relies on verbal descriptors. Pain measurement largely overlaps with the quantitative semantics of pain-suffering since an individual's discomfort is assessed through his/her particular endorsement of the "language of pain" (Gracely, 1979; Jensen & Karoly, 2001; Melzack & Katz, 2001). For classical measurement theory this is a major shortcoming: not only words lack a physical metric but, more seriously for present concerns, they do not lend easily to consensus over conveyed magnitudes. This idiographic character of words has confined search for lawful relations to coarse statistical norms in the cases when some majority of subjects happens to agree on a few descriptors' values. In contrast, information integration theory (IIT) has the key feature of conjoining nomothetic rules and personal idiographic values. This feature rests first on the independence of the valuation and integration operations: while the former can vary widely with individuals, an invariant integration rule governs the combination of the individually different values (Anderson, 1981, 1982, 1996). Additionally, aspects formally pertaining to valuation can achieve a nomothetic status through association with the integration law. One such case are the weighting patterns embedded in the rule, which are obtainable by designs with personally tailored stimuli. Likewise, when individual reordering of the stimuli is accommodated in the design, the total span of values can be given a lawful meaning by using the integration rule as a frame for measurement.

The present paper illustrates some of the prospects offered by IIT and functional measurement methodology in the field of multidimensional pain assessment. More specifically, it attempts to show how general analytical understanding can be obtained about the interplay of affective and sensory dimensions embodied in descriptor-based measurement instruments, virtually disregarding the issue of consensus over descriptors' values.

Method

Subjects

Seventy-two undergraduate students at the University of Coimbra took part in the study in exchange for course credits. All of them ignored the purpose of the study.

Stimuli

Three sets of words (hereafter called descriptors) expressing the sensory or affective dimension of pain were selected from three widely used measurement instruments, the *Pain Perception Profile* (PPP, Tursky et al., 1982), the *Short Form McGill Pain Questionnaire* (MPQ, Melzack, 1987), and the *Descriptor Differential Scale* (DDS, Gracely & Kwilosz, 1988). Selection of descriptors was made preserving a fair representation of the maximum range afforded by each instrument. The selected descriptors were translated to Portuguese by one translator and back to English by another translator to maximize translation accuracy. Three sets of descriptors were formed, hereafter called Tursky's, Melzack's, and Gracely's descriptors. Tursky's descriptors were five sensory and four affective descriptors taken from the PPP, Melzack's descriptors were 11 sensory and four affective descriptors (actually, the entire set of descriptors) taken from the MPQ, and Gracely's descriptors were five sensory and five affective descriptors taken from the DDS. Examples of these descriptors may be found in Figure 3.

Tursky's affective descriptors were a subset of Gracely's affective descriptors and Tursky's sensory descriptors were a subset of Melzack's sensory descriptors. Melzack's affective descriptors and Gracely's sensory descriptors were unique. This uniqueness should stem from Gracely's intent of obtaining "sensory intensity" descriptors that could be used "with any sensation" (Gracely & Naliboff, 1996, p. 288) and, plausibly, also from Melzack's consideration of a third general dimension, called "evaluative", whose distinction regarding affective factors has always been problematic (Fernandez & Turk, 1992, p. 206). This partial overlapping of descriptors prompted us to address each set of descriptors through separate designs.

Designs and procedure

Stimuli appeared in the middle of a computer screen located at 60 cm from the subject. They were one either single sensory or affective descriptor, or were one sensory descriptor and one affective descriptor aligned horizontally in counterbalanced position.

Three full factorial repeated-measures designs with sensory and affective descriptors as factors were used. The number of levels of factors varied according to the particular set of sensory and affective descriptors: 5×4 for Tursky's, 11×4 for Melzack's, and 5×5 for Gracely's descriptors. Each full design was supplemented with both one-way subdesigns to test for averaging (Anderson, 1982). The designs were submitted to each subject with order counterbalanced across subjects. For each design, the stimuli were presented four times in random order.

On a 0-20 numerical scale, subjects were asked to rate the overall pain intensity defined by each pair of descriptors in the full designs and by each single sensory or affective descriptor in the subdesigns. Two different instructions were used. Half the subjects were asked to produce their ratings assuming that descriptors referred to a brief phasic pain. The other half was asked to think of the descriptors as applying to a long-lasting tonic pain. Roughly, these instructions defined acute and chronic pain, respectively.

A variable number of training trials preceded the regular trials. After the ratings were accomplished, subjects were asked to separately rank order Gracely's and Melzack's descriptors (which included Tursky's descriptors) in terms of sensory or affective magnitude.

Results

Cognitive algebra

Figure 1 shows the results. Factorial diagrams were plotted after reordering individual data on the basis of each subject's ranking of descriptors. Due to this reordering, the position on the abscissa and the factorial curves may not correspond to a unique descriptor. The progressive increase from left to right of mean rated overall pain intensity and the separation of factorial curves show that rated overall pain intensity varied with both the sensory and the affective dimensions of pain. All factors had highly significant main effects for both acute and chronic pain.

Tursky's descriptors (top row of panels). Visual inspection shows near parallelism of factorial curves for both acute and chronic pain. By virtue of the parallelism theorem of IIT, this indicates the operation of an additive-type rule and simultaneously validates the response scale as linear (Anderson, 1981). The interaction was significant for acute pain ($p < 0.05$) and not significant for chronic pain.

Melzack's descriptors (middle row of panels). Factorial curves are essentially parallel for acute pain and converge rightward for chronic pain. The interaction was significant for chronic pain, concentrated on the linear-linear component ($p < 0.005$), and not significant for acute pain.

Gracely's descriptors (bottom row of panels). Factorial curves converge rightward. The interaction was highly significant for both acute and chronic pain. The linear-linear, linear-quadratic, and quadratic-linear components of the interaction were significant for acute pain ($p < 0.05$) and the linear-linear and linear-quadratic components were significant for chronic pain ($p < 0.005$).

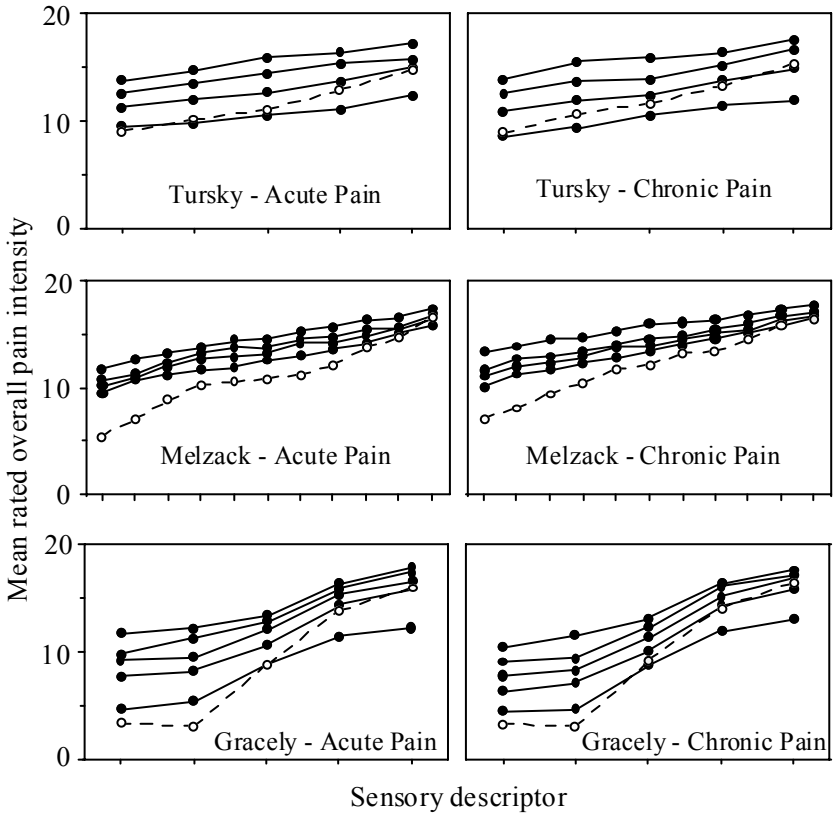

Figure 1. Mean rated overall intensity of pain plotted against sensory descriptors. Filled circles: results when ratings were produced in response to a sensory descriptor (abscissa) combined with an affective descriptor (curve parameter). Open circles: results when ratings were produced in response to only the sensory descriptor.

The dashed lines show mean ratings for the sensory descriptors presented in isolation. In each panel, the crossover of this line with the solid lines rules out summation and supports averaging (Anderson, 1982). Thus, it seems plausible that individuals average the amount of sensation and affect (expressed by descriptors) to produce their judgment of overall pain intensity. Depending on the descriptors, this rule uses equal-weighting of levels in each factor (Tursky's descriptors) or differential weighting (Gracely's descriptors). Differential weighting may also occur depending on the kind of pain (Melzack's descriptors).

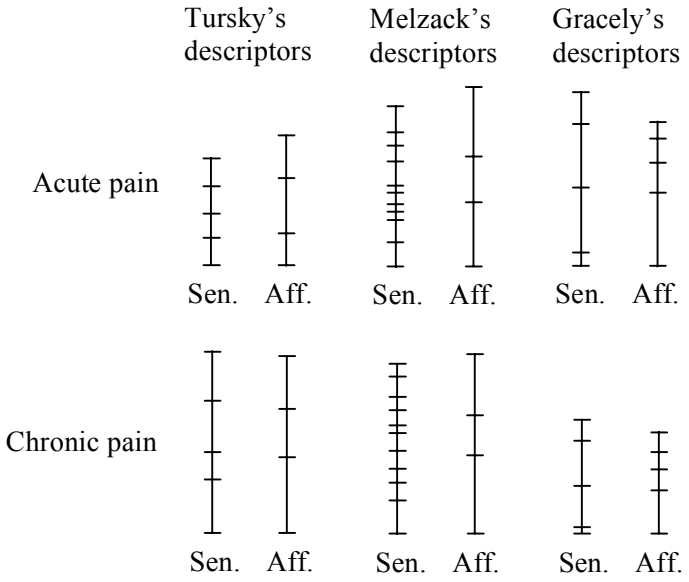

Figure 2. Vertical lines representing the ranges of functional values of sensory and affective components of pain for different sets of descriptors and kinds of pains. Marks in vertical lines show the spreading of descriptors over the functional range.

Hierarchical cluster analyses was performed on the data from each design (complete linkage method, squared-Euclidian-distance measure, and data standardized by subjects). No subgroup regarding the integration pattern was found. This result shows the stability of the integration operation despite large individual differences in valuation.

Functional measurement

Establishing an algebraic rule paves the way for the determination of the functional weights and values of factors. According to the parallelism theorem, in the case of equal-weight averaging the marginal means are linear estimates of the functional scale values of factors (Anderson, 1981, 1982; Weiss, 2006). Marginal means allow for interval comparisons within each factor but not across factors. To make comparisons across factors, one needs independent estimates of weights and scale values for both the equal- and differential-weighting averaging models.

Weights and scale values were estimated by the AVERAGE program (Anderson, 1982; Zalinski & Anderson, 1987, 1991). The equal-weighting

model accounted well for the results for Tursky's and Melzack's descriptors for chronic and acute pain, respectively. The results for Melzack's descriptors for acute pain were well fitted by averaging with positivity weighting in the affective factor. An averaging model with differential weighting in both factors yielded a good fit to the results for Gracely's descriptors.

Comparisons of weights

Within each design, weights can be legitimately compared across factors since they vary on a ratio scale (Anderson, 1982). In other words, a direct comparison of the importance of the sensory and affective dimensions is possible. In the cases of differential weighting, the mean of all weights in a factor was taken as an index of its overall importance. For acute and chronic pain, the sensory dimension was more important in Gracely's [$t(35) = 5.12$ and 10.98, $p < 0.005$, respectively] and Melzack's descriptors [$t(35) = 13.18$ and 8.26, $p < 0.005$, respectively]. Instead, the affective dimension was more important in Tursky's descriptors for acute and chronic pain [$t(35) = 2.69$, $p < 0.05$, and 3.04, $p < 0.005$, respectively].

Although estimated weights cannot be meaningfully compared across kinds of pain, the ratio of sensory (W_S) to affective (W_A) weight can. This enables comparison of the importance of sensory and affective dimensions relative to each other, across measurement instruments and kinds of pains. Means and standard deviations of the obtained W_S / W_A ratios are reported in Table 1. One-way analyses of variance were separately run for acute and chronic pain. The relative importance of the sensory factor was larger for Melzack's descriptors for both acute and chronic pain ($p < 0.005$). No other differences were found.

Between-subjects comparisons across kinds of pains showed that Melzack's sensory dimension was less important, and the respective affective dimension more important, for chronic pain [$F(1, 70) = 25.7$, $p < 0.005$].

W_S / W_A	Tursky's descriptors		Melzack's descriptors		Gracely's descriptors	
	Mean	*SD*	*Mean*	*SD*	*Mean*	*SD*
Acute pain	0.99	0.99	4.06	2.93	1.24	0.30
Chronic pain	0.94	0.75	2.00	0.94	1.16	0.10

Table 1. Mean W_S / W_A ratios and corresponding standard deviations for different sets of descriptors and different kinds of pains.

Comparisons of scale values

For each of the present full designs, estimated scale values were on a linear scale with common unit and unknown origin (Anderson, 1982). Thus estimated scale values allowed for "distance" comparisons across factors. Individual reordering of factor levels prevented this to be done for specific descriptors, but allowed it for "substantive" order positions such as the position of the lower and upper scale values that define the subjective dynamic range of valuation. Additionally, a representation of the spreading of descriptors – considered as a whole – over the subjective range could also be obtained. Figure 2 graphically illustrates both kinds of comparisons.

Paired-samples *t* tests revealed significant differences between the sensory and affective ranges for acute pain (Tursky's descriptors: $p = 0.05$; Melzack's descriptors: $p < 0.01$; Gracely's descriptors: $p < 0.005$). The sensory dimension had a larger range for Gracely's descriptors, while the opposite was true of Melzack's and Tursky's descriptors.

A final group of comparisons concerned estimated scale values obtained for specific descriptors from major subgroups of subjects who produced the same rank orders of descriptors. Figure 3 shows the obtained functional scales. Functional values of descriptors were normalized by representing them as the proportion of the corresponding overall functional range, to make scales for the same stimulus easily comparable across kinds of pains or across tasks. These results show how the assumption of equal interval spacing between response categories can be properly tested along these lines. Equally worth noticing is the close agreement between some of the functional scales obtained from different tasks, for example, the scale for Gracely's and Tursky's affective descriptors for chronic pain. Besides their intrinsic interest, cumulative findings of "stimulus invariance" support the capability of estimation through AVERAGE to recover sensible scale values from the partialling out of weighting strategies.

Discussion

The results of this study show that individuals use an averaging rule to integrate the affective and sensory dimensions expressed by pain descriptors of instruments for the measurement of pain. This rule of cognitive algebra could be established through the reordering of stimuli on the basis of individual rankings. The finding of an equal-weight averaging rule for some sets of descriptors is of significance for response measurement. Since factorial curves for these sets of descriptors were essentially parallel, the linearity of

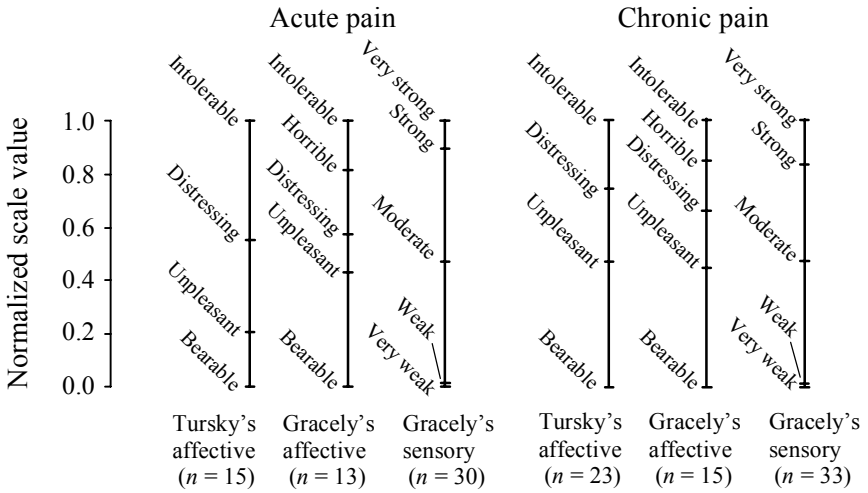

Figure 3. Normalized functional scale values of some descriptors from three sets of descriptors and for different kinds of pains.

the response scale was supported (Anderson, 1982). Since all the sets of descriptors were tested with the same response scale, the finding of nonparallel factorial curves for some of these sets was due to differential weighting rather than to response nonlinearity.

The present finding of an averaging rule has practical consequence for current scoring procedures. Two of the four pain indices of MPQ consist of sums of scale values or of ranks of words (Melzack, 1975; Melzack, 1987). Thus, since summing and averaging differ substantively, it is possible that these composite scores misrepresent the amount of pain communicated by individuals by the use of words.

As a general benefit of the integration rule, functional measurement could be used to disclose further nomothetic layers in raw judgments. Estimation through the AVERAGE program afforded proper measures of importance (weights) on a ratio scale for both factors, which allowed direct comparisons among dimensions as well as comparisons of relative importance (indexed by "sensory weight/affective weight") across measurement instruments and kinds of pains. Differently from other non-functional indices of importance (Gracely, 1979; Fernandez & Turk, 1992; Leavitt, Garron, Whisler, & Sheinkop, 1978; Price, Harkins, & Baker, 1987; Tursky et al., 1982), weights avoid the confounding of importance with circumstantial variance, scale units of factors, or scale values of descriptors (Ander-

son, 1982, 1996). As such, they adequately express the tacit knowledge of subjects regarding the importance of sensation and affect in determining the judged overall pain.

Functional measurement provides estimates of functional values of the sensory and affective dimensions involved in the judgment of pain. Range comparisons across these dimensions have been attempted with partial success (Gracely, McGrath, & Dubner, 1978; Tursky et al., 1982). Since estimated scale values for both dimensions shared a common unit, these comparisons could be done straightforwardly in the present case.

Equality of intervals between descriptors is an assumption needed in MPQ scoring procedures (Tursky et al., 1982; Wijk & Hoogstraten, 2004). As illustrated in Figure 3, when there was agreement over the ranking of descriptors, distances between consecutive descriptors on each factor could be rightfully checked for equality.

Our use of pain-free young individuals as subjects may look as a flaw of the study. However, one should note that most of the compiling, organization, and measurement of pain descriptors has so far been made with subjects free of pain (Melzack, 1975; Gracely, 1979; Wijk & Hoogstraten, 2004). Torgerson's (1988) distinction between *semantic meaning* (how descriptors are arranged in the language of pain) and *associate meaning* (how different groups of people in pain arrange descriptors) shows the need of extending the present study to individuals suffering different kinds of pains.

In general, this study shows that functional measurement can unfold a cascade of nomothetic consequences while being in harmony with an idiographic basis of valuation. In doing so, consensus on valuation ceases to be a required first condition for measurement. It becomes at most a residual concern, depending on the substantive problem being addressed. Our results also suggest that valid indications, often of practical significance, can be obtained from applying IIT and functional measurement methodology to existing pain assessment instruments.

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Abstract

Multidimensional pain assessment is based on the notion of separability of pain into sensory and affective components but lacks an understanding of the process of integration of these components into the overall experience of pain. This poses limits on the development of adequate composite indices of pain and on the generality of a quantitative approach to the language of pain. The present paper reports the results of an empirical study which was made to determine how individuals integrate the sensory and affective components of pain expressed by pain descriptors taken from three measurement instruments. The results support a weighted average integration rule with weights being equal or differential depending on the measurement instrument. This paper shows how functional measurement provides a way to unfold successive layers of nomothetic generality of both substantive and practical value, leaving room for the idiographic valuation of pain descriptors.

Riassunto

La valutazione multidimensionale del dolore è basata sulla nozione di separabilità del dolore nelle componenti sensoriale e affettiva, ma senza permettere di capire il processo di integrazione di queste componenti nella esperienza complessiva del dolore. Questo pone dei limiti allo sviluppo di indici compositi del dolore adeguati e alla generalità di un approccio quantitativo al linguaggio del dolore. Il presente articolo riporta i risultati di uno studio empirico volto a determinare come gli individui integrano le componenti sensoriale e affettiva del dolore espresse da descrittori del dolore di tre strumenti di misurazione. I risultati danno supporto ad una regola di integrazione con media pesata in cui i pesi sono uguali o differenziali in dipendenza dello strumento di misurazione. Questo articolo mostra che la misurazione funzionale fornisce una via per scoprire strati successivi di generalità nomotetica di valore sia sostantivo che pratico, lasciando spazio per la valutazione idiografica dei descrittori del dolore.

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