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The Validation of Visual Analogue Scales as Ratio Scale Measures for Chronic and Experimental Pain

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Summary

Visual analogue scales (VAS) of *sensory intensity* and *affective magnitude* were validated as ratio scale measures for both chronic and experimental pain. Chronic pain patients and healthy volunteers made VAS sensory and affective responses to 6 noxious thermal stimuli (43, 45, 47, 48, 49 and 51°C) applied for 5 sec to the forearm by a contact thermode. Sensory VAS and affective VAS responses to these temperatures yielded power functions with exponents 2.1 and 3.8, respectively; these functions were similar for pain patients and for volunteers. The power functions were predictive of estimated ratios of sensation or affect produced by pairs of standard temperatures (e.g. 47 and 49°C), thereby providing direct evidence for ratio scaling properties of VAS.

VAS sensory intensity responses to experimental pain, VAS sensory intensity responses to different levels of chronic pain, and direct temperature (experimental pain) matches to 3 levels of chronic pain were all internally consistent, thereby demonstrating the valid use of VAS for the measurement of and comparison between chronic pain and experimental heat pain.

Introduction

Assessments of human pain have evolved from a reliance on threshold and tolerance determinations of the intensity of pain to the use of a wide variety of psychological and physiological methods for scaling multiple dimensions of experi-

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mental and clinical pain [1,4,7,12,18,19]. Despite a diversity in approach ranging from simple category choices to recordings of reflex and brain activity, all methods share a common goal of representing accurately the human pain experience. Although investigators have different emphases, there is general agreement as to the principal criteria for an accurate pain measure; pain measures should be valid, measuring unequivocally a specific dimension of pain, and reliable, yielding consistent results over time [5,19,20,29]. Also, pain measures should be versatile, applicable both for experimental pain and for acute and chronic clinical pain and practical in a variety of medical settings.

However, there is controversy regarding which pain assessment procedures satisfy these criteria. Additional controversy centers on the type of pain scale that is produced by each procedure [9,11]. Procedures which yield ratio rather than interval scales are preferable since ratio scales would allow meaningful statements about the magnitude of pain sensation [27] and therefore enable both valid comparisons between different types of pain and valid interpretations of analgesic efficacy.

The use of direct scaling techniques in pain measurement, such as cross-modality matching (CMM), should result in ratio scales of pain magnitude. The validity of these scales could be determined by comparing the psychophysical function obtained from CMM to those obtained with other direct scaling measures because the different responses to the same stimulus should be related by characteristic power functions [27]. Visual analogue scales (VAS), a form of CMM in which line length is the response continuum, have been reported as valid and reliable measures for the intensity of pain [2,14,16,17,22,25,26,30]. Also, the verbal anchor points on VAS can be modified to delineate the different dimensions of pain so that although subjects use the same type of scale, they could respond differentially to multiple dimensions of the pain. However, no studies have examined the validity and reliability of VAS for assessing the affect, as well as the sensation intensity, for both experimental and chronic pain. Also, no studies have tested directly the predictions about pain response based on the assumption that the psychophysical functions derived from VAS have true ratio properties.

The purpose of this study is to examine the validity and reliability of VAS for assessing two dimensions of pain. Are simple VAS sufficient for discriminating between the intensity and affective (unpleasantness) dimensions of pain? Do VAS provide valid and reliable measures of experimental and chronic pain? Do VAS yield pain measures on ratio, rather than interval, scales?

Methods

Subjects

Thirty chronic pain patients (15 men, 15 women; ages 22–78, mean age 48.0 years) and 20 healthy volunteers (10 men, 10 women; ages 25–40, mean age 31.2 years) participated in this research study. Pain patients, who were referred to the Medical College of Virginia for treatment, had experienced either low back (85% of patients) or upper back and shoulder pain (15% of patients) for 4.5 months to 20 years (mean pain duration 3.6 years). The volunteers were healthy with no history of chronic pain. All participants were informed that the purpose of the experiment was to assess the sensation intensity and affective magnitude of pain produced by heat pulses applied to their skin. All participants signed a consent form in which they acknowledged that both the research study and the thermode system had been explained adequately, that the chance of tissue damage from heat pulses was minimal, and, that they were free to withdraw, without prejudice, from the study at any time. Each patient or subject participated in 2 experimental sessions in which 6 intensities of contact heat varying from 43 to 51°C were applied to the ventral forearm. Also, during each of these sessions pain patients adjusted the intensity of experimental heat pain to match the lowest, usual, and highest intensities of the chronic pain that they had experienced during the previous week. These patients also made VAS responses to both the sensation intensity and the affective magnitude associated with these 3 levels of their chronic pain. The response order was counterbalanced.

Stimulation procedures

Noxious heat stimuli of 5 sec duration were delivered to the ventral forearm of subjects by a hand-held contact thermode (1 cm surface diameter). The design of the thermode system has been described in detail previously [3]. The temperature at the thermode-skin interface rose rapidly from a baseline of 35°C to a peak at one of 6 temperatures 43, 45, 47, 48, 49 or 51°C and then returned to baseline by an active cooling mechanism. Several locations on both forearms were stimulated. There was a 5 min interval between stimuli applied to the same location in order to prevent suppression or sensitization of primary nociceptive afferents [23] and to prevent tissue injury.

Response measures

Visual analogue scales were used to rate the sensation intensity and affective magnitude of both experimental heat pain and chronic clinical pain. The VAS consisted of 150 mm lines whose endpoints were designated as 'no sensation' and 'the most intense sensation imaginable' and as 'not bad at all' and 'the most intense bad feeling possible for me' for the sensation and affect scales, respectively.

In order to standardize the scaling instructions and to clarify the distinction between the intensity and affective dimensions of pain, the following instructions were used for all subjects.

> There are two aspects of pain which we are interested in measuring: the intensity, how strong the pain feels, and the unpleasantness, how unpleasant or disturbing the pain is for you. The distinction between these two aspects of pain might be made clearer if you think of listening to a sound, such as a radio. As the volume of the sound increases, I can ask you how loud it sounds or how unpleasant it is to hear it. The intensity of pain is like loudness; the unpleasantness of pain depends not only on intensity but also on other factors which may affect you.

There are scales for measuring each of these two aspects of pain. Although some pain sensations may be equally intense and unpleasant, we would like you to judge the two aspects independently. Please mark the dotted line to indicate the relative intensity of your pain sensation; the further to the right, the greater the intensity. Similarly, mark the second dotted line to indicate the relative unpleasantness of your pain sensation.

Noxious heat stimuli were also used as response measures.

Experimental pain

Each subject participated in 2 experimental sessions in which they used VAS to rate the sensation intensity and affective magnitude of the pain evoked by heat pulses at 43, 45, 47, 48, 49 and 51°C. Each temperature was presented twice per session in randomized order; several locations on both forearms were stimulated during each session. All 20 subjects made responses to sensation intensity; 10 of these subjects made responses to the affective magnitude of each stimulus during a different session. Comparisons were made to test whether the stimulus-response functions generated separately for sensation intensity and affect reflect ratio scale judgements. This could be verified if perceived ratios of magnitude evoked by different standard temperatures are consistent with those which could be predicted on the basis of the stimulus-response functions shown in Figs. 2, 3, 4 and 6. Therefore, following the VAS scaling series the temperatures of the thermode were adjusted until subjects acknowledged that the sensation intensity of experimental

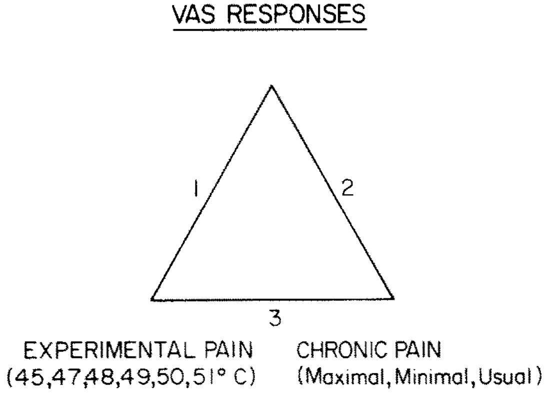

Fig. 1. Strategy used to assess both experimental pain evoked by thermal stimulation and natural chronic pain. Subjects used sensory intensity visual analogue scales (VAS) to rate the relative magnitude of the experimental acute and the natural chronic pain. They also used affective VAS to rate the relative unpleasantness of the experimental and natural pain. Then, the intensity of chronic pain at 3 levels (minimal, usual, maximal) was quantified by determining the 3 stimulus intensities of experimental thermal pain that produced equivalent sensations. The scaled relative magnitudes (VAS) and the points of subjective equality (experimental stimuli) determined the match points for the chronic pain. These match points are then compared to the stimulus-response function that was derived initially from scaling the experimental stimuli.

pain was double that evoked by a stimulus of 43 or 45°C. Subjects were also asked to compare pairs of standard temperatures, 47 versus 49°C and 45 versus 47°C, in terms of how much more unpleasant the higher temperature was than the lower temperature. They were asked to express this comparison in terms of a ratio and were told they could use fractions. For example, the higher temperature could be perceived as 1.6 times as unpleasant as the lower temperature. These comparisons were made twice for each subject; the order in which the higher and lower temperatures were presented was counterbalanced across subjects.

A triangulation procedure, which provides a measure of internal consistency [13] was used for the measurement of clinical pain. As shown in Fig. 1, the VAS responses to experimental heat pain (leg 1) produce a stimulus-response function for which the regression line is plotted. The VAS responses to chronic pain (leg 2) can be plotted along the ordinate of this graph. Their positions along the abscissa are determined by the direct experimental heat pain values that were chosen to match the sensation intensity of chronic pain (leg 3). If all responses have been made consistently, the plot of the intersection of X and Y axis positions will approximate the regression line.

Results

VAS measures of experimental pain

All subjects scaled similarly the sensation intensity and the affective magnitude of noxious heat pulses; between-subject variability was small. Between-session reliability was high ($r = 0.97$). There were no significant differences between the healthy volunteers and the chronic pain patients in their sensory or affective VAS responses to heat pulses (two-tailed t test; $P = 0.3$–0.5). In Fig. 2, the log relative magnitudes averaged over all subjects for sensation intensity (Fig. 2A) and for affective magnitude (Fig. 2B) are plotted as a function of log stimulus intensity. The exponents for the least squares linear regression lines fitted to these points are 2.1 and 3.8, respectively. The linearity in log coordinates indicates that the relationship between sensation intensity (S) and stimulus intensity minus baseline temperature (T-34) is a power function where $S = k \log (T\text{-}34)^{2.1}$, and that the relationship between affective magnitude (A) and stimulus intensity is a power function where $A = k \log (T\text{-}34)^{3.8}$.

VAS measures as ratio scales

The power functions derived from the VAS scaling of the sensation intensity and affective magnitude of noxious heat pulses were tested in terms of their ability to predict ratio judgements of sensation intensity and affective magnitude. All subjects chose easily a heat pulse stimulus that was perceived as twice as intense as the 43°C standard stimulus. As shown in Fig. 3, where mean sensation intensity is plotted as a function of pulse temperature, the observed value for the doubled standard (46.5 ± 1.6°C) coincides with the predicted value (46.4°C). Such coincidence between predicted and observed would occur if the psychophysical function represented a true ratio scale. When 45°C was used as the standard stimulus, the observed value

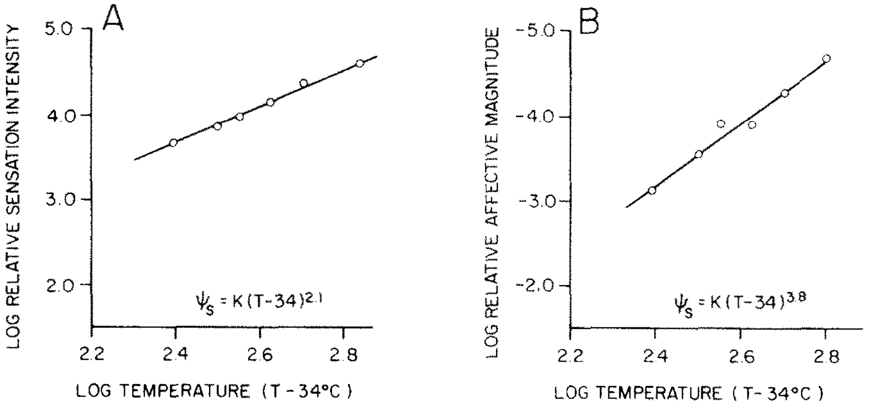

Fig. 2. Mean log relative magnitudes derived from VAS of the sensation intensity (A) and the affective magnitude (B) of noxious thermal stimulation are plotted as a function of log stimulus intensity minus baseline skin temperature. Each point represents the geometric mean of 40 observations (20 subjects ×2 trials). The function describing the least squares linear regression line fitted to these points is shown below the line. In this and the following figures, sensation intensity (ψ_s) is expressed as a power function of stimulus intensity.

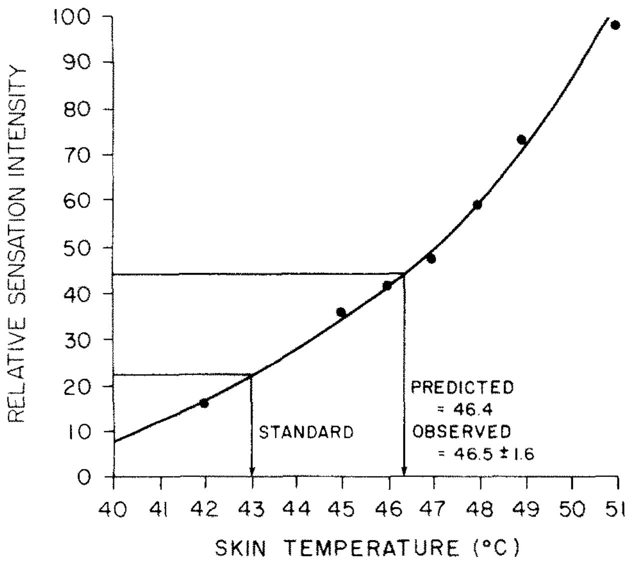

Fig. 3. Mean relative magnitudes derived from VAS of the sensation intensity of noxious thermal stimulation are plotted as a function of temperature (°C) at the thermode-skin interface. Each point represents the geometric mean of 40 observations (20 subjects×2 trials). The vertical arrows intersecting the function represent the standard temperature (43°C) and the temperature (46.4°C) predicted from the function as twice as intense as the standard (see also horizontal lines). The obtained mean temperature was 46.5°C.

for the sensation intensity perceived as double that of the standard 49.4 ± 0.2°C, was again nearly coincident with the predicted value (49.5°C). When asked to compare the relative affect evoked by two standard temperatures of 45 and 47°C, the mean ratio arrived at by 20 subjects was 1.9 (±0.4°C). This value is equal to that predicted on the basis of the power function shown in Fig. 2B. Similarly, subjects rated 49°C as 1.8 times (±0.5°C) more unpleasant than 47°C, a value close to that predicted on the basis of the VAS derived power function for pain affect (Fig. 2A).

VAS measures of clinical pain

Pain patients scaled easily the sensation intensity and affective magnitude of their own chronic pain at its minimal, usual, and maximal levels during the week preceding their visit. The mean intensity values were 20.0, 49.3 and 72.3, respectively (where 100 = most intense sensation imaginable); the unpleasantness values were 16.2, 51.5 and 78.4, respectively (100 = most unpleasant pain imaginable). They also chose easily 3 noxious temperatures as direct matches to their chronic pain at its minimal, usual and maximal intensity levels; the mean values were 43.1, 46.2 and 48.8°C, respectively.

In Fig. 4, the filled circles represent the experimental pain matches for the 3 levels of chronic pain. The values for these points on the ordinate were determined by the patients' mean VAS responses; the values on the abscissa were determined by the patients' mean temperature matching responses. If both experimental and chronic pain have been accurately scaled and matched, the measures for chronic pain will lie near the regression line and demonstrate the internal consistency of the scaling method. This internal consistency was demonstrated for most pain patients and for the group (Fig. 4).

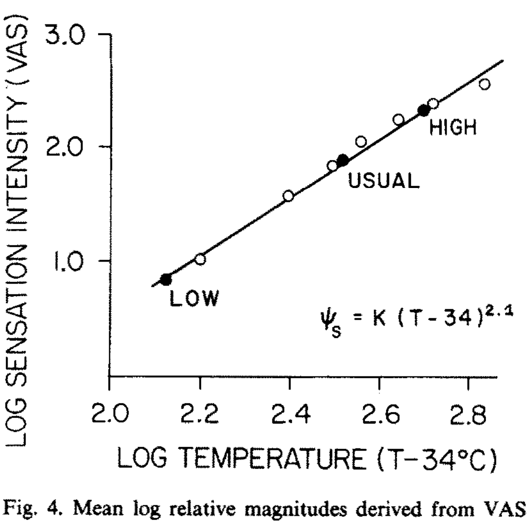

Fig. 4. Mean log relative magnitudes derived from VAS of the sensation intensity of noxious thermal stimulation are plotted as a function of log stimulus intensity minus baseline skin temperature. Each open circle represents the geometric mean of 60 observations (30 patients × 2 trials). The least squares linear regression line was fitted to the VAS judgements of the experimental stimuli. The filled circles show the VAS judgements and the match points for the chronic pain.

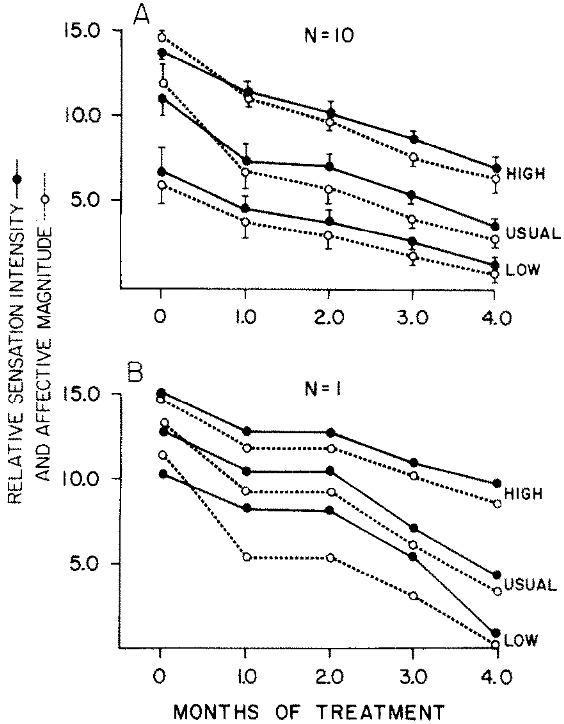

Fig. 5. Mean relative magnitudes derived from VAS. The sensation intensity (filled circles) and the affective magnitude (open circles) of 3 levels of chronic back pain are plotted as a function of acupuncture treatment. Treatment consisted of 8 bi-weekly sessions, in which 0.5 msec pulses, 2 Hz, at 4 mA were applied to lower back and leg acupuncture points for 20 min. Each point in A represents the geometric mean of 10 single responses for all patients. Each point in B represents an individual response for one patient.

VAS measures — discriminative validity

Ten low back pain patients, who were successfully treated with a combined program of TENS and acupuncture, used the VAS monthly to rate the sensation intensity and affective magnitude of their chronic pain for 4 months. Fig. 5 shows the relative magnitude for 3 levels of back pain (minimal, usual, maximal) as a function of treatment time for all patients. The VAS responses were correlated ($r = +0.70$) with the physician's ratings of the patients improvement. Although as shown in Fig. 5, sensation intensity and affective magnitude co-vary, the ratio of affect to sensory intensity changes with both pain sensation level and with treatments. Prior to treatment, the affective to sensory ratio is greater than 1.0 when pain is at its maximal level, approximately 1.0 at usual level, and less than 1.0 when pain is at its minimal level. However, post treatment the affect to sensory intensity ratios are less than 1.0 for all 3 levels of chronic pain.

Discussion

Among the numerous psychophysical procedures for assessing human pain, direct scaling procedures such as cross-modality matching have gained popularity because of their simplicity, versatility, relative insensitivity to bias effects, and the assumption that the procedures yield numerical values that are valid, reliable and on a ratio scale. Although the major disadvantage of cross-modality matching procedures for pain assessment has been their inability to discriminate among the various dimensions of human pain [6,8,15,28], this study demonstrates that one type of cross-modality matching procedure, the visual analogue scale, can be used as a valid and reliable measure for both the intensity and the unpleasantness of human pain. Also, these visual analogue scales can be used reliably to measure either experimentally induced pain or chronic clinical pain.

The exponent for the power function describing the affective magnitude of pain evoked by thermal pulses was higher than that describing the sensation intensity of pain. This result is consistent with previous findings when line production was used to assess affect (Fig. 6). The ratio of pain affect to pain intensity may reflect the influence of perceived situational factors that serve to selectively reduce or enhance the affective dimension. For example, the unpleasantness of chronic pain may be selectively reduced or enhanced by knowledge about the cause of the pain or by uncertainty about eventual relief. As shown in Fig. 5, the ratio of affective magnitude to sensation intensity for pain changes with analgesic treatment and with changes in the pain level itself. The similarity of power functions derived from VAS and direct line production methods confirms that VAS methods are a variant of cross-modality matching and that no radical scaling biases are introduced by anchoring each continuum with verbal descriptors.

Our findings that visual analogue scales provide valid and reliable assessments for the affective magnitude, as well as the sensation intensity, of pain differ from those in previous studies [6,28]. However, earlier studies did not provide as detailed an explanation of the difference between the two dimensions of pain and this methodological difference alone presumably accounts for the disparity in results. Direct temperature matches to the different levels of chronic pain were reliable from one set of measures to the next, and our combined use of temperature matches and VAS responses provided additional evidence as to the accuracy of both methods. The internal consistency between VAS responses and direct temperature matches to different levels of chronic pain indicates that VAS methods provide meaningful information about the magnitude of clinical, as well as experimental, pain. Although the sensation intensity of experimental pain can be compared with that of clinical pain, such comparisons were difficult to make for the affective magnitude because the situational context of experimental pain is very different from that of chronic pain. Affective responses to pain are more sensitive to contextual factors than are sensory responses [15,24].

Power functions derived by visual analogue scales of pain can predict accurately pain intensity and pain affect along ratio, not interval, scales. The verification of this attribute is clearly important for future studies in analgesia and pain. Ratio scales

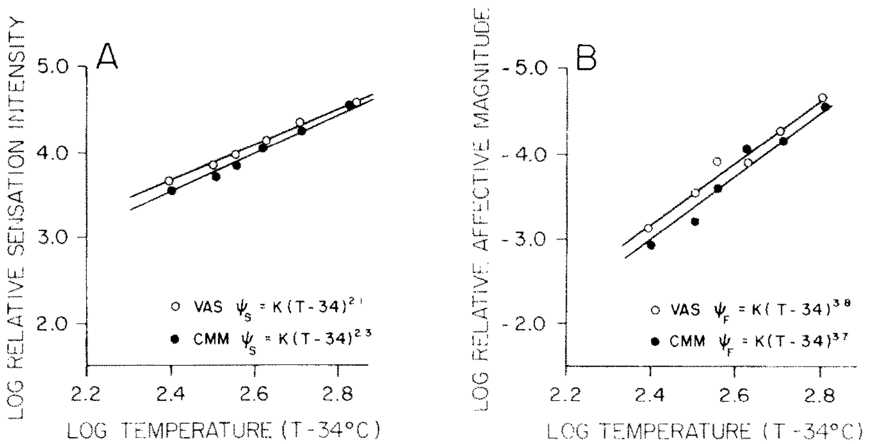

Fig. 6. Mean log relative magnitudes derived from cross-modality matching: VAS (open circles) and line production (filled circles) of the sensation intensity (A) and the affective magnitude (B) of noxious thermal stimulation are plotted as a function of log stimulus intensity minus baseline skin temperature. Each open circle represents the geometric mean of 40 observations (20 subjects × 2 trials). Each filled circle represents 21 observations from a previous experiment [24]. The functions describing the least squares linear regression lines fitted to the 2 sets of values are shown below the lines.

are crucial in comparing levels of pain across different groups of patients or subjects and comparing different levels of pain within the same individual. Thus, only when pain is measured on a ratio scale can one meaningfully state that a patient's pain is reduced by a given per cent or that one analgesic treatment is a certain per cent more effective than another.

In addition, visual analogue scales are relatively simple so that the majority of patients as well as experimental subjects can easily respond to these scales. Each scale refers simply to pain intensity or to emotional intensity. Verbal descriptor measures of affect may often refer to several different emotional responses or meanings, all of which are unlikely to lie on a single continuum. Affective verbal descriptor scales [10,20] imply that as pain increases beyond 'discomforting' it becomes 'distressing.' This is a possible but not an invariant progression that can occur. Pain may become frustrating or depressing rather than distressing. When subjects are forced to choose these descriptors from a limited list, they may often choose a word that does not reflect accurately the subject's affective state. Visual analogue scales which distinguish unequivocally between affective magnitude and the sensation intensity components of pain can circumvent this problem.

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