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ABSTRACT

Multidimensional scaling (MDS) offers a rigorous approach to many problems in perception, emotion, personality, and cognition, where the stimuli are too complex to be quantified by other means. In these procedures similarity ratings of the stimulus objects are modeled as points in multidimensional space, such that perceived similarity is represented by spatial proximity. The stimulus objects may be physical stimuli or words describing qualities of pain. In this study, Individual Differences Scaling (INDSCAL) was used to examine the dimensions of pain obtained from similarity judgments made to verbal descriptors of global pain by 16 patients suffering cancer-related pain and by 16 healthy volunteers. The INDSCAL analysis yielded similar two-dimensional solutions for both groups. The major dimension was magnitude of sensory pain: mild pain to intense pain. The second dimension, pain qualities, contained two components: a somatosensory attribute (e.g., burning) and an unpleasant affect attribute (e.g., miserable). The two groups differed in where they located certain descriptors in the space. For example, mild pain was more emotion laden for the cancer patients, but more of a somatosensory sensation for the healthy volunteers. Although much work remains to be done with a wider range of descriptors, it is clear that MDS procedures such as INDSCAL, have much to offer in the investigation of pain and other complex stimuli. (Author/ABL)

A Multidimensional Scaling (INDSCAL) Approach to Pain: Comparison of Cancer Patients and Healthy Volunteers

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ABSTRACT

Multidimensional scaling (MDS) offers a rigorous approach to many problems in perception, emotion, personality,, cognition, etc. where the stimuli are too complex to be quantitified by other means. In these procedures similarity ratings of the stimulus objects are modeled as points in multidimensional space, such that perceived similarity is represented by spatial proximity. The stimulus objects may be physical stimuli, e.g. noxious themal stimuli, musical passages, faces, or the stimulus objects may be words, e.g., those describing the sensory, emotional, and other qualities of pain. Examination of the map or configuration of stimulus objects reveals the dimensions present the group stimulus space.

In the present study, Individual Differences Scaling (INDSCAL) was used to examine the dimensions of pain obtained from similarity judgments made to verbal descriptors of global pain by patients suffering cancer-related pain and by healthy volunteers. The INDSCAL analysis yielded similar 2-dimensional solutions for both groups. The major dimension was magnitude of sensory pain: Mild Pain to Intense Pain. The second dimension, pain qualities, contained two components: a somatosensory attribute (e.g., Burning) and an unpleasant affect attribute (e.g., Miserable). The two groups did, however, differ in where they located certain descriptors in the space. For example, Mild Pain was more emotion laden for the cancer patients, but more of a somatosensory sensation for the healthy volunteers.

Although much work remains to be done with a wider range of descriptors, more patient groups, etc., it is clear that MDS procedures such as INDSCAL, in which the subjects, not the experimenter determine the number of dimensions, has much to offer in the investigation of pain and other complex stimuli.

INTRODUCTION

Clinical pain is a complex percept, now generally thought to involve not only pain intensity itself, but many other attributes. Historically, speculation concerning the number of pain qualities or dimensions has varied from a single quality -- variously considered to be either purely emotional, or purely sensory -- to as many as five, including affective, motivational and cognitive aspects (Melzack, 1973).The discussion of "pain" dimensions presents a semantic problem because "pain" is commonly used with two quite different meanings. As used clinically, "pain" refers to the total pain experience, which includes pure pain sensation, somatosensory sensations, as well as emotional, motivational, and cognitive components. This multidimensional "pain" may be termed "global pain". On the other hand, especially as used in the laboratory, "pain" often refers solely to "sensory pain," that is, the pure pain sensation itself without any of its other, adjunctive qualities, sensory pain, for example, is that relatively pure, elemental pain produced by moderate electrical tooth-pulp stimulation in a well-trained, relaxed subject.

Neither psychophysical nor statistical procedures have yielded agreement on the dimensionality, that is, the number of dimensions, of global pain. Classical psychophysical procedures, such as the method of limits, force the subject to compress the various pain dimensions into a single dimension. Sensory decision theory yields but two dimensions, sensory-discriminative and attitudinal. The number of dimensions based on magnitude estimation procedures depends upon the hypothesis of the experimenter, some opt for two, others for three. Finally, factor analytic studies have failed to reach agreement, for example, the number of dimensions found with the McGill Pain Questionnaire range from one to seven in various studies.

Multidimensional scaling (MDS) offers a new approach to many problems in perception, emotion and cognition (Shepard 1980). Without quantitative information about the physical properties of colors, tones, speech, or words we can learn something about how humans process these stimuli from ratings of perceived similarity. MDS has received wide acceptance in the examination of complex stimuli such as odors, in economic and political analyses, in the classification of anthropological data, and even in the advertising industry (Carroll and Arabie, 1980). In a general sense, the basic concept is not new; proposals that stimuli be modeled as points in space, such that perceived similarity is represented by spatial proximity go back to Isaac Newton, who suggested that hues in the visible spectrum be represented on a circle. In spite of its widespread use and ancient antecedents, MDS has rarely been used to examine the dimensions of pain.

Of the various MDS procedures and models available, the Individual Differences Scaling (INDSCAL) model developed by Carroll and Chang (1970) appears singularly appropriate for the study of pain, because the dimensions obtained are readily interpretable, and it yields data on each individual. These advantages stem from the fact that it is a "three-way" MDS method, and thus differs from "two-way" MDS methods which utilize a single matrix (a two-way array) of proximities averaged over subjects. In contrast, the data entered into the INDSCAL analysis consists of separate matrices, one for each subject. This three-way MDS method allows for large systematic differences amongst the matrices, that is, between subjects. In the two-way procedures these differences appear as error, which often obscures the underlying dimensions. Furthermore, the INDSCAL model exploits the differences amongst the set of individual subject matrices to achieve a unique orientation of the coordinate axes. Thus, in INDSCAL, the axes play a special role which other methods, e.g., factor analysis and "two-way" MDS procedures do not. This alignment of the dimensions along the coordinate axes greatly simplifies their interpretation, especially for higher dimensional solutions.

PROCEDURE

The INDSCAL method was used to compare the group stimulus space (dimensions) of global pain of 16 in-patients suffering cancer-related pain, and of 16 matched, pain-free healthy volunteers. The subjects made similarity judgments on a scale from 0 to 10 to randomly presented pairs of descriptors presented on a card. The 9 descriptors were typical of cancer-related pain: Burning, Cramping, Shooting, Annoying, Miserable, Sickening, Mild Pain, Intense Pain and Unbearable Pain. The subjects' judgments made to the 36 pairings of different descriptors were entered into half-matrices (Fig. 1).

Example of card presented to the subject:

Rate the similarity of the two descriptor words below by circling a number on the scale from 0 to 10 where 10 represents Complete Similarity and 0 represents absolutely No Similarity.

MISERABLE BURNING

No Similarity 0 1 2 3 4 5 6 7 8 9 10 Complete Similarity

RESULTS

The 16 half-matrices (Fig. 1), one for each individual, were subjected to 1, 2 and 3 dimensional analyses by the INDSCAL program. The patients and controls were analyzed separately. The 2-dimensional solution was interpretable for both groups. For the patients and controls, respectively, dimension-1 accounted for 38% and 34% of the variance, and dimension-2 accounted for 15% and 22% of the variance. In INDSCAL, variance accounted for does not have its usual statistical meaning; here it is a measure of goodness of fit, and a dimension with values of 10% and above is generally regarded as meaningful.

The 2-dimensional display for the cancer-patient group appears in Fig. 2. The first step in interpreting a dimension is to note the properties of the stimuli at each pole. Since Mild Pain and Intense Pain appear at opposite ends of the abscissa, this axis may be interpreted as expressing sensory pain magnitude. A dimension may be further interpreted by projecting the stimulus points onto each coordinate axis in turn. Here, Mild Pain is followed by Annoying, then the somatosensory and unpleasant affect descriptors, and finally by Unbearable and Intense Pain (see lower Fig. 4). As one might expect, the affect descriptors, Sickening and Miserable, are somewhat closer than the somatosensory descriptors to the more painful end of this dimension. The clear ordering of the stimuli with respect to pain intensity identifies this dimension as a quantitative rather than a bipolar, qualitative dimension.

The second dimension, pain qualities, reflects the somatosensory and emotional attributes of global pain (Fig. 2). For the patients the somatosensory descriptors, Shooting, Burning and Cramping, are at the lower pole, and the unpleasant affect descriptors, Miserable and Sickening, are at the upper pole. The interpretation of such a dimension is more difficult than for a quantitative dimension, because the ordering of the stimuli reflects the influence of two attributes rather than one. When projected onto the ordinate (left side of Fig. 5) the pain qualities dimension is seen to contain two attributes: a somatosensory attribute and an unpleasant affect or emotional attribute. Towards the lower pole the somatosensory attribute becomes relatively more prominent than the emotional component, while towards the upper pole, the unpleasant affect attribute becomes increasingly prominent. It is interesting to note that, as one might expect from this two attribute interpretation, Mild Pain and Annoying, with an almost equal admixture of the two attributes, appear towards the middle of the dimension. Furthermore, the Mild Pain descriptor lies closer to the sensory pole, while the Unbearable and Intense Pain descriptors are closer to the emotional, negative affect pole.

The 2-dimensional display for the healthy volunteers appears in Fig. 3. The abscissa (upper Fig. 4) expresses the sensory pain magnitude dimension, with Mild Pain and Annoying at one pole and Intense Pain and Unbearable Pain towards the other. Burning also appears at the extreme pain pole, suggesting that the healthy volunteers view Burning as possessing an extreme form of sensory pain. The second dimension, pain qualities, (right Fig. 5) shows the descriptors Sickening and Miserable Pain at the affect pole and Burning and Mild Pain at the somatosensory pole. Although the upper affect pole is well defined in the healthy volunteers, the lower pole is less so, since Mild Pain appears at the sensory pole (along with Burning and Shooting), while Cramping lies towards the affect pole.

DISCUSSION

To aid comparisons of the two groups, Fig. 6 combines Figs. 4 and 5. It is apparent that for both the patients and the controls, the sensory pain magnitude dimension is the major dimension of global pain and that the second dimension is related to the somatosensory-affective attributes of global pain. However, there are differences between the groups. The groups differ with respect to (a) the location of some of the somatosensory descriptors, and (b) the location of the Mild Pain and Annoying descriptors. For the controls, the somatosensory descriptors extended out along both dimensions; thus, Cramping relatively high on negative affect and low on the sensory pain magnitude dimension, while Burning is relatively low on affect but high on the pain magnitude dimension, while Shooting falls midway on both dimensions. In contrast, the patients do not differentiate amongst the somatosensory descriptors with respect to painfulness, but cluster them at the somatosensory pole of the pain qualities dimension and in the center (moderate pain) of the sensory pain magnitude dimension.

The second difference between the two groups is that for the healthy controls Mild Pain and Annoying are located further away from the affect pole. Apparently, the controls considered Mild Pain in terms of its sensory aspects, without any strong negative affect (emotional content), just as one might view a minor burn or pin prick without strong emotion. On the other hand, the cancer patients appear to conceptualize even Mild Pain as being emotionally loaded. Mild pain may be less than Unbearable Pain, but it is still cancer and the patients continue to attach considerable negative emotion to it. Thus, the INDSCAL analysis demonstrates that Mild Pain has a quite different meaning for the two groups.

The quality of pain dimension with its two attributes may appear complicated, but this type of dimension is not exceptional. Kruskal and Wish (1978) note that, although interpretation of dimensionality often involves one attribute per dimension, at times there may be more than one relevant characteristic (attribute) to a dimension. An attribute may have an effect on a dimension, that is, be represented within it, yet may not contribute strongly enough to become distinguishable as a separate dimension. This can happen if the stimuli are chosen from too narrow a range, or because the two attributes are correlated. In this study the sensory and affect dimensions are probably hidden because they are negatively correlated: for, as the somatosensory dimension weakens, the affect dimension strengthens. It is possible that if the descriptors were chosen from a wider range of sensations and emotions and were increased in number, that these sensory and affect attributes would emerge as independent dimensions. While on this topic of descriptor selection, it can be seen that the intense pain and unbearable pain descriptors are very close on the sensory pain magnitude dimension and yield essentially the same information; accordingly, one could be dropped. These considerations on choice of descriptors demonstrate another advantage of the MDS approach: the direction which subsequent experiments should take, and the new set of stimulus objects to be used to improve the definition of the group stimulus space, are readily apparent. This aspect of INDSCAL contrasts with other procedures, such as magnitude estimation, where the results usually do not so clearly suggest new directions and new stimuli for future research.

Clark et al (1983) used INDSCAL to determine the dimensionality of warm and noxious thermal stimuli presented to healthy volunteers. The major dimension, that is, the one which explained most of the variance, was the strength of sensation dimension, while the pain-heat dimension was secondary. This is in contrast with the descriptors for global pain, where the pain magnitude dimension was the major dimension. Furthermore, with the thermal stimuli no solid evidence was found for the unpleasant affect attribute which emerged so clearly with the verbal descriptor stimuli. The lack of the emotional dimension in the laboratory pain testing situation is to be expected; the stimuli vary in perceived intensity and reach noxious levels, but they are not life threatening nor even anxiety arousing to an experienced subject. INDSCAL reveals that laboratory pain is not clinical pain because it lacks the emotional dimension.

It may be concluded from this INDSCAL analysis that global pain has three qualtities: a purely sensory pain dimension and a quality of pain dimension which contains somatosensory and unpleasant affect attributes. These three qualtities fuse into the experience of global pain. The consistency of the global pain dimensions across the extremely disparate cancer and control groups is extremely encouraging. The major difference appears to be in the precise location of some of the descriptors, not in the dimensions themselves. Although further studies using more descriptors are needed, it is clear that INDSCAL has a great potential for increasing our knowledge of complex perceptual-emotional experiences.

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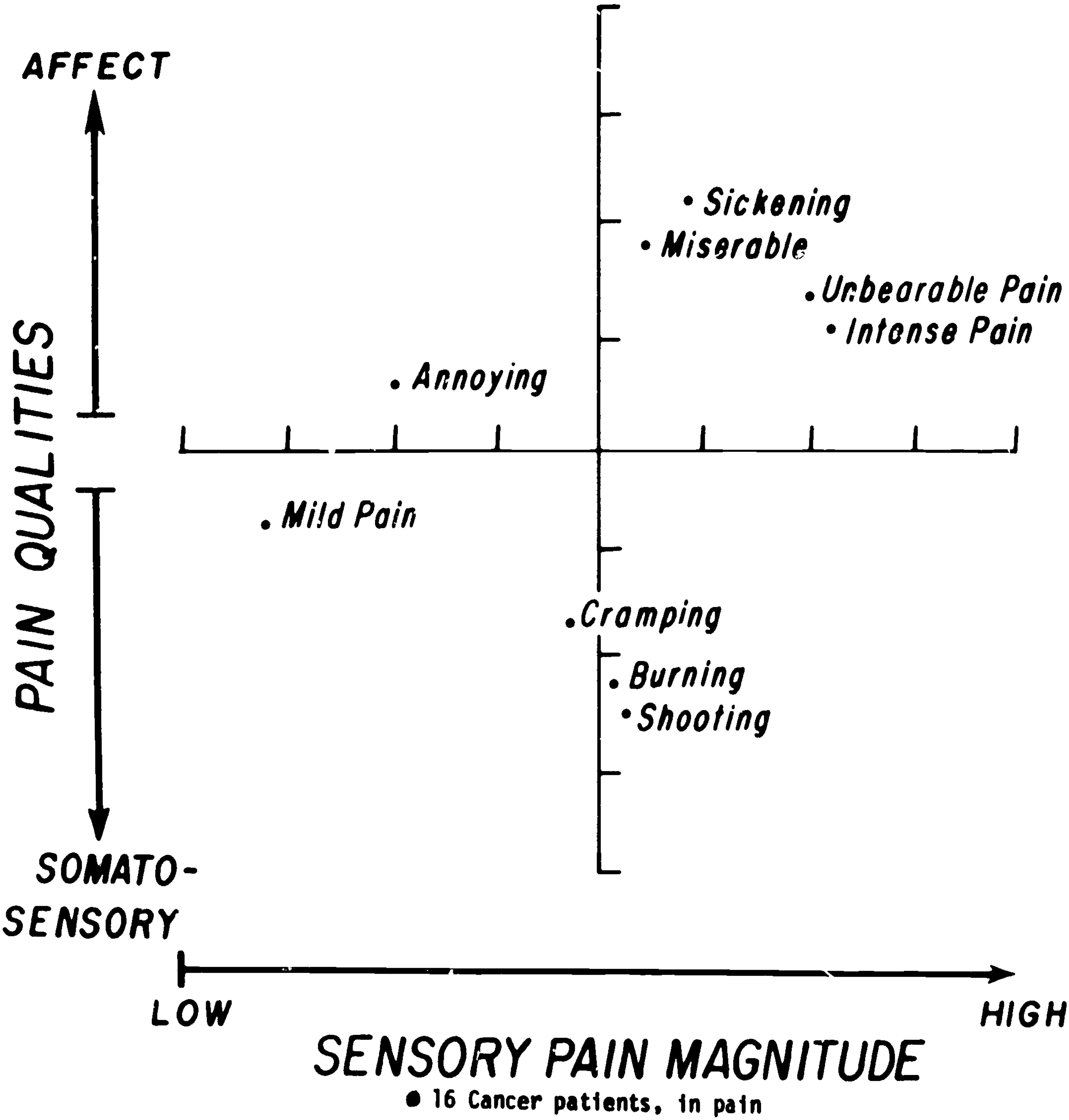
Patient's Name ______________

Date ____

BLANK RESPONSE SHEET ("HALF-MATRIX") FOR ENTERING AN INDIVIDUAL'S SIMILARITY JUDGMENTS.

		MILD PAIN 1	INTENSE PAIN 2	UNBEARABLE PAIN 3	BURNING 4	CRAMPING 5	SHOOTING 6	ANNOYING 7	MISERABLE 8
INTENSE PAIN	2								
UNBEARABLE PAIN	3								
BURNING	4								
CRAMPING	5								
SHOOTING	6								
ANNOYING	7								
MISERABLE	8								
SICKENING	9								

FIG. 1


AFFECT
PAIN QUALITIES
SOMATO-
SENSORY
• Sickening
• Miserable
• Unbearable Pain
• Intense Pain
• Annoying
• Mild Pain
• Cramping
• Burning
• Shooting
LOW
HIGH
SENSORY PAIN MAGNITUDE
● 16 Cancer patients, in pain

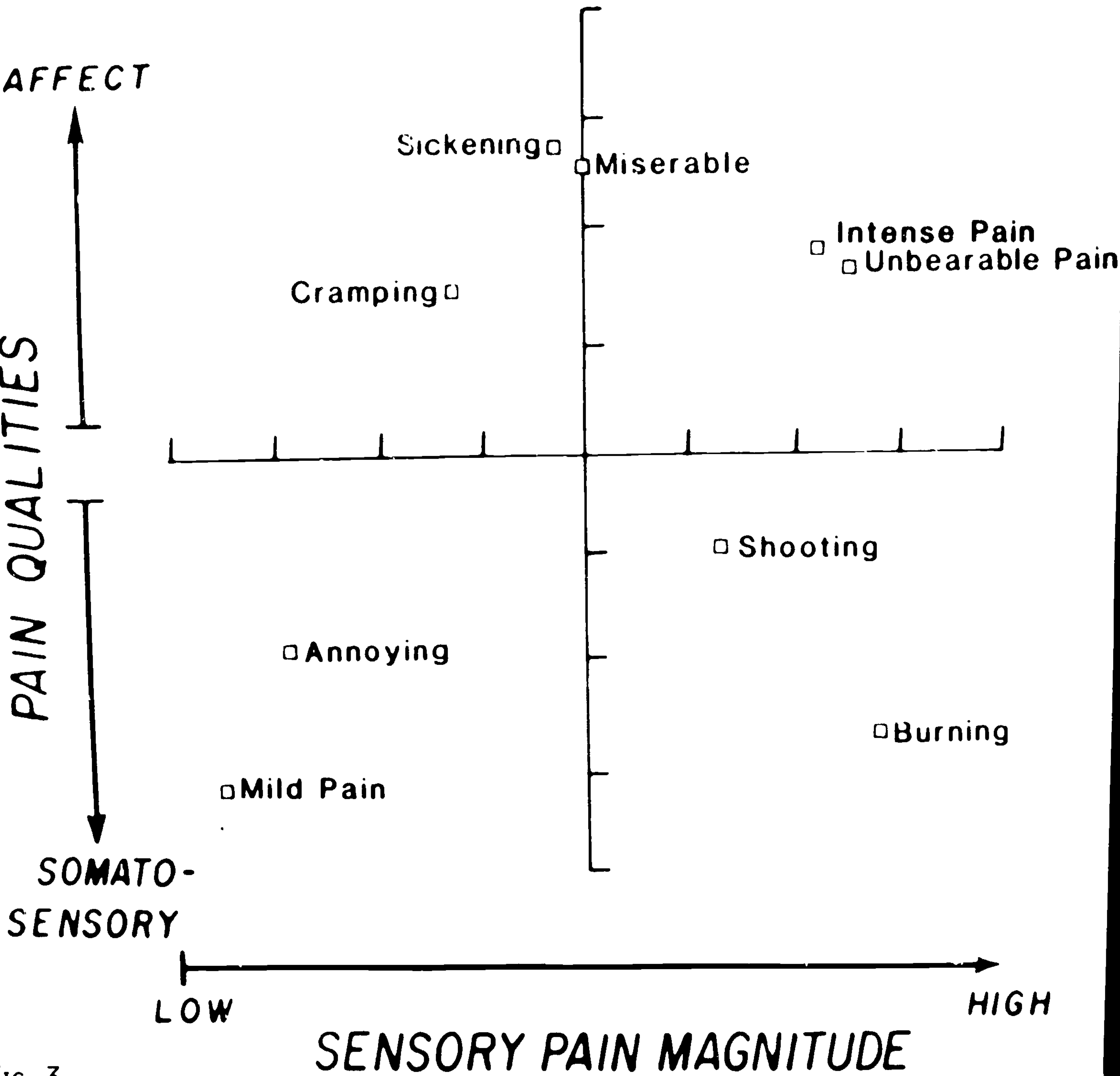


Fig. 3

□ 16 Matched healthy volunteers

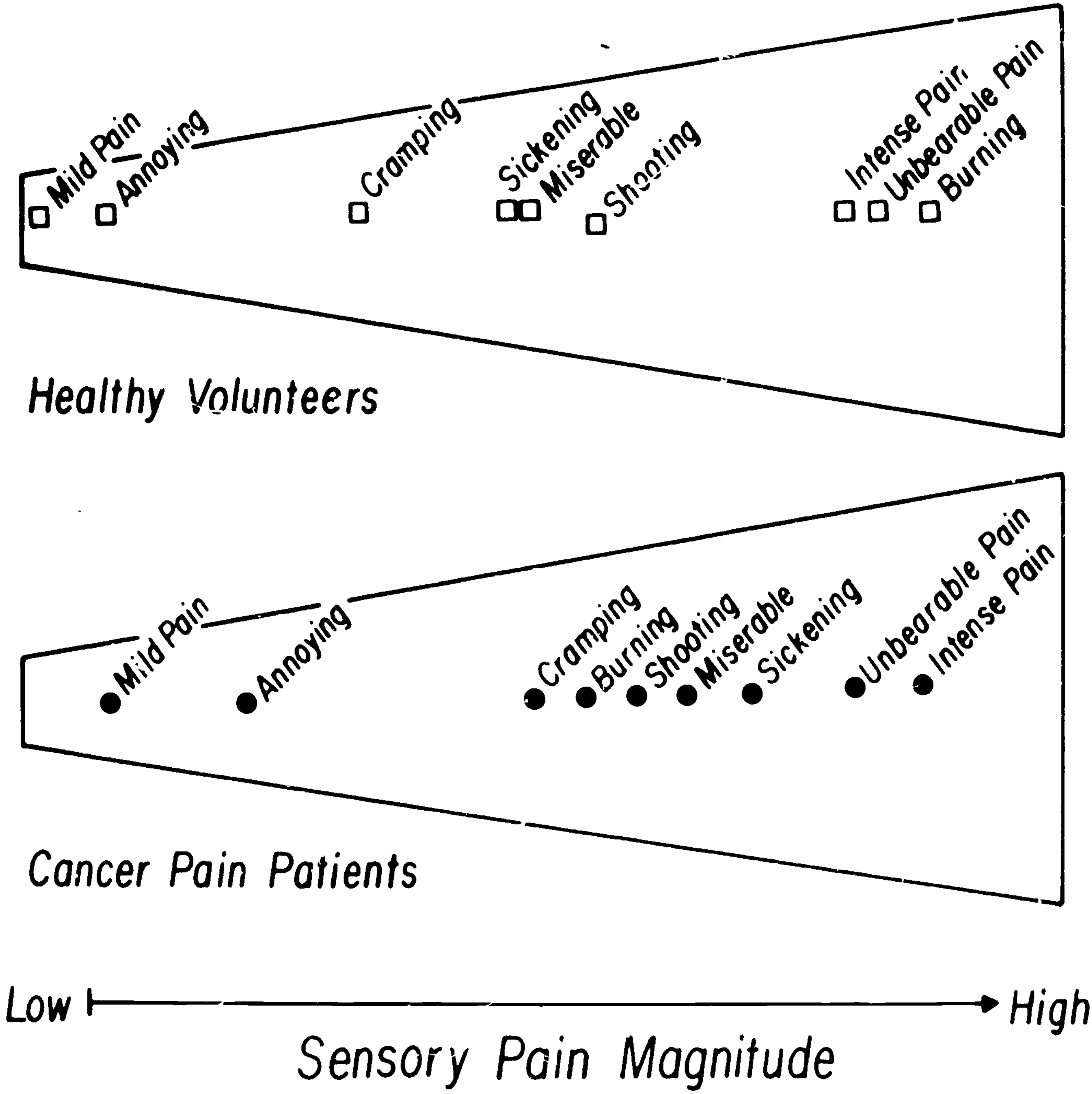

Mild Pain
Annoying
Cramping
Sickening
Miserable
Shooting
Intense Pain
Unbearable Pain
Burning
Healthy Volunteers
Mild Pain
Annoying
Cramping
Burning
Shooting
Miserable
Sickening
Unbearable Pain
Intense Pain
Cancer Pain Patients
Low
High
Sensory Pain Magnitude

FIG. 4

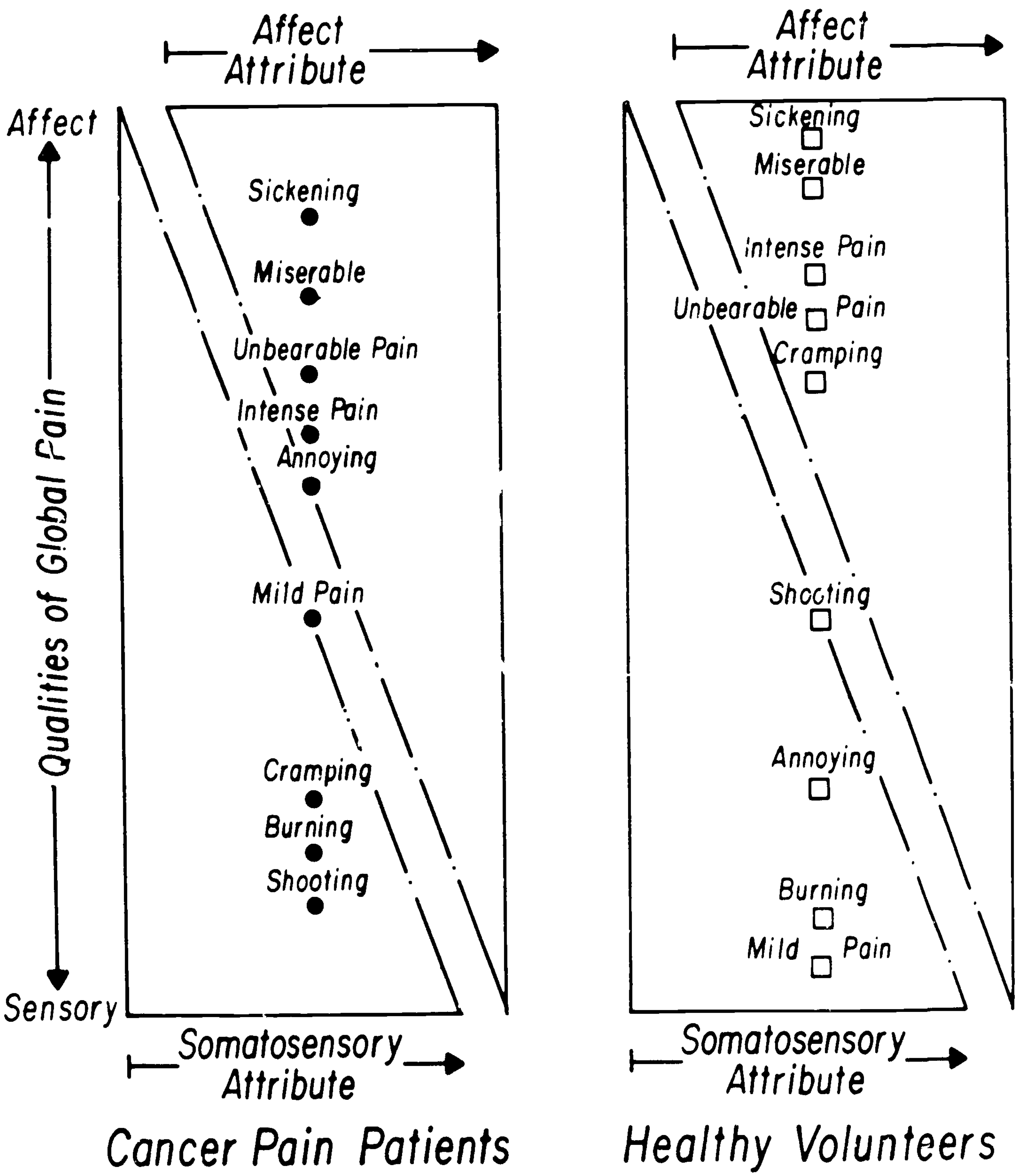

Affect
Attribute
Affect
Sensory
Qualities of Global Pain
Sickening
Miserable
Unbearable Pain
Intense Pain
Annoying
Mild Pain
Cramping
Burning
Shooting
Somatosensory
Attribute
Cancer Pain Patients
Affect
Attribute
Sickening
Miserable
Intense Pain
Unbearable Pain
Cramping
Shooting
Annoying
Burning
Mild Pain
Somatosensory
Attribute
Healthy Volunteers

FIG. 5

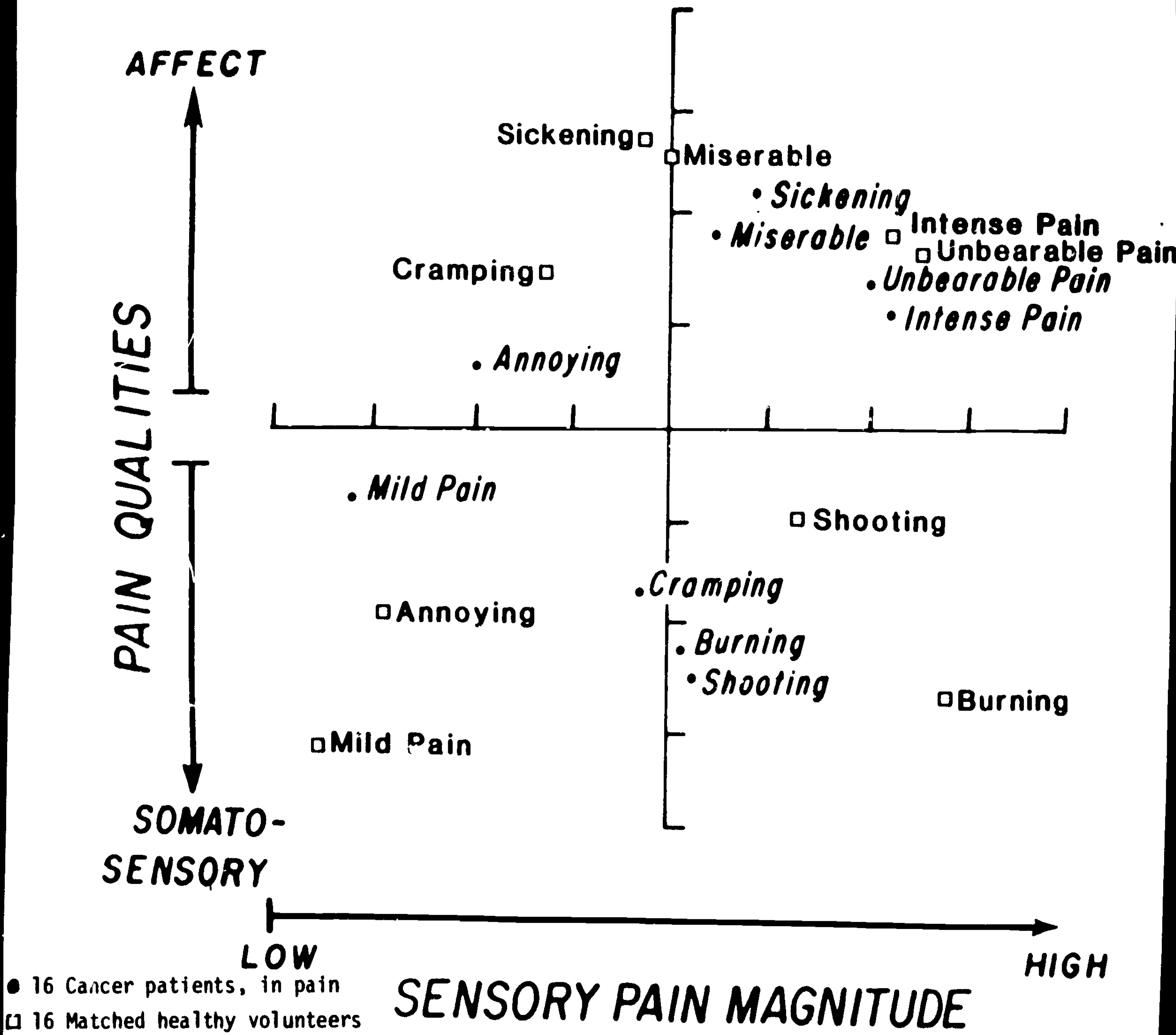

AFFECT
PAIN QUALITIES
SOMATO-SENSORY
Sickening
Miserable
Sickening
Miserable
Intense Pain
Unbearable Pain
Cramping
Unbearable Pain
Intense Pain
Annoying
Mild Pain
Shooting
Cramping
Annoying
Burning
Shooting
Burning
Mild Pain
LOW
HIGH
SENSORY PAIN MAGNITUDE
● 16 Cancer patients, in pain
□ 16 Matched healthy volunteers

FIG. 6