Psychophysical Approaches to Cognition
D. Algom (Editor)

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COGNITIVE EFFECTS IN PAIN AND PAIN JUDGMENTS

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I. Introduction

Near the beginning of "Les Belles Soeurs," a black comedy by Quebec playwright Michel Tremblay, a very elderly woman is heard, offstage, to fall out of her wheelchair. One woman asks her daughter-in-law, "She's not hurt, I hope," and receives the reply, "Oh no, she's used to it."

The exchange is predicated on the assumptions that pain can be measured or assessed and that cognitive variables, such as those incorporating previous pain experiences, can modulate or influence current pain.

The reader may take the first of these assumptions as a given, but prominent experts have challenged the foundations of a pain psychophysics. Wall (1979) writes:

> The delight of psychophysicists is their ability to establish thresholds of sensation and to measure lawful relations between stimulus intensity and the strength of sensation. They have obviously been very successful in vision and hearing. No such psychophysics exist for sensations such as hunger or thirst but there have been persistent attempts to establish thresholds and scales relating experimental stimuli to evoked pain. The results are farcical in their wild variability when compared to vision, hearing, smell, task and touch. The persistent failure of subjects to relate stimulus intensity to pain intensity is one of the strongest reasons to question the classical attempt to group pain with the familiar sensations evoked by external sources.

Researchers in the common senses have come to appreciate that their data, too, are often marked by "wild variability" in inter-subject and intra-subject judgments. Rollman and Harris (1987) reviewed studies in audition, vision, olfaction, and somesthesis. Thresholds for pure tones had a standard deviation of 5.7 to 10.7 dB for frequencies between 80 Hz and 15 KHz (Dadson & King, 1952). Vibration sensitivity on the finger tip had standard deviations on the order of 10 dB (Goff, Rosner, Detre, & Kennard, 1965). Thresholds of a group of dark-adapting subjects varied over a 4-fold range (Hecht & Mandelbaum, 1948). After correction for stimulus noise and measurement errors, olfactory sensitivity still spanned a 20-fold range (Rabin & Cain, 1986).

Ippolitov (1972) tested thresholds in a variety of modalities for a large group of observers. Careful examination of those most consistent in their performance still revealed a 28-fold range of scotopic visual threshold, a 15.5 dB range in pure-tone threshold, a 3.5 fold range in mechanical pressure threshold using von Frey hairs, and a 6-fold range in electrocutaneous threshold for constant voltage stimulation.

Consequently, the 8-fold range for pain threshold induced by constant current stimulation or the similar range for pain tolerance (Rollman & Harris, 1987) seemed quite comparable. The sensory and cognitive factors which underlie signal detection theory procedures (Green & Swets, 1966) are certain to apply to the traditional five senses and to pain.

Is Pain a Special Sense?

Pain has, however, often stood apart from the traditional five senses. Boring (1942) noted that pain had generally been classified as a *Gemeingefuhl* rather than a component of touch; part of the "classificatory catch-all for everything that did not fit the *Tastsinn*." The view that "all intense stimuli are painful" irrespective of modality was widely debated during the 19th Century, with challenge coming from those who directly stimulated the optic nerve to yield a very bright, but painless, flash or those who felt that surgical intervention in the spinal cord differentially interrupted the experience of pain and touch.

The debate became even more lively in the late 1890's when Blix and Goldscheider first claimed to have found distinct pain spots on the skin and, later, reversed their positions and declared that pain is common sensibility. Meanwhile, von Frey argued that pain is a separate skin modality, with multiple pain spots served by free nerve endings (Boring, 1942). Von Frey's theory has been discredited on anatomical and psychological grounds (Melzack & Wall, 1962), but its simplicity, coupled with the logical appeal of a direct, linear pain system extending from the periphery to the cortex, gave it credence in medical textbooks until the present day.

II. The Gate Control Theory

The advent of Melzack and Wall's (1965) gate control theory challenged the traditional model, replacing a linear system with one possessing multiple nodes of interaction. Melzack and Wall recognized a number of difficulties with a straight-through pain model. First, it predicts that interruption of ascending pain tracts abolishes the experience of pain, but surgical experience failed to confirm that. Second, it associates increased peripheral activity with increased pain, yet common responses to pain involve rubbing or massaging the affected area or applying heat or cold - methods which increase afferent input but *reduce* the pain experience. Third, anecdotal and clinical evidence suggested that severe injury can often occur without severe pain. There are many accounts of athletic injuries, wounds sustained during military battles, or civilian trauma in which major tissue damage is sustained without immediate pain. Likewise, distraction, expectation, emotion, and suggestion can modulate the pain experience.

In order to incorporate the failure of surgical interruption of ascending tracts, Melzack and Wall (1988) had to consider the possibility of multiple ascending pathways, the establishment of new connections, and the notion that the absence of normal tonic input to central structures may be as disruptive to central processing as an abundance of peripheral activity.

To account for the paradoxical inhibition of pain by mechanical or thermal input, the gate control model suggested a complex interplay of inputs from small peripheral fibers (which respond to noxious inputs and are consequently labelled nociceptors) and from larger myelinated fibers which have lower thresholds and faster conduction velocity. As shown in Figure 9.1, which represents a modification of the original gate control model (Melzack & Wall, 1988), the activity transmitted in small diameter fibers is proposed to have facilitatory effects on

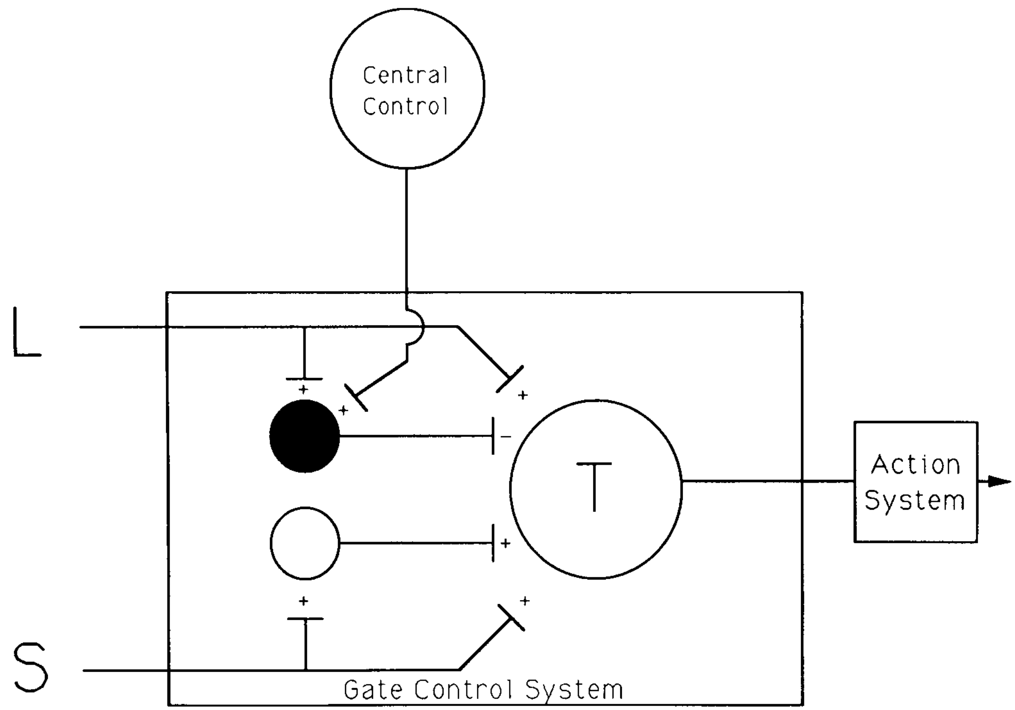

Figure 9.1: A schematic representation of Melzack & Wall's (1988) revised gate control model. The solid and open circles show cells in the substantia gelatinosa of the dorsal horn which exert inhibitory (solid circle) and the excitatory (open circle) influences on nearby transmission cells (T) after activation of large (L) and small (S) diameter afferent fibers. The input from the central control areas depicts the modulating influence of higher nervous system activity.

transmission cells in the dorsal horn of the spinal cord, both directly and via excitatory interneurons in the nearby substantia gelatinosa. The model also proposes that the large fibers, because of their connections to inhibitory interneurons in the substantia gelatinosa, are capable of modifying, by pre- and post-synaptic inhibition, the firing level of the T cells and, consequently the nature of the message sent to more central sites.

This gating mechanism, whereby large fiber inputs can modulate the transmission of nociceptor signals, allows for peripheral inputs to influence activity at the spinal cord level. It suggested that electrical stimulation of large fibers could reduce pain experiences and the subsequent confirmation of this in laboratory and clinical settings led to the development of commercially available transcutaneous electrical nerve stimulation (TENS) devices (e.g., Eriksson, Rosen, & Sjolund, 1985).

The evidence concerning the profound effects of distraction, suggestion, expectation, and emotion on pain experiences indicted that pain is not only the purview of anatomists, neurophysiologists, and medical personnel. It made clear that both the study and treatment of pain is very much in the domain of psychology.

The gate model provided for a vague "central control" trigger which descends from the brain to provide further modulation of T cell activity. While the physiological and neurochemical nature of such descending controls was unknown in 1965, it is now known that electrical and chemical activation of cells in such areas as the hypothalamus, the periaqueductal grey of the midbrain, and the nucleus raphe magnus of the medulla, can exert powerful analgesic effects. The subsequent discovery of endogenous opioid peptides in the hypothalamus, midbrain, medulla, and spinal cord, and evidence that they could be released by factors as diverse as physical activity (Colt, Wardlaw, & Frantz, 1981; Janal, Colt, Clark, & Glusman, 1984), stress (Maier, Laudenslager, & Ryan, 1985), and cognitive mechanisms (Bandura, O'Leary, Taylor, Gauthier, & Gossard, 1987) provided further testimony to the decisive role of descending inhibitory mechanisms and their dependence on psychological factors.

The Nature of Pain

The Oxford English Dictionary defines pain as "A primary condition of sensation or consciousness, the opposite of pleasure; the sensation which one feels when hurt (in body or mind)" and "a distressing sensation of soreness (usually in a particular part of the body)." Aside from problems related to the imprecise operational nature of the first definition ("feels when hurt") and the fact that such a rigid linkage is untrue and to the circular nature of the second definition (pain is soreness and soreness is pain), it is also improper that pain should be considered simply a "sensation."

Melzack and Casey (1968) observed that "pain has a unique, distinctly unpleasant, affective quality that differentiates it from sensory experiences such as sight, hearing, or touch." While aficionados of Old Master paintings, Puccini operas, or silk bed sheets may take issue with the notion that sight, hearing, or touch lack affective quality, they may well agree with Melzack and Casey's further observation, "To consider only the sensory features of pain, and ignore its motivational and affective properties, is to look at only part of the problem."

Melzack and Casey (1968) declared that it is erroneous to consider a sequential model of pain perception in which primary "pain sensation" is followed by secondary "reactions to pain" which involve motivational (driving "the organism into activity aimed at stopping the pain as quickly as possible") and cognitive processes. Were that the case, pain sensation could be blocked by cognitive mechanisms, producing the "paradox of nonpainful pain." They considered it more reasonable to say that noxious inputs could be "blocked or modulated by cognitive activities before it could evoke the motivational-affective processes that are an integral part of the total pain experience."

Citing the capacity of brain activities to "influence the gate control system through central control efferent fibers," Melzack and Casey proposed, among other things, that "neocortical or higher central nervous system processes, such as evaluation of the input in terms of past experience, exert control over activity in both the discriminative and motivational systems."

The components of their conceptual model are presented in Figure 9.2. The "action system" of the original gate control model is replaced with a detailed system of mutually interactive elements, with the "sensory-discriminative" component of pain mediated by the neospinothalamic projection system, the "motivational-affective" component tapping into reticular and limbic structures, and what has come to be called the "cognitive-evaluative" component (although here was labelled simply "central control processes") being served by "higher central nervous system" activities.

Melzack and Casey (1968) incorporated a host of data under the "central control" rubric: effects on pain of anticipation, anxiety, attention, suggestion, placebos, cultural background, evaluation of meaning, hypnosis, early experience, and prior conditioning. They provided for the central control processes to modify the spinal gate and to influence (and be influenced by) the motivational-affective and sensory-discriminative systems. As well, they noted that cognitive variables underlying such effects as suggestion and placebos may "modulate the motivational-affective dimension and leave the sensory-discriminative dimension relatively undisturbed," a notion to which we'll return below.

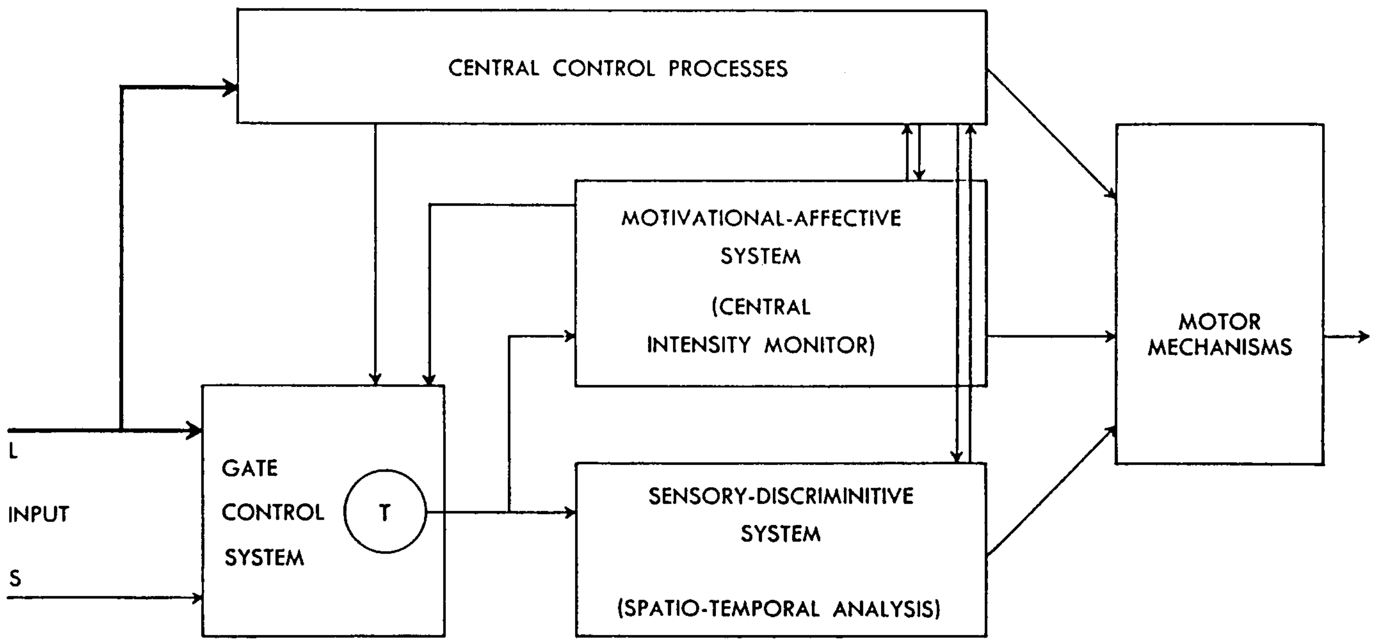

Figure 9.2: A conceptual model of sensory-discriminative, motivational-affective, and central control components of pain and their interactions suggested by Melzack and Casey (1968) (from R. Melzack & K.L. Casey 1968, Sensory, motivational, and central control determinants of pain: A new conceptual model. In D. Kenshalo (Ed.), The skin senses pp. 423-443, reprinted by permission).

Implications of the Melzack and Casey Model

Although elements of the gate control theory were challenged on a number of physiological grounds, the conceptual model proposed by Melzack and Wall (1965) and extended by Melzack and Casey (1968) provided considerable heuristic value in thinking about the components of the pain experience, the neural elements underlying them, and the possible therapeutic implications of a variety of treatments targeted at sensory, emotional, or cognitive systems.

Moreover, the expanded model led to a widely used (although still debated) definition of pain, adopted by the Subcommittee on Taxonomy of the International Association for the Study of Pain (Merskey, 1986): "Pain is an unpleasant sensory and emotional experience associated with actual or potential tissue damage, or described in terms of such damage." The definition gives relatively short shrift to cognitive variables, making passing reference to processes of association or description, but it clearly broadens the domain of pain beyond a pure sensory experience.

Melzack and Torgerson (1971) broadened the domain in another manner. Scanning the clinical literature relating to pain, they selected 102 words which were used to describe the phenomenon. The adjectives were classified into smaller groups, falling into 3 major classes and 13 subclasses. Subsequently, they were scaled as to how much pain each word represents. Based upon the results of this analysis, Melzack (1975) devised the McGill Pain Questionnaire, an adjective scale used to assess the multiple components of the pain experience. Other attempts to quantify such distinctions will be examined below.

Cognitive Manipulation of Pain

Another major outcome of the broadened conception of pain was a growing realization that traditional analgesic procedures, which generally utilized pharmacological or surgical interventions aimed at altering sensory transmission or analysis, were often inadequate in dealing with pain problems. Consequently, techniques which had been applied with success to problems of depression (Meichenbaum, 1977) began to be employed in the treatment of chronic pain, under the heading of "cognitive behavioral therapy" (Tan, 1982; Turner & Chapman, 1982a; Turk, Meichenbaum, & Genest, 1983). As Turner and Chapman (1982b) noted, "A basic assumption is that the cognitions (attitudes, beliefs, and expectations) people maintain in certain situations can determine their emotional and behavioral reactions to those situations. As cognitive (e.g., distraction, significance of the pain for the individual) and emotional variables (e.g., anxiety) influence the experience of pain, it seems logical that the modification of cognitions could be used to alter the pain experience."

Tan (1982) added, "Cognitive methods are those which attempt directly to modify thought processes in order to attenuate pain. The underlying assumption of these approaches is that a person's 'cognitions' or appraisals of his environment are critical determinants of his experiences and emotions. Hence faulty 'cognitions' lead to negative experiences, including exacerbation of anxiety, depression and pain. By altering such 'cognitions' to more adaptive ones, negative experiences may be attenuated."

A number of strategies have been utilized by cognitive-behavioral therapists: relaxation, imagery, relabelling sensations, education, self-monitoring, thought-stopping, information, distraction, and calming self-statements. As this list shows, cognitive and behavioral methods are frequently blended in a treatment package.

The cognitive strategies were first tested in laboratory settings, utilizing pain induced by immersion of the arm in ice water or exposure to shock, pressure, heat, or muscle ischemia. Turk, Meichenbaum, and Genest (1983) distinguish between strategies that attempt to alter the appraisal of the painful situation and those that attempt to divert attention away from the pain. Attention diversion strategies include:

1. **Imaginative inattention** - ignoring the pain by establishing a mental image of a scene or activity that is incompatible with the experience of pain. ("I am frolicking in the surf at Waikiki").
2. **Imaginative transformation of pain** - interpreting the sensations as something other than pain or treating them as trivial or unreal ("My arm is numbed by local anesthetic or is mechanical").
3. **Imaginative transformation of context** - the noxious sensation is acknowledged, but the setting is altered ("A foreign agent is attempting to interrogate me").

Whereas the first three called upon the production of an image to divert attention, the following three involve a refocusing of attention.

4. **Focusing attention on physical characteristics of the environment** - diversion of attention to external objects such as counting ceiling tiles or studying the composition of a nearby object.
5. **Mental distractions** - diversion of attention to self-generated thoughts such as doing mental arithmetic or singing the words of a song.
6. **Somatization** - focusing attention on the body part exposed to noxious stimulation in an "objective, rather than subjective, manner." The subject is told to analyze the sensations as if preparing to write a scientific report.

The data from a large number of laboratory studies utilizing such techniques to increase pain threshold or tolerance or to decrease pain report are, as Tan (1982) noted, "inconsistent and often contradictory." In somewhat more than half of the studies, greater effects were observed for subjects asked to utilize specific strategies than for control subjects (some of whom, presumably were using self-generated strategies).

Tan (1982) and Turk, Meichenbaum, and Genest (1983) pointed to a number of methodological and procedural differences which may have contributed to the equivocal results. These include different pain induction techniques, different dependent pain measures, different instructions, motivational differences among subjects, the use of pre-tests, and the spontaneous use of self-generated strategies.

Harris and Rollman (1985) exposed 40 subjects to three forms of experimentally-induced pain: trains of constant current electrical pulses delivered to the volar forearm, the cold pressor test in which the arm is inserted into a tank of circulating ice water, and a constant pressure algometer, which applies a weighted wedge against the forefinger. After baseline measures, subjects were given strategies for attention diversion, dissociation, transformation of the sensation, and imaginative diversion. Significant increases occurred in tolerance levels for all three stressors, but the largest increases occurred for those subjects whose baseline tolerance was already high. If one can extend this to a clinical setting, those who needed the greatest assistance from the cognitive intervention benefitted the least.

One possible reason is that the observers with a high baseline tolerance were already using self-initiated coping strategies before they received instruction in the specific techniques of the study. Indeed, a coping strategies questionnaire revealed that those subjects who had used such strategies showed larger changes in tolerance for the stressors. Use of a coping strategy in the pretest did not preclude an increase in later tolerance. If anything, it facilitated the benefit.

Cognitive-behavioral strategies for pain control have also been examined directly within a clinical context. For acute pain, there is considerable evidence of the efficacy of such techniques in dealing with post surgical pain, dental pain, headaches, burn treatments, and labor pain (Turk, Meichenbaum, & Genest, 1983). For chronic pain, cognitive-behavioral approaches have surpassed control or relaxation training conditions in studies of recurrent headache (Bakal, Demjen, & Kaganov, 1981), low back pain (Turner & Clancy, 1986), pain of the facial temporomandibular joint (Stam, McGrath, & Brooke, 1984), and rheumatoid arthritis (Bradley, Young, Anderson, Turner, Ggudelo, McDaniel, Pisko, Semble, & Morgan, 1987), among others.

Three points should be noted. First, these cognitive-behavioral approaches go beyond the imagery and attention diversion techniques mentioned earlier. The therapeutic packages typically also include training in stress-coping, elimination of "catastrophic thoughts" and "irrational cognitions," counteracting attitudes of helplessness, and self-monitoring (Prkachin & Cameron, 1990). Few studies (e.g., Vallis, 1984) have attempted to separate the various components of such programs in order to see which cognitive interventions are necessary or sufficient in order to achieve significant pain reduction. Second, the clinical studies have generally been conducted over a relatively brief time span. There is little evidence about the long-term utility of cognitive interventions aimed at reducing clinical pain. Finally, descriptions of "cognitions" involved in altering pain experiences need to be broadened to include concepts such as "self-efficacy" (Bandura, 1977), even when applied to behavioral analyses. As Prkachin and Cameron (1990) observed, "self-efficacy refers to individuals' belief in their ability to perform requisite behaviors. Individuals must acquire a sense of self-efficacy if they are to attempt and persist in coping behaviors. The effectiveness of different procedures in bringing about behavior change is proportional to their ability to induce expectations of personal efficacy."

III. Laboratory Assessment of Pain

Laboratory studies of pain have typically given considerable attention to stimulus and response variables and less attention to intervening cognitive factors. Even in selecting a stimulus, however, cognitive factors deserve consideration. Smith and Andrew (1970) described six characteristics of a satisfactory pain source:

1. A severity comparable to a surgical incision, or, even better, comparable to a muscle splitting incision.
2. Controllable as to severity, so pain intensity could be decreased or increased as desired.
3. Ends instantly when desired.
4. No tissue injury produced.
5. Repeatable with good degree of uniformity of results.
6. No startle component.

The major items on Gracely's (1989) list of properties of an ideal pain stimulus are, for the most part, similar:

1. Rapid onset.
2. Rapid termination.
3 Natural.
4. Repeatable with minimal temporal effects.
5. Similar sensitivities in different individuals.
6. Excite a restricted group of primary afferents.

Smith and Andrew's quest led them to a ramped train of electrical pulses while Gracely concluded that thermal stimuli come closest to his ideal. There is room for debate on such lists of appropriate noxious stimuli. An intensity comparable to a "surgical incision" is certainly not necessary for all pain studies, nor is a "natural" stimulus (ruling out electrical pulses that bypass receptors and excite afferent nerve fibers [Higashiyama & Rollman, 1991; Rollman, 1975]) or one that activates only a single class of nociceptors. Among the four common classes of noxious stimuli: electrical, thermal, mechanical, and chemical, the last group has typically been avoided because of the problems, among others, of stimulus control, rapid termination, tissue damage, and repeatability, but each of the others have been widely used.

Harris and Rollman (1983) measured pain threshold and pain tolerance for trains of electrical shocks, the cold pressor task (in which the arm is immersed in a container of ice water), and a mechanical device which applies a constant pressure against a small area of skin on the second phalanx of the finger. The correlations between the threshold and tolerance measures for each of the stressors were examined using multitrait-multimethod analysis (Campbell & Fiske, 1959). Strong evidence was found for both convergent and discriminant validity. The high correlations between measures for cold and pressure confirm the earlier results of Brown, Fader, and Barber (1973) and Davidson and McDougall (1969). Cold and pressure, as applied here, increase with the passage of time, induce deep pain, and are highly familiar experiences. Pain produced by electrical shock has different sensory qualities, and, perhaps more important here, is unfamiliar and often accompanied by reports of anxiety and stress. Thus, while thermal and mechanical stimuli may produce qualitative effects closer to many clinical pains than do electrical stimuli, significant alterations in affective and evaluative dimensions produced by shock may cause it to be preferred in assessing the effects of cognitive manipulations.

The evidence for discriminant validity in the Harris and Rollman (1983) study came from the finding that pain thresholds and pain tolerance levels across stressors correlated more highly with each other than did correlations for the two measures within a stress condition. Thus, for example, cold threshold and presser threshold levels had a correlation of 0.88, whereas cold threshold and cold tolerance had a correlation of only 0.28. Threshold and tolerance measures, then, represent different components of the pain experience, with the former, perhaps, reflecting the discrimination of nociceptive quality from non-nociceptive (sensations such as touch, warmth, or cold), while the latter indicates an unwillingness to receive more intense stimulation. Tolerance should be more susceptible to cognitive manipulations, a concept supported by findings as diverse as Sternbach and Tursky's (1965) report that tolerance was appreciably more influenced by ethnic group membership than was threshold, by Harris' (1981) observation that tolerance changed more than threshold after cognitive-behavioral therapy, and by Turk and Kerns' (1983) finding that catastrophic thoughts about the possible damage to the limb caused by immersion in ice water had enormous influences on pain tolerance but little on pain threshold.

Classical Pain Measures

Beecher (1959) said, "Pain is measured in terms of its relief." For clinical pain states, this is often the case, but for induced pain, pain relief is generally measured only indirectly. If an analgesic agent raises pain threshold or pain tolerance, one assumes that a stimulus presented at the baseline threshold or tolerance level will now be less painful than before and that pain relief has been achieved. Direct scaling procedures allow more direct examination of this issue.

Beecher (1959) realized that both pain threshold and tolerance reflect important cognitive contributions. "Pain does not 'occur' in the periphery," he wrote; "it is a phenomenon of the central nervous system. Evidence has been accumulating that consciousness of pain has more to do with the cortex than was once believed." He went on to cite Bishop's (1946) observation, "it is not clear whether the increased perceptual threshold under drugs, etc., is in effect a result of changed mental attitude, lack of attention, interest, or less careful discrimination." Likewise, Cattell (1943) said, "It may well be that the threshold raising effect [of analgesics] is secondary to influences on the mental state of the subject, who otherwise is likely to be preoccupied with the painful experiences. Just as environmental distractions cause a rise in pain threshold, so do mood changes or the interference with mental processes through drug action. The rise in threshold which may accompany analgesia must then be looked upon as incidental to the changes in mental function, with awareness of pain not necessarily altered."

Pain threshold and tolerance measures reflect a combination of sensory and response bias components. Although neither is a "pure" measure of any of the components of the pain experience, they can still be of considerable value in identifying whether a manipulation has an effect on pain or whether two groups differ in some respect in their pain behaviors. As noted earlier, threshold and tolerance measures have discriminant validity. There is evidence for reliability both within and across repeated sessions. While direct scaling methods may have a greater precision (gained after appreciably longer testing sessions), they are not independent of the traditional measures.

Rollman and Harris (1987) found that the exponents of individual power functions for a group of 40 subjects had a significant negative rank order correlation (rho = -.60) with the pain sensitivity range (the range between pain threshold and tolerance). Individuals with a small dynamic range had steep power functions, suggesting that they may be mapping a constant response range onto individually differing stimulus ranges (Teghtsoonian, 1971). This relation between the response continuum and the dynamic range lends support to the notion that threshold and tolerance measures, particularly the latter, reflect interindividual differences in pain judgments similar to those underlying scaling performance.

Limitations of Threshold and Tolerance Measures

Taub and Campbell (1974) measured pain threshold by determining the displacement of a needle pressed onto the skin just maximal to the nailbed until "pain was first reported." Two sessions were run with each observer: one baseline and one while stimulating the finger with continuous 100 Hz electrical current at one of the two currents. The lower current had no effect on pain threshold; the higher current raised it significantly. These findings, coupled with reductions in the averaged compound action potential, led the authors to conclude that the current caused peripheral blockade of smaller myelinated fibers, the A-delta nociceptors, creating nearly full analgesia to pinprick.

Bobey and Davidson (1970) had subjects rehearse the experience of exposure to radiant-heat pain on separate days, followed by actual application of the heat. Rehearsal increased the duration of exposure before subjects reported tolerance. Since rehearsal did not affect tolerance when an intervening day was not provided, Neufeld and Davidson (1971) suggested that the extended period may have provided "extended opportunity for the person to invoke strategies of coping with the impending harm."

In the first of these experiments, the authors interpreted the change in pain threshold as a sensory alteration. In the second study, cognitive mechanisms were invoked. Threshold and tolerance measures, alone, don't readily distinguish between the two.

Blitz and Dinnerstein (1971) asked one group of subjects to immerse their hands in ice water and report pain threshold. A second group was given instructions to "focus your attention and concentrate on the cold and try to ignore or focus away from the component of discomfort or pain," while a third group was told, "imagine that it is a very hot day and that the water is refreshing and pleasantly cool." The attentional redirection groups both showed large elevations in pain threshold. Blitz and Dinnerstein raised an essential question, "was the change in pain threshold a reflection of changes in perception, or might it simply reflect a change in the subjects' reporting of pain in an attempt, for example, to please the experimenter?" They noted that "the present data cannot differentiate between those alternatives" but indicated that questioning of their subjects suggested a sensory alteration in that "most subjects felt that on the instruction trials the pain was less intense."

Overview

The threshold and tolerance data reported above demonstrate that these variables can provide data indicating a change in pain behavior, but they don't distinguish between sensory and response alterations. Two very different approaches, sensory decision theory methods and differential scaling of intensity and affect have attempted to provide greater insight into the nature of such behavior shifts.

IV. Sensory Decision Theory Methods

At first blush, sensory decision theory or signal detection theory (SDT) (Green & Swets, 1966) techniques might seem optimum for separating sensory from response bias changes in pain reports. The SDT approach provides a means of independently measuring two components of an observer's performance when detecting a stimulus or discriminating between two different ones: sensitivity and response bias, therefore separating the sensory and cognitive factors responsible for the person's responses.

Common SDT experiments in psychoacoustics or vision investigate detection processes, examining the confusion between signal and noise. Pain studies, however, require intense levels of stimulation, but the presentation of strong electrical, mechanical, or thermal stimuli mixed with blank trials would not create the uncertainty needed to extract the sensitivity and criterion measures (Rollman, 1977). Consequently, pain researchers using SDT methodology have had to present pairs of intense stimuli of somewhat different intensity and to ask the observer to distinguish between them.

Typically, pain researchers have had their observers using rating scales, so that "5" means strong pain, "3" means "warmth" and "1" means "nothing." Although this marks a departure from the usual discrimination procedure (in which "5" means certainty that the presentation was stimulus A, "3" means uncertainty, and "1" means certainty that the presentation was stimulus B), the ability to partition responses to two stimuli into several classes makes it possible to use cumulating procedures and plot receiver operating characteristic curves and to determine sensitivity and criterion parameters.

Rollman (1977) reviewed a series of studies which examined the effects of placebos, drugs, age, sex, verbal suggestions, exposures to models, acupuncture, dorsal column stimulation, and transcutaneous electrical nerve stimulation (TENS). The literature was marked with inconsistencies, methodological inadequacies, and questionable interpretation of the data.

In prototypical experiments, subjects rated the subjective pain levels produced by several levels of radiant heat before, during, or after acupuncture (Clark & Yang, 1974) or various currents of tooth pulse stimulation before and after acupuncture (Chapman, Gehrig, & Wilson, 1975). Clark and Yang found that subjects assigned lower numbers to the thermal stimuli. However, since sensitivity parameter for the discrimination of adjacent levels did not change after acupuncture, while the criterion parameter was higher, they concluded that acupuncture had no sensory effects and that "the sole effect of acupuncture was to cause the subjects to raise their pain criterion in response to the expectation that acupuncture works." Consequently, they attributed acupuncture analgesia to cognitive alterations.

Chapman et al. (1975) reported that subjects reduced the discriminability of adjacent stimulus pairs and that acupuncture also reduced the criterion for describing the stimulus as painful. Thus, they concluded that the treatment caused a true sensory loss plus a change in response bias.

Rollman (1977) examined the assumptions underlying such interpretations [e.g., i) a reduction in neural activity will produce a reduction in d' and ii) a reduction in d' indicates a reduction of neural activity]. He challenged the first assumption, noting that an analgesic which reduces neural activity at a peripheral or central site could reduce the activity produced by *both* the weaker and the stronger of a stimulus pair, shifting their distributions to the left along a sensation continuum, as shown in Figure 9.3, but leaving the distance between them, and the sensitivity parameter, unchanged. As a consequence, a strict interpretation of signal detection theory parameters would lead to an erroneous conclusion. Under the above conditions, where the neural activity produced by each of the noxious stimuli is modulated by a putative analgesic, the sensitivity parameter (which reflects the ability to discriminate between the stimuli, not their level of painfulness) is unchanged but the criterion parameter is increased.

Such an apparent change in the criterion parameter can arise even though the criterion has not changed. The distributions of the two noxious stimuli may have shifted relative to a constant criterion, leaving the spurious outcome of a seeming criterion shift. It is then inappropriate to conclude that acupuncture produces a placebo-like effect.

Signal detection theory methods fail to permit an unequivocal separation between changes in pain responsiveness cause by sensory modulation and those due to changes in criterion or response bias. Both can appear to produce alterations in the "criterion" parameter. Moreover, even when the "sensitivity" parameter is reduced, it is impossible to conclude that a true analgesic effect has occurred, since all one can say with certitude is that the stimuli are less easily distinguished. They may be less painful, equally painful, or even more painful than before treatment.

Furthermore, "noise" or "variability" is not limited to the underlying sensory processes. Coppola and Gracely (1983) presented a model which incorporates decision variability as well as variability in sensory transduction. The parameter was reduced by transducer and criterion variability alike. Consequently, as they note, a "change in discrimination could represent a change in the cognitive criterion process due to increased criterion variability resulting from such factors as memory deficits or response perseveration."

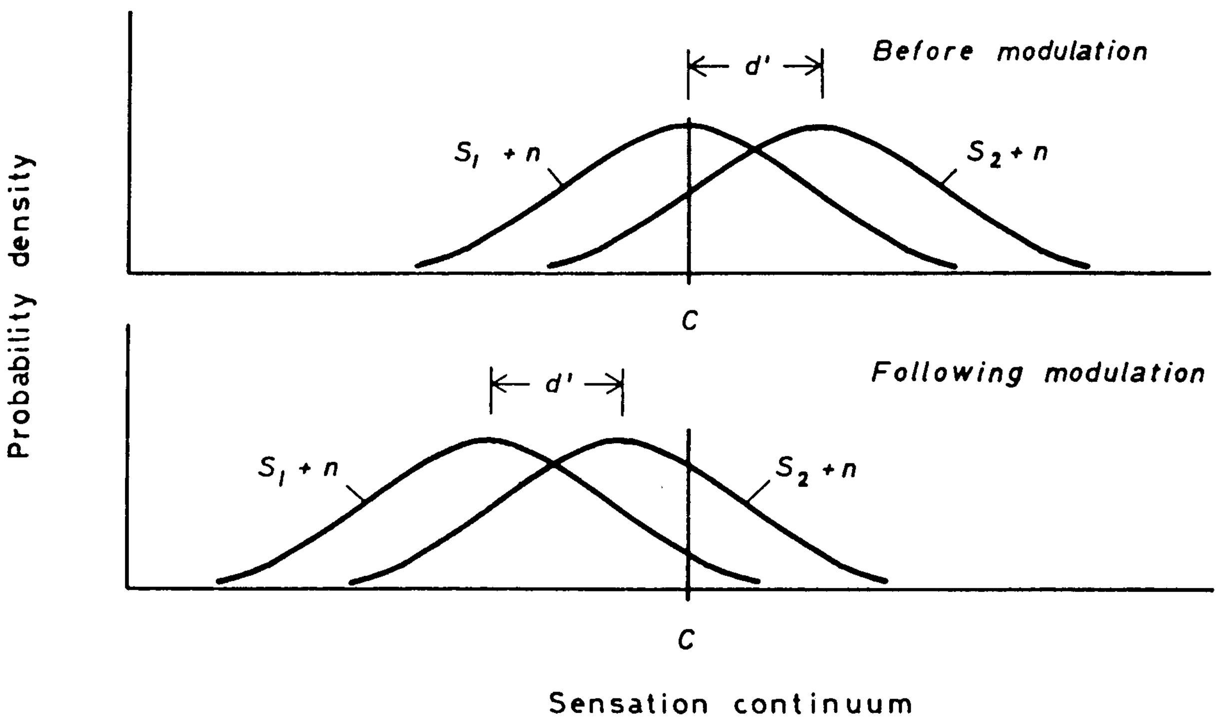

Figure 9.3: Representation of a possible change in sensory input produced by an analgesic modulation. The neural effects of noise plus both the weaker (S_1) and stronger (S_2) of two noxious stimuli are reduced, but the discrimination index remains unchanged, (from G.B. Rollman, (1977) Signal detection measurement of pain: A review and critique. *Pain*, **3**, 187-211, reprinted by permission).

SDT experiments have typically required subjects to make ratings of "painfulness" without elaboration of the component of pain which is described. Rollman (1983b) asked subjects to focus upon a specific pain dimension (intensity or unpleasantness). Other data were obtained for judgments of "pain or for discrimination capacity" (certainty that it was the stronger or the weaker member of the pair of electrocutaneous trains). For each of a number of discrimination indices, values were ordered such that the discrimination task gave the highest value, "pain" and "unpleasantness" gave approximately equal intermediate values, and intensity gave the lowest (see Figure 9.4).

This outcome suggests that discrimination of noxious stimuli is not performed on a global basis. Stimuli that can be discriminated from one another on some basis can still be equivalent in "unpleasantness." As well, stimuli equivalent in "intensity" may be unequal in "unpleasantness." This indication that intensity is less discriminable than unpleasantness also suggests that power function exponents may be steeper for unpleasantness than for intensity, a question that has received recent attention.

More recently, Irwin and Whitehead (1991) presented a model which "incorporates into the standard theory of signal detection an additional component of variance that attaches to the act of judgment itself." Their extended model includes several different kinds of criteria that determine the label, description, or identification that is assigned to a noxious stimulus. They, too, found higher sensitivity (d') scores for a resolution task (which required subjects to rate their confidence that the larger of two stimuli had been presented) than for an identification task (in which subjects attempted to identify which of 6 stimuli had occurred on that trial). A description task (in which subjects rated currents from 1 for "not painful" to 6 for "very painful") produced the worst performance.

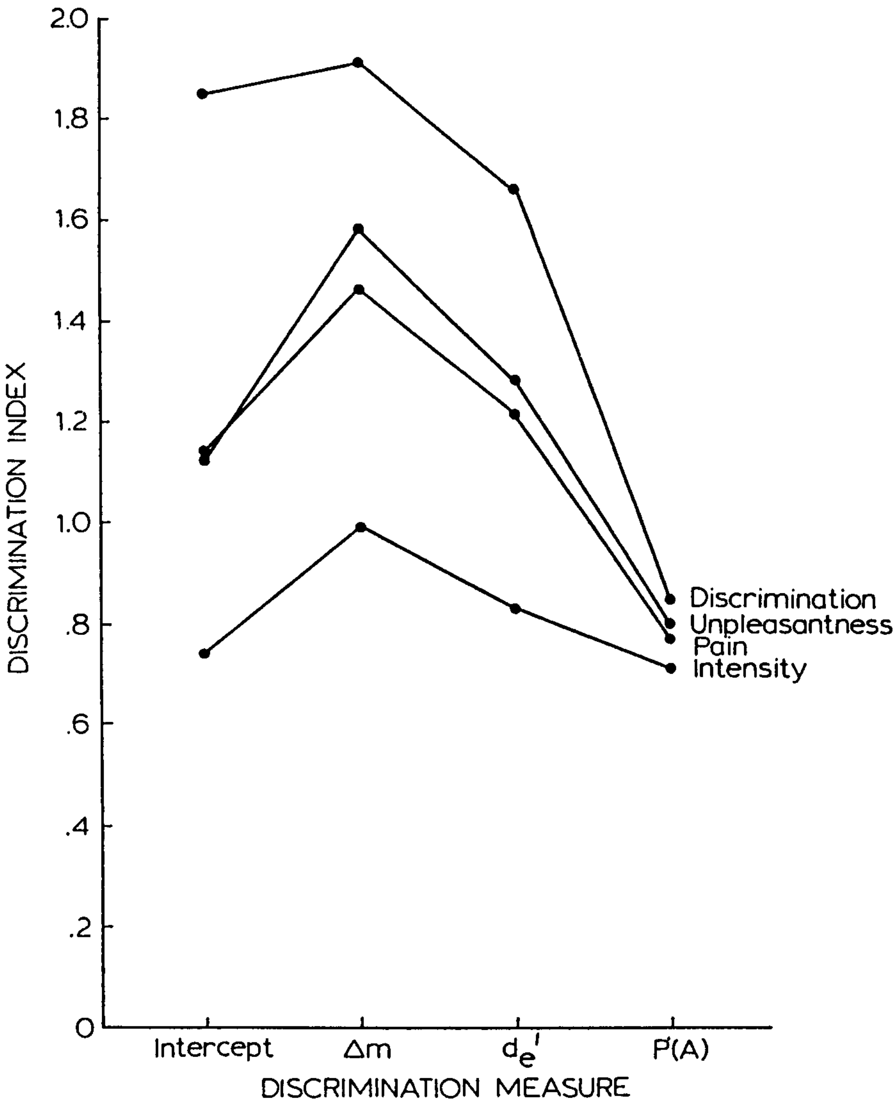

Figure 9.4: Values of several discrimination indices vary as a function of the judgmental task. (From G.B. Rollman (1983) Multiple subjective representations of experimental pain. In J.J. Bonica, U. Lindblom, & A. Iggo (Eds.), Advances in Pain Research and Therapy, Vol. 5 (pp. 865-869), reprinted by permission).

V. Verbal Scaling of Intensity and Unpleasantness

Gracely (1979) noted that most pain measures, whether using numerical scales, visual analog or graphic scales, or verbal categories, assessed pain "as if it were a simple sensation varying only in intensity." Given the considerable evidence that pain is multi-dimensional, unitary pain measures seem inadequate.

An initial approach to developing ratio scales of sensation and affect was indirect. Gracely, McGrath, and Dubner (1978a) had subjects scale the apparent magnitude of two sets of pain-descriptive adjectives: 15 sensory terms (e.g., "faint," "mild," "barely strong," and "very intense") and 15 affective ones (e.g., "distracting," "irritating," "dreadful," and "excruciating"). Subjects made magnitude estimates of these terms and of seven line lengths. They then made cross-modality matches to the adjectives and the lines using a hand dynamometer. The resulting power function between magnitude estimates and line lengths had an exponent of 0.85, while that for handgrip force and line length had an exponent of 0.48. Power functions could not be determined for the ratings of cross-modality matches to the words, since there was no suitable metric. Consequently, Gracely et al. transformed the numerical ratings and handgrip forces for each word to equivalent "line lengths" (utilizing the finding that the perceived magnitude of length has a nearly unitary relationship with actual length). A power function was determined for the relationship between the handgrip and the magnitude estimate for each of the words in a set.

The rationale for relating verbal stimuli and magnitude estimates to line length (rather than directly scaling the adjectives) was to eliminate regression bias effects. Relative magnitudes derived from handgrip and magnitude estimation showed strong agreement (Figures 9.5 & 9.6). The function for the affective words spanned a relative magnitude range of about 1 log unit (10 fold) whereas that for the sensory words spanned a nearly 2 log unit range (about 85 fold). By themselves these data do not indicate that unpleasantness grows at a faster rate than intensity, since there may be differences in the valences of the adjectives (that is, "extremely weak" and "very weak" convey a smaller magnitude than "bearable" and "distracting"), and, therefore, the "stimulus" ranges are not equivalent.

Gracely et al's (1978a) data indicate that "very weak" is about twice as intense as "extremely weak," that magnitude doubles again for "weak" and again for "mild." "Strong" is about 5 times as great as "mild" and "very intense" about twice as great as "strong." Similar comparisons can be made for affective descriptors: "distressing" is twice as unpleasant as "distracting" and "excruciating" gives twice the value of "dreadful."

Such "scaled descriptors" were then used by Gracely, McGrath, and Dubner (1978b) to study the analgesic effects of the tranquillizer diazepam (Valium). In their first experiment, subjects received trains of electrical pulses to the arm. Up to ten current levels were presented and the observers made handgrip and time duration responses proportional to the intensity or unpleasantness of the evoked sensations and chose appropriate adjectives from the lists used in the earlier study. While the exponents for time duration (1.1) and handgrip force (about 0.7) differed, equivalent functions were obtained for judgments of intensity and affect. However, when the "group mean relative magnitudes" derived from the earlier study were used to plot verbal descriptor functions relating perceived magnitude of intensity and unpleasantness as a function of current, radically different exponents were obtained, 1.6 for the sensory and 0.8 for the affective. Gracely et al. (1978b) acknowledge that the differences

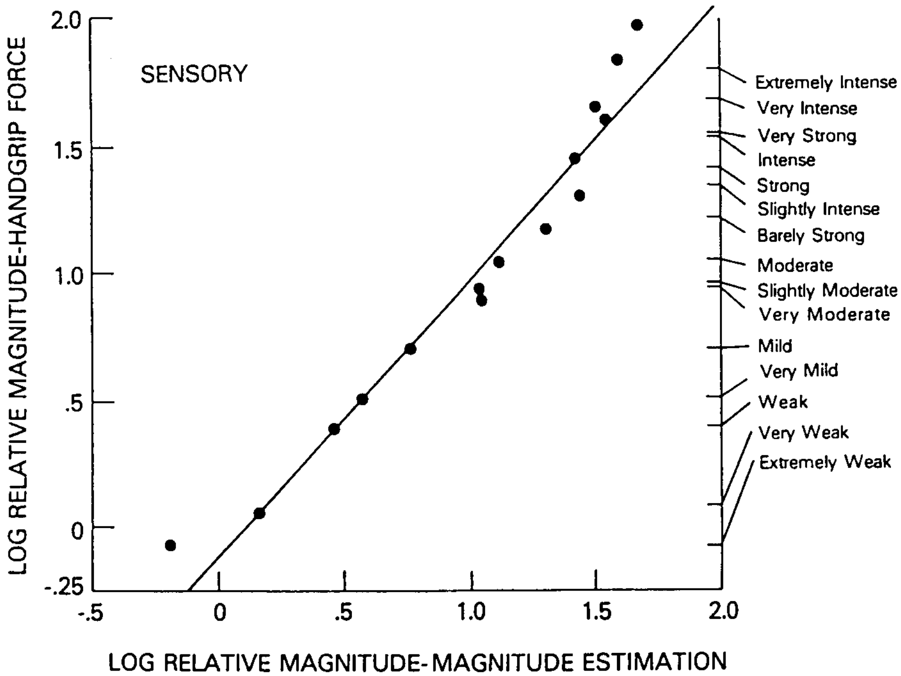

Figure 9.5: Relative handgrip force and magnitude estimation judgments for a series of adjectives describing the sensory component of the pain experience. The right ordinate shows the mean of the two magnitudes for each descriptor. (From Gracely, R.H., McGrath, P., & Dubner, R., 1978a. Ratio scales of sensory and affective verbal pain descriptors. *Pain*, **5**, 5-18, reprinted by permission).

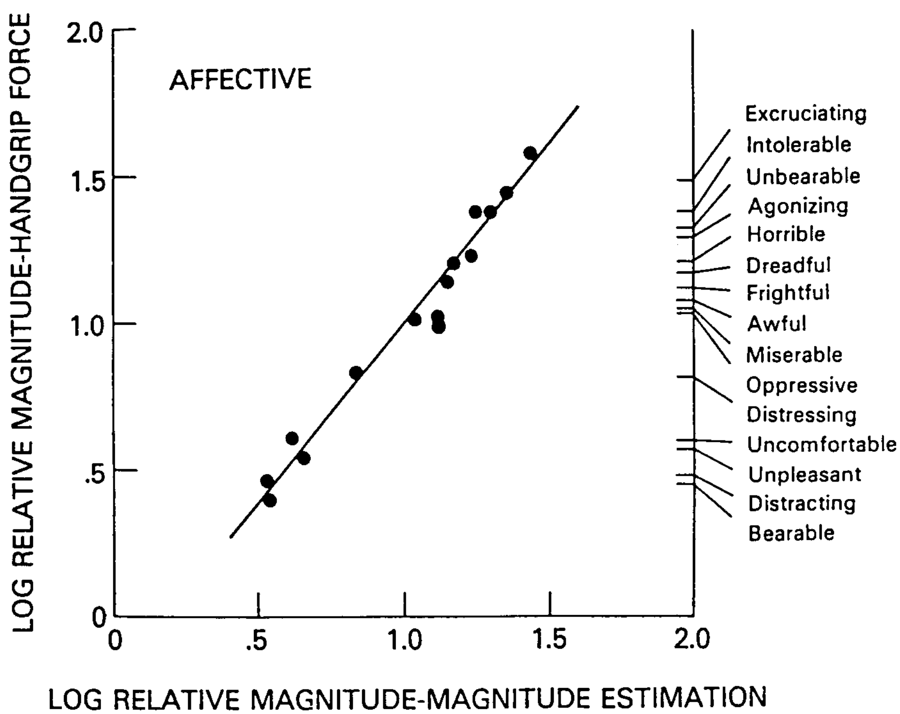

Figure 9.6: Relative handgrip force and magnitude estimation judgments for a series of adjectives describing the affective component of the pain experience. The right ordinate shows the mean of the two magnitudes for each descriptor. (From Gracely, R.H., McGrath, P., & Dubner, R., 1978b. Validity and sensitivity of ratio scales of sensory and affective verbal pain descriptors: Manipulation of affect by diazepam. *Pain*, **5**, 19-30, reprinted by permission).

may arise from "floor effects," since the affective dimension did not include adjectives with very low values, but they believe that such is not the case.

Next, a group of dental patients scheduled for oral surgery performed handgrip and verbal descriptor tasks before and after diazepam infusions. Matching handgrip force for both sensory and affective components revealed no effect of the drug. The scaled verbal descriptors for the sensory component of the pain experience associated with each level of current applied to the arm also did not change after diazepam administration, but the affective descriptors were reduced in the intermediate current range.

The authors noted that "the affective verbal descriptor and cross-modality functions were different, suggesting that one method is invalid." They believed that the former method is correct, citing similar slopes for cross modal sensory and affective functions but different slopes, even at baseline, for the verbal descriptors. Furthermore, since diazepam is an "ideal anxiety-reduction agent" and because "anxiety is assumed to be an important determinant of pain affect," the experimenters took the depression of affective verbal descriptors to be the valid outcome measure. Consequently, they concluded that "naive subjects failed to discriminate between sensory and affective dimensions on the cross-modality procedure" and that "words with affective connotations help naive subjects to discriminate between the sensory and affective qualities of the electrocutaenous stimuli."

Gracely et al. acknowledge that trained observers may more readily be able to distinguish between sensory and affective components of pain. However, naive subjects were able to consistently and differentially match handgrip force to sensory and affective words. As well, those showing a reduction in the relative magnitude of the affective descriptors were a different group than those describing the pain using sensory terms.

Any use of scaled verbal descriptors seems to require individualized determination of relative magnitudes for the adjective lists. While functions such as those shown in Figures 9.5 and 9.6 are based on group data, Gracely, Dubner, McGrath, and Heft (1978) presented individual functions relating log relative magnitude for sensory and affective terms to the current applied to tooth pulp. The individual power functions differed appreciably in both slope and intercept, but it is difficult to know whether this represents individual differences in the growth of pain functions or in the use of the adjectives. Subjects were asked to describe the intensity and unpleasantness of ethyl chloride applied to the exposed dentin of a cavity preparation by using verbal descriptors or cross-modal matches to electrical tooth pulp stimuli. The verbal descriptors were also used to describe the electrical pulses. In general, if a particular adjective was used to describe the cold pain produced by the ethyl chloride, the subject used the same adjective to describe the matching electrically-induced discomfort.

Tursky, Jamner, and Friedman (1982) developed a Pain Perception Profile which also included scaled verbal descriptors (in addition to pain threshold and tolerance determinations, magnitude estimation of electrocutaneous stimuli, and a pain diary). Their relative scale values for "intensity" (terms such as "weak," "mild," and "intense") "reaction" (e.g., "tolerable," "miserable," or "agonizing") and "sensation" (e.g., "tingling," "throbbing," and "shooting"), were derived, in part, from the McGill Pain Questionnaire. A series of descriptors were scaled using cross-modality matching to handgrip and loudness as well as direct magnitude estimation. As with the data obtained by Gracely et al. (1978a), affective terms spanned a smaller range (7 fold) than the intensity ones (28 fold). As well, subjects did not assign low numerical or matching values to the descriptors of unpleasantness.

Experimenters seem to have some difficulty deciding whether certain terms describe intensity or affect. Tursky et al. (1982) included "excruciating" in their list of intensity terms while Gracely et al. (1978a) listed it as an affective descriptor. The rank ordering of adjectives in the two studies, however, agreed very well, and, with a few exceptions, so did the relative magnitude. "Uncomfortable" and "intolerable" were on both the "intensity" and "reaction" lists used by Tursky et al. Interestingly, the intensity scale values for both descriptors were higher than the reaction values. Moreover, while "intolerable" is nearly three times as intense as "uncomfortable" it is more than four times as unpleasant.

Subjects are also aware that many of the adjectives load onto two or more dimensions. Jamner and Tursky (1987) had 21 subjects indicate whether a descriptor belonged to the intensity or affective category. While all 21 agreed that "very strong" was an intensity term, only 11 considered "very weak" to classify intensity. Numerous other terms received less than two-thirds agreement. A similar outcome occurred for the affective descriptors. All agreed that "uncomfortable" belonged in the affective category, but fewer than two thirds judged "agonizing," "intolerable," "unbearable," "tolerable," or "bearable" as describing reaction rather than intensity. Such confusion about categories raises serious questions about the claim by Gracely, McGrath, and Dubner (1978b) that discrimination between sensation and affect is "greatly facilitated in naive subjects by limiting their responses to randomized lists of verbal descriptors specific to that dimension."

Urban, Keefe, and France (1984) took a group of chronic pain patients and asked them to use the psychophysical scaling methods presented in the Pain Perception Profile developed by Tursky et al. (1982). About 10 percent failed to perform well (a correlation of at least 0.9 between stimulus and response variables) when doing magnitude estimations of line length; a somewhat higher number had difficulty in drawing lines proportional to random numbers. Patients had reasonable success in assigning numbers or line lengths to intensity descriptors ("mild," "moderate," "strong," etc.), but only 18% could reliably scale the unpleasantness words ("tolerable," "distressing," "awful," etc.). This value rose to only 50% for a group given specific training in the task.

These findings were confirmed by Morley and Hassard (1989). Using the same intensity and affective descriptors as Urban et al. (1984), and testing on two occasions, internal consistency criteria ($r \geq 0.90$) were met by 65 to 70% of their pain patients for intensity terms but only 25 to 40% for words describing unpleasantness. Analysis of regression coefficients between individual and group scale scores revealed considerable between-subject and within-subject variability. Correction for regression bias showed a strong tendency to underestimate large values on the affective scale, but still left substantial session to session variability even in the patients who were internally consistent in their response patterns.

Morley and Hassard (1989) suggested the failure of patients to consistently scale unpleasantness descriptors may suggest that the terms don't represent a single dimension. If so, they observed, unpleasantness descriptors might be located in multidimensional perceptual space rather than along a single perceptual continuum.

Morley (1989) examined this proposition. Noting that pain "might be both 'bearable' and 'distressing'," he hypothesized that affective descriptors are drawn from more than one dimension within a general affective domain. A group of subjects, consisting of both pain patients and healthy controls, sorted terms used in the Pain Perception Profile into an unrestricted number of groups with similar meaning and made similarity ratings of all possible pairings within the intensity and affect lists.

Multidimensional scaling analysis of the sorting data indicated that intensity and unpleasantness terms are not clearly separated within a 2-dimensional space. A 3-dimensional solution provided the best fit for the similarity data obtained for the affective descriptors (with the dimensions associated with tolerability, emotional reaction, and focus of attention). Intensity terms were described by a unidimensional representation.

The Relationship Between Sensation and Affect

Reduction in the sensory component of pain, as assessed by scaled verbal descriptors, is not necessarily accompanied by a reduction in affect. If the two components were truly independent, of course, such would readily be the case, but common wisdom suggests that reduction in the intensity of a noxious stimulus ought to be accompanied by reduction in its unpleasantness. Gracely, Dubner, and McGrath (1979) had subjects rate the sensory intensity and unpleasantness of electrically-evoked tooth pulp pain, using scaled descriptors, before and after the administration of saline or the synthetic narcotic fentanyl.

As can be seen in Figure 9.7, the saline placebo reduced the unpleasantness of the low and moderate stimuli, but had no effect on the intensity. Fentanyl reduced the sensory intensity, but the unpleasantness to each of the current values remained the same. The authors suggested that the dysphoria produced by the narcotic, with possible nausea and dizziness, may have countered its analgesic effects.

One interpretation of the collection of findings reviewed in the previous section is that the cognitive components of the pain experience are less amenable to psychophysical analysis than are the sensory components. That may be particularly the case for pain patients, since Morley (1989) found that headache sufferers placed greater weight on the emotional and attention diversion dimensions of the affective descriptors than did healthy volunteers. Their less

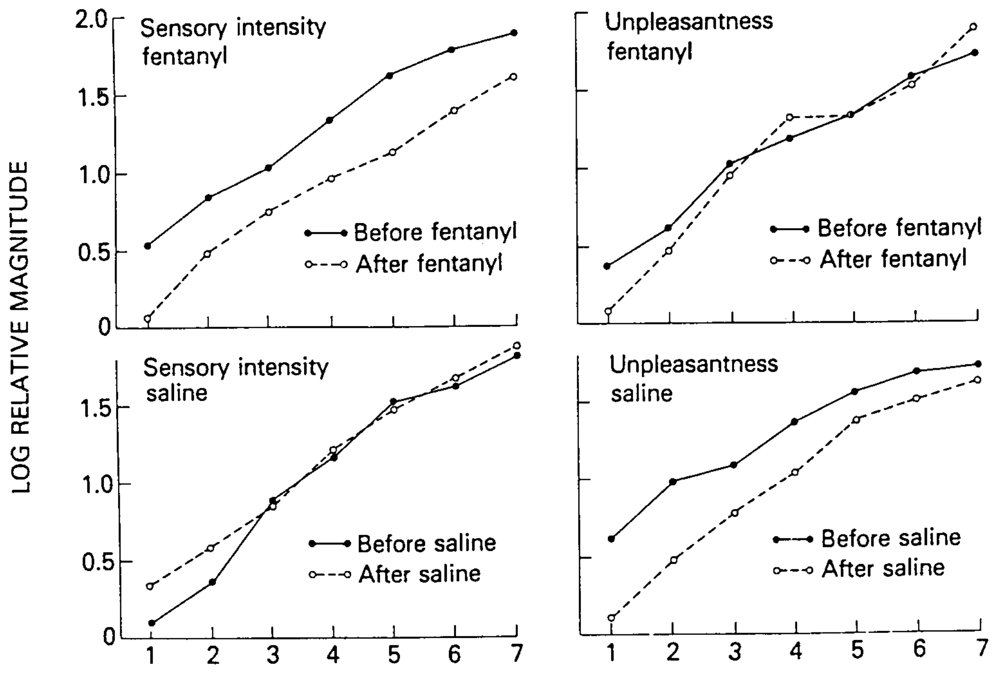

Figure 9.7: Relative magnitude of the sensory and affective (unpleasantness) components of pain induced by electrical tooth-pulp stimuli of different intensities before and after administration of saline or the synthetic narcotic, fentanyl. (From Gracely, R.H. (1979). Psychophysical assessment of human pain. In J. Bonica, J.C. Liebeskind, & D.G. Albe-Fessard (Eds.), Advances in Pain Research and Therapy, Vol. 3 (pp. 805-824), reprinted by permission.)

reliable performance may occur because they respond to different attributes on different occasions.

Support for this distinction between patients and control subjects comes from a multidimensional scaling study conducted by Clark et al. (1989). They had cancer patients and non-pain controls rate the similarity of 9 pain descriptors which dealt with pain quality (e.g., "burning" and "cramping"), intensity ("mild," "intense"), affect ("sickening") and evaluation ("annoying," "miserable," and "unbearable"). A 3-dimensional solution indicated that stimulus weights were further apart for patients than controls, that the patients found some sensory descriptors to have strong emotional qualities, and, perhaps surprisingly, that the healthy volunteers gave significantly more weight to the emotional quality dimension than did the patients.

The use of scaled verbal descriptors to establish the magnitude of sensory and cognitive components of pain clearly adds several steps to the assessment process. Its use requires lengthy sessions with multiple magnitude estimation or cross-modality matching trials and, even then, it is uncertain whether group values represent individual perception or whether magnitudes of descriptive adjectives remain constant across days.

Gracely and Dubner (1987) addressed this matter in a study which derived relative magnitudes for overall painfulness (e.g., "mildly painful," "rather painful," and "decidedly painful"). Correlations between handgrip force and matching time duration for each of the descriptors was 0.99 for the group as a whole, but ranged from 0.55 to 0.96 for individual subjects (mean = 0.85). Correlations within individuals across sessions (0.92) matched the mean correlation of the data of each subject to the list of the group (0.93). The range of such values and their absolute value rather than ordering will likely reflect considerably greater variability.

VI. Direct and Cross-modal Scaling

Notwithstanding this support for verbal descriptors, there is a sizeable body of literature on direct magnitude estimation and, more recently, on cross-modality scaling of pain, particularly using variants of matched line length procedures. Magnitude estimates of electrically-induced sensations have yielded power functions with widely different exponents, ranging from near 1.0 to beyond 3.0 (see Rollman & Harris, 1987). The differences arise, at least in part, because of the effects of stimulus parameters, regression and range effects, the painfulness of the presentations, the experience of the observers, and correction of the stimulus intensities for threshold.

Rollman and Harris (1987) determined power functions for electrical pulse trains. All stimuli were within the pain range determined for each subject. Exponents varied considerably, but the median slope of 1.73 agreed well with other data. Correction of the data for individualized pain threshold had a marked effect on exponent, reducing the median value to 0.70 and the mean to 0.83.

Bromm and Treede (1980) obtained exponents, using a visual analog scale, for nonpainful and painful ranges of current applied to the fingertip. Although there were considerable interindividual differences in perceived magnitude for each current, data spanning the full range yielded a function with a slope of 1.03 when plotted on linear-linear coordinates. When the data were transformed to logarithmic functions, a power function with a slope of 1.60 was obtained. Brown and Treede attribute this to a disproportionate influence of low intensities on the double logarithmic plot, whereas "in the linear scale the values for higher stimulus intensities, essential in measuring pain, gain in weight for the curve approximation." Correcting the "prepain" sensations for detection threshold and the "pain" sensations for pain threshold produced a pair of power functions, each with a slope of about 1.0. Bromm (1984) has suggested that if analgesic treatments increase pain threshold intensity, reliance on the baseline pain threshold will produce "fictitious" changes in the exponent of post-treatment power functions. This important point has not received the attention it deserves.

These data point to the importance of the pain threshold value as a key element in pain evaluation. In the case of functions with exponents greater than unity, the effect of threshold corrections is to sharply reduce the value. Lautenbacher, Moltner, and Strian (1991) have examined power functions for contact thermodes applied to the hand. Although Adair, Stevens, and Marks (1968) found exponents for pain induced by radiant heat to be close to unity, the work of Price (1988), with contact thermodes, points to much more expansive functions (exponents of about 2.0). Price corrected for base temperature (34 or 35° C), although the pain threshold is generally about 44 to 45° C (Watkins, 1988. Lautenbacher et al. showed that exponents are steeper in the pain range than in the heat range. Functions which span the two have exponents close to 2.0, but correction for pain threshold brings values in the pain range close to unity.

Anderson (1989) observed that the use of a zero point of 34° C by Price, McGrath, Rafii, and Buckingham (1983) suffers from a "fatal objection." "Since normal body temperature is 37° C, their result implies that a finger in the mouth would feel painfully hot." While Price et al. certainly did not intend to leave such an impression, their use of a 34° C threshold in this and later studies seems inappropriate.

Price, Barrell, and Gracely (1980) examined whether experiential factors selectively influence an affective component of pain. Noting that the division of the pain experience into two dimensions is "an oversimplification since affective responses are so critically dependent on the psychological context of the person, including such factors as the cognitive strategy with which one deals with unpleasant situations," they hypothesized that the unpleasantness of warm and noxious heat stimuli will be influenced by expectations and goals.

Affective and sensory magnitudes were expressed by drawing lines on 28 cm strips of paper and, since the exponent for the power function relating line length to a series of random numbers between 5.5 and 100 had a value close to unity, were taken as direct magnitude estimates. Overall, signalled warnings that the temperature produced at a contact thermode would shift to an intense range (45-51°C) led subjects to describe the sensation as equally "intense" as on unsignalled trials but to consider the stimuli as producing less of a "negative feeling." Further analysis showed that 4 of 7 subjects had their affective responses modified by the warning stimulus; the other three were unaffected.

A combination of a verbal descriptor and linear scaling method was developed by Gracely and Kwilosz (1988). Their Descriptor Differential Scale presents sensory and affective words at the center of a printed line, with a minus sign anchoring the left end and a plus sign anchoring the right. Patients are instructed to rate the magnitude of their pain in relation to each descriptor. If, for example, the pain is moderate, subjects might place a mark somewhere along the left side of the line when the reference word is "strong," "intense," "extremely intense," etc. and somewhere on the right for key words such as "faint," "weak," or "mild." The length of the line is described in "dash widths," so that 0 to 9 represent values to the left of the descriptor and 11 to 20 values to the right.

Gracely and Kwilosz (1988) plotted the item response score for each descriptor at one point in time (abscissa) against the scores at the later time (ordinate), finding functions that are generally linear. Downward shifts in the Y-intercept of the regression line would represent analgesic shifts in intensity or unpleasantness. Individual item correlations between periods one and two hours after removal of a molar tooth ranged from 0.61 to 0.83 (mean = 0.71) for intensity descriptors and 0.43 to 0.71 (mean = 0.59) for unpleasantness items.

The correlations between items at the two testing periods provide a useful measure of individual consistency. Most subjects performed well, but the repeated measures task permitted the identification of some who provided unreliable information and allowed an increase in overall reliability coefficients.

Visual Analog Scales

Price and his colleagues have typically had pain intensity scaled by having subjects mark a 150 mm wide visual analog scale whose endpoints are "no sensation" and "the most intense sensation imaginable" and examined pain affect by a similar scale ranging from "not bad at all" to "the most intense bad feeling possible for me."

A concern regarding this form of cross-modality matching is that the anchors restrict the scale from being open-ended and, consequently, the obtained values may not have true ratio properties. Price, McGrath, Rafii, and Buckingham (1983) addressed the first of these concerns by comparing sensory and affective VAS scales for contact thermode temperatures of 43 to 51° C with those obtained in the earlier Price, Barrell, and Gracely (1980) study that used line production as the cross-modal match. In both instances, the exponent (corrected for 34° C) for the affective function (3.87) was steeper than that for the sensory one (2.1) (thus stimuli became unpleasant much faster than they became intense), but the two methods yielded essentially identical data.

The second issue, that of ratio scale properties, was examined by having subjects adjust the temperature until it was double that evoked by a stimulus of

43 or 45°C. Subjects also used direct magnitude estimation to compare the unpleasantness of two temperature pairs. The values obtained in these tasks showed excellent agreement with the predictions based on the visual analog scale power functions.

Pain patients used visual analog scales to describe the intensity of their own chronic pain during the previous week, describing it at its minimal, usual, and maximal levels. Obviously this task places demands on memory phenomena (Erskine, Morley, & Pearce, 1990; Jamison, Sbrocco, & Parris, 1989; Hunter, Philips, & Rachman, 1979; Roche & Gijsbers, 1986), but the visual analog scale values generally well-matched the temperature values the patients selected as equalling the intensity of their chronic pain at the same three levels.

Given this evidence that visual analog scales may have ratio properties and that subjects can use them to scale at least the intensity of their clinical pain, Price's group examined whether sensory-intensive and affective dimensions can be selectively influenced. In one study (Price, Von der Gruen, Miller, Rafii, & Price, 1985), low doses of morphine reduced the affective visual analog scale responses to a range of heat pain stimuli, but did not change the sensory components. Higher doses of the narcotic reduced both. The difference in outcome from the fentanyl study conducted by Gracely et al. (1979) was explained in terms of "radically different psychological contexts" in that the subjects in the earlier experiment walked around after receiving the drug (possibly inducing adverse side effects) whereas Price et al.'s subjects lay on beds throughout the session. Alternatively, VAS affective responses may be more sensitive than the verbal descriptors (although the data of Duncan, Bushnell, & Lavigne [1989] suggest the opposite).

In a follow-up study (Price, Harkins, Rafii, & Price, 1986), intravenous administration of fentanyl to low back pain patients reduced both the intensity and affective visual analog scale responses to thermal pain as well as similar components of their clinical pain. Whereas the reductions in the two components of experimental discomfort were roughly equal, the drug produced a greater effect on the affective than the intensity component of the clinical pain.

These differential effects may reflect a steeper sensory-affective relationship for clinical pain. In particular, the cognitive-evaluative and motivational-affective components of pain are more likely to reach high levels for a chronic pain, with its potentially debilitating or disabling outcome, than for a short-acting experimental pain. As Price et al. (1986) note, morphine may have anti-anxiety or euphoric effects that are mediated at supraspinal sites and, consequently, it will have a larger effect on the non-sensory reactions produced by clinical pain than by experimental pain.

VII. Serial and Parallel Processing

In instances such as this, where intensity and affect are reduced by an analgesic, the question remains as to whether both components are directly influenced by the treatment or whether a reduction in pain intensity is the primary outcome and the reduction in affect is secondary. The first instance is described by a parallel model of information processing in nociceptive pathways; the second represents a serial or sequential model.

Melzack and Casey's (1968) conceptual model provided for a number of interacting systems. The primary paths run from the spinal gating system to separate sensory and affective modules which feed into neocortical and higher "central control processes" that evaluate the dual inputs on the basis of cognitive processes and exert descending inhibitory control over the lower systems.

If affect simply followed sensation, then, if the two were not related by a function with unitary slope, at the least they ought to have a monotonic relationship. Generally, that's the case. There are, however, differences among studies in whether intensity or affect takes on greater values. In most experiments (e.g., Price et al., 1983, 1985, 1986) affective scores are lower than sensory ones (but they generally have a greater slope).

Price, Harkins, and Baker (1987) assessed the sensory and affective components of a variety of clinical pain states (minimum, usual, maximum) as well as for experimental pain. For the latter, at each of a series of temperatures, affective scores were lower than sensory ones. For most clinical pains, however, such as back pain, causalgia (a burning pain which can follow nerve injury), and cancer pain, affective scores, particularly at usual and maximum levels, were significantly higher than intensity ones. The one exception was labor pain where, for the later three stages of the birthing process, the unpleasantness of the experience was significantly lower than its intensity. Clearly, cognitive factors shape the relative valence of pain sensation and pain affect.

The precise nature of the linkage among these components is not revealed by such experiments. Price (1988) presents a sequential processing model which challenges Melzack and Casey's parallel processing one. He suggests that nociceptive stimulation engages sensory and arousal mechanisms whose joint input influences cognitive appraisals. That is, "the evoked emotional response can be one of fear, anxiety, frustration, or anger depending upon the meanings that occur in relation to the nociceptive sensations and to the psychological context in which they occur." Attitudes, memories, and personality factors are held to influence cognitive appraisals. These, then, give rise to affective-motivational states. As Price notes, "People say that pain is unpleasant because it hurts, suddenly arouses and alarms them, and produces thoughts of concern or annoyance." It follows, then, that reductions in pain sensation will generally reduce pain affect. Pain affect, however, can be diminished by cognitive manipulations without concurrent declines in pain intensity.

Cognitive Comparison Processes

The sequential model of Price (1988) presents one formulation of a cognitive-sensory-affective interaction. Others, clearly, are possible as well. The psychological and psychophysical studies presented in this chapter make clear that pain has multiple components and that selective manipulation of each of them can be produced and can be measured.

Rollman's (1979) demonstration that noxious stimuli are not judged on an absolute basis, but within the context of the set of stimuli occurring within a session, suggests that the values assigned to equally-spaced stimuli within the usual psychophysical experiment may also be capable of contextual manipulation. The adaptation level theory of pain (Rollman, 1979) posited that pain patients use their endogenous pain level as an anchor or reference point for judging experimentally induced pain. Considerable confirmatory evidence has been gathered (Naliboff & Cohen, 1989; Rollman, 1983a, 1989) to show that pain patients suffering from various disorders have higher pain threshold or tolerance than normal controls and that these levels decline as pain diminishes. The apparent paradox of a lessened clinical pain and increased discomfort to a stimulus earlier judged as innocuous becomes understandable within such a contextual model.

Other pain disorders (Rollman, 1989; Scudds, Rollman, Harth, & McCain, 1987) are accompanied by a heightened degree of responsiveness or hypervigilance (Chapman, 1978), which leads to lower than normal pain threshold or tolerance. These shift towards higher levels with successful treatment (Scudds, McCain, Rollman, & Harth, 1989), suggesting an adjustable set point.

Such integration of clinical and experimentally-induced pain can be conceptualized within the framework of integration psychophysics (Anderson, 1970; see his chapter in this volume). Algom, Raphaeli, and Cohen-Raz (1986, 1987) have shown that multiple noxious stimuli summate in a linear manner. Further , the integration of such intense signals across modalities (e.g., strong shocks and loud tones) points to the role of higher order processes within the central nervous system. It remains to be determined whether there are different integration patterns within the functional measurement approach for sensory, affective, or cognitive judgments than for overall ratings of painfulness.

Such can be the case for stimuli that are spatially separated. Price (1988) states, "a pain sensation occurring in one part of the body does not add to the intensity of pain that occurs in another part of the body" (although this requires experimental confirmation and may well be incorrect) but "the unpleasantness of the two pains tend to combine into an overall experience."

Although integration psychophysics provides for additive combinations such as might occur in instances of hypervigilance, where internal pain may contribute to the discomfort of an externally-applied stimulus (e.g., Lautenbacher, Galfe, Karlbauer, Moltner, & Strian, 1990), it also provides (Anderson, 1989) for an averaging model which "implies that placing greater weight on one stimulus necessarily decreases the relative weight of any other stimulus." The adaptation level model of pain provides for such relative suppression effects. Frequently, pain patients will say something to the effect that "this stimulus is nothing compared to the pain within my body."

VIII. Final Observations

In the end, whether the interest is in diagnosis and evaluation of pain patients, in studying pain mechanisms in the laboratory, or in learning about the scaling of noxious signals, a behavioral response will remain the most certain measure. Although there have been some interesting developments in the use of human single peripheral nerve responses (e.g., Torebjork & Ochoa, 1984), cortical evoked potentials (e.g., Chen, Chapman, & Harkins, 1979), and magnetic resonance imaging and positron emission tomography (Talbot, Marrett, Evans, Meyer, Bushnell, & Duncan, 1991), their data can only be confirmed and validated against expressed human experience. For better or worse, numbers, words, and matches will tell us about pain.

The questions which confront psychophysicists interested in pain are the same ones which apply to other modalities (Gescheider & Bolanowski, 1991): what do subjects judge, what are the response biases, how do we deal with individual differences, what is the value of absolute magnitude estimates vs. matching tasks, do we study psychological magnitude or the judgment of psychological magnitude, is there a psychophysical law? The multiple dimensions of the pain experience, of which the cognitive has probably received the least attention (witness that only one of the 20 scales on the McGill Pain Questionnaire claims to measure the cognitive-evaluative component), provide added challenges. The importance of obtaining answers to these questions and the lively debate that punctuates that quest supply sustenance.

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