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The Validity of Experimental Pain Measures

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Summary

Forty subjects served in a study investigating the characteristics of experimental pain measures. Subjects indicated when their pain threshold and tolerance levels had been reached with each of three stressors: cold, pressure, and electrical shock. Using the multitrait-multimethod matrix procedure, the measures of threshold and tolerance were found to show both generality and discriminant validity across stressors. Threshold judgements, which emphasize discrimination of nociceptive quality, and tolerance decisions, which indicate an unwillingness to receive more intense stimuli, are not equivalent measures of responsiveness. Both should be obtained in studies involving experimental pain. Stressors, while related, are also not equivalent. Minimum method variance was associated with the discomfort produced by electrical pulse trains.

Introduction

Do various forms of experimental pain induction produce common behavioral effects? A continuing question in pain research is that of the generality of pain measures across different stressors. The outcomes of studies in this area have been equivocal [1,3,4,8,11,18,19]; some investigators have reported that certain kinds of noxious stimuli yielded a high level of agreement, while others failed to find consistent relationships.

In some instances, estimates of both pain threshold and tolerance were obtained with each of the stressors; in others, there was only one measure. Although the two are often used interchangeably as indices of pain responsiveness, there is evidence

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which suggests that threshold and tolerance assess the multiple components of the experience following noxious stimulation in different ways [7,17]. Are they each valid operations?

Clearly, the answer to this question determines how the results of a study on the generality of pain responses should be interpreted. In past research, a high correlation between a pain measure obtained with different stressors has been taken as sufficient evidence of generality and, in some instances, of similarity to clinical pain. The question of the validity of the measure has not been addressed. Nor, for that matter, has there been an examination of the variance and covariance attributable to alternative pain induction methods.

Campbell and Fiske [2] have developed a multitrait-multimethod matrix procedure which is well suited for inspecting these issues. Their approach, which has been widely adopted in the fields of personality and social psychology, has requirements which are straightforward. If the investigator examines more than one trait (such as pain threshold or pain tolerance) utilizing more than one pain induction method (such as electrical shock, cold, or mechanical pressure), the Campbell and Fiske analysis provides evidence concerning convergent and discriminant validity of the traits and the variance associated with the methods.

Convergent validation involves confirmation by independent processes; discriminant validation requires that a test be distinguishable from other procedures from which it is intended to differ. In order to make the necessary comparisons, it is convenient to establish a matrix of all the intercorrelations which result when each of several traits is tested by each of several methods. Specific analysis rules are then applied.

In the case of pain measurement, one might paraphrase the rules as follows:

(1) The relationship of each pain measure to itself, across stressors, should be significantly different from zero at a level of confidence sufficient to warrant further examination.

(2) The correlations obtained for any one pain measure, across stressors, should be higher than those between that measure and any other pain measure. For example, the pain threshold measure obtained with an electrical stimulator should be more highly related to the pain threshold found with another stressor, such as cold or pressure, than it is to the tolerance measure obtained with those other stressors.

(3) A pain measure should be more highly related to the same measure, obtained with a different stressor, than to another measure obtained with the same stressor. For example, shock pain threshold should correlate more highly with cold or pressure pain threshold than it does with shock pain tolerance.

It can be seen that these requirements, the first for convergent validity and the other two for discriminant validity, are progressively more rigorous. An examination of the generality literature indicates, however, that even the simple criterion for discriminant validity given in the second rule is often not met.

Campbell and Fiske [2] also noted that the presence of method variance and covariance can be inferred from differences in the degree of correlation between parallel values in single stressor (monomethod) and across-stressor (heteromethod) relationships. For example, if shock pain threshold correlated much more highly with shock pain tolerance than with pain tolerance measured with another stressor, that would be evidence of method variance with shock. Further, a matrix of elevated correlations in a heteromethod block, such as two pain measures (traits) across two stressors (induction methods), indicates the presence of method covariance. These problems can be seen to exist with the data for cold and pressure in the Davidson and McDougall [4] study, for example.

Method

Subjects

Forty students, 20 male and 20 female, enrolled in an introductory psychology course, served as subjects. The age range was from 18 to 30, with a mean of 20 years.

Apparatus

Three stressors were used to obtain measures of pain threshold and tolerance.

(1) Electrical stimulation. A constant current stimulator delivered trains of 40 1-msec monophasic square wave pulses at 100 Hz to the left volar forearm through a pair of Grass silver electrodes filled with Grass electrode paste. Stimulation was increased in discrete steps of 0.15 mA, beginning at 0.075 mA. An upper limit of 7.5 mA was used, but the subjects were not informed of this.

(2) Cold water pressor. Observers inserted their right arm into a tank of circulating ice water. The temperature of the water was constantly monitored by a thermistor with a digital display. The mean water temperature was 1.8°C with a standard deviation of 0.29°C. The tank was furnished with a handle which subjects held lowered to the bottom, so that the angle of their arms in relation to the flow of water was identical. The ice was kept behind a wire mesh to prevent it from touching the skin. A 300-sec, unannounced, upper limit was used.

(3) Pressure. A Forgione and Barber [5] pressure algometer applied a 2000 g weight to the first phalanx of the subject's left forefinger. Individuals placed and removed the weight themselves. Again, the maximum exposure was limited to 300 sec.

Procedure

Subjects had the stressors and tasks described to them and were asked if they wished to continue. They were also given a blood pressure test to screen out any with resting pressures above 130/80 or 150/100 mm Hg while squeezing a hand dynamometer.

Each subject was exposed to the three stressors in one of the six possible random orders. Estimates of both pain threshold and pain tolerance were obtained. For cold and pressure, pain threshold was defined as the amount of time elapsed between the beginning of stimulation and the point at which it became painful. Pain threshold for shock was the current level at which the subject reported that its quality first changed from touch to faint pain.

Tolerance, for cold and pressure, was defined as the amount of time between the beginning of stimulation and withdrawal from the apparatus. For shock, tolerance

TABLE I

THRESHOLD AND TOLERANCE LEVELS FOR EACH OF THE STRESSORS

Stressor	Threshold		Tolerance	
	Mean	S.D.	Mean	S.D.
Shock (mA)	1.57	0.66	4.12	2.12
Cold (sec)	15.57	24.91	72.10	86.25
Pressure (sec)	21.45	50.39	112.14	123.18

was the intensity at which the subject indicated that he or she did not want to receive the next higher stimulus.

Results

There was considerable variability, across observers, in the threshold and tolerance levels for each of the stressors. The means and standard deviations are provided in Table I. As well, there was variation, across stressors, in the proportion of subjects who achieved the allowable stimulus limits during tolerance determinations. Six of the 40 observers reached 7.5 mA during the electrical shock trials, 4 reached 300 sec during cold water immersion, and 11 hit that limit while enduring pressure. In each such case, the limiting value was taken as the tolerance. One person reached the limits for all three stressors; 5 went to the maximum value for two of the three.

Correlations were obtained between all threshold and tolerance measures and are presented in Table II. The numbers enclosed by the solid lines in this multitrait-multimethod matrix are what Campbell and Fiske [2] called the 'validity diagonals.'

TABLE II

CORRELATIONS OF THRESHOLD (Thr) AND TOLERANCE (Tol) MEASURES FOR ELECTRICAL SHOCK, COLD, AND PRESSURE

The 'validity diagonals' are the correlations for a given measure (e.g., threshold) across stress conditions. Their use in the multitrait-multimethod matrix analysis is discussed in the text.

		Shock		Cold		Pressure	
		Thr	Tol	Thr	Tol	Thr	Tol
Shock	Thr						
	Tol	0.25					
Cold	Thr	0.56 ***	−0.03				
	Tol	0.21	0.42 **	0.28 *			
Pressure	Thr	0.36 *	0.18	0.88 ***	0.36 *		
	Tol	0.21	0.24	0.36 *	0.47 ***	0.40 **	

* $P < 0.05$.
** $P < 0.01$.
*** $P < 0.001$.

These are the correlations of traits (pain measures) across methods (pain stressors), such as shock threshold with cold threshold and pressure threshold or shock tolerance with tolerance for the other two.

Campbell and Fiske's first requirement (convergent validity) is that these values, representing the relationship of threshold or tolerance measures across stressors, should be significant. This is achieved in five of the six comparisons and, nearly so, in the sixth (tolerance for shock and pressure).

The second requirement (discriminant validity) is that the correlation of each nociceptive measure to its counterpart for different stressors should be higher than its correlation with a different measure for those other stressors. For instance, the correlation of cold pain threshold with pain threshold for shock and for pressure should be greater than its correlation with shock or pressure tolerance. This is met in 22 of 24 comparisons; they are equivalent once.

The third requirement (also discriminant validity), that a pain measure should relate more highly to that same measure with different stressors (e.g., pain threshold for shock with pain threshold for cold and for pressure) than it does to another measure obtained with the same induction method (e.g., shock pain threshold with shock tolerance), is generally met. Of the 12 possible comparisons, the correlations are in the required direction on 9 occasions. Two of the three exceptions, plus the one in the previous test, are due to the low correlation (0.24) between the tolerances for shock and pressure.

It should be noted, again, that each requirement is progressively more stringent. One finds that the last requirement, particularly, is rarely perfectly met.

One can also assess the contribution of method variance and covariance from these data. To do this, one compares each heterotrait-monomethod correlation, for example, that between shock threshold and tolerance (see Table II), with its heterotrait-heteromethod counterparts, shock threshold/cold tolerance and shock threshold/pressure tolerance. The more similar these three correlations are, the less method variance is present. Shock appears to have the least contribution from method variance, particularly for the threshold trait (correlations of 0.25, 0.21, and 0.21). Method covariance results in the elevation of all correlations in the heteromethod block, including those in the validity diagonal. This can be seen in the block for cold and pressure in Table II.

Discussion

Interesting conclusions stem from the multitrait-multimethod analysis. Threshold and tolerance measures, while related, do not tap identical components of the pain experience. Each of them shows validity as a trait, since correlations are higher for thresholds (or tolerance levels) across stressors (methods) than are threshold and tolerance measures (traits) within a stress condition.

These findings are impressive, particularly considering that the time or intensity to pain threshold is a component of the time or intensity to tolerance [6,16]. The results obtain with a sample of university students and should be replicated with clinical populations and after procedural variations, such as the administration of analgesics. They do, however, demonstrate that threshold and tolerance judgements are dissimilar. The first emphasizes the discrimination of nociceptive quality; the second, an expression of unwillingness to receive more intense stimulation. As a consequence, both response indices should be obtained in studies involving experimental pain.

There is, according to these data, a generality of responsiveness when alternative noxious stimuli are used. Individual differences in reacting to pain were maintained across the various stressors. The intercorrelations obtained were not perfect, but they were of a respectable order of magnitude. Indeed, one would not expect perfect correlations, given the unlike qualities of the sensations produced by each stressor and the different neural mechanisms involved. Nevertheless, there was a strong common element. Whatever combination of sensory, affective, and cognitive variables gives rise to these threshold and tolerance measures seems to remain fairly consistent within an individual when he is exposed to different pain induction methods [12].

Some earlier studies suggested that electrical, mechanical, and thermal stimuli tap a common factor, while others indicated a lack of generality. However, the multitrait-multimethod procedure provides evidence of method variance and covariance in several of those experiments. In one study [4], for instance, correlations between threshold and tolerance for a single stressor were much higher than the correlations of thresholds or tolerances across stressors. Method variance was far greater in that experiment than in the present one, possibly due to a number of procedural details: shock was always presented last, personality questionnaires were completed between each stress condition, and the water temperature was higher, leading to an upper exposure limit of 12 min. Campbell and Fiske's [2] requirements for discriminant and convergent validity were not met. A second study [1] also showed lack of discriminant validity and evidence of method variance.

Davidson and McDougall [4] interpreted their data as showing a lack of generality across stressors; nonetheless, they suggested a similarity between pain responses obtained with cold and pressure. Brown et al. [1] reported the same finding and, indeed, the present study showed the highest correlation between these two stressors. We have seen, however, that there is considerable method covariance associated with these stimuli, inflating the actual relationship. These two forms of pain induction, in which discomfort normally increases with the passage of time, share both sensory qualities (deep pain) as well as affective and cognitive ones (subjects are familiar with the sensations of cold and pressure and recognize that they can terminate the stress by removing their hand or arm from the apparatus).

Cold and pressure, however, also share a problem. Although cold pressor pain increases with time over brief intervals [e.g., 14], there are indications that some subjects find it subsides after several minutes [9,10] before rising again. Likewise, pressure pain does not increase monotonically. Subjects in this experiment who could tolerate the pressure for more than 30 sec frequently reported that their fingers became numb.

It was shock which showed the smallest contribution from method variance.

Electrical stimulation has different qualities than do thermal or mechanical activation of the somatosensory system. Its perceived magnitude increases as a power function of current within the pain sensitivity range [13]. It is unfamiliar and, because of personal concerns about possible adverse effects, often is accompanied by reports of anxiety and stress. This raises an interesting issue, cogently examined by Sternbach [15], about the tradeoffs involved in selecting a stressor for use in evaluating analgesic procedures with experimentally induced pain. Although cold and pressure may produce effects similar in quality and duration to chronic pain, the relative absence of anxiety limits generalization to the clinical setting. Electrical shock, although different in quality, likely produces more significant alterations in the affective and evaluative dimensions.

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