Reports

Demonstration of the Influence of Stimulus and Response Categories upon Difference Limens

Abstract. Representative types of stimulus and response categories were used with the same subjects in determining the difference threshold for visual velocity discrimination. The observed interaction between these variables and difference limens was pronounced.

Data have been reported in *Science* (*1*) which indicate that the difference threshold for the velocity of a seen object "passes through a minimum in the 1-to-3 degrees-per-second region of the range of initial velocities." In subsequent research (*2*) concerned with various aspects of differential velocity and acceleration judgments, an interesting demonstration of the influence of type and number of stimulus and response categories upon threshold magnitude has been observed. That such an interaction exists is, of course, well known to experimental psychologists. We know, however, of no other study in which comparative data have been gathered systematically for the particular categories here employed, and in which the same subjects were used throughout.

The procedure was as follows: The subject was seated in front of a cathode-ray tube (P11) and regarded a 1.5-in. "window" cut into an opaque material superimposed upon the face of the tube. A chin-rest assured a constant (binocular) viewing distance of 10 in. After presenting a ready signal, the experimenter initiated movement of a stimulus spot across the median plane of the window, from just beyond the left to beyond the right edge. The particular velocity of the spot was preset by the experimenter. Approximately 3 seconds after termination of this traverse, a second spot, having the same or different velocity, was similarly flashed across the window. Before each presentation, the subject was told whether the exposure was to be a "standard" or a "comparison." His task was to compare the latter with the former, using one of the sets of response categories shown in Fig. 1, the particular set having been previously specified by the experimenter. For sets I and II, each of the six standards was compared ten times with each of five comparison stimuli: two faster, two slower, and one equal. For example, the slowest standard, 20.06 minutes of visual angle per second, was compared with stimuli of 17.83, 18.95, 20.06, 21.17, and 22.29 min/sec; the fastest standard, 512.71, was compared with stimuli of 334.38, 423.54, 512.71, 601.88, and 691.04 min/sec. (Preliminary trials with each of the standards assured the selection of comparison values which ranged from values which were almost never to values which were almost always judged correctly.) Each standard, then, was compared a total of 50 times with other stimuli. In the case of set II, the subject was not permitted to make a response of "equal," even though equal velocities were presented. For sets III*a* and III*b*, only "faster" and "equal" stimuli were shown, and the only responses permitted were "faster" and "equal."

In set III*a*, the same total number of choices (50) was maintained as for sets I and II, this being accomplished despite the omission of the two slower comparison stimuli by adding a corresponding number of comparison stimuli of the same value as the standard. Thus, for this set, the standard 20.06 was compared with 20.06, 21.17, and 22.29; but three-fifths (or 30) of the total trials consisted of 20.06-versus-20.06 presentations. For set III*b*, the number of standard-versus-standard presentations was kept to ten, the number of such presentations being thereby equated with the number of presentations of each of the two comparison stimuli (a total of 30 trials).

Partial counterbalancing of practice effects was accomplished by having each of the four subjects start the experiment with a different set of response categories. Upon completion of half the total required judgments on a randomly selected standard, each subject was shifted to another standard, as well as to another response-category set. Comparison stimuli were randomized within each of these blocks of trials. At no time were the subjects informed of the accuracy of their judgments. Incremental thresholds were computed for each subject, according to the graphic z-score method (*3*). These thresholds were then averaged, with the results shown in Fig. 1.

The generally consistent separation of these threshold functions, as well as the approximately fourfold disparity between the "worst" judgments (set I) and the "best" judgments (set III*b*) are quite striking, although—as previously noted—not entirely surprising (*4*). Less obvious are the precise reasons for these findings. However, we can specify several factors which, taken together, are probably interacting to produce the effects depicted in Fig. 1. These include (i) the number and type of response categories available; (ii) the number and type of stimulus choices available; (iii) the correspondence between i and ii (for example, to gather the data of set II, the "forced choice" technique was used, in which, although slower, equal, and faster stimuli are presented, only the responses "slower" and "faster" are permitted); and (iv) the influence of serial or "expectancy" effects.

It may be noted that set III*b* has response categories similar to the category previously reported (*1*), as well as standard stimuli included in the range of values examined in the earlier work. Despite this, the thresholds are much lower in the present study. This may merely reflect the use of different or of more practiced subjects or a lesser number of comparison stimulus values in the 1957 study (two, as opposed to five).

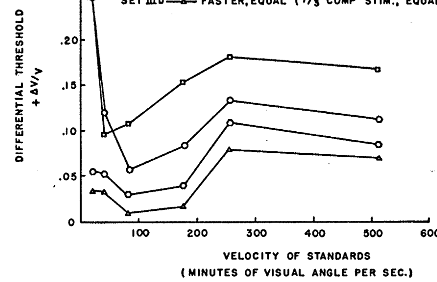

Fig. 1. Incremental difference threshold for the velocity of a seen object as a function of velocity. The parameter consists of various stimulus and response categories.

Instructions for preparing reports. Begin the report with an abstract of from 45 to 55 words. The abstract should *not* repeat phrases employed in the title. It should work with the title to give the reader a summary of the results presented in the report proper.

Type manuscripts double-spaced and submit one ribbon copy and one carbon copy.

Limit the report proper to the equivalent of 1200 words. This space includes that occupied by illustrative material as well as by the references and notes.

Limit illustrative material to *one* 2-column figure (that is, a figure whose width equals two columns of text) or to *one* 2-column table or to *two* 1-column illustrations, which may consist of two figures or two tables or one of each.

For further details see "Suggestions to Contributors" [*Science* **125**, 16 (1957)].

It is possible, however, that the disparity is due to the method of stimulus presentation. In the earlier study, a 3-inch frame was used, the standard being shown for the first half of the frame, the comparison for the second. The increment in velocity (if any) was added instantaneously at the center of the oscilloscope face. Accordingly, the actual acceleration (visually, the "jerk") provided a cue, in addition to the disparity in isometric traverse time. One intriguing speculation is that these subjects may have treated the problem as one requiring a judgment concerning the presence or absence of "jerk," instead of as a comparison of two velocities or two traversal times. Behaviorally, the psychophysical judgment for the subjects in the earlier tests may have been that for the absolute threshold of acceleration instead of that for the difference threshold of velocity, even though mathematically the two stimulus conditions are, of course, equivalent.

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References and Notes

1. J. M. Notterman and D. E. Page, *Science* **126**, 652 (1957).
2. This research was supported by the U.S. Air Force under contract No. 49 (638)–381 monitored by the Air Force Office of Scientific Research of the Air Research and Development Command.
3. R. S. Woodworth and H. Schlosberg, *Experimental Psychology* (Holt, New York, 1954).
4. S. W. Fernberger, *Psychol. Rev.* **37**, 107 (19[illegible] W. S. Verplanck, G. H. Collier, J. W. Cot[illegible], *J. Exptl. Psychol.* **44**, 273 (1952).

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Recognition of Paired Trigrams as a Function of Associative Value and Associative Strength

Abstract. The accuracy of visual recognition of tachistoscopically presented paired nonsense trigrams was shown to vary directly with the associative value and associative strength. Parallel results were previously reported for meaningful verbal material. It is argued that the same perceptual processes underlie the learning of nonsense and of meaningful material.

Perceptual processes that apply to the visual recognition of meaningful words (*1*) should apply also to the recognition of nonsense trigrams. This report shows that verbal performance is related to accuracy of recognition of nonsense verbal material, as measured by associative value and associative strength (*2*).

Associative value refers to the degree to which a trigram composed by a consonant, a vowel, and a consonant suggests words within a given period of time—for example, 30 seconds. The value of each nonsense trigram is determined by the percentage of subjects who associate meaningful words to it, the value ranging from 0 to 100 percent. Associative value, therefore, is a measure of response evocation.

Associative strength refers to the degree of bond linking a stimulus trigram to a response trigram. The degree of bond and consequent ease of learning of a pair is determined by a variety of intercorrelated measures needed to meet a criterion of learning, usually one errorless repetition of a list of such paired trigrams presented on a memory drum. The most frequently used measures of associative strength are number of trials or of correct responses to criterion. Both measures are highly correlated with each other (mean $r = .94$) and both are related inversely to the associative strength of each pair of trigrams (*2*). Associative strength, therefore, is a measure of response acquisition or of response strengthening for both the stimulus and response terms of a paired trigram.

The relationship between associative value and associative strength of paired nonsense trigrams has been summarized as being nonlinear and nonadditive. Associative strength increases geometrically as the associate values of each pair increase. The higher the associative values of the stimulus and of the response, the easier it is to learn the pair of syllables—that is, the smaller the number of trials to the criterion of learning (*2*). This relationship is shown in the first part of Table 1.

Table 1. Associative values, associative strength, and mean number ($\pm$ standard deviation) of correct recognitions for paired nonsense trigrams (consonant, vowel, consonant).

Associative values		Associative strength (No. of trials to criterion)	Correct visual recognitions (No.)		
Left	Right		Left	Right	Left + Right
100	100	13.43 $\pm$ 6.56	2.38 $\pm$ .34	1.63 $\pm$ .52	4.01 $\pm$ .68
0	100	16.81 $\pm$ 4.61	2.06 $\pm$ .39	1.44 $\pm$ .60	3.50 $\pm$ .75
47	47	19.00 $\pm$ 6.84	2.01 $\pm$ .37	1.33 $\pm$ .58	3.34 $\pm$ .81
100	0	22.47 $\pm$ 5.65	2.19 $\pm$ .46	1.34 $\pm$ .52	3.53 $\pm$ .71
0	0	34.57 $\pm$ 9.53	1.96 $\pm$ .41	1.21 $\pm$ .40	3.17 $\pm$ .63

To find how visual recognition of paired nonsense trigrams is related to associative value and to associative strength, the procedure outlined by Heron (*3*) was followed: three lists of 116 pairs of nonsense syllables were typewritten in upper case letters. One trigram was presented to the left of a fixation point, the other to the right. Thus, six letters were shown at a time. The pairs had been originally ranked on the basis of their associative values and their associative strength. Five combinations of associative values for the left and right syllables were used: 100–100, 0–100, 47–47, 100–0, and 0–0 (*2*).

The pairs were projected tachistoscopically on a glass-beaded, white screen that was uniformly illuminated by a 60-watt bulb at a distance of 5 feet. The angle subtended at the retina by both trigrams was 8°26′. The tachistoscope was a Keystone overhead projector furnished with a Keystone No. 4 universal flashmeter set to expose both syllables simultaneously at 1/100 second. The exposure time for each pair was kept constant throughout the three sessions (one session for each of the three lists). The intensity of the light was adjusted during the presentation of five practice pairs of trigrams that preceded the presentation of the experimental pairs.

The order of presentation within each list was reversed from subject to subject and from session to session to counterbalance serial and fatigue effects. After the presentation of each pair, the subjects were asked to spell out the materials presented to them immediately from left to right, even if they had to guess.

The subjects were 15 men and 15 women from the professional staff of a medical institution. The ages of the men ranged from 22 to 32 years. The ages of the women ranged from 20 to 50 years. Most subjects were in their late 20's. None reported gross visual defects. Ten men and eight women wore corrective glasses.

The results of mean correct visual recognitions as a function of the associative values and associative strength of the trigrams are summarized in Table 1. The mean number of correct recognitions decreases from four out of six for 100–100 associative values to slightly more than three per pair for associative values of 0–0. An analysis of variance performed on the mean number of total (left plus right) correct recognitions yielded a highly sig-