An experimental validation of the signal detection theory for active touch*

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Signal detection theory is tested in a task involving active touching. The task consisted of the detection of a signal nail higher than the noise nails after one passage with two fingers on a "carpet" of nails. The results strongly support signal detection theory if one assumes normality and unequal variances for signal and for noise distributions. The study of the decision criteria demonstrates how the Os organize their decision strategies in order to give discriminative responses to the stimulations.

Signal detection theory (SDT) has already been validated in the field of tactile sensitivity (e.g., Rollman, 1969), and, therefore, the importance of the central decision processes has been established for that sensory modality as well as for vision and audition. The task, in those experiments, involved what could be called passive touch; an example is the detection of electric pulsations applied to the skin. Some authors, however, have shown that passive touch, or being touched, ought to be distinguished from active touch, or touching (for a detailed review of this question, see Gibson, 1962). The main differences between these two types of tactile sensitivity refer to the characteristics of the phenomenal object and to the information received from the proprioceptors (Zayan, 1971). The purpose of the present experiment is to test the validity of the SDT in a kind of task involving active touch.

APPARATUS

Three rectangular metallic sheets (20 x 30 cm) were placed horizontally one above the other, with a distance of 12 mm between each sheet. The two upper sheets were perforated in their center by 300 holes, with 5 mm between each hole; the holes were dispersed on a 15 x 20 rectangle. A certain number of nails, varying in length from 40 to 43 mm, were placed in these holes. When noise alone was presented, the length of the nails was between 40 and 42 mm (40.0, 40.5, 40.8, 41.1, 41.4, 41.7, and 42.0 mm in equal proportions). The signal was one nail higher than the others: it could measure 42.50, 42.75, or 43.00 mm.

The disposition of the nails in the holes thus presented a "carpet" of nails, one of which protruded. Under three experimental conditions, 25, 50, or 75 nails were placed in the holes. It later appeared that varying the number of nails did not change the results; therefore, the results of the three conditions will be considered together.

The apparatus was concealed from the O by a screen.

OBSERVERS

The Os were five undergraduate students of the University of Louvain.

PROCEDURE

The O's task was to pass once, and only once, on the carpet of nails with the thumb and the index finger of the dominant hand. The time was left free within reasonable limits. The O made his detection or no-detection response on a subjective scale of five categories: "5" indicated that he was quite sure there had been a signal; "4" that he thought there was one; "3" that he was unsure; "2" that he thought there was no signal; and "1" that he was quite sure there was no signal.

There were three experimental conditions, in which the signal took the following values: 1.50, 1.75, and 2.00 mm higher than the mean height of the noise nails. The nails of different heights were randomly dispersed, the signal, when it occurred, was also randomly presented. The probability of signal and the probability of noise were equal during the entire experiment. Each experimental condition included 1,200 observations for each O. The 3,600 observations per O were presented in 18 sessions, with 200 observations per session.

Preliminary training consisted of 200 presentations, and each session began with a few warm-up presentations. The feedback which followed each presentation told the O whether or not a signal had been present during the observation. The experiment was designed to avoid serial learning effects by alternating the presentation of the experimental

conditions in ascending and descending sequences.

RESULTS

As can be seen in Fig. 1, two empirical ROC curves have been constructed for each O under the three conditions: the first expresses the cumulative proportion of hits as a function of the cumulative proportion of false alarms, while the second relates the same variables expressed in standard deviations (for a detailed description of the method followed for analyzing these results, see Green & Swets, 1966). A regression line of function $Y = a + bX$ was computed from the data expressed in standard deviations. The Pearson correlation r between the two axes was calculated, permitting an estimation of the linearity of the relation (Guilford, 1956). The correlation values are high, since the lowest equals 0.958. The SDT with assumption of normality then appears to be a model which predicts fairly well the observed behavior. A correction must, however, be added: the variances of the signal and of the noise distribution are unequal. In fact, the slope of the function $z(S/s) = a + b[z(S/n)]$ is always less than one. It can also be seen from the figure that the slope is not constant.

When the slope is not equal to 1, the d' parameter which evaluates the performance must be replaced by ΔM —the intercept of the ROC curve at $P(S/s) = 0.50$ —or by d'_e —twice the projection on either axis of the intersection of the ROC curve with the negative diagonal. In fact, neither of these measurements is completely satisfactory. In an as yet unpublished study, Citta (1971) proposes to evaluate the area under the ROC curve and then to find the d' value for the symmetrical ROC curve of the same area. These estimates can be made from existing tables. This procedure has been used in this experiment. The three measures agree. This procedure for calculating d' , however, can be experimentally limited: low values of the slope are less important when the performance is good (from $d' \approx 2.50$) than when the performance is poor. If the values of d' and the values of the signal intensity are expressed logarithmically, the relations take the form of straight lines. The performance is thus in bilogarithmic relation with signal intensity.

A 5-point rating scale leads to four β s, each of which is a particular likelihood ratio. β_1 defines the boundary between two response categories: R_i and R_{i+1} . The examination of the decision criteria reveals that β_4 is higher and β_1 is lower when signal intensifies. There are only two exceptions: for the third O

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Fig. 1. The empirical ROC curves expressed in cumulative proportions and in standard deviations for the five Os under the three experimental conditions.

importance of decision processes in the choice of responses is established in a new experimental situation involving active touch. The existence of a noise is evidenced in this task as well as in visual and auditory detection, or in the tasks involving passive touch. And finally, the rating procedure demonstrates how the Os organize their decision strategies in order to give discriminative responses to the stimulations.

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