Limits on the applicability of signal detection theories¹

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Two auditory signals were presented in random sequences in which the more intense signal came on .2, .5, or .8 of the trials. Each trial began with an intermediate tone which was identified in the instructions as either the standard for comparison or simply as a warning tone. Half the Os were instructed to discriminate whether the signal was "louder" or "softer" than the standard, the other half to recognize which signal had been presented. For both discrimination and recognition tasks, the total proportion of "louder" judgments was independent of the presentation probabilities, accuracy for each signal varying inversely with its probability of presentation. These results suggest strict limitations on the response optimization posited by theories of signal detection.

The optimization processes posited by detection models imply that the probability of correctly reporting the presence of weak signals embedded in background noise varies directly with the probability of signal presentation (Green & Swets, 1966). The O uses his knowledge of the probabilities of different events to optimize correct detections and minimize false detections. Results of detection studies are generally consistent with these implications (Atkinson, Carterette, & Kinchla, 1962; Friedman, Carterette, Nakatani, & Ahumada, 1968; Green, 1960).

Although detection models require that the O know the a priori probability distributions of the stimulus events (Luce, 1963; Peterson & Birdsall, 1953), the results of detection studies indicate that he need not be informed of these probabilities, either by instructions for judgment or by informational feedback after each response (Atkinson et al, 1962; Grundy, 1961). Even without this explicit information, detection probabilities shift in the direction of optimization. However, when the task is to identify fusible but easily detected signals, i.e., recognition rather than detection, the overall response probabilities seem to be independent of the signal probabilities (Parducci & Sandusky, 1965; Schoeffler, 1965; Tanner, Haller, & Atkinson, 1967).

The logic of the experimental task in this type of recognition study requires the O to compare the presented stimulus with preceding presentations. But insofar as his preceding judgments are inaccurate or he doubts their accuracy, they cannot provide

an unambiguous standard for comparison. This ambiguity is absent from the detection task in which the background noise provides a properly labeled standard, i.e., a "no-signal" baseline against which the addition of a signal may be compared.

To determine whether or not the presence of a properly labeled standard is a sufficient condition for response optimization, the present experiment employs a constant standard which precedes each of the signals. Judgments are obtained in two tasks that differ only in the rules defining the categories of judgment. The discrimination task asks that each signal be discriminated from the standard, as in the traditional psychophysical method of constant stimulus differences. The instructions for the recognition task imply comparison with presentations on other trials, as in the method of single stimuli. If defining the standard were the key to the differences between detection and recognition results, response optimization should be greater for the discrimination task.

METHOD

Instructions

For the discrimination task, Os were instructed to judge on each trial whether the comparison tone was "louder" or "softer" than the standard that preceded it. For the recognition task, the instructions stated that the first tone merely identified the start of a new trial—that it would serve as an approximate reference, but that both of the recognition tones might seem louder or softer than this warning tone. Thus, Os had to recognize the tone in the second position as the "louder" or "softer" of the two tones that could appear in that position.

Stimuli and Procedure

The signal presentations were the same for both tasks. Each of 300 successive trials began with a 1-sec burst of random noise, presented via earphones at 70 dB SPL. After a 2-sec interval of quiet, another 1-sec burst was presented, either more or less intense than the first. The amplitude of the two alternative bursts in the second position differed by 1 dB, having been adjusted by pretesting to be approximately equally discriminable from the standard (the louder actually being closer in intensity to the standard, since a negative time-order error of about .25 dB was found). Judgments were made by inserting a plug in one of two

sockets during the 5-sec interval of quiet separating the trials. The presentations were random, with the restriction that the more intense signal was presented on .2, .5, or .8 of the trials. No information was provided concerning these a priori probabilities.

Subjects

A total of 96 undergraduates served as Os, 16 under each combination of task and signal probability. Three Os were eliminated for showing either no discrimination or reversed discrimination of the signals.

RESULTS AND DISCUSSION

Figure 1 shows that the direction of the effects of signal probability is the same for both tasks: the greater the probability of the more intense signal, the smaller the probability of "louder" judgments conditional on either signal. This effect is statistically significant, $F(2,90) = 15.03$, $p < .001$. Neither the interaction between the effects of probability and task nor the higher-order interaction between the effects of stimulus, probability, and task is significant ($p > .05$). These data are thus inconsistent with the hypothesis that a properly labeled standard would produce a pattern of response optimization. In fact, the patterns are extraordinarily similar for these two tasks. The insignificant higher-order interaction simply means that there is no evidence that the discriminability of the two signals, as indicated by the slopes in Fig. 1, is affected by the other conditions. This is consistent with the sensory process posited by detection theories, measures of sensitivity remaining invariant over different stimulus probabilities. The only significant effect of task is upon the overall bias toward "louder" judgments; the bias is greater for the recognition task, $F(1,90) = 7.39$, $p < .01$.

It appears that the presence of a constant stimulus value, even when it is designated as the standard for comparison, is not sufficient to mediate the shifts in judgment implied by signal detection theories. Perhaps the a priori probabilities cannot be learned for this type of stimulus without information feedback. Indeed, the total proportion of "louder" judgments was independent of the stimulus probabilities. These proportions for the discrimination conditions were .50, .46, and .50 for the .8, .5, and .2 conditions, respectively; for the recognitions, the corresponding proportions

Fig. 1. Proportion of "louder" judgments conditional upon the presentation of either the softer (S) or louder (L) intensity. The parameter values are the probabilities of presentation for the louder intensity.

were .54, .54, and .56. In this respect, the data resemble those obtained when no standard is provided (Parducci & Sandusky, 1965; Schoeffler, 1965; Tanner et al, 1967).

In other respects, the data are quite different. In these earlier studies, the response to each stimulus depended upon whether or not the same stimulus had been presented on the preceding trial: accuracy was much lower on repetition trials than on alternation trials. First-order sequential effects were not found for either of the present tasks, accuracy on each signal being virtually independent of which signal had been presented on the preceding trial. This means that the interpolated, constant stimulus value, whether labeled as a standard or simply as a warning signal, effectively blocked the trial-to-trial effects found in the previous recognition experiments. It also means that the sequential models developed for those experiments cannot account for the present data.

Although generalization of the theory of signal detection to recognition and discrimination has been proposed (Tanner, 1956), the results of the present experiment suggest that the domain of situations for which detection-like results can be expected

is much smaller than is commonly assumed. The theory has recently been applied to the discrimination of differences in situations similar to the present tasks (Galanter & Holman, 1967; Shipley, 1967). In these cases, it has proven useful for describing the effects of varying monetary pay-offs; but the present data show that its predictions of the effects of signal probabilities are in the wrong direction.

How might the signal probabilities be learned in detection studies? Perhaps, if the signal-to-noise ratio is not too small (Friedman et al, 1968), the O can use perceptual information available from each presentation. That he cannot do this in tasks requiring comparison with previous presentations implies that detection experiments provide an immediate basis for judgmental comparison—a basis which has yet to be specified.

REFERENCES

- ATKINSON, R. C., CARTERETTE, E. C., & KINCHLA, R. A. Sequential phenomena in psychophysical judgments: A theoretical analysis. *Institute of Radio Engineers Transactions on Information Theory*, 1962, 8, 155-162.

- FRIEDMAN, M. P., CARTERETTE, E. C., NAKATANI, L., & AHUMADA, A. Feedback and frequency variables in signal detection. *Perception & Psychophysics*, 1968, 3, 5-10.
- GALANTER, E., & HOLMAN, G. L. Some invariances of the isosensitivity function and their implications for the utility of money. *Journal of Experimental Psychology*, 1967, 73, 333-339.
- GREEN, D. M. Psychophysics and detection theory. *Journal of the Acoustical Society of America*, 1960, 32, 1189-1203.
- GREEN, D. M., & SWETS, J. A. *Signal detection theory and psychophysics*. New York: Wiley, 1966.
- GRUNDY, R. F. Auditory detection of an unspecified signal. *Journal of the Acoustical Society of America*, 1961, 33, 1008-1012.
- LUCE, R. D. A threshold theory for simple detection experiments. *Psychological Review*, 1963, 70, 61-79.
- PARDUCCI, A., & SANDUSKY, A. Distribution and sequence effects in judgment. *Journal of Experimental Psychology*, 1965, 69, 450-459.
- PETERSON, W. W., & BIRDSALL, T. G. The theory of signal detectability. *Electronic Defense Group, University of Michigan, Technical Report No. 13*, 1953.
- SCHOEFFLER, M. S. Theory of psychophysical learning. *Journal of the Acoustical Society of America*, 1965, 37, 1124-1133.
- SHIPLEY, E. F. Detection and recognition: Experiments and choice models. *Journal of Mathematical Psychology*, 1965, 2, 277-311.
- TANNER, T. A., HALLER, R. W., & ATKINSON, R. C. Signal recognition as influenced by presentation schedules. *Perception & Psychophysics*, 1967, 2, 349-358.
- TANNER, W. P. A theory of recognition. *Journal of the Acoustical Society of America*, 1956, 28, 882-888.

NOTES

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