XX. SIGNAL DETECTION BY HUMAN OBSERVERS[*]

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A. AN ANALYSIS OF SEQUENTIAL DECISIONS

In Quarterly Progress Report No. 52, page 181, we reported our finding that, at least on a macroscopic level, the statistical theory of sequential decision developed by Wald provides a good description of the behavior of human observers in a sequential decision task. It will be recalled that in a sequential detection task the observer makes as many observations as he chooses before deciding whether the sequence of observations arose from noise or from signal plus noise. Our data showed that the error rates and the mean number of observations preceding a terminal decision vary appropriately with changes in the values associated with the various decision outcomes. Subsequent analysis of these data — in particular, analysis of the number of terminal decisions made at each observation stage — has suggested a simpler model for the observer's behavior in this task. This model assumes that each decision is based upon the information obtained from the last observation, and from that one alone, rather than upon an integration of the information gained from all of the preceding observations. This simpler model fits our data very well. That is to say, on a microscopic level, the data do not support the Wald model.

We have now conducted another experiment on sequential decisions in which we explicitly instructed our observers to attempt to integrate the information contained in the entire sequence of observations preceding a terminal decision. The results of this experiment show that the observers are capable of integration; that is to say, a fine-grained analysis of these data supports the Wald model rather than the "amnesic-observer" model. We have also verified in another experiment the statement made in Quarterly Progress Report No. 52, page 181, that human observers show greater efficiency in a sequential task than in a task in which the experimenter fixes the number of observations preceding a terminal decision. The sequential tests yield the same error rates with a 30-50 per cent saving in the mean number of observations.

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B. STIMULUS AND RESPONSE THEORIES OF SIGNAL UNCERTAINTY

The theory of individual choice behavior developed by Luce (1) and adapted by Shipley (2) finds support in experimental results reported by Pollack (3) for the suggestion that the decrement in the detectability of signals in noise which results from

uncertainty about the signal frequency can be accounted for without postulating a sensory filtering. Tanner, Swets, and Green (4) had proposed a single-band model that incorporates a narrow sweeping filter after the pattern of the searchlight analogy of attention, and Green (5) had proposed a multiband model that assumes a linear combination of the outputs of filters centered on each of the possible signal frequencies, to account for the decrement. The first model predicts a larger decrement than the second; existing evidence shows that one or the other of these models fits the data of the majority of observers, with the data of the remaining observers lying in between the two predictions.

Luce's theory yields two predictions: one is exactly coincident with the prediction of the single-band model, and the other is indistinguishable from the prediction of the multiband model. Luce's theory, however, implies that the uncertainty affects the response alternatives rather than the mechanism of observation, and implies, in particular, that if the observer is informed of the signal frequency after his observation, but before making his response, the decrement will not appear. We have performed an experiment that provides a direct test of this proposition. The results support the sensory-filtering hypothesis; postsignal information about the frequency presented does not affect the size of the decrement resulting from presignal uncertainty. This experiment also attempted to distinguish more clearly than heretofore the validity of the two models (single-band and multiband) for the size of the decrement by employing conditions that maximize the difference in their predictions. The data are well fitted by the prediction of the single-band model; they permit rejection of the multiband model for this task.

Another experiment showed that presignal information about which of two frequencies was to be presented aids detection considerably, but such information does not entirely eliminate the decrement. That is to say, detection of one of two frequencies, even with presignal cuing as to which signal will occur (by means of lights or the tones themselves with the noise level dropped), is poorer than detection when a single frequency is employed over a series of trials. This result has relevance to the experiment discussed in Section XX-C, in its suggestion that detection performance varies with the degree of opportunity that is provided the observer to get "set" for the signal that is to be presented.

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References

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C. CUING AS A DETERMINER OF APPARENT VARIABILITY IN SENSITIVITY

The grouping of correct and of incorrect responses over trials in psychophysical experiments has often been regarded as reflecting changes in sensitivity. We suggest another way of accounting for such data. We hypothesize that a given trial can offer cues to the nature of the stimulus. The adequacy of the cue is presumably determined by the effective stimulus intensity. Stronger stimuli should provide, on the average, better cues than weaker stimuli, and trials in which correct responses are made should offer better cues than do incorrect trials. Thus correct responses should follow correct responses. Data were collected by a two-alternative, temporal, forced-choice procedure in which strong and weak signals were presented at random. The proportion of correct responses on the trials following correct responses to the strong signal was higher than the proportion of correct responses on the trials following correct responses to the weak signal. This is consistent with the notion that the adequacy of the cues on pre-ceding trials influences the probability of a correct response. The opposite results would be expected if only fluctuations in sensitivity are involved, since a correct response to a weak signal implies a greater average sensitivity than a correct response to a strong signal.

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