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OPTIMAL LEARNING IN DETECTION SITUATIONS

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Several authors have proposed models for the improvement of performance observed in psychoacoustical tasks (Bush, Luce, and Rose, 1964; Schoeffler, 1965; Tanner and Wilcox, 1966). However, very little systematic experimentation has actually been done in an attempt to isolate the relevant parameters for improved performance. Moreover, apparently none of these studies has actually been guided by an attempt to choose between the proposed models or even to point up the conditions under which these models may be adequate.

Rudiments of Two Basic Learning Models

We shall present here, in a non-rigorous way, the main ideas behind two quite distinct models which have been proposed to describe pre-asymptotic changes in performance.

In a simple detection task the input conditions to the observer have been generated under two experimental manipulations (for example, tone or no-tone in a background of random noise). The task of the observer is to identify which of these two manipulations was performed on each trial. (For example, the observer's task is to detect the presence or absence of the tone.) It is commonly assumed that the observer has a gradation of sensory effects which arise from the applied input stimulation. These sensory effects have distributions conditional upon the manipulation of the input conditions. Thus, it is further assumed that the observer may construct a decision axis which is the likelihood ratio (or at least some monotone function of likelihood ratio) that a particular sensory effect was obtained under one of the manipulations of the input. A choice may then be made by the observer on each trial by placing a cutoff on his decision axis, so that if the likelihood ratio of the sensory effect is greater than the cutoff, he says "Yes" (tone was present) and otherwise says "No." (These assumptions are explained in greater detail in Green and Swets, 1966).

The first model of psychophysical learning, called the variable-bias theory, is based on the notion that the cutoff on the observer's decision axis varies from trial to trial. It may be shown from this assumption that the resulting mixture of decision criteria invariably leads to a decrement in the performance of the observer. Thus, conversely, if over a sequence of experimental trials the variability in the criterion (or response cutoff) decreases, an increase in the observer's level of performance in the task will be observed. A model has been proposed which builds on this theory by adding to it a specific assumption regarding the changes in bias as a result of feedback from the experimenter (Schoeffler, 1965).

A second theory for improvement in performance states the "true" likelihood ratio of sensory events is not perfectly known to the observer. The observer does have, however, an estimated likelihood ratio on each trial which depends upon a prior distribution for the parameter set characterizing the distribution of the likelihood of a sensory event. Because of an internal sampling of sensory events, a reduction in uncertainty about the parameter set occurs. The observer's estimated likelihood ratio thus becomes an improved statistic for discrimination between the events generating the sensory effects. Hence, this theory, the variable sensitivity theory, also predicts that learning will occur in the form of improved observer performance over trials (Tanner and Wilcox, 1966).

Both the variable bias theory and the variable sensitivity theory are based on assumptions that stem from the theory of signal detectability as applied to human detection performance. The theories differ, however, in the manner in which the observer processes information available from the environment to improve his performance. The variable bias theory is a response-learning theory of improved performance. It maintains that less-than-the-best-possible performance in the task is due solely to motivational conditions which determine the observer's criterion. In this theory, the observer's response bias is conditioned by the payoff structure and feedback conditions in the task, but not by the stimulus configuration itself. On the other hand, the variable sensitivity theory maintains that the observer is unable to attain better performance in the task until he has accumulated statistical evidence regarding the importance of different sensory effects to the task of choosing between the manipulations on the input.

Despite the considerable conceptual difference between these two theories of psychophysical learning, it is very difficult to obtain experimental evidence to choose between them by using current psychoacoustical procedures. (These procedures are reviewed in Green and Swets, 1966, Appendix III.) One of the basic reasons for the difficulty in obtaining adequate experimental evidence is that the experimenters do not know what the input conditions to the observer are on a trial-by-trial basis. Experimenters in the past have had only average statistics of the input process, which, of course, are often adequate for studying the asymptotic detection behavior of observers. For the experimenter to know the input conditions is, essentially, an instrumentation problem.

The instrumentation problem of obtaining certain kinds of trial-by-trial specifications of the input process has been solved at the Sensory Intelligence Laboratory. Currently, we are making progress in the construction of apparatus to provide the necessary measurements on the input waveform to conduct a variety of experiments on human learning processes in detection tasks.

Current Research

Several projects are currently underway as a direct result of the present research support.

A thesis entitled "Sensory Processing Models of Human Monaural Auditory Detection" is being completed by Gordon Wilcox. This thesis contains an exposition of the variable sensitivity theory in the context of improved detection performance by human observers in auditory tasks. It has been necessary to explore the implications of the theory of signal detectability in greater depth in order to obtain predictions in learning situations. A general class of models for learning has been obtained within the framework of detectability theory. Each member of the class depends upon assumptions regarding the mode of sensory processing which the observer can assume.

Data have been obtained on the early stages of practice in the use of confidence judgments as response measures of performance in a simple monaural detection task. The objective of this study is an attempt to ascertain the improvability of information production capability for human subjects. An extension of this study is aimed at determining whether an observer's information production capability is deteriorated by increased noise levels. The issue, it may be noted, is not whether there is a decrease in observer sensitivity for lower signal to noise levels (S/N), but rather whether there is a decrease in efficiency at lower S/N levels. In the current program of study an attempt is being made to decompose the decrement into two sources: that which occurs on trials when the signal is present and that which occurs on trials when signal is absent. It is expected that this research will shed some light on the problem of the degree of interobserver agreement, which appears to depend upon the presence or absence of signal in noise.

References

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