Aerospace Medical Assoc. 35th Annual Mtg., Miami Beach, Fla., May 11-14, 1964

4p

THE ROLE OF FEEDBACK IN ADAPTIVE PERCEPTUAL PROCESSES [redacted]

By

Ronald A. Kinchla*
and
Richard C. Atkinson**

This paper deals with some factors which influence an observer when he attempts to identify partially discriminable stimuli. A common discrimination task is one in which the observer attempts to identify which of two stimuli is presented on each of a series of trials. The stimuli are partially discriminable if the difference between them is so small, or degenerated by noise, that there is only a partial correlation between the stimulus and response sequences. We shall consider the manner in which an observer's performance is influenced by certain stimulus presentation schedules and the amount of information feedback he is given concerning the correctness of his responses.

In the present experiment each observer attempted to discriminate (detect) whether or not a 100 msec. 1000 cps. tone was, or was not added to a constant background of band limited Gaussian noise. The tone stimulus will be denoted by S_1 and the no-tone stimulus as S_2. The correct response for each stimulus will be denoted by A_1 and A_2 respectively.

The observer's performance can be summarized by estimates of two probabilities: $P_r(A_1|S_1)$ and $P_r(A_1|S_2)$. Both of these probabilities have been shown to be positively correlated with $P_r(S_1)$ under simple stimulus presentation schedules in which $P_r(S_1)$ is the same on all trials. This schedule effect has been attributed to the observer's tendency (response bias) to resolve stimulus ambiguity by making an A_1 response. The subject is viewed as matching his response bias to what might be termed his "subjective estimate" of $P_r(S_1)$.

A simple threshold model is outlined in Fig. 1. Performance is represented by the stimulus-response transition matrix P, in which $p_1 = P_r(A_1|S_1)$ and $p_2 = P_r(A_1|S_2)$. This matrix is defined as the product of two theoretical processes: an activation process relating the external stimulus events to hypothetical sensory states (D_0, D_1, and D_2), and a decision process relating these sensory states to overt responses. Activation is defined by the stochastic matrix A and decision

*NASA Ames Research Center, Moffett Field, California
** lifornia

by the stochastic matrix D. Thus, P is simply the matrix product AD. The single parameter in A, α, represents the observer's <u>sensitivity</u>, since it determines the amount of information about the stimulus variable contained in the sensory variable. The single parameter in D, g, represents the <u>response bias</u>, since it is the probability of an A_1 response given the ambiguous sensory state D_0. This state is ambiguous because it may be induced by either S_1 or S_2. Notice that estimates of both theoretical parameters, α and g, may be obtained directly from p_1 and p_2.

Theories have been developed in which the response bias, g, is modified by the stimulus presented on each trial: S_1 stimuli increase g and S_2 stimuli decrease g. Thus, the average value of g tends to approach $P_r(S_1)$ as an asymptote. An obvious question relative to models of this sort is the importance of telling the subject whether or not each response was correct; i.e., providing feedback.

To investigate the influence of feedback, we ran subjects 500 trials a day for 24 days on the simple detection task described earlier. Only on alternate days did the subjects receive information feedback concerning the correctness of each response. In addition, and unknown to the subjects, we used stimulus presentation schedules which made a subject's knowledge of the stimulus presented on one trial highly relevant to his estimate of $P_r(S_1)$ on the next trial. Eighteen subjects were run under a schedule where the stimuli on adjacent trials were identical 75 percent of the time. Six subjects were run on a schedule in which the stimuli were repeated only 25 percent of the time. Thus, under one schedule $P_r(S_{i,n}|S_{i,n-1}) = 3/4$ and on the other schedule $P_r(S_{i,n}|S_{i,n-1}) = 1/4$, where $S_{i,n}$ denotes the stimulus on trial n (i=1,2).

In Fig. 2 we have presented the average performance of the subjects in each group. The four data points on each graph were obtained by partitioning the data in terms of the immediately preceeding trial. For example, the open circle on each graph indicates the value of p_1 and p_2 based on all the trials which were preceeded by a trial with an S_2 stimulus and an A_1 response.

There are two important features of these results. First, the subjects clearly learned to modify their performances in a manner consistent with the first order conditional presentation schedule both p_1 and p_2 were higher following S_1 trials on the high repeat schedule and lower following S_1 on the low repeat (high alternati schedule. Second, with feedback the performance shifts were bas primarily on the stimulus (or feedback) on the previous trial. W no feedback, the response occurring on the previous trial was th most important factor. The magnitude of the sequential effects appears to be attentuated without feedback.

[redacted]

The same effects are evident in the contingent estimates of response bias shown in Table 1. These estimates are based on the same partitioning of the data as the points in Fig. 2. It is clear that the response bias shifts are consistent with the particular stimulus schedule. Also, the bias shifts are controlled primarily by the stimulus (or feedback) events when feedback is supplied. When no feedback occurs, the subject appears to base his bias primarily on what he "thought he heard" (what he reported) on the previous trial, rather than what was actually presented.

Table 1: CONDITIONAL ESTIMATES OF RESPONSE BIAS

Previous Trial	$P_r(S_{i,n} \mid S_{i,n-1}) = 1/4$		$P_r(S_{i,n} \mid S_{i,n-1}) = 3/4$	
	Feedback	No Feedback	Feedback	No Feedback
S_1A_1	.191	.212	.564	.480
S_1A_2	.270	.454	.439	.339
S_2A_1	.633	.225	.323	.431
S_2A_2	.761	.459	.298	.302

A Mann-Whitney U test on the individual subject data was sufficient to demonstrate better than .01 significance for the first order stimulus effects with feedback, and the first order response effects with no feedback. Evaluation of the possible stimulus and response effects is beyond the scope of the present paper. It should be pointed out, however, that such differences could arise purely from our partitioning procedure, since trials following an S_1A_1 would tend to have a higher bias value than trials following an S_1A_2.

In conclusion, the chief implications of this study are: one, subjects learn to utilize higher order statistical properties of the stimulus presentation schedule in their performance; and two, with no feedback, the sequential effects appear to be attenuated and based primarily on the proceeding response, rather than the proceeding stimulus as was the case with feedback.

A SIMPLE THRESHOLD MODEL

$$\text{PERFORMANCE}: P = \begin{array}{c} \\ S_1 \\ S_2 \end{array} \begin{array}{c} \begin{array}{cc} A_1 & A_2 \end{array} \\ \begin{bmatrix} p_1 & 1-p_1 \\ p_2 & 1-p_2 \end{bmatrix} \end{array}$$

$$\text{ACTIVATION} \quad A = \begin{array}{c} \\ S_1 \\ S_2 \end{array} \begin{array}{c} \begin{array}{ccc} D_0 & D_1 & D_2 \end{array} \\ \begin{bmatrix} 1-\alpha & \alpha & 0 \\ 1-\alpha & 0 & \alpha \end{bmatrix} \end{array}$$

$$\text{DECISION} \quad D = \begin{array}{c} \\ D_0 \\ D_1 \\ D_2 \end{array} \begin{array}{c} \begin{array}{cc} A_1 & A_2 \end{array} \\ \begin{bmatrix} g & 1-g \\ 1 & 0 \\ 0 & 1 \end{bmatrix} \end{array}$$

$$P = AD = \begin{bmatrix} \alpha+(1-\alpha)g \;, & (1-\alpha)(1-g) \\ (1-\alpha)g \;, & \alpha+(1-\alpha)(1-g) \end{bmatrix}$$

$$\text{SENSITIVITY}: \hat{\alpha} = p_1 - p_2$$

$$\text{RESPONSE BIAS}: \hat{g} = p_2/1 - p_1 + p_2$$

Figure 1.

FIRST ORDER CONDITIONAL OPERATING CHARACTERISTICS

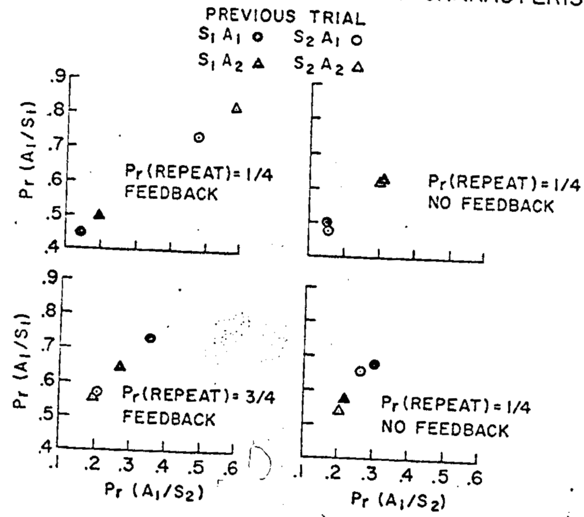

Figure 2.