THE EFFECT OF BUZZER-SHOCK UPON THE PREDICTIVE BEHAVIOR IN A TWO-CHOICE SITUATION*

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So far there are a number of articles about the predictive response in a two-choice situation. In these articles many authors reported that the asymptotic probability of the subject's predictive response of the more frequent stimulus matched the probability of its reinforcement (2, 5, 6, 7, 8, 9, 10). This phenomenon was called the *probability matching behavior* and it was found with animals such as rats and fishes as well as human subjects. Estes and Straughan (5) tried to interpret the probability matching behavior according to their stimulus sampling model. In accordance with the model, under the two-choice situation of alternatives A_1 and A_2 , when the relative frequency of reinforcing A_1 , i.e. π , is larger than that of reinforcing A_2 , i.e. $1 - \pi$, the asymptotic probability of response of A_1 is equal to π if the alternatives are exhaustive and if they are mutually exclusive. However, there are the experimental evidencies in which we could not agree to Estes' model and these results were tried to be interpreted by the secondary reinforcement model or the theory of game (1, 11).

The present paper is concerned with the effect of buzzer-shock given to S when his response was incorrect, and with a non-fixed θ model. Estes and Burke (4) assumed that a subset of stimulus elements is sampled on each trial in an experimental situation, and that these stimulus elements are connected to one of the given responses. As a simple case it is assumed that sampling probability of stimulus elements does not vary but fixes over the whole trial. However, sampling probability of stimuli may vary on every trial. If some other conditions are given in the reinforcing situation the hypothesis of fixed sampling probability such as Estes' may not be held. For example, if some informational value is given only to S 's incorrect response the effect of stimuli sampled on the incorrect trial upon the next trial response may be different from that on the correct trial under noncontingent procedure, which we designate the *non-fixed θ model* throughout this paper. In the next paragraph we shall describe the non-fixed θ model which will fit the experimental results.

NON-FIXED θ MODEL**

In the two-choice situation of noncontingent procedure the events of responses are A_1 and A_2 , and the proportions of occurrence of reinforcing events E_1 and E_2 we specify π and $1 - \pi$, respectively. We shall assume the subject is in State 1 if sampled stimuli are connected to A_1 and he is in State 0 if they are not connected to A_1 in Markovian notation. Suppose some informational value is given on the trial when S responds incorrectly, on which sampling probability is θ_2 , but it is θ_1 if he does correctly. Then, the matrix of transition probabilities from one State to another can be written as follows:

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** The derivation of equations in this paragraph was based upon the technique used in Estes' article (3).

$$Q = \begin{pmatrix} 1 - \theta_2 + \theta_2\pi & \theta_2(1 - \pi) \\ \theta_1\pi & 1 - \theta_1\pi \end{pmatrix}, \quad (1)$$

and by direct multiplication, we obtain in two-steps

$$Q^2 = \begin{pmatrix} \theta_1\pi + \theta_1\pi(1 - \theta_2 - \theta_1\pi + \theta_2\pi) & 1 - \theta_1\pi - \theta_1\pi(1 - \theta_2 - \theta_1\pi + \theta_2\pi) \\ + (1 - \theta_2 - \theta_1\pi + \theta_2\pi)^2 & - (1 - \theta_2 - \theta_1\pi + \theta_2\pi)^2 \\ \theta_1\pi + \theta_1\pi(1 - \theta_2 - \theta_1\pi + \theta_2\pi) & 1 - \theta_1\pi - \theta_1\pi(1 - \theta_2 - \theta_1\pi + \theta_2\pi) \end{pmatrix} \quad (2)$$

and in general, we can write down

$$Q^n = \begin{pmatrix} \pi_\theta + (1 - \pi_\theta)(1 - \theta_\pi)^n & (1 - \pi_\theta)[1 - (1 - \theta_\pi)^n] \\ \pi_\theta[1 - (1 - \theta_\pi)^n] & 1 - \pi_\theta[1 - (1 - \theta_\pi)^n] \end{pmatrix} \quad (3)$$

where

$$\pi_\theta = \theta_1\pi / (\theta_2 + \theta_1\pi - \theta_2\pi)$$

and

$$\theta_\pi = \theta_2 + \theta_1\pi - \theta_2\pi. \quad (4)$$

If he shall define $q_1^{(n)}$ and $q_0^{(n)}$ to be the probabilities of State 1 and State 0 after n trials and $Q^{(n)}$ to be

$$Q^{(n)} = (q_1^{(n)}, q_0^{(n)}). \quad (5)$$

By direct multiplication we can write that

$$Q^{(1)} = Q^{(0)}Q, \quad (6)$$

and by mathematical induction we can derive

$$Q^{(n)} = Q^{(0)}Q^n. \quad (7)$$

Assuming p_n the probability of A_1 response on trial n is equal to the probability of sampled elements conditioned to A_1 on trial $n - 1$, then

$$\begin{aligned} p_n &= \pi_\theta - (\pi_\theta - p_1)(1 - \theta_\pi)^{n-1} \\ &= \frac{\theta_1\pi}{\theta_2 + \theta_1\pi - \theta_2\pi} - \left(\frac{\theta_1\pi}{\theta_2 + \theta_1\pi - \theta_2\pi} - p_1 \right) (1 - \theta_2 - \theta_1\pi + \theta_2\pi)^{n-1}. \end{aligned} \quad (8)$$

From (8), after large n trials the asymptotic probability of A_1 response is

$$p_\infty \cong \theta_1\pi / (\theta_2 + \theta_1\pi - \theta_2\pi). \quad (9)$$

In the above derivations, we assumed that sampling probability on S 's incorrect trial is different from that on S 's correct trial. But now, if we assume there is no difference between these two sampling probabilities, that is, $\theta_1 = \theta_2 = \theta$, we can change equation (8) to

$$p_n = \pi - (\pi - p_1)(1 - \theta)^{n-1}, \quad (8')$$

and this equation is one derived from Estes' model.

In general, we usually represent the learning process with the average percentage of a given response per block of trials. Therefore, we must transform (8) to the equation to be able to represent it per block. Assuming the number of trials of a block k , we can write the response probability in block m

$$P_m = \pi_\theta - \frac{1}{k\pi_\theta} (\pi_\theta - P_1) (1 - \theta_\pi)^{k(m-1)} [1 - (1 - \theta_\pi)]$$

and assuming the initial response probability in block 1 P_1 , we can derive

$$P_m = \frac{\theta_1 \pi}{\theta_2 + \theta_1 \pi - \theta_2 \pi} - \left(\frac{\theta_1 \pi}{\theta_2 + \theta_1 \pi - \theta_2 \pi} - P_1 \right) (1 - \theta_2 - \theta_1 \pi + \theta_2 \pi)^{k(m-1)}. \quad (10)$$

We shall assume that some informational value (for example, a buzzer-shock as in the following experimentation) is added only to S 's incorrect responses and that it is not to S 's correct responses. Therefore, θ_1 must be equal to θ in Estes' model since θ_1 is sampling probability in the case of S 's correct responses to which no other conditions are given. We can get the parameter value* of θ_1 or θ from the results of usual two-choice experiments without any specific conditions. Then, if we get the parameter value of θ_2 , we can calculate P_m from (10). To get θ_2 value, we sum P_m ,

$$\sum_m P_m = r\pi_\theta - (\pi_\theta - P_1) \frac{[1 - (1 - \theta_\pi)^{kr}]}{1 - (1 - \theta_\pi)^k}.$$

However, since kr is very large, $(1 - \theta_\pi)^{kr}$ almost equals to zero. Therefore,

$$\begin{aligned} \sum_m P_m &= r\pi_\theta - (\pi_\theta - P_1) \frac{1}{1 - (1 - \theta_\pi)^k} \\ &= \frac{r\theta_1 \pi}{\theta_2 + \theta_1 \pi - \theta_2 \pi} - \left(\frac{\theta_1 \pi}{\theta_2 + \theta_1 \pi - \theta_2 \pi} - P_1 \right) \frac{1}{1 - (1 - \theta_2 - \theta_1 \pi + \theta_2 \pi)^k}. \end{aligned} \quad (11)$$

Then, if we get θ from Estes' model, we can get the value of θ_2 from (11) and we may compare the predicted learning curve with the empirical data.

Here, it will be necessary to consider the properties of θ_1 and θ_2 . If $\theta_1 = \theta_2 = \theta$, P_∞ becomes equal to π asymptotically. This result agrees to the conclusion of asymptotic probability of response in Estes' model in which sampling probability of stimulus is θ . If θ_1 is larger than θ_2 , assuming $\theta_1 - \theta_2 = \varepsilon_1 > 0$,

$$P_\infty \simeq \frac{\theta_1 \pi}{\theta_1 - (1 - \pi)\varepsilon_1} > \pi \quad (12)$$

since $\theta_1 - (1 - \pi)\varepsilon_1 < \theta_1$. Therefore, when the effect of θ_2 is smaller than θ_1 in the experimental situation, the asymptote of S 's response probability will tend to be larger than the probability of reinforcement π . If $\theta_1 < \theta_2$, similarly

$$P_\infty \simeq \frac{\theta_1 \pi}{\theta_1 + (1 - \pi)\varepsilon_2} < \pi, \quad (13)$$

assuming $\theta_2 - \theta_1 = \varepsilon_2 > 0$. In the experimental condition with larger value of θ_2 than θ_1 the asymptote of response probability will tend to be lower than π .

Thus, in the present model, it is dependent upon the additional conditions in the experimentation whether the asymptotic probability of A_1 response is higher, or lower than π , or to be equal.

METHOD

Subjects—The S s were 20 male and female undergraduate students at the University of Hiroshima. They were divided into two groups, an experimental group of 9 S s and a control group of 11 S s. S s received

* To obtain θ_1 value from the model, from (8') we can write

$$\sum_m P_m = r\pi (\pi - P_1) \frac{1}{1 - (1 - \theta)^k} \quad (11')$$

and from (11') we can get the θ_1 value.

Fig. 1 Apparatus

implied that pressing of the right key meant the prediction of the right lamp on the standing panel-board to turn on and that pressing of the left key meant the prediction of the left lamp. After *S* pressed either the right or the left key, one of two lamps turned on, which reinforced *S*'s guessing. A 6-v. buzzer-shock given to *S* if he guessed incorrectly. It was held by *S*'s left hand over the trials in order to strengthen shock* or noxious effect to be given to *S*. The signal lamp was lit for 2 sec. and after the rest period of 2 sec. one of reinforcing lamps was lit for 2 sec. *S* must guess which lamp turned on before the reinforcing event occurred. The intertrial interval was 4 sec. These time intervals and duration of the buzzer sound were controlled automatically behind the apparatus and a screen was set such that *S* could not see its control.

Procedure — After all *Ss* were explained about the apparatus they were given an instruction in that *Ss* must guess, by pressing one of keys, which lamp will be lit on each trial and that they must respond correctly and try to get as many correct responses as they could. *Ss* in the experimental group received buzzer-shock when they guessed incorrectly but *Ss* in the control group did not. About half of the *Ss* in each group were run under the condition of 75% reinforcement for the right lamp and the other about half under the condition of 75% for the left lamp. It was determined randomly which lamp turned on on each trial in consideration that a reinforcing event occurred in 75% per 20 trials, and that the same event did not continue to occur more than six times. *S* received a total of 200 trials without pause.

RESULTS AND DISCUSSION

Learning curves — The average percentages of responses to the more frequent stimulus in blocks of 20 trials were presented in Figure 2. Learning curves in experimental and control conditions are similar up to 120 trials but the distinction between the two groups appears in block 7 and it tends to be large towards the last block. Figure 2 does not show the smooth learning curves in both conditions. This would result in inappropriate stimulus sequence presented in blocks 3 and 6 since two curves are very similar with each other.

In the control condition we assume θ_1 and θ_2 equal to θ in Estes' model because no additional information was given to this group. Then, we can calculate θ from (11') and we obtained .026. By substituting θ value into (8), and by calculating P_m , we had

Fig. 2 Empirical and theoretical curves.

* It may not be appropriate to use the term of "shock" here. However, the author used term, shock, throughout this paper since all *Ss* reported that they had the noxious effect by the sound and the vibration of the buzzer. In the paragraphs to follow, the terms "shoce" and "buzzer-shock" will be used interchangeably.

a smooth learning curve (a dotted line in Fig. 2). Since Ss in the experimental group received buzzer-shock when they guessed incorrectly, we shall assume $\theta_1 > \theta_2$. But it is assumed that θ_1 equals to θ since Ss were given no special information concerning the reinforcing light when they guessed correctly. We can obtain θ_2 value from (11) by substituting $\theta_1 = .026$, $P_1 = .510$, and $\pi = .75$. We verified the assumption $\theta_1 > \theta_2$ since θ_2 was .020. A smooth curve in Fig. 2 is the theoretical learning curve in the experimental condition.

The asymptote.—We often deal with a model in the asymptotic level when we discuss the evaluation of the model. The average response probability of the more frequent stimulus during the last 80 trials was .740 in controls, and the theoretical asymptote was $\pi = .75$. As shown in Table 1, the average response probability during the last 80 trials in the experimental group was .801 and the theoretical asymptote P_∞ was .796 obtained from (9). The t values for differences between observed and theoretical values in two groups seem satisfactorily low.

Table 1. Predicted and Observed Response Probabilities of A_1 during the Last 80 Trials.

Group	Observed	Predicted	t	df
Exp.	.801	.796	0.09	8
Cont.	.740	.750	0.18	10

The *Mann-Whitney U Test* shows that the difference between two groups in terms of the asymptotic response probability during the last 80 trials is significant at the .05 level. Therefore, we can say that the effect of buzzer-shock upon S's choices resulted in increasing the proportion of choosing the more frequent stimulus.

In this experiment, the buzzer-shock given to the incorrect responses may operate to inhibit Ss to make incorrect responses, especially much more to inhibit incorrect responses of the less frequent stimulus.

We made an attempt to quantify the behavior effected by the shock, assuming that the sampling probability of stimulus elements depends upon the presence or absence of the shock. The experimental results support the proposed model with respect to the asymptotic level. However, we must say this model is a special one because we, in general, assume that the sampling probability of elements may vary on each trial in acquisition.

SUMMARY

This paper is concerned with the effect of the buzzer-shock upon the guessing behavior in a two-choice situation. Buzzer-shock was given to Ss in an experimental group when they guessed incorrectly. The acquisition trials were 200 trials. Ss were 20 undergraduate students.

After 121 trials the differences between the experimental group and the control group (without buzzer-shock) were found, and the asymptotic probability of guessing the more frequent stimulus was significantly different between the two groups. It was concluded that buzzer-shock for incorrect responses tends to increase their choices of the more frequent stimulus.

The non-fixed θ model was applied to the data, in which it was assumed that the sampling probability of stimulus elements depends upon the presence or absence of the shock. The present model seems to fit the experimental findings with respect to the asymptotic response level.

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