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Decision Theory in Studies of Discrimination in Animals

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The work of Boneau, Holland, and Baker on wavelength discrimination in the pigeon (*1*) shows clearly that the tendency to respond to stimuli in which reward is never available is increased on trials immediately following reward. However, there was little if any decrease in the ability of the pigeon to respond *differentially* to closely spaced wavelengths, despite this general increase. The authors say they "can only describe the effect somewhat inexactly as a change in response bias."

I would like to suggest that their data are entirely consistent with an application of decision theory to the detection or recognition of stimuli in psychophysical experiments with human subjects. In this theory (*2*) the internal effects of stimuli are represented as Gaussian distributions of equal variance. When two stimuli differ physically by very little, their distributions overlap, and the observer is viewed as having to decide which distribution gave rise to his observation on a particular trial. In order to maximize expected value, he must weigh the probabilities and values of the outcomes and establish a criterion observation level, above which he always makes a certain response. The theoretical probability of response to a stimulus is given by the area under its distribution above the criterion. As the criterion varies, the probabilities of correct and incorrect responses covary according to a receiver-operating-characteristic (ROC) curve. This function has a parameter called d' which is equal to the difference between means of the distributions divided by their standard deviation. Invariance of d' under various experimental manipulations indicates that the discriminability of the stimuli has not changed, while the particular values of the response probabilities reflect the criterion level as well as discriminability.

If more than two stimuli are presented, as in the work of Boneau *et al.*, the theoretical probability of response to each stimulus is given by the area under its distribution which exceeds the criterion. If that criterion is lowered, response probabilities are increased. If these sets of response probabilities are plotted against each other, a curve of ROC form results, in which the parameter reflects the amount by which the criterion has changed.

In order to apply this theory to the data of Boneau *et al.*, I took the probabilities of responding to the stimuli in which rewards were never available from their Figs. 1 and 2 for trials immediately preceding ($T_0 - 1$) and immediately following ($T_0 + 1$) presentation of reward, and plotted them against each other. The results of this plot are shown in Fig. 1, together with a theoretical curve for a criterion change of 0.7 standard-deviation units.

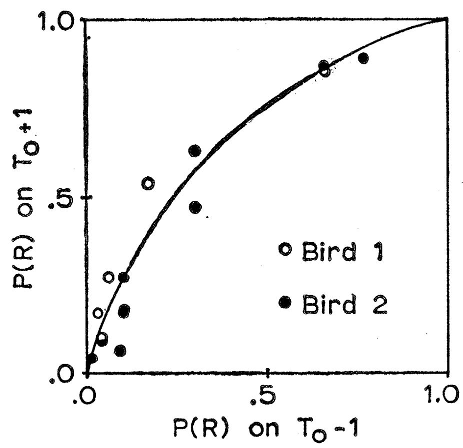

Fig. 1. Probability of response of two birds (*1*, figs. 1 and 2) to stimuli in which rewards are never available on trials immediately following reward ($T_0 + 1$) plotted against probability of their response to the same stimuli on trials immediately preceding reward ($T_0 - 1$). For description of theoretical curve, see text.

Both birds' data are reasonably well described by the curve.

It is by no means clear that decision theory is applicable in detail to operant discrimination experiments of this sort. In particular, we cannot evaluate rewards, the effort involved in responding, and the consequences of unrewarded responding in terms which make the maximization of expected value meaningful. However, the theory has been useful in integrating work on threshold processes in human psychophysics, and it may be fruitful in studies of animal discrimination performance as well. At the least, it may provide a technique for evaluating the effects of rewards on response bias.

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