A note on single- and double-correct responses in the dichotic two-response paradigm

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A simple random-guessing model of the dichotic two-response paradigm is used to predict the proportions of single- and double-correct responses at different performance levels. Comparisons with real data show that the proportions of double-correct responses are generally overpredicted. By introducing an additional free parameter to account for nonindependence of channels (ears), the model is made to fit closer to empirical data, but the value of the parameter is not the same for different sets of data. This may be due to differences in stimulus characteristics between experiments. While the model is oversimplified in many ways, it nevertheless provides a rudimentary formal framework for the interpretation of dichotic data, particularly with regard to changes in the proportions of single- and double-correct responses with performance level.

Despite a large amount of research and theoretical speculations on dichotic listening, little thought has been given to formulating and testing mathematical models of the response processes involved. The present paper briefly examines the simplest conceivable formal model and derives some predictions from it. The model is clearly an oversimplification. However, the purpose of the exercise is to point out some basic relations between several dependent variables in dichotic listening experiments. These relations are likely to hold up approximately even if the model that predicts them is not precisely true, and they need to be taken into account in the interpretation of dichotic data.

The simplest model of response selection in the dichotic two-response paradigm makes the following three assumptions: (1) The stimuli in the two ears are perceived independently of each other. (2) A stimulus is either perceived correctly or a random guess is made. (3) Errors in dichotic performance arise only from a very general form of processing limitation that reduces accuracy for both ears relative to monaural performance but permits independent perception of the degraded stimuli in each ear (cf. the "perceptual noise" hypothesis of Repp, 1975a, 1975b). If P_R^* and P_L^* are the "true" probabilities of correctly perceiving the stimuli in the right and left ear, respectively, P_R and P_L are the observed proportions of correct responses to the two ears, and N is the number of different stimulus categories in the experiment, then

$$P_R = P_R^* + (1 - P_R^*) P_L^* [1/(N-1)] + (1 - P_R^*)(1 - P_L^*)(2/N), \tag{1}$$

$$P_L = P_L^* + (1 - P_L^*) P_R^* [1/(N-1)] + (1 - P_L^*)(1 - P_R^*)(2/N). \tag{2}$$

The three additive terms in these equations are (1) the probability of correctly perceiving the stimulus in the ear concerned; (2) the probability of making a correct guess when the stimulus in the other ear is correctly identified; and (3) the probability of making a correct guess when no stimulus is perceived correctly.

The proportion of double-correct responses, P_D, predicted by this simple guessing model is

$$P_D = P_R^* P_L^* + (1 - P_R^*) P_L^* [1/(N-1)]$$
$$+ P_R^* (1 - P_L^*) [1/(N-1)]$$
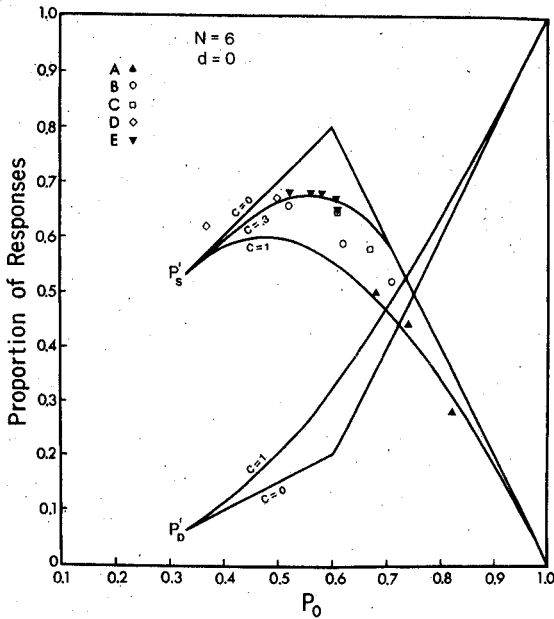$$+ (1 - P_R^*)(1 - P_L^*) [2/N(N-1)] . \tag{3}$$

FIG. 1. P_S' and P_D' as a function of P_o and c, for the special case of six stimulus (response) categories ($N=6$) and no ear difference ($d=0$). Data points from Table I.

a multiplicative factor c if the stimulus in the other ear has been correctly perceived. Thus,

$$P_R^*|L \text{ correct} = cP_R^*|L \text{ not (yet) correct, and} \quad (6)$$

$$P_L^*|R \text{ correct} = cP_L^*|R \text{ not (yet) correct} . \quad (7)$$

The constant c varies between 0 and 1. $c=0$ indicates that, if the stimulus in one ear is correctly perceived, the other stimulus can never be correctly identified except by a random guess; $c=1$ indicates complete independence of the two channels. The full model, stated in terms of the predicted proportions of double- and single-correct responses (which will be called now P_D' and P_S', respectively), is

$$P_D' = cP_R^*P_L^* + [P_R^*(1-cP_L^*) + P_L^*(1-cP_R^*) + (1-P_R^*)P_L^*$$
$$+ (1-P_L^*)P_R^*]/2(N-1) + (1-P_R^*)(1-P_L^*)$$
$$\times [2/N(N-1)] \quad (8)$$

and

$$P_S' = [P_R^*(1-cP_L^*) + P_L^*(1-cP_R^*) + (1-P_R^*)P_L^*$$
$$+ (1-P_L^*)P_R^*][(N-2)/2(N-1)] + (1-P_R^*)$$
$$\times (1-P_L^*)(2/N) . \quad (9)$$

In this model, it makes a difference which channel is processed first; this results in the additional terms in the equations and in the additional "2" in the numerator. The simplifying assumption needs to be made that each channel is equally likely to be processed first, so that ear differences rest solely on differences between P_R^* and P_L^*. (Relaxing this assumption would lead to a more complex model which cannot be considered here.)

Figure 1 compares the model to the data of Table I. P_D' and P_S' are plotted as a function of P_0, the observed

The proportion of single-correct responses, P_S, is

$$P_S = P_R^*(1-P_L^*)(N-2)/(N-1)$$
$$+ P_L^*(1-P_R^*)(N-2)/(N-1)$$
$$+ (1-P_R^*)(1-P_L^*)(2/N) . \quad (4)$$

The overall performance level P_0 is defined as

$$P_0 = \tfrac{1}{2}(P_R + P_L) = \tfrac{1}{2}P_S + P_D . \quad (5)$$

Several studies in the literature report sufficiently detailed results for several experimental conditions with different performance levels. These data and the predictions from the model are shown in Table I. The predictions $\hat{P}_D$ and $\hat{P}_S$ were derived graphically for given values of P_0 and $d = P_R - P_L$. (See Repp, 1977, for details.) It can be seen that the model overpredicts P_D and underpredicts P_S in all cases but one. In other words, the observed proportions of double-correct responses are consistently smaller than predicted by the model. This indicates a negative dependency between P_R^* and P_L^*, such that the probability of perceiving the stimulus in one ear correctly is reduced if the stimulus in the other ear has already been perceived correctly. This is plausible in view of factors like fusion, selective attention, and loss from memory, all of which tend to reduce perceptual accuracy for one channel to the degree that they increase accuracy for the other. Also, Cullen et al. (1974) have shown that reducing the quality of the stimuli in one ear raises the scores for the other ear, which proves that the two channels are not independent.

This more specific processing limitation can be modeled by introducing a free parameter into the model. Let us assume that the conditional probability of perceiving the stimulus in one ear correctly is reduced by

TABLE I. Comparison of some reported proportions of double- and single-correct responses with the predictions of the simple guessing model.[a]

	P_o	d	P_S	P_D	$\hat{P}_S$	$\hat{P}_D$
A: Initial consonants[b]	0.68	0.12	0.50	0.43	0.49	0.43
A: Medial vowels	0.82	0.02	0.28	0.69	0.32	0.66
A: Final consonants	0.74	0.06	0.44	0.52	0.42	0.53
B: 30 dB[c]	0.52	0.12	0.66	0.19	0.58	0.22
B: 40 dB	0.62	0.07	0.59	0.32	0.54	0.35
B: 50 dB	0.71	0.12	0.52	0.45	0.46	0.48
C: Before practice[d]	0.61	0.17	0.65	0.28	0.56	0.32
C: After practice	0.67	0.20	0.58	0.38	0.52	0.40
D: Clinical[e]	0.37	0.10	0.62	0.06	0.56	0.09
D: Normal	0.50	0.11	0.67	0.18	0.60	0.20
E: 5 years[f]	0.52	0.06	0.68	0.18	0.60	0.22
E: 7 years	0.56	0.08	0.68	0.22	0.58	0.27
E: 9 years	0.58	0.09	0.68	0.24	0.57	0.30
E: 11 years	0.61	0.10	0.67	0.27	0.55	0.33
E: 13 years	0.61	0.11	0.65	0.28	0.55	0.33

[a]All studies used natural speech and the six stop consonants preceding /a/ (study A used CVC utterances).
[b]A = Studdert-Kennedy and Shankweiler (1970).
[c]B = Cullen et al. (1974).
[d]C = Porter et al. (1976).
[e]D = Tobey et al. (1976).
[f]E = Berlin et al. (1973).

performance level.[1] The long curvilinear functions are for $c = 1$, the short linear functions for $c = 0$. Functions with c between 0 and 1 lie between these two extremes, starting at the same points at the left and extending up to points on the long linear segments which represent the maximal (minimal) expected scores for different values of c. Only the observed P_S scores from Table I are plotted. (The differences between observed and predicted P_S scores are exactly twice as large at those between observed and predicted P_D scores, and therefore make discrepancies easier to see.)

Either of two conclusions can be drawn from Fig. 1. If all data points are to be fit by a single function (and it seems that they could be), then the model is incorrect, for it cannot generate this function. On the other hand, it is possible that different experiments, stimuli, or groups of subjects require different functions. The three data points of study A (Studdert-Kennedy and Shankweiler, 1970) are fit by a function with $c = 1$, indicating virtual independence of channels. Eight of the other 12 data points seem to be fit by a function with approximately $c = 0.3$ (which has been drawn in Fig. 1), indicating substantial negative dependencies between channels. The other data points require intermediate values of c, except for one point which falls completely outside the range of the model. Variations in c as a function of stimuli or subjects are not implausible. The stimuli of study A, for example, were different in several ways from those of studies B–E, which all come from the same laboratory. In this case, c may serve as an indicator of the degree of channel interaction (e. g., fusion) in an experiment.

The model should be of interest to researchers who have focused on P_D as a possible indicator of auditory processing capacity (Berlin et al., 1973; Dermody and Noffsinger, 1976; Tobey, Cullen, and Rampp, 1976). The results of two such studies are included in Table I and in Fig. 1. Tobey et al. (1976) noted that their two groups of subjects (children with and without auditory processing disorders) did not differ in P_S but only in P_D. Similarly, Berlin et al. (1973) found that P_D increased with age, while P_S decreased, but to a much lesser extent. As can be seen in Table I and Fig. 1, both findings are predicted by the present model. The subjects in both studies performed at relatively low levels, where P_S is predicted to remain nearly constant with changes in performance level, while P_D increases. Therefore, the findings probably reflect changes in overall performance level, not in a factor specifically tied to double-correct responses, as the data might suggest. A true change in auditory processing capacity would lead to a change in c between conditions, which does not appear to be the case (within each single study). Thus, the present model makes it possible to tease apart changes in overall accuracy and changes in channel capacity—a useful theoretical distinction.

[1]The functions were obtained by first substituting different values of P_R^* and c into Eqs. (8) and (9), assuming $P_L^* = P_R^*$, i. e., no ear difference. (Effects of small to moderate ear differences on the functions are negligible—cf. Repp, 1977.) The resulting graphs of P_D' and P_S' as a function of $P_R^* = P_o^*$ for different values of c (Fig. 4 in Repp, 1977) were then replotted as a function of P_o, using a graph relating P_o to P_o^* (Fig. 2 in Repp, 1977).

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