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Do dichotic listening procedures measure lateralization of information processing or retrieval strategy?

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The data from two dichotic studies, both of which evaluated spontaneously generated response strategies under free recall and one of which also manipulated retrieval strategy by instruction, supported a conception that what dichotic procedures mostly measure are response strategies—mobile and readily deployed without loss of mnemonic capability. Consequently, competitional methods which are heavily influenced by output factors appear to be unreliable as a means of evaluating input processing dominance.

Although the idea that the cerebral hemispheres are differentially specialized has been generally accepted, methods for evaluating dominance remain controversial. A case in point is the use of free recall ear retrieval differences following dichotic stimulation. In numerous research reports, striking incongruities appear between the concept of hemispheric specialization and the supporting evidence obtained with dichotic procedures. First, if the left lobe in the normal right-hander is specialized for processing verbal information (Kimura, 1961, 1964; Milner, 1971), it might be expected that measurements reflecting such specialization would yield robust differences. In actuality, the differences when obtained in the expected direction are rather small, often 2%-6% (e.g., Kimura, 1961, 1964; Knox & Boone, 1970; Spreen & Gaddes, 1969). Second, measured dominance would be expected to be a stable phenomenon. The only study reporting retest reliability (1-month interval) reveals substantial inconsistency (30%) (Pizzamiglio, DePascalis, & Vignati, 1974). Finally, lateral differences have often not been found in well-controlled studies where they were clearly expected (e.g., Bryden, 1963; Inglis & Ankus, 1965; Katzin, Corballis, & Lockhart, 1972; Repp, 1975, 1976; Yates, 1972).

A possible explanation of this pattern of results was suggested by a group of recent studies concerned with the processing of competing inputs (Madsen, Rollins, & Senf, 1970; Rollins, Everson, & Schurman, 1972; Savin, 1967; Schurman, Everson, & Rollins, 1972) in which different stimulus conditions were found to be associated with different spontaneous response biases, but these biases were easily manipulated or reversed by instruction without detriment to mnemonic competence. On this basis, inquiry was made as to whether dominance relationships found in normals with dichotic listening tests might also be a function of mobile and easily reversed response biases, often not under experimental control and hence a major source of unreliability. To answer the question, free recall data from dichotic lists, six pairs long, previously found to yield maximal ear advantages (Bartz, 1968; Bryden, 1967) were reexamined in relationship to retrieval strategy. The results were then reevaluated in a new experiment in which the free recall procedure was first replicated, and response strategy was then manipulated in the same subjects by means of instructions.

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EXPERIMENT 1

Method

Subjects. Twenty right-handed male college students fulfilling a course requirement in introductory psychology served as subjects. They were free of hearing impairment (self report) and naive regarding dichotic procedures or the hypotheses of the study. Handedness was determined by means of a modified version of the Harris questionnaire (Harris, 1958). Each subject gave at least 9 of 10 "right" responses when asked which hand was used in various activities such as writing, holding a fork, etc.

Apparatus. A Concertone Model 2001 stereophonic tape recorder and Koss 2A earphones were used. A dichotic tape was prepared containing 12 trials, each consisting of six pairs of numbers presented at the rate of 2/sec, one of each pair on each stereophonic channel. Stimuli were all consecutive numbers between 1 and 20, except for 7, 11, and 17. The numbers were randomly assigned to trials but not repeated within a trial. Across trials, each number was used at least four times but not more than

five on each channel. Stimuli were paired at random provided they were of equal syllable length. The tape was recorded in a male voice after practice in synchrony with a metronome. The criterion for accepting a recording was the subjective judgment of equality for loudness and simultaneity. Subsequent determination of the degree of synchrony revealed substantial random asynchronies. The data will not be presented partitioned according to these findings because separate tests revealed no relationship to retrieval pattern.

Procedure. The dichotic recall test was one of a battery of brief sensory and information processing tasks whose sequence was varied randomly across subjects. Instructions, recorded on the tape, were to report all the numbers that could be remembered in any order during a 10-sec interval between trials (free recall). Three practice trials were given. Starting position of headphones, which determined which tape channel stimulated which ear, was systematically varied across subjects and was reversed after the sixth trial. Responses were written down in sequence by the experimenter.

Determination of response strategy. Retrieval from each ear for each serial position was determined for each trial for each subject. It was assumed that the sequence of responses on any particular trial (with regard to whether the input was to right or left) *was* the subject's sampling strategy for dealing with competing inputs on that trial. The following strategies were differentiated, and each trial was classified where it first qualified in the following sequence. The small number of errors of repetition and intrusion were disregarded in this experiment.

(1) Right before left (R : L). Recall begins with a number presented to the right ear and all further recall from the right precedes any from the left. Among the sequences included here are RRRR, RLLLLLL, and RRRRRL. (It will be noted that strategy definition does not bias significantly the amount retrieved from each side.)

(2) Right before left-approximate (R * L). Recall begins with a number presented to the right, and what follows meets the criteria of Strategy 1 with one exception. If the single exception were removed, a response sequence fitting Strategy 1 would remain. Among the sequences included here are RRLR (begins R, and either the third or the fourth response alone does not meet criteria for Strategy 1); RRRLLLR (begins R and only the seventh response does not fit Strategy 1); RLRL (begins R and the second or the third response alone does not fit Strategy 1); and RLLR (begins R and only the fourth response does not fit Strategy 1).

(3) Left before right (L : R). The opposite of Strategy 1.

(4) Left before right-approximate (L * R). The opposite of Strategy 2.

(5) Mixed. All other strategies are included here. Since prior classifications encompass all sequences up to four responses and many of five, there is a bias which admits only longer response chains to this category.

Results

Data are presented in Section A in Table 1. When strategies are combined and direct comparisons are possible (column on left), raw data (the number of the stimuli retrieved) are used. When the results for strategies (a post hoc determination whose frequency cannot be controlled) are evaluated, the statistic for the subject was the proportion of the input retrieved when using that strategy (even though there were several instances when the strategy was used only once); and for the group, the mean of the proportions.

When strategies are combined (A, column combined) retrieval from the right is significantly superior to that from the left. The findings accord with a general model of left-hemisphere dominance for verbal information processing (Milner, 1971).

The data for separate strategies (A, Columns 1-5), however, present a different picture. The subjects (all right-handed) most often adopted a response strategy beginning on the right. When they did, they showed a very strong right-ear advantage. When they spontaneously used the opposite strategy, the "dominance" pattern also reversed, although differences in retrieval from the two sides were not significant. That the "dominance" pattern shifted when retrieval strategy changed is supported statistically if the more reliable features of the data are examined. Eight subjects used Strategies 1 and 3 (R : L and L : R) at least twice each. Differences in retrieval from the two sides were significant and *opposite in direction* for the two strategies (Wilcoxon's T in both instances = 1, $p < .01$). When the difference between the differences was evaluated, the direction of the influence of response strategy was identical in all eight subjects ($p < .01$), increasing retrieval from the side to which response was made first. On the other hand, there was no relationship between response strategy and total retrieval (R + L). Strategies 2 and 4 (the approximate strategies) yielded findings similar to the "parent" strategies, although in somewhat attenuated form.

Discussion

The results support the inference that what is measured by dichotic tests has to do with the way the subject responds to the challenge of competing inputs. Thus, response biases and output processes exert powerful influences even though there is evidence (asymmetry in retrieval differences with different strategies and predominance of right-first strategies) for input lateralization. The asymmetry found with spontaneous strategies under free recall conditions should persist with directed strategies if input factors are significant. This was evaluated in another experiment where the subjects were given both free and directed recall.

EXPERIMENT 2

Method

Subjects. Thirty-two subjects met the same criteria as in Experiment 1, except that 15 were postgraduate and 8 were advanced undergraduate volunteers.

Procedure. Using the same apparatus and tape recording, all subjects were first administered the free recall procedure used in Experiment 1. The same stimuli were then readministered under one of four directed recall conditions to which the subjects were randomly assigned in groups of eight. These were: Group 1—free recall control, repetition of the same instructions; Group 2—right first, instructions to recall stimuli presented to the right ear before the left; Group 3—left first, instructions to recall stimuli presented to the left ear before the right; Group 4—alternate, instructions to alternate between ears. Actual results were analyzed as in Experiment 1.

Table 1
Mean Recall From Each Ear of Dichotically Presented Numbers When Using Different Retrieval Strategies and With Retrieval Strategies Combined

	Retrieval Strategy					
	Combined	1. R:L	2. R*L	3. L:R	4. L*R	5. Mixed
A. Experiment 1						
Percent Trials	100	33.7	18.3	14.2	12.1	21.7
Number of Subjects	20	19 (18)	17 (16)	17 (16)	13 (11)	18 (14)
Mean Retrieval L	23.6	13.8	25.8	49.7	56.0	46.1
Mean Retrieval R	43.6	72.4	70.5	37.2	39.6	53.0
Wilcoxon's T	11	1	0	39	17.5	26.5
p	< .01	< .01	< .01	n.s.	n.s.	n.s.
B. Experiment 2: Free Recall						
Percent Trials	100	22.7	25.5	19.3	17.2	15.4
Number of Subjects	32	25	31 (28)	29 (27)	27 (20)	24 (21)
Mean Retrieval L	27.8	15.8	29.4	47.4	51.4	48.7
Mean Retrieval R	38.5	66.8	59.0	38.1	40.4	56.5
Wilcoxon's T	99.5	0	15	139	50.5	54
p	< .01	< .01	< .01	n.s.	< .05	< .05
Error/Number Retrieved	.067	.079	.097	.076	.048	.026
C. 2d Free Recall						
Percent Trials	100	25.0	24.0	11.5	20.8	18.7
Number of Subjects	8	7	8 (7)	7	8 (7)	6 (2)
Mean Retrieval L	29.1	25.0	34.2	41.6	55.6	50.8
Mean Retrieval R	36.6	56.9	62.1	40.6	34.9	50.8
Wilcoxon's T	6	3	0	9	3	1
p	n.s.	n.s.	< .02	n.s.	n.s.	n.s.
Error/Number Retrieved	.127	.145	.092	.179	.189	.069
D. Right First						
Percent Trials	100	56.3	30.2	2.1	6.3	5.2
Number of Subjects	8 (7)	8	8	2	3	4
Mean Retrieval L	12.4	6.5	29.3			
Mean Retrieval R	53.5	81.9	70.9			
Wilcoxon's T	0	0	0			
p	< .01	< .01	< .01			
Error/Number Retrieved	.070	.062	.060	.30	.133	.067
E. Left First						
Percent Trials	100	1.00	1.0	68.8	24.0	5.2
Number of Subjects	8	1	1	8	8	4
Mean Retrieval L	55.1			80.0	72.1	
Mean Retrieval R	11.4			12.5	22.5	
Wilcoxon's T	0			0	0	
p	< .01			< .01	< .01	
Error/Number Retrieved	.066	.20	.50	.053	.068	.129
F. Alternate						
Percent Trials	100	19.8	28.1	10.4	24.0	17.7
Number of Subjects	8	8	7 (5)	4	8 (5)	7
Mean Retrieval L	25.6	25.8	29.9		40.3	50.9
Mean Retrieval R	29.5	43.1	44.9		33.8	44.1
Wilcoxon's T	8.5	9	0		4	3
p	n.s.	n.s.	?		n.s.	n.s.
Error/Number Retrieved	.077	.083	.076	.109	.078	.060

Note—For details see Results (Experiment 1) and for definition of retrieval strategy see Procedure (Experiment 1). R = right, L = left. Numbers in parentheses designate the number of subjects whose R and L scores were not tied, the N for Wilcoxon's test.

Results

Results are presented in Table 1. Under free-recall conditions (B), the earlier findings are generally replicated. Again, the dominance patterns reverse when left-first strategies are employed (Strategies 3 and 4), and this time the difference between sides is significant with Strategy 4. On the other hand, the small difference favoring the right with mixed strategies (Strategy 5) is consistent enough across subjects to attain significance. Fourteen of 32 subjects used Strategies 1 and 3 at least twice. Of these, none retrieved more from the left when using Strategy 1, but six retrieved more from the right when using Strategy 3. In this instance, differences in retrieval from each side with Strategy 3 fell short of significance, but the difference between the differ-

ences found with the two strategies was again significant ($p < .01$), since in only two subjects did the pattern of response differences not vary in the direction of the retrieval strategy. When free recall is repeated (C), the results have the same configuration as the first time, but the differences are attenuated and unreliable and even Strategy 1 differences are insignificant.

With directed strategies, dominance differences were significantly related to response strategy. In the groups instructed to retrieve from one side before the other (D and E), total retrieval did not vary significantly from what the same subjects had accomplished earlier under conditions of free recall and nor did the opposing instructions lead to any significant differences in total recall. The results were tested by means of analysis of variance, with the four recall conditions as between measures and the two phases (free and directed) as within. The within measure and the interaction of phases and conditions were significant ($F = 4.78$, df 1,28, $p < .05$; and $F = 2.98$, df 3,28, $p < .05$). The means are presented in Table 2. Evaluation of the differences between the means (Duncan's new multiple range test) indicated that all the significant differences were attributable only to the drop in scores of the group instructed to alternate, a strategy probably never used spontaneously. The main finding, therefore, is that total retrieval does not change if the left ear is attended to first.

Dominance relationships were directly and significantly related to response strategy instruction. There was no differential advantage to the "dominant" side in either pattern of directed recall ($\overline{X}$% advantage on right with Strategy 1 in Group D = 68.5; $\overline{X}$% advantage on left with Strategy 3 in Group E = 75.38; $t_{diff} = 0.835$, $p = .43$). On the other hand, for the group directed to alternate (Group F), no findings of significant advantage appeared on either side no matter which strategy was actually used. Finally, approximate strategies (2 and 4) again yielded similar, if attenuated, patterns in comparison to their "parent" strategies.

Table 2
Mean Total Retrieval for Each Phase of Experiment 2

Type Directed Recall	Free Recall	Directed Recall
Free	68.8%	65.8%
Right First	67.1%	65.9%
Left First	64.8%	66.5%
Alternate	64.2%	55.1%

DISCUSSION

The evidence is that there is a strong influence of response strategy in dichotic tasks. Shifts in response strategy were associated with shifts in "dominance" relationships. Such changes occurred in the same direction and with no loss of total recall both with free recall and under directive instruction, but there were differences in pattern under the two conditions. Instructed response strategies (other than to alternate) were associated with equivalent retrieval patterns; "dominance" on the left with left-first strategy was as great as "dominance" on the right with right-first strategy. Response strategies appearing under free recall conditions were associated with asymmetric retrieval patterns, "dominance" on the right being greater on the right with right-first strategy than on the left with left-first strategy.

The issues of concern in this report are not new. The controversy in the earlier literature was whether evidence for hemispheric dominance existed or was an artifact of order of report, defined largely as the ear reported first. The issue appeared settled by a scholarly and influential review by Bryden (1967). He mustered the evidence supporting a perceptual specialization effect. Perhaps because of the thrust of his concern, he did not emphasize what his data clearly display—that with the dichotic method the magnitude of the order effect is much larger than that attributable to lateral differences. Using Bryden's data, it is entirely obvious that a determination of "dominance" based on ear differences will yield a strong left-ear advantage if left-ear input is reported first and the converse if right-ear input is reported first. He also found that when ear differences were compared under both starting conditions, an inference as to the direction of dominance could be drawn that was independent of response bias. However, these differences were much attenuated, and consequently potentially less reliable. As cited in the introduction, in later work they often do not appear at all.

The evidence in the present study and in much earlier work is clear. If subjects are assigned to brain dominance categories on the basis of a right- minus left-ear retrieval score, the determination is largely at the whim of the ear to which response is first made and the explicitness of the response bias. Although there is recurrent evidence for a right-ear bias in attention with verbal materials, it has also generally been found that total retrieval does not vary with the response option exercised.

The most parsimonious way to reconcile the available evidence about *dichotic* dominance is to conceptualize it as occurring largely in output, in a mobile selecting and attending system. Such a concept is consistent with the revisions in input dominance theory recently approached in two reviews on hemispheric relationships (Marshall, 1973; Milner, 1971) and supports the research and theory propounded by Kinsbourne (1974). It is also consistent with evidence which indicates that lateral differences in evoked potentials found when processing verbal materials (McAdam & Whitaker, 1971; Morrell &

Salamy, 1971) are artifacts of glossokinetic potentials, a by-product of effector mechanisms (Grabow & Elliott, 1974). Finally, it accords with a subtle shift in terminology in the hemispheric specialization literature. Earlier reports tended to use words like "perception," "listening," and "detection" (e.g., Bryden, 1963; Kimura, 1961, 1964; Satz, Achenbach, Pattishall, & Fennell, 1965), implying lateralization of input and decoding processes. Later reports have tended to use terms like "speech" (e.g., Satz, Achenbach & Fennell, 1967; Springer, 1973), implying output and encoding processes.

All competitional methods may be unreliable means for the evaluation of input specialization (e.g., Bryden, 1976). It is much more certain that simple dichotic methods are unreliable for this purpose.

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