Effects of modality categorization on unimodal and intermodal sequential information processing in normals and retardates*

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Varying length sequences of pulses were presented to a single modality, alternated between two modalities, and alternated among three modalities in adolescent educable retardates, equal mental-age normals, and equal chronological age normals. Ss reported the number of pulses in each modality. Errors increased significantly in the order $R > MA > CA$, with increasing numerosities, and from the unimodal to the multimodal conditions. Compared to an earlier study, in which Ss reported the total number of stimuli in sequences identical to those employed here, all groups made significantly smaller errors under the two multimodal conditions, and error reduction was predominantly in the magnitude of underestimations. It was concluded that instructions to report pulses in each modality reduced depth of attention to individual stimuli, thereby decreasing switching time from one modality to another.

When brief pulses are alternated repetitively between two or three modalities, their perceived number is less than when pulses are presented at the same rate within a single modality (Holden, 1970). If, as these findings suggest, processing time is lost in shifting attention from one modality to another, any parameter which decreases this shifting time should reduce the underestimation errors associated with intermodal sequences. Broadbent & Gregory (1961), for example, have reported the effects of differential instructions on the recall of digits alternated between the eye and ear. When Ss were instructed to recall all digits in one modality and then those in the other, they recalled significantly more than when they were instructed to recall the digits in the order of their occurrence.

The purpose of this study (Study II) was to investigate modality callout instructions as a parameter for decreasing intermodal shifting time in normals and retardates. It was a basic premise that switching rate and depth of attention are inversely related and that in the previous study (Study I), Ss were allocating an unnecessary quantity of attention to each stimulus presentation. Consequently, it was hypothesized that by instructing Ss to report the number of stimuli in each modality, vis-à-vis the total number of stimuli as in Study I, attention would be more equitably distributed and there would be a reduction in the time required to switch from one modality

to another. On the other hand, these instructions were not expected to have any effect under the unimodal condition compared to Study I. Predictions with respect to differences between the two multimodal conditions were conjectural, since there are two conflicting sources of evidence to be considered. (1) In Study I, there were no differences between the bimodal and the trimodal conditions, but (2) Monty & Taub (1965) have reported that when Ss had to report the number of occurrences of each of several symbols, errors increased as the number of categories increased from two to four.

The relative effects of modality callout instructions in normals and retardates should depend upon the extent to which these groups utilized organization or switching-reducing strategies under the total numerosity report condition in Study I. Although retardates have a basic counting rate deficiency, as implied by their greater errors with unimodal sequential stimulation (Holden, 1970; Thor, 1971; Thor & Holden, 1969), there is evidence to suggest that they would benefit relatively more than normals under the bimodal and trimodal single alternation conditions in the present study (Holden, 1971).

SUBJECTS

The Ss were 30 educable retardates (18 boys, 12 girls; $\bar{CA} = 16.2$, $SD = 1.9$; $\bar{IQ} = 64.5$, $SD = 6.2$) in residence at the Edward R. Johnstone Training and Research Center, 30 equal-MA normals (16 boys, 14 girls; $\bar{CA} = 10.4$, $SD = 0.9$; $\bar{IQ} = 107.8$, $SD = 9.8$) from a neighboring elementary school, and 30 equal-CA normals (14 boys and 16 girls; $\bar{CA} = 16.1$, $SD = 0.9$; $\bar{IQ} = 108.6$,

$SD = 13.5$) from two neighboring high schools. None of the Ss had participated in Study I.

APPARATUS AND STIMULI

Essentials of the apparatus and stimuli are described in Study I. The task required S to report the number of light, sound, and vibrotactile stimuli presented successively in sequences varying from 3 to 10. All stimuli were .05-sec pulses delivered at a constant rate of 2.2 pps ($ISI = .40$ sec). Each of these eight numerosities was administered in combination with three different modality conditions. Two different combinations of each Numerosity by Modality condition were presented, and these were randomized within two blocks of 24 trials so that each numerosity and modality condition occurred an equal number of times in both blocks. The combinations of numerosities and modality conditions for all 48 trials are presented in Table 1. These combinations are identical to corresponding trials in Study I. The trimodal double alternation condition from that study was not theoretically essential for present purposes and so was omitted to meet time limitations of the experimental session.

PROCEDURE

The Ss were tested individually in sessions requiring approximately 25 min. Except for explicit instructions to report the number of each kind of stimulus present in the sequences (vis-à-vis total numerosity), the experimental procedure may be considered identical to that in Study I. The Ss were instructed to guess whenever they were not sure of their answers, and they were never told whether their specific responses were correct or incorrect. As a warning signal, each sequence was automatically preceded 1 sec by extinction of the testing-cubicle ceiling light, which reappeared approximately 1 sec later. Intertrial interval varied between 5 and 10 sec. Half of the Ss in each group received Trial Block 1 followed by Block 2, the remaining Ss receiving these blocks in reverse order.

RESULTS

For each numerosity sequence, S's error score was derived by summing the absolute differences between the number of stimuli presented in each modality and the number reported in each modality. For example, if three visual and three auditory stimuli were presented and S reported two visual and four auditory, the error magnitude score for that sequence would be a total of two.

Total error magnitude per numerosity for each S group under the three modality conditions are presented in Table 2. A three-factor repeated-measures variance analysis of

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Table 1
Numerosity × Modality Condition for the 48 Stimulus Sequences

Num- erosity	Unimodal (U)		Bimodal Single Alternation (BS)		Trimodal Single Alternation (TS)	
	1	2	1	2	1	2
3	VVV or*	VVV or*	VTV	AVA	AVT	VTA
4	AAAA	TTTT	TATA	ATAT	TAVT	ATVA
5	VVVVV	TTTTT	VTVTV	TVT VT	ATVAT	TAVTA
6	AAAAAA	VVVVVV	AVAVAV	VTVTVT	TVATVA	ATVATV
7	TTTTTT	AAAAAAA	VAVAVAV	AVAVAVA	VTAVTAV	TVATVAT
8	VVVVVVV	TTTTTTTT	TATATATA	VAVAVAVA	VTAVTAVT	AVTAVTAV
9	AAAAAAA	VVVVVVVV	ATATATATA	TATATATAT	AVTAVTAVT	VATVATVAT
10	TTTTTTTTT	AAAAAAA	TVT VTVTVT	ATATATATAT	TAVTAVTAVT	VATVATVATV

*When the last trial block, then 1/3 VVV, 1/3 AAA, and 1/3 TTT V = visual A = auditory T = tactile

Table 2
Total Error Magnitudes

Num- erosity	Equal CA Normals			Equal MA Normals			Retardates		
	Uni- modal	Bimodal Single	Trimodal Single	Uni- modal	Bimodal Single	Trimodal Single	Uni- modal	Bimodal Single	Trimodal Single
3	2	4	2	10	20	4	16	37	18
4	4	2	13	10	13	40	26	23	59
5	6	12	11	16	29	40	22	59	67
6	4	10	9	14	34	35	39	54	69
7	3	16	26	12	48	40	44	70	103
8	5	9	36	8	26	44	47	77	100
9	7	40	15	3	62	31	40	109	113
10	5	27	38	7	67	75	57	108	129

these scores demonstrated significant group [$F(2,87) = 56.79, p < .001$], modality condition [$F(2,174) = 52.30, p < .001$], and numerosity [$F(7,609) = 44.10, p < .001$] effects and significant Group by Modality Condition [$F(4,174) = 5.12, p < .001$], Group by Numerosity [$F(14,609) = 7.91, p < .001$], and Modality Condition by Numerosity [$F(14,1218) = 9.66, p < .001$] interactions. The triple interaction was not significant. Duncan multiple-range tests of group differences at each modality condition were all significant ($p < .01$ or better), except for that between the equal-MA and equal-CA groups under the unimodal condition. Within-group comparisons between modality conditions showed a highly significant increase in error magnitude from the unimodal to the bimodal single alternation condition for all groups ($p < .001$). Only in the retardate group was there a significant difference between the bimodal single and trimodal single alternation conditions ($p < .05$).

Mean error magnitudes subclassified with respect to direction of error, i.e., greater than or less than the correct numerosity, for each Group by Modality condition are depicted in Fig. 1. Also plotted are corresponding data from Study I. The magnitudes of over and under errors for each group at each modality condition in the present study were compared by *t* tests for correlated means. Unlike Study I, where all groups demonstrated more underestimations than overestimations under the bimodal single and trimodal

single alternation conditions, the only significant statistic among these comparisons was a greater magnitude of errors in the negative direction for retardates under the bimodal single alternation condition ($p < .005$).

The differential effects of instructions to report the number of stimuli in each modality, vis-à-vis instructions to report total numerosity in each sequence, were determined by *t* comparisons of error magnitudes in the present study with corresponding error magnitudes in Study I. Under the unimodal condition, there were no significant differences, but under the bimodal and trimodal conditions, all groups made significantly smaller errors ($p < .05$ or better) in the present study. All of these differences, except that for the equal-MA group under the bimodal condition ($p < .06$), can be explained by significant decreases ($p < .01$) in the size of underestimations.

Finally, to compare group error differences between Study I and Study II under the two multimodal conditions, each S's error score in Study II was subtracted from the corresponding group mean in Study I. Comparisons of these differences with *t* tests for independent means demonstrated a significantly greater difference for retardates compared to the equal-CA normals under the bimodal condition ($p < .002$). No other comparisons were significant.

Three important changes differentiate these results from those in Study I: (1) In all groups, there were significantly smaller errors under

the bimodal and trimodal single alternation conditions. (2) With one exception, underestimations did not significantly exceed overestimations. (3) Retardates demonstrated a significant increase in error magnitude from the bimodal to the trimodal single alternation conditions. However, several other findings in the present study replicate relationships obtained between error magnitude and experimental parameters in Study I: (1) Error magnitude increased as a function of increasing numerosity, for the retardate group under the unimodal condition and for all groups under the two multimodal conditions. (2) Error magnitude increased significantly from the unimodal to the bimodal single alternation condition for all groups. (3) In the equal-CA and equal-MA groups, there were no significant differences between the bimodal single and trimodal single alternation conditions. (4) Error magnitude increased in the order of equal-CA, equal-MA, and retardate groups for all modality conditions except the unimodal, where the equal-CA and equal-MA groups did not differ from each other.

DISCUSSION

The smaller error magnitudes in Study II compared to Study I for all groups under the two multimodal sequence conditions provide affirmative support for the notion that modality callout instructions facilitate processing of simple stimuli presented sequentially to two and three modalities. The most parsimonious interpretation of these results appears

Fig. 1. Mean magnitudes of underestimations and overestimations for the unimodal (U), bimodal single alternation (BS), and trimodal single alternation (TS) conditions in the three S groups. Also shown (open circles) are corresponding data from Study I (Holden, 1970).

to be that modality callout instructions effect a more equitable distribution of attention among the three modalities, thereby decreasing investiture in individual stimuli and, consequently, increasing the rate with which attention shifts from one modality to another.

Although Monty & Taub (1965) have shown that when normal adults had to report the number of occurrences of different symbols, errors increased with the number of categories, there is no evidence that this should occur with multimodal categorization. Failure to find

differences between the bimodal single and trimodal single alternation conditions for the two normal groups in the present study suggests that increasing the number of intermodal categorizations does not present the same difficulty as increasing categories within a single modality. This is consistent with the results of a study (Monty, 1968) which demonstrated that different regular spatial locations for different categories in the same modality decreased errors compared to when the different categories appeared in the same location or when they were randomized among different

spatial locations. If the different modality conditions in the present study are considered to be different spatial locations (and they are, both anatomically and perceptually), then there is even more reason to accept the validity of the beneficial effects of modality callout. For the retardate group, increased errors from the bimodal to trimodal conditions in the present study suggests an additional processing load imposed by storing in three, as opposed to two, modalities.

In this study, as in Study I, retardates are characterized by a larger under- to overestimation ratio compared to the two normal groups, confirming previous findings that their deficiency obtains from information losses concomitant with slower processing rates. However, the significantly greater improvement for retardates compared to the equal-CA normals from Study I to the present study under the bimodal condition suggests that callout instructions maximized a strategy spontaneously utilized to a greater extent by the normals. Failure to find a similar difference under the trimodal condition may reflect the additional processing load presumably imposed by three-modality storage.

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