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ABSTRACT

Verbal recall of bisensory memory tasks was compared among 48 9- to 12-year old boys in three groups: normal readers, primary deficit readers, and secondary deficit readers. Auditory and visual stimulus pairs composed of digits, which incorporated variations of intersensory and intrasensory conditions were administered to Ss through a Bell and Howell Language Master. Continuous monitoring of heart rate and Galvanic Skin Response was performed, and reading error types were analyzed. Results supported the validity of the reading classification system of R. Rabinovitch for differentiating groups of deficient readers. Recall performance was found to differ for visual information processing and sequential recall, with more errors for both observed in the secondary reading group. Findings were consistent with a hypothetical model based on attentional and cognitive factors important for visual and auditory processing in reading. (Author/CL)

Verbal Recall of Auditory and Visual Signals by Normal and Deficient Reading Children

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Learning to read requires the processing of information through auditory and visual channels. Consequently, the understanding of intrasensory and intersensory modality integration is important if reading deficits are to be ameliorated.

A number of researchers have studied intrasensory and intersensory relationships in normal groups (Connolly and Jones, 1970; Rasof, 1968; Nelson, 1970; Majaron 1970; Reudel and Tueber, 1964; Hancock, Moore and Smith, 1969). Although the focus of these studies differ, they provide data that confirm the observations of Pick, Pick and Klein (1967), and Blank and Bridger (1964). According to these authors, intersensory discrimination is inferior to that found for intrasensory stimuli. The findings related to the dominance of one sense modality over the other are unclear. Generally, the data supports a more efficient visual mechanism.

Studies of sensory integration in deficient reading children report findings which support the view that reading deficit is associated with a less efficient ability to integrate sensory information from auditory and visual channels (Birch, 1964; Berry, 1967; Ford, 1964; Shipley and Jones 1969; Senf and Freundl, 1971). Interpretation of the findings from the studies in this area are diverse. These include the following: failure of dominant visual system; dominance of auditory over visual modality; and deficient ability to reject auditory distraction with the presentation of visual stimuli.

In a series of experiments reported by Senf and Freundl (1971), bisensory memory tasks with stimuli consisting of single digits presented auditorially or visually in sequence were used with a sample of learning disabled children and a matched group of normal readers.

Two recall tasks were used, one in which subjects were required to recall the stimuli pairwise (DP) in the order presented and one in which the subjects were to recall linearly the three visual digits followed by the three auditory ones (DM). The recall responses were scored for order errors, i.e., correct digits in a wrong serial order and for gross errors, i.e., digits were omitted or erroneous ones substituted.

Differences in the gross error and the order error scores for visual recall on DP tasks were not found between the groups. However, more errors (both gross and order) were found for the learning disabled group than for the control group on paired auditory recall. Greater errors (both order and gross) were found on the linear tasks in visual and auditory recall for the learning disabled than for the control group. Senf and Freundl (1971) interpreted the differences on the linear visual recall and lack of difference on the paired visual recall between the groups to support a hypothesis that deficient reading children may have a greater auditory dominance over the visual modality than do normal readers.

The approach described by Senf and his associates to study sensory integration capabilities using a non-mechanistic model of stimuli masking and higher order cognitive factors appears to provide a worthwhile approach to the problem. Separation of the masking process from that of distraction may prove to be arbitrary and not realizable experimentally. Therefore, these two factors were included as part of a more generalized attentional capability in the experimental design used in the present study of sensory integration in deficient readers.

Physiological methods were used here to measure the attentional factors associated with sensory input since they provide an independent estimate of the attentional parameter.

In most of the studies of sensory integration in deficient reading children reviewed (Birch, et al, 1964; Ford, 1964; Berry, 1967; Senf and Freundl, 1971), an intrasensory comparative base and a classification scheme for deficient reading groups were not included. Furthermore, in most of these studies, alteration of the modality in the recall tasks was not adequately controlled. The experimental design of the present study incorporated these additional features.

METHOD

Subjects

The subjects were forty-eight males with a mean age of eleven years (range 9 to 13 years) and a mean IQ of 112 (range 90 to 135 IQ). Of thr total sample, sixteen children who were reading at grade level or above composed the control group of normal readers (NR). The remaining thirty-two children had a reading level of one or more years below expected grade level for age and IQ (mean reading lag = 3.0 grades). Of these, sixteen met the criteria for primary readers deficit group (PRD) and sixteen met the criteria for secondary deficit readers (SRD). Statistical summary of ages and IQ of reading classification groups is shown in Table 1.

Insert Table 1 here

Classification of Reading Deficit Groups

The classification categories proposed and defined by Rabinovitch (1954) and extended by Fuller (1969) using the Minnesota Percepto-Diagnostic Test were used in this study. Children classified as having organic reading deficits were eliminated from the study leaving only primary and secondary categories as subject to investigation.

Experimental Conditions

Auditory and visual stimulus pairs composed of digits, which incorporated variations of intersensory and intrasensory conditions were administered by means of a Bell and Howell Language Master. The same digits were not paired and the presentation was balanced using a Latin square design.

Eight experimental tasks (four intersensory and four intrasensory) which required paired and serial verbal recall with an alteration of the first recalled modality (auditory or visual) were used. Ten trials of each of the eight experimental conditions were given. Each trial was divided into three, six-second periods, preperiod, stimulus presentation and recall. On each trial, three pairs of stimuli were presented two seconds apart during the stimulus period. Continuous monitoring of cardiac activity and GSR responsivity was recorded on an E & M physiograph during the entire experiment. Physiological methodology is described in detail elsewhere (Levine, 1975).

Quantification of Recall Errors

For the intrasensory tasks, the independent variables represent the three error types, gross, order and interchange. Gross errors were scored for omission of the correct digits or substitution by other digits. Order errors were scored for digits properly recalled but out of sequence. Therefore, only correct digits were scored for order errors. Interchange errors were counted for pairs of digits properly recalled in which an inversion occurred, i.e., in a VA pair, the auditory digit was recalled as a visual digit. The measure of dependent variable is the mean of errors during recall for ten trials for each task for each subject. Similar measures are used for the intersensory errors except that there are five independent error types: gross auditory, gross visual, order auditory, order visual and interchange.

Results and Discussion

Expected differences in heart rate among the reading classification groups was not supported by the measurements of mean heart rate. The measure employed, an averaged heart rate over ten trials, was not sensitive to heart rate changes on each trial resulting in a masking of the differences among subjects which were observed with the heart rate deceleration measure.

For the total sample, as shown in Figure 1, higher heart rate means in preperiod and stimulus period were found for intersensory than for intrasensory conditions. These results were in a direction opposite to that which would have been expected. Since the intersensory conditions used stimuli from two modalities (auditory and visual) greater attentional effort with a concomitant heart rate deceleration would have been expected. The observed finding may be due to a higher anticipatory stress for intersensory tasks which resulted in a higher mean heart rate in preperiod and stimulus periods.

Insert Figure 1 here

A decrease in mean heart rate occurred in the recall period for the intersensory tasks 1, 2, and 3 (Figure 1). No significant change in mean heart rate was found for the tasks 4, 7, and 8. The latter two were solely auditory tasks and task 4 was a linear intersensory one in which the auditory is recalled first. The direction of mean heart rate change for the intrasensory visual tasks, 5 and 6, differed from those of the intersensory and intrasensory auditory tasks since there was a mean heart rate decrease in stimulus period followed by an increase in recall period.

Lewis and Wilson (1970) have proposed that "cardiac responsivity is influenced by at least three factors: (1) the intent of S (i.e., his taking in or rejecting external stimulation); (2) S's state (i.e., his capacity in terms of general IQ and personality variables such as achievement needs); and (3) the objective environmental situation (i.e., the difficulty of the task)." The results of the present study would support the suggestion that the perceived level of difficulty of the task by the subject (mental set) mediated the level of mean heart rate and the direction of change in mean heart rate across periods. The mean heart rate data indicated that the instructions in the intersensory tasks produced anticipatory stress; instructions requiring the auditory response first, or solely auditory response resulted in no significant cardiac change; whereas instructions requiring visual responses produced decreases in mean heart rate during the stimulus period and may be a modality specific response.

Porges et al (Porges, 1972; Porges and Raskin, 1969; Porges, Arnold and Forbes, 1973) have shown that heart rate variability is related to attention. Uniformly, it was found in these studies that a decrease in mean heart rate variability accompanied an increase in attention. These findings have been replicated in the present study.

The results indicate that the normal reading group had a greater capacity for the adjustment of attentivity levels than did the deficit reading groups. This conclusion was supported by the data shown in Figure 2, where greater plasticity in heart rate variability for the eight experimental conditions was found for the normal reading group than for the reading deficit groups.

Insert Figure 2 here

The mean heart rate variability of the primary reading deficit group was lower than that of the normal readers group on each of the eight tasks. These results have a $p < .01$ level of occurring by chance (Wilcoxon Matched-Pairs Test, two tailed, $n = 8$, $n+ = 0$, Siegel, 1956, p. 75). Only for task 3 did the mean heart rate variability of the primary reading deficit group exceed that of the secondary reading deficit group. The lower heart rate variabilities found in the primary reading deficit group compared to the secondary reading deficit group on each of the remaining seven tasks were better than random, $p < .02$ (Wilcoxon Matched-Pairs Test, two tailed, $n = 8$, $n+ = 1$, Siegel, 1956, p. 75).

For the intersensory data an analysis of heart rate variability for reading classification groups indicated that in the secondary reading deficit group heart rate variability decreased between preperiod and stimulus period and then increased in recall period. An increase in heart rate variability occurred in the recall period over the stimulus period for the normal reading group, whereas the heart rate variability of the primary reading deficit group remained stable across the periods.

A conservative criterion for heart rate deceleration was used in which the lowest beat in the preperiod on each trial was taken as a base and compared to lowest beat in the succeeding periods (stimulus and recall). Significant (based on an ANOVA) heart rate deceleration was observed only for the normal reading group. The heart rate deceleration results for the normal reading groups support the reported findings in the literature that a heart rate decrease is associated with increased attention (Lacey, 1959; Kagan & Lacey, Moss, 1962; Graham & Clifton, 1966).

For the eight tasks and two periods an analysis of the frequency of heart rate deceleration without regard to magnitude found that the heart rate in the normal reading group decelerated (Sign test $p < .02$) for the combined stimulus and recall periods in accord with the ANOVA results. The heart rate in the primary reading deficit group did not decelerate according to the frequency analysis. However, the heart rate in the secondary reading deficit group did decelerate in recall (Sign test $p < .03$).

The heart rate deceleration data provides evidence of defective attentional mechanisms in the deficit reading groups. The magnitude and frequency of heart rate deceleration also differs for the three reading groups. Greater magnitude and more frequent occurrences of heart rate deceleration occurred in stimulus and recall periods for the normal reading groups ($n = 11$). Fewer heart rate decelerations were observed for the primary reading deficit group in both periods ($n = 5$). Although the magnitude of change was too low to be significant in the secondary reading deficit group, the frequency of occurrence ($n = 7$) was high in the recall period. The analysis of occurrence of heart rate deceleration was carried out in order to elucidate whether the pattern of cardiac activity differs in the reading groups or if differences that were observed by the ANOVA are attributed solely to differences in the level of magnitude.

These results indicate that both the magnitude and the frequency of occurrences of heart rate deceleration are attributes of the differences in attentional mechanism found among the reading classification groups.

The capacity of the normal reading group to adjust levels of physiological activity was also observed in the finding of greater GSR responsivity for intrasensory, auditory tasks than for the intrasensory, visual ones. Similar adjustment capability was not indicated for the deficit reading groups.

As expected, the level of recall errors was related to the reading classification groups. As shown in Figure 4, the mean total errors for the secondary deficit reader group exceeded those of the normal readers and primary deficit readers group and the mean errors of the primary deficit readers group exceeded those of the normal readers. These results support the validity of the reading classification system (Rabinovitch, 1954) for differentiating groups of deficit readers.

Insert Figure 4 here

The interchange (reversal of pairs of digits) error type was usually low and did not differ for reading classification groups. Analysis of Task X Error Type interaction showed that only in the intrasensory, visual, linear task 5 were order errors less than gross errors. For the remaining tasks no significant differences were found between gross and order means.

Comparison of intersensory and intrasensory conditions for mean, gross and order errors showed that more errors of both types occurred in intrasensory conditions than in the intersensory ones for the total sample. These results contradict the frequently reported findings in the literature.

Although linear tasks are inherently more difficult, as shown by the intrasensory results, a higher level of confounding occurs for intersensory pairing tasks which is sufficient to cause more errors than for the corresponding linear, intersensory tasks. Figures 5 and 6 show that these results which are found for the total sample holds for the gross and order error types observed in normal reading and primary reading groups and for gross error type in secondary reading group. However, for the latter, the intersensory and intrasensory, order errors on the pairing tasks are the same. The order errors reflect a capacity to use cues to process a sequential memory task. For the pairing tasks, Figure 5, the secondary reading deficit group made fewer intrasensory than intersensory gross errors indicating modality confounding, but made the same amount of order errors in both intersensory and intrasensory experimental conditions.

Insert Figure 5 here

These results indicate that compared to the other reading groups the secondary reading deficit group has a poorer ability for memory sequencing. This conclusion is also supported in Figure 6 where the secondary reading deficit group made the same number of gross and order errors for linear, intrasensory tasks, whereas, the other groups made fewer order than gross errors.

Insert Figure 6 here

One of the factors cited by Senf [redacted] 1971) as possible basis for reading deficits was auditory dominance which they defined as, "(1) the preference for, or (2) the disrupting effect of auditory stimulation on recall of visual material when the auditory stimuli also must be recalled." Senf and Freundl postulated the auditory dominance hypothesis based on a preference exhibited by the learning disabled subjects of their study for this modality and differences in errors on auditory and visual recall between the groups of normal and deficit readers. The results obtained in the present study argue against an auditory dominance hypothesis. Vandervoort and Senf (1973) in a review and report of more recent intersensory studies which included spatial, temporal as well as auditory spatial parameters concluded that auditory dominance and auditory-visual integration are not substantiated as the primary factors involved in reading deficits.

For the total sample, Intersensory Task X Error Type data, shown in Table 2, the gross visual errors exceeded the gross auditory errors.

Insert Table 2 here

In task 1, where the recall of visual stimuli is first in the paired response, order errors in the auditory modality exceed those found in the visual and implies that the visual mode is "dominant" and affects the auditory recall. The results on task 2, which has the auditory response first, support this view since order errors in auditory recall do not significantly exceed those in the visual. This finding is supported in a study of learning disabled children by Estes and Huizinga, 1974. Using a paired association learning task they found that a shift from visual to auditory presentation of the same tasks produced an interference effect not observed when shifting from auditory to visual presentation. For the linear responses, tasks 3 and 4, shown in Figure 7, any "dominance" effects are blanked by the obvious results in which fewer errors are made in the modality where the first responses are required.

For the normal reading group, the Task X Error Type did not exhibit interaction significance. Greater auditory errors did not occur for task 1, indicating that for the normal reading group the confounding of the auditory modality by the visual was not observed. However, the generalized effect for the linear responses in which the errors are less for the tasks in the modality recalled first is found. This interpretation is supported by the results for task 4, (gross auditory $<$ order visual and gross visual; gross visual $>$ order auditory; order auditory $<$ order visual). The mean of the four highest values in task 3 and 4 is compared with that of the four lowest, (t = 3.56, df = 5[illegible], $p < .005$) and supports the view that in linear tasks less errors are made in the first recalled modality.

The findings that poor readers confound stimuli in two modalities to a greater extent than normal readers is supported. However, the evidence of this study indicates a "primacy effect" for the modality recalled first in experimental conditions which alternate the instructions. However, overall visual processing "dominate" over the

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Insert Figure 7 here

The analysis of reading classification across error type, shown in Figure 8, indicates that the normal reading group make fewer errors than both reading deficit groups across all error types. However, for the visual (ET4) and auditory order errors (ET3) differences were not observed between the normal reading and the primary reading groups. From these results it appears that the primary deficit reading group and the normal reading groups have a more efficient processing of visual information than the secondary reading deficit group.

Insert Figure 8 here

The inference based on the physiological measures (Levine, 1975) that the normal reading group has greater controlled attentivity than the deficient readers is supported by lack of Task X Error Type interaction for this group, whereas significant interactions are found for both reading deficient groups. Apparently, the normal reading group appears better able to adjust attention and cognitive factors to the requirements of the task and thus their performance was more uniform.

The results of the present study and those of the physiological measures (Levine, 1975) are consistent with a hypothetical model based on attentional and cognitive factors which are important for the processing of visual and auditory stimuli and relate to reading ability. Adjusting the levels of the factors as well as their interactions with specific modality appear to be important for each step in the overall process. Normal readers appear to be able to adjust the factor levels to a greater extent than do deficient reading children. The reading problems of children with primary reading deficits appear to be primarily caused by a lack of sufficient "attentivity" for the initial processing steps. Major problems for children with secondary reading deficits appear to be derived from an inability to relax the attentivity factor which apparently interferes with reaching the proper cognitive level for optimum performance on a step in the processing chain. These children also appear to have more deficient capability for processing visual information and sequential recall of auditory and visual stimuli. This conclusion is supported by Guthrie and Goldberg (1972) who found poorer visual sequential memory in reading deficient subjects than in normal readers. However, they did not distinguish between secondary and primary reading deficits in their sample population.

Future studies should attempt to elucidate the relationship of sequential processing and the attention-cognition interaction in secondary deficit readers. Whether these are independent factors has not been determined in the present study.

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TABLE 1. A statistical summary of the ages and IQ of the reading classification group and for total sample.

Reading Group	n	Chronological Age			Performance IQ[a]		
		Mean	Range	SD	Mean	Range	SD
Normals	16	11 yrs 3 mos	9-13 yrs	12.6 mos	119	99-133	11.3
Primary	16	11 yrs 5 mos	9-13 yrs	13.9 mos	106	90-135	13.8
Secondary	16	11 yrs 0 mos	9-13 yrs	12.0 mos	111	92-128	7.8
TOTAL	48	11 yrs 2 mos	9-13 yrs	12.9 mos	112	90-135	11.2

[a]Wechsler Intelligence Scale for Children Performance Scales were administered to total sample.

TABLE 2 --Simple effects analysis of variance for intersensory tasks across error types for total sample.

Task	Error Types					F
	Gross A	Gross V	Order A	Order V	Inter.	
1	0.388	0.538	0.506	0.383	0.206	14.75**
2	0.365	0.610	0.458	0.404	0.175	21.54**
3	0.477	0.210	0.419	0.181	0.021	11.20**
4	0.058	0.575	0.102	0.425	0.000	54.65**
F	9.44**	9.78**	9.53**	3.69*	3.14*	
Marg.	0.322	0.483	0.371	0.348	0.101	

** $p < .01$

* $p < .05$

V = Visual

A = Auditory

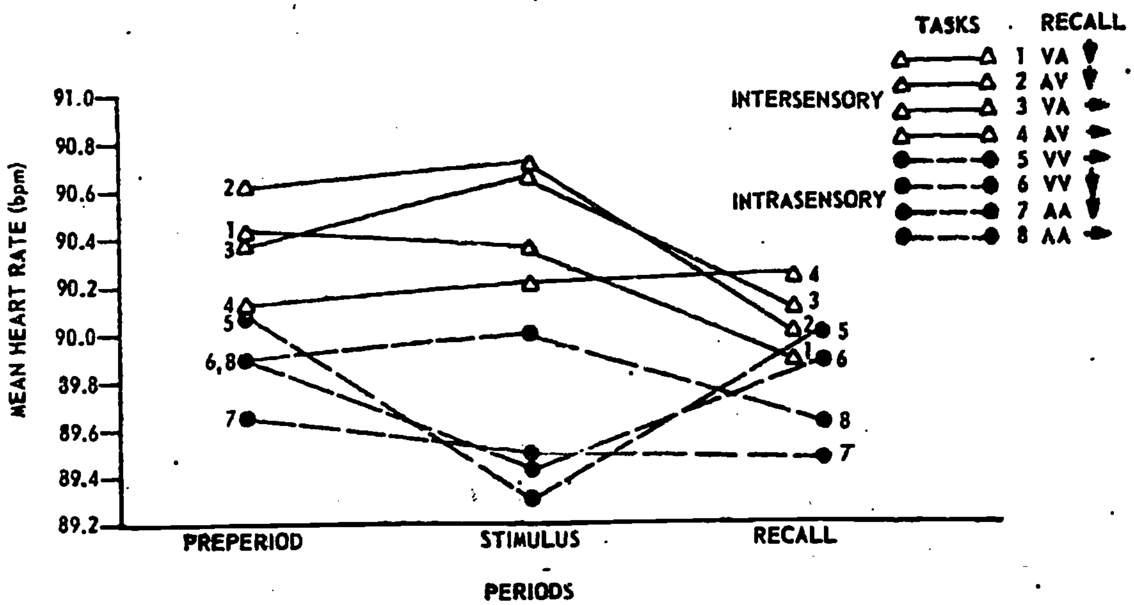

FIG. 1--MEAN HEART RATE FOR INTRASENSORY AND INTERSENSORY TASKS AS FUNCTION OF PERIODS FOR TOTAL SAMPLE

↓ = pairing
→ = linear

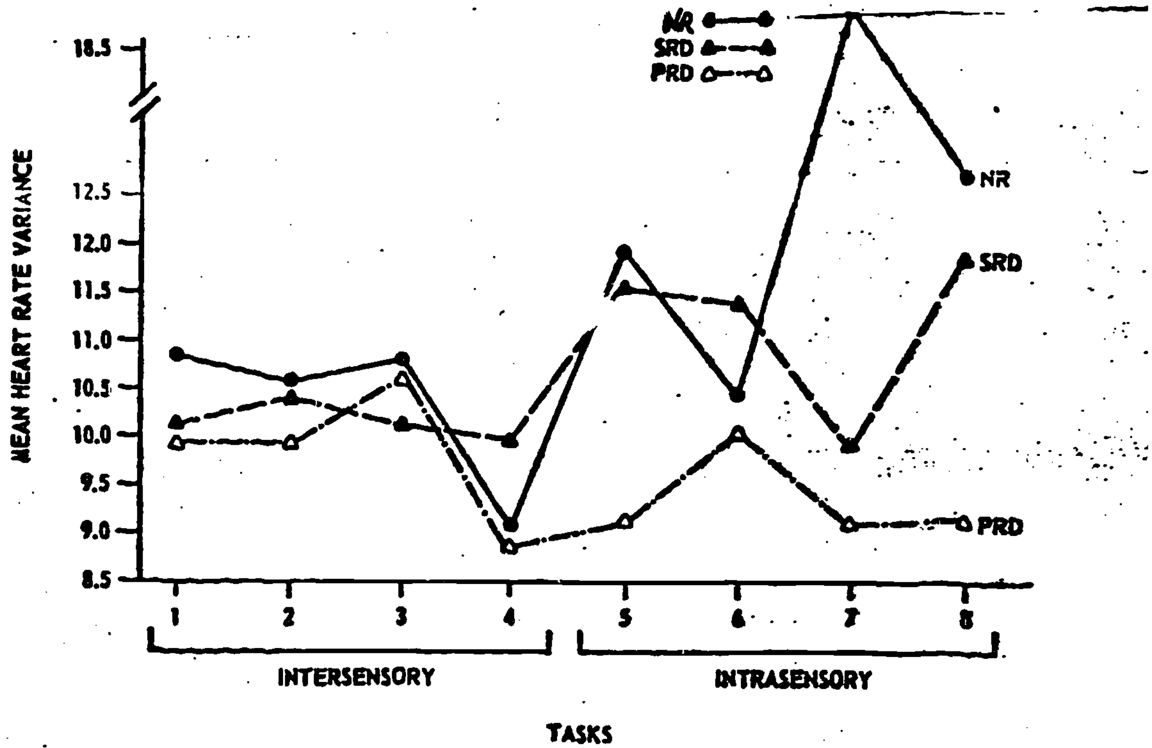

FIG. 2— THE EFFECT OF TASKS ON THE MEAN HEART RATE VARIABILITY OF THE THREE READING CLASSIFICATIONS

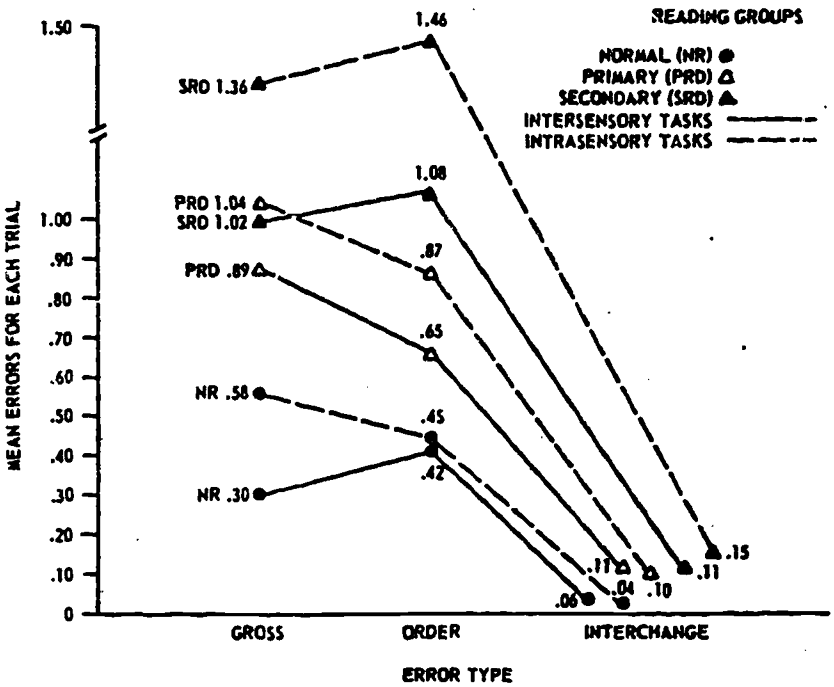

FIG. 4—MEAN ERRORS FOR READING CLASSIFICATION GROUPS IN INTERSENSORY AND INTRASENSORY TASKS ACROSS ERROR TYPES (GROSS, ORDER AND INTER)

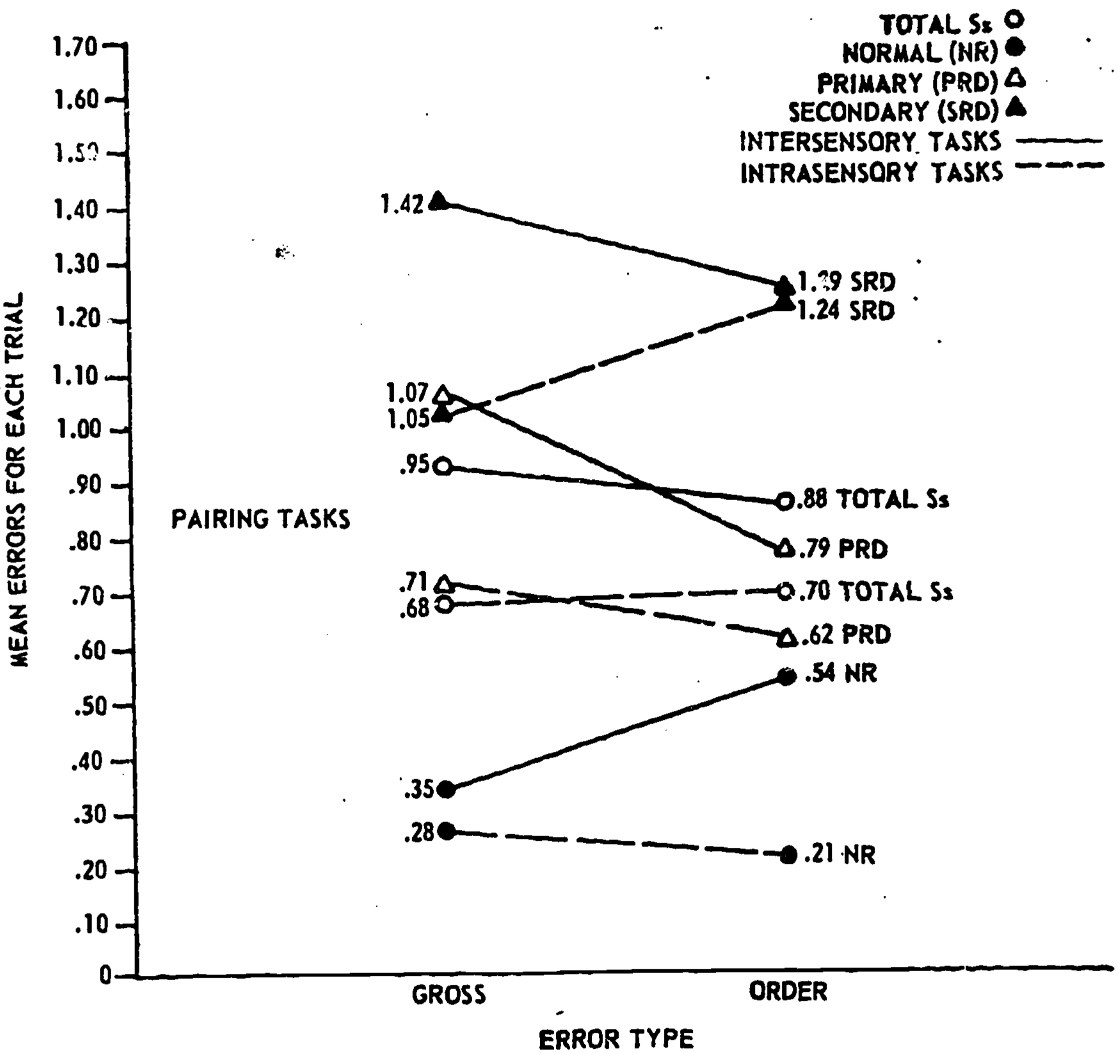

FIG. 5 -- MEAN ERROR TYPES FOR READING CLASSIFICATION GROUPS AND TOTAL SAMPLE ON INTERSENSORY AND INTRASENSORY PAIRING TASKS

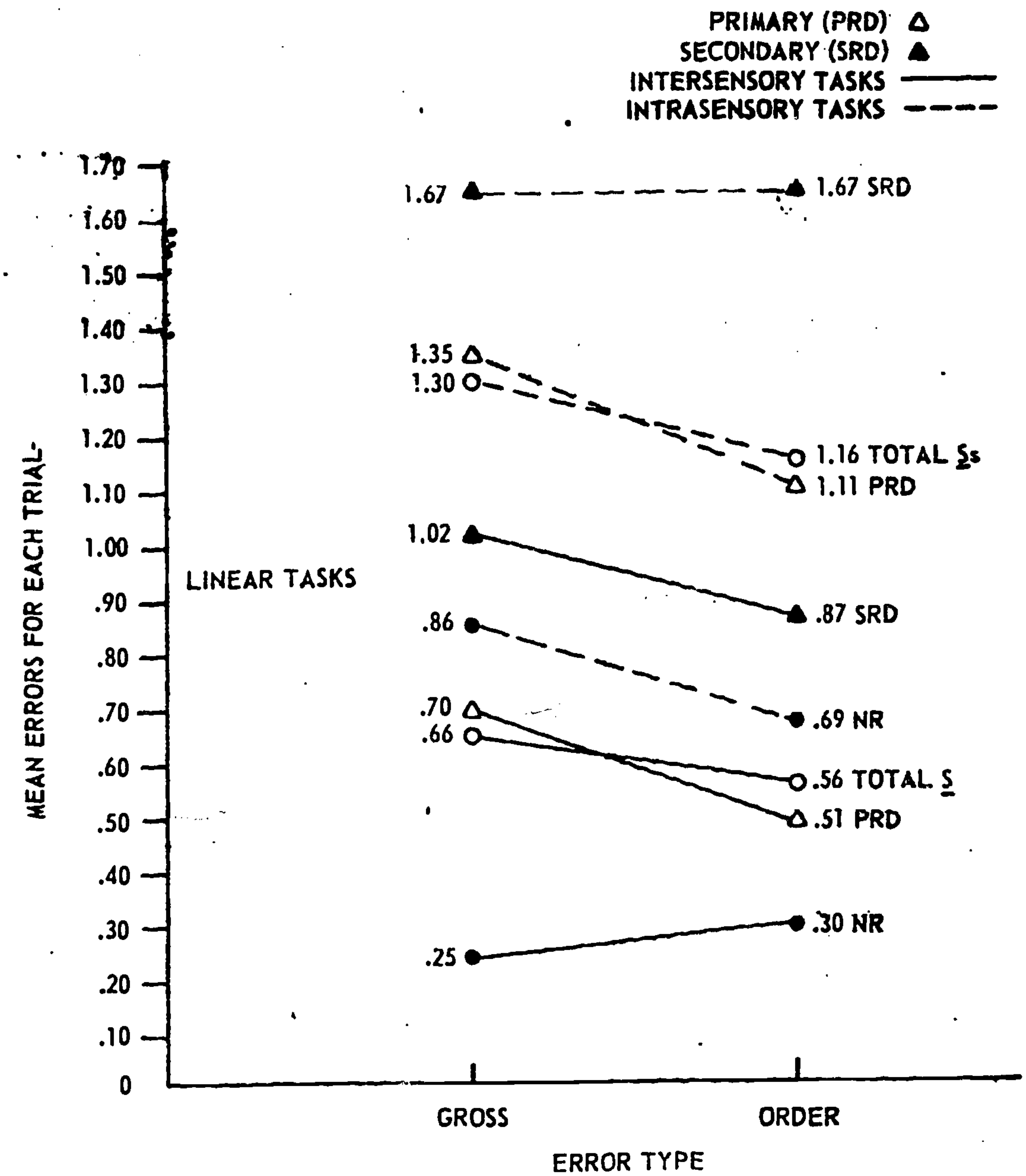

FIG. 6 --MEAN ERROR TYPES FOR READING CLASSIFICATION GROUPS AND TOTAL SAMPLE ON INTERSENSORY AND INTRASENSORY LINEAR TASKS

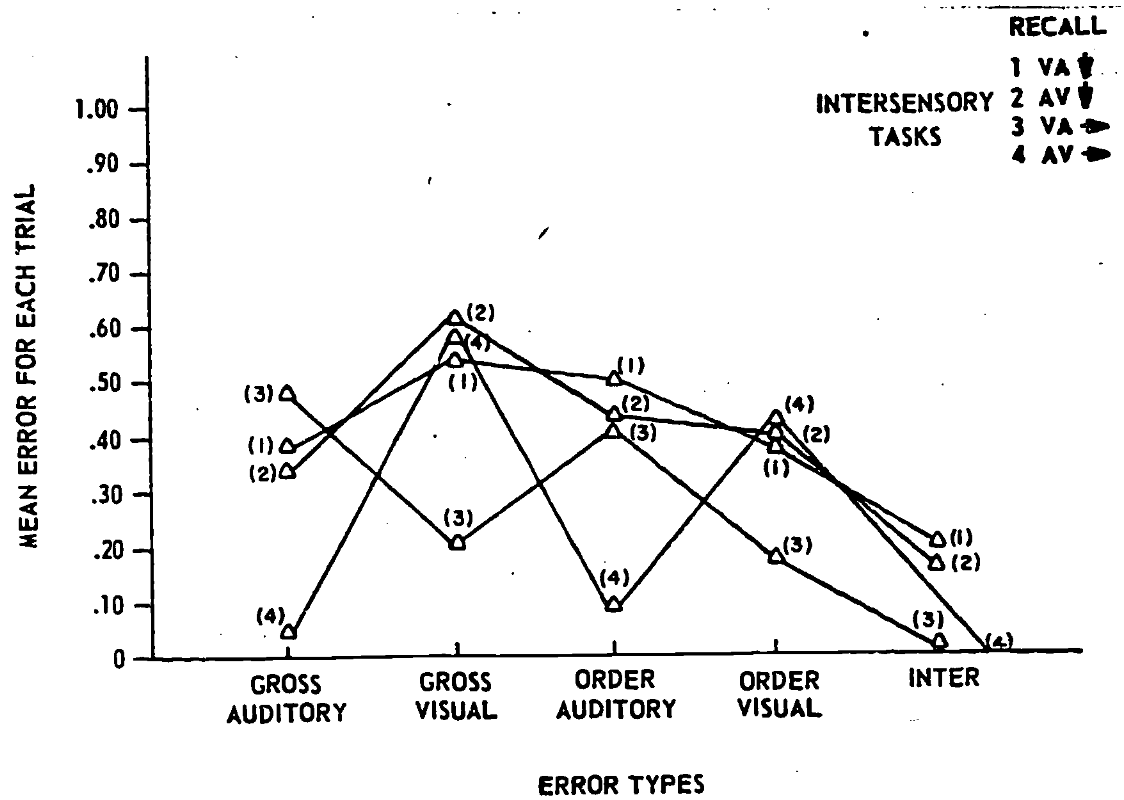

FIG. 7 -- MEAN ERRORS FOR INTERSENSORY TASKS ACROSS ERROR TYPES FOR TOTAL SAMPLE

↓ = paired

→ = linear

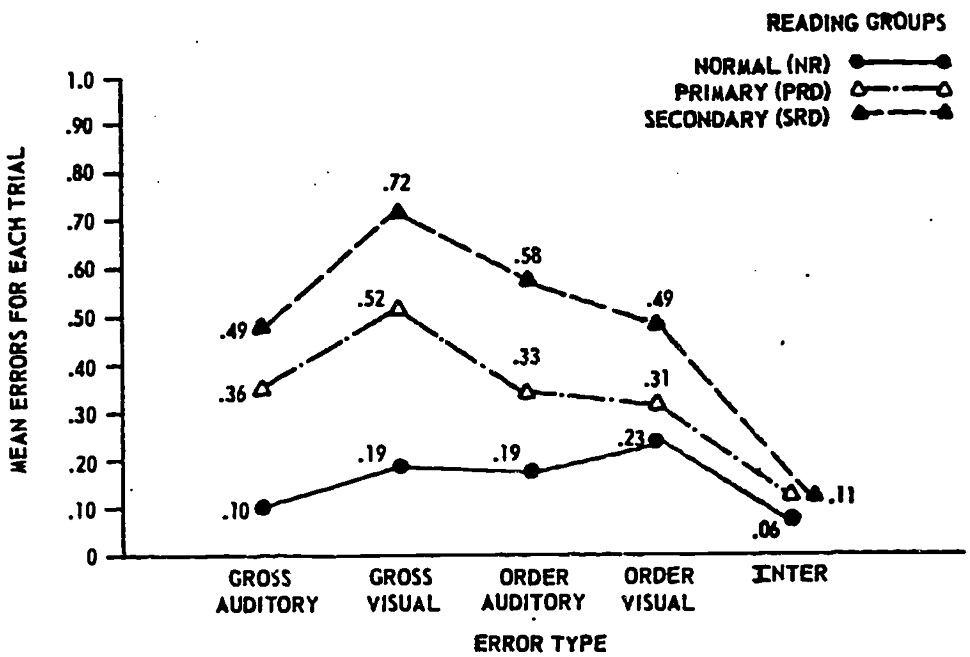

FIG. 8—MEAN ERRORS OF READING CLASSIFICATION GROUPS ACROSS ERROR TYPES IN INTERSENSORY TASKS