PHYSIOLOGICAL RESPONSES IN INTRASENSORY AND INTERSENSORY INTEGRATION OF AUDITORY AND VISUAL SIGNALS BY NORMAL AND DEFICIT READERS

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ABSTRACT

PHYSIOLOGICAL RESPONSES IN INTRASENSORY AND INTERSENSORY INTEGRATION OF AUDITORY AND VISUAL SIGNALS BY NORMAL AND DEFICIT READERS

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This study compared the psychophysiological parameters of attention involved in the processing of bisensory memory tasks and their recall in groups of normal and deficit readers. The specific experimental predictions derived from the major hypotheses were tested using physiological measures. Differences among the physiological measures employed; the interactions of the modality characteristics of the tasks (auditory or visual) and the intersensory and intrasensory parameters of the tasks were observed in a set of eight experimental conditions.

Auditory and visual stimulus pairs composed of digits one through nine, which incorporated variations of intersensory and intrasensory conditions were administered simutaneously 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.

The Ss were composed of 16 normal readers (NR), 16 primary reading deficit (PRD), and 16 secondary reading deficit (SRD). Operationally, primary and secondary reading deficit groups were established on the bases of performance on the Minnesota Percepto-Diagnostic Test (MPD), a standardized measure of visual motor performance. Both reading deficit groups, primary and secondary, read one or more grade levels below the standard expected for age and IQ.

The independent variables used in the various experimental conditions were the following: reading classification consisting of three reading groups, to which Ss belonged, NR, PRD and SRD; the three experimental periods, preperiod, stimulus and recall; the eight tasks and five recall error types. The recall error scores, GSR, mean heart rate, heart rate variability, heart rate deceleration and heart rate acceleration were the dependent variables.

Magnitude and frequencies of heart rate deceleration in the normal reading group exceeded that of the reading deficit groups. Differences in mean heart rate and heart rate acceleration measures among reading groups were not observed. Mean heart rate of the total sample was dependent on interaction of the intersensory and intrasensory parameters of the tasks. A decrease in heart rate variability was found to be consistent with proposed increase in "attentivity." Increased GSR activity was observed during the recall period. Since during this period a heart rate decrease occurred, it was interpreted that the GSR increase was a measure of cognitive activity. As expected, recall performance of the reading deficit groups was inferior to the normal reading group on all bisensory tasks. Recall performance between the reading deficit groups was found to differ for visual information processing and sequential recall with more errors for both observed in the secondary reading deficit group.

A model composed of "attentivity" and "cognitive processes" factors is proposed to explain the results obtained. Analyses of physiological and performance results indicate that the normal reading group can adjust the "attentivity" and "cognitive processing" factors to optimize the effectiveness of the stages in the total processing chain.

The primary reading deficit group appears to have difficulty with the "attentivity" factor. For the secondary reading deficit group, "overattending" which seems to cause a delay in effective cognitive activity along with defective visual information processing and sequential recall appears to be sources of their reading problems.

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Maureen Julianne Levine

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CHAPTER I

INTRODUCTION

The inability of significant numbers of children to make adequate progress in educational programs has become a matter of increasing concern. Since reading is a basic learning skill many studies have been directed toward elucidating the psychological attributes characteristic of children with reading deficits. The act of learning to read involves the integration of the perception of sound with the sight of printed words. Consequently, the understanding of intrasensory and intersensory modality integration is important if reading deficits are to be ameliorated. In reviewing the literature of sensory integration, findings with normal groups will be examined first and then the evidence of sensory integration in reading deficit groups will be reviewed.

Sensory Integration in Normal Groups

Visual-Kinesthetic Intrasensory and Intersensory Studies in Normal Groups

Connolly and Jones (1970) compared the performance of *S*s ranging in age from 5 years 4 months to 11 years 1 month with a group of adults on intrasensory and intersensory matching tasks. Estimation of length of straight line was the task used in the following four conditions: visual-visual (V-V), kinesthetic-kinesthetic (K-K), visual-kinesthetic (V-K), and kinesthetic-visual (K-V). The kinesthetic measure was the drawing of the stimulus line by Ss. Performance scores decreased for the experimental conditions in the following order, V-V, K-K, K-V, V-K. For all experimental conditions performance improved with age. The asymmetrical intersensory results, i.e., K-V processing being better than V-K supports the model proposed by Connolly and Jones in which kinesthetic storage is less efficient than visual.

In light of the fact that a drawing task was used the possibility exists that time estimation was a mediating variable, thereby the K-V condition would have provided more information than the V-K condition. The overall results confirm the observations of Pick, Pick and Klein (1967) and Blank and Bridger (1964). According to these authors intersensory discrimination is inferior to intrasensory performance in normal groups. However, both intersensory and intrasensory performance increases in accuracy with age.

The findings reported by Rudel and Teuber (1964) conflict with the above studies in that intrasensory transfer in tactile tasks was found to be poorer than visual-tactile and tactile-visual performance in the normal group.

The discrepancies may be related to the experimental designs of the respective studies as well as differences in tactile and kinesthetic processing as defined by respective authors. Further, Rudel and Teuber used three dimensional stimuli, whereas two dimensional stimuli were used in the other studies. Doehring (1968) and Levine and Fuller (1972) used three dimensional stimuli to measure tactile performance. The reading deficit group in the latter studies were superior to normal reading group on tactile discrimination tasks. As noted by Connolly and Jones (1970) the "purely tactile as distinct from kinesthetic or haptic, processing may have diminishing significance for the normally developing child." An interesting postulate is that the significance of tactile stimulation may persist in reading deficit groups. However, Bakker (1966) proposed that children with reading deficits differ from normal readers not from a greater kinesthetic discriminative ability as much as a lower visual sensitivity. [Bakker's (1966) work will be discussed in greater detail later.] In an investigation of intersensory transfer of learning, Rasof (1968) found the order of accuracy for modal discrimination of form to be visual-visual, visual-haptic, haptic-visual, and haptic-haptic in groups of _S_s four years to eight years of age. These results confirm the dominance of visual systems found by Connolly and Jones (1970) as well as inferiority of tactile (haptic) systems reported by Rudel and Teuber (1964). As noted previously the discrepancies may result from differences in haptic and kinesthetic processes.

Since most of the above work is limited to analysis of visual and kinesthetic systems a brief review of studies dealing with auditory and visual systems will be examined next. The following review is limited since the major interest in this section is the comparison of children with reading deficits and normal readers.

Auditory and Visual Intrasensory and Intersensory Studies in Normal Groups

Hancock, Moore and Smith (1969) investigated the effectiveness of providing groups of second graders and fourth graders with programmed spelling via visual, auditory and visual-auditory modes. Achievement, retention, and effectiveness of single vs. two channel presentation were analyzed. Two channel presentation of stimulus was no more effective than one channel in learning spelling for the total sample, confirming, according to the author, Broadbent's (1958) position that a single channel system operates most efficiently only for perceptual processing. An interesting finding from this study was that Ss with the lowest IQ and lowest reading comprehension in both grades achieved the most via the auditory mode and Ss with the highest IQ and reading comprehension achieved most from auditory-visual combination. _S_s with intermediate IQ and reading comprehension achieved the most with visual stimuli. In a study designed to measure recall performance with auditory, visual and auditory-visual presentation, for _S_s in two groups with mean age of 5 years 4 months and 8 years 4 months, Horowitz (1969) found that recall under visual and auditory-visual modes was better than under auditory presentation. _S_s were divided into groups of "label" and "non label" in which labeling _S_s recited the name of the stimulus following presentation. Labeling facilitated performance, however the differences among the modalities were in the same direction as previously reported. No significant age X modality interaction was found. Both 5 year olds and 8 year olds showed better recall with visual mode. The author suggests that "age preference for different modalities as measured by recall scores may not exist." Since the stimulus material used in visual and auditory presentation differed, words were read to _S_ for auditory mode (via tape recording) and pictures of stimulus material were presented for the visual mode. Failure to control for effects of imagery may have influenced the results.

A number of researchers have expanded the study of intrasensory and intersensory relationships, i.e., effects of modal preference on learning, (Nelson, 1970); concept of body image on intersensory integration, (Majaron, 1970);

speed of intersensory shifting, (Jones, 1970). Although the focus of the above studies differs, they generally provided data confirming the findings of Connolly and Jones (1970).

The difficulty of determining modal preferences in young Ss was demonstrated by Nelson (1970). Only 13.6 percent of a sample of 457 Ss could be identified as having a visual or auditory preference, 5.3 percent were classified as visual dominant and 8.3 percent were classified as auditory dominant. Nelson noted that the auditory and visual scales of the reading readiness test used in the study were not sufficiently sensitive to determine modal preference in normal groups.

Summary and Review

Overall, the literature suggests that intrasensory and intersensory discrimination improves with increasing age in normal groups. Children, five years and older, appear capable of dealing with intrasensory and intersensory transfer of stimulus inputs. The information on sensory integration in children under five years of age is limited. Allen and Fitzgerald (1974) have provided some insights into methodological limitations of intermodal study with infant and pre-school age groups. As noted by these authors, the design of intersensory and intrasensory experimental studies involves the use of language and the negative findings with infants and pre-school children may be due to linguistic incompetence rather than lack of sensory integration. In view of this limitation, Allen and Fitzgerald (1974) used a habituation paradigm to study intrasensory and intersensory integration. The results of their study will be covered in more detail in following sections. Since linguistic competence is a factor in reading deficit groups the same limitations as noted by Allen and Fitzgerald in the above studies may exist with the reading deficit group.

The findings related to efficiency of intrasensory vs. intersensory integration are not clear-cut, although more supportive evidence favors intrasensory integration.

The dominance of one sense modality over another is also unclear. The differences in cited studies may be attributed to experimental design. However, the findings generally support a more efficient visual mechanism.

Research on sensory integration with reading deficit groups will be considered next.

Sensory Integration in Reading Deficits Groups

The most consistent overall finding from a number of studies that have examined dimensions of intrasensory and intersensory integration in reading deficit groups is that sensory integration in these children is inferior to that of normal readers. As a result of a number of studies which showed that a relationship existed between reading achievement and auditory-visual integration, Birch hypothesized that failure of a dominant visual system might lead to reading deficits (Birch, 1962; Birch & Belmont, 1964, 1965).

A number of authors have noted the limitations inherent in the Birch _et al_. studies such as the lack of ceiling in measures of auditory-visual integration (A-V), omission of intrasensory comparisons, inadequate control groups, etc. (Berry, 1967; Ford, 1967; Rubenstein & Gruenberg, 1971). The A-V integration measure used by Birch _et al_. and adapted by other authors such as Ford (1967) and Berry (1967) is an auditory-visual matching-to-sample task. The procedure requires _S_ to listen to a pattern of beats and then match the standard auditory pattern to a similar visual configuration from a set of three choices.

Rubenstein and Gruenberg (1971) observed that in the above studies results on A-V measure may have been confounded by the following factors: (1) lack of control for temporal mediations, (2) number of elements varied in items, (3) variation in item length.

As pointed out by these authors, rhythmic pattern recognition experiments are subject of spatial and temporal controls in particular with children and brain damaged groups. Berry (1967) redesigned the A-V measure to control for spatial and temporal factors and replicated the Birch (1964) study. She found, in a sample of American children, that reading deficit groups were inferior to normal readers on auditory-visual integration. Intrasensory measures were not used.

Visual and Kinesthetic Intersensory Study in Reading Deficit Groups

In a study designed to compare deficit readers and normal readers on visual and kinesthetic sensitivity using a difference-threshold measure, Bakker (1966) found in a sample of 32 Dutch children matched with a control group of normal readers that deficit readers have higher visual threshold. Kinesthetic threshold for deficit readers was lower than normal, but not at significant levels. The rank differences, visual minus kinesthetic threshold, were larger in the deficit reading group than normal group (low threshold scored low rank) in the direction of higher visual threshold. In view of these results, Bakker suggests that the lower visual sensitivity found in deficit readers may account for differences found in sensory dominance between the groups.

Auditory and Visual Intrasensory and Intersensory Studies in Reading Deficit Groups

Senf and Freundl (1971) report the most recent results of a continuing series of studies (Senf, Rollin &

Madsen, 1967; Senf, 1969; Madsen, Rollin & Senf, 1970; Senf & Feshbach, 1970) which deal with attempts to elucidate the psychological factors of auditory and visual intersensory and intrasensory integration involved in reading deficit groups. These factors are defined as (1) auditory masking, (2) auditory distraction, (3) deficient visual information processing, and (4) deficient information-organization ability. The experimental methods all involved bisensory memory tasks (BMT) and the stimuli consist of single digits presented aurally or visually. In an early experiment the audio digit was presented simultaneously with a different digit shown visually and three such pairs were presented in serial order. The task was to recall the order of the pair presentation. A deficit reading sample, labeled learning disabled children (LDC) was compared with a matched group of normal readers (NC). On the ordering task the LDC and NC performed equally well. However, the LDC group performed worse when the task required recalling the individual stimuli in each modality separately, V_1 V_2 V_3 A_1 A_2 A_3, in the order presented. On the basis of these initial results it was hypothesized that LDC group had greater difficulty in processing simultaneously presented auditory-visual stimuli.

To test this hypothesis an experiment was devised to determine whether LDC had higher preference than the NC for a modality recall rather than recalling the individual items pairwise.

The sample consisted of 48 LDC and a matched group of NC. These were divided into three age groups with a mean of 9.5, 12.2, and 14.6 years and designated young, middle, and old respectively. Half of the experimental and control Ss were given preinduction exercises designed to develop a preference for recalling the stimuli pairwise, i.e., V_1 A_1, V_2 A_2, V_3 A_3 rather than modality grouping, i.e., V_1 V_2 V_3, A_1 A_2 A_3. In the experimental task Ss were simply instructed to recall stimuli which had been presented in the usual three pairs of simultaneous V-A stimuli. It was found that for the control condition (no preinduction) the LDC and NC Ss preferred the modality to the pairwise recall about ten to one and that there were no significant changes in preference for the control group with age of S. Similarly the pre-set, LDC group showed the same preference for modality recall as control groups. However, the preferences of the pre-set NC group for pairwise recall rapidly increased with age, from that of the young group which was the same as the other Ss of that age to about half of the responses being pairwise for the old group. These results suggest that the LDC group resist pairing V-A stimuli and do not respond to external orienting experiences which promote pair recall. These results are not in complete agreement with the related experiments of Siller (1968), who found in a sample whose age corresponded with the middle and old group that success on V-A integration tasks correlated with reading ability and that performance of the poorest group improved with V-A integration training.

Using the same Ss as in the experiment described above, Senf and Feshbach (1970) modified the tasks. In this series of studies half the Ss were directed to recall the stimuli pairwise (DP) in the order presented and the remaining Ss were to recall the three visual followed by three audio stimuli (DM). For half the presentation the interval between the stimuli was 0.5 seconds and for the remainder 2 seconds. The replies were scored for visual order errors, i.e., correct digits in wrong serial order. The intervals between paired stimuli did not significantly effect the error scores. The authors suggested that intersensory deficiency of the LDC is not related to attentional switching difficulty which would be expected to depend upon length of the time between stimulus pairs.

The "young" LDC Ss scored more errors than the NC sample for the DM tasks, but there was no difference in errors for DP tasks. The error scores of the "middle" and "old" Ss were the same and not different for the LDC and NC for the DM task. However, there was a large decrease in the DP error scores with increase age for the NC group. The results were also scored for gross error scores in which a digit was omitted or an erroneous one substituted.

Differences for gross error score were not found for any age, experimental or normal sample. However, an analysis of total order error scores was different for the LDC and NC group. The authors interpret the results of the experiment to support the view that poor readers have deficit storage or memory capacity.

In the most recent series of experiments reported by Senf and Freundl (1971), only Ss in the "young" age bracket were used. Using the "young" group Senf and Freudl (1971) tested the auditory masking hypothesis. Three different methods of bisensory stimuli presentation were used: (1) simultaneous, (2) visual followed 0.5 second later by auditory complement and (3) visual followed 0.4 second later by auditory. It was reasoned that if masking occurs then there should be less recall errors for the delay than for simultaneous presentation. Both DP and DM recall tasks were used. Differences in errors were not found for the presentation paradigms. The authors interpret the results to indicate that auditory masking of the visual stimuli is not related to causes of reading deficits. Unfortunately, the authors do not report variations of their experiment in which the auditory stimuli is presented ahead of the visual. Physical simultaneity may not correspond to neurological simultaneity when bisensory stimuli are presented. It has been known for some time (Shipley, 1964) that auditory reaction times are faster than visual ones. Thus, the separation (V-A) of the stimuli would tend to produce a neurological simultaneity which may have been greater than that found in the presentation of physically simultaneous signals.

Differences in gross error and the order error scores for visual recall on DP tasks were not found between LDC and NC groups. However, more errors (both gross and order) were found for the LDC than NC group on DP auditory recall. Greater errors (both order and gross) were found on the DM tasks in visual and auditory recall for the LDC than NC group. Senf and Freundl (1971) interpret the differences on the DM visual recall and lack of difference on DP visual recall between the LDC and NC groups to support a hypothesis that deficit readers have a greater auditory dominance over the visual modality than do normal readers.

Shipley and Jones (1969) used a visual matching task to test the recall capabilities of dyslexic and normal children in a closely matched sample (including IQ). The age range was similar to the sample used by Senf and Feshbach (1970). Noise was interjected during different phases of the experiment and the errors were scored. Four experimental conditions were studied, (1) no noise (control), (2) noise during exposure to visual stimuli, (3) noise during rest delay, (4) noise during recall test.

Shipley and Jones (1969) found that more recall errors were made by the dyslexic group than the normal control group for all conditions. An increase in errors occurred for the dyslexic _S_s when the noise was presented during the exposure period with no differences when noise was presented during rest delay or recall test period. An increase in errors for the normal group (over control conditions) occurred only when noise was presented during test recall period. Shipley and Jones' (1969) results support the view that dyslexics have deficit ability to reject auditory distraction when receiving a visual stimulus. It is reasonable to expect that inadequate capacity to integrate V-A stimuli would have an associated deficit to reject auditory stimuli affecting visual processing. The results of Shipley and Jones (1969) support the hypothesis that in dyslexics auditory distraction rather than auditory dominance is an important characteristic. This is indicated by the finding that visual recall of normal readers was affected by noise in the test recall period, whereas the dyslexic group had visual recall impaired when noise was presented during the exposure period when auditory distraction or masking would be expected to be important.

Summary and Review

Although there are contradictory views regarding the specific factors involved, evidence exists which supports the view that reading deficit is associated with a poor ability to integrate sensory information from different modalities. The complexity of the visual stimuli used in these studies appears to be an important factor which has not received adequate attention. The apparent inconsistencies in the findings of Senf and Freundl (1971) and those of Shipley and Jones (1969) might be the result of the relatively simple stimuli used by the former authors compared to those used by the latter. The very interesting age effects which Senf (1969) reported in his studies have not been noted by other experimenters using the same range of ages in their samples. The approach described by Senf and Freundl to study the 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 empirically possible. Treating these two factors as part of a more generalized attentional capability in an experimental design to study sensory integration in deficit readers is indicated. Using physiological methods to measure attentional factors associated with sensory input is suggested since it could provide estimation of an independent variable. Previous work cited above assumed theoretical models in order to analyze for an attentional factor. The capability to measure this factor by physiological measurements should lead to elucidation of the models.

Physiological Measures of Sensory Input

A very useful perceptual theory dealing with physiological measure of sensory processing was proposed by Sokolov (1960, 1963). An important aspect, for the present study, involves the attentional response. According to Sokolov, S reacts to an input stimulus by building a model in the central neural system. The incoming intrasensory stimulus is compared to the cortical model and if they match then habituation takes place. On the other hand, a lack of correspondence or mismatch leads to evocation of the orienting reflex. There is general agreement with Sokolov's view that an increase occurs in the receptivity to sensory input during the orienting reflex. This characteristic of the orienting reflex model makes it reasonable to use it as a basis for formulating hypotheses to be used in designing experiments for studying intrasensory and intersensory processes related to reading deficits. The orienting reflex clearly involves attentional capability which is also an important factor in reading deficits.

Attentional factors have been extensively considered by theorists dealing with discrimination learning. A comparative review is given by Zeaman and House (1963). A common element in the various theories is the probabilities that relevant and non relevant stimulus cues can be observed. The subsequent probabilities of cue processing are also taken into account. Models based on conditional probabilities may be of value for studies in bisensory integration. In their own work Zeaman and House found that attending to the relevant stimulus dimension and approaching the correct cue in that dimension were important factors in learning.

Sokolov's (1960, 1963) theory of reflex behavior proposed that autonomic activity increased during the orienting reflex with a resultant increase in heart rate. Lacey (1959) and Lacey et al. (1963) have demonstrated that heart rate deceleration is a specific component of the orienting reflex and generally occurs when there is a greater sensitivity to environmental stimuli. A large body of research supports Lacey's position. Graham and Clifton (1966) reviewed the experimental evidence relating to changes in heart rate as a component of the O.R. and essentially their analysis supports Lacey's view. Lewis et al. (1966) reviewed much of this work as well as reporting a study on 24 week old infants in which they obtained significant rank order correlation (.54 for boys and .44 for girls) between attention as measured by fixation time and heart rate deceleration.

Kagan, Moss and Siegel (1963) and Lee, Kagan and Rabson (1963) suggest that grade school children can be classified as "analytic" or "non analytic" in regard to the methods used to process a set of presented pictures of objects. The "analytic" child will group according to the similarity of detail, whereas, the "non analytic" will classify according to other conceptual categories which are more general. Kagan and Rosman (1964) hypothesized that "analytic" Ss would have a greater measure of attentiveness than "non analytics," and therefore should show greater heart rate deceleration than "nonanalytic" Ss. Using first and second grade boys who were classified as "analytic" and "non analytic," decrease in heart rate was found for both groups during the period when Ss were attending to the presented stimuli than during the prior rest or task durations. Nevertheless, the decrease was greater for the "analytic" Ss than for "non analytic" Ss supporting Lacey's view that attention to sensory input results in heart rate deceleration. The research reviewed above indicates that heart rate deceleration occurs during attention to stimuli being received in a single modality, i.e., intrasensory. Is this the case for intersensory perception? Some indirect support for this view is afforded by the work of Allen and Fitzgerald (1974). They used a habituation paradigm to investigate intrasensory and intersensory integration of form. Haptic or visual stimuli were presented in the first phase of the experiment. In the second phase similar or different stimuli were presented. Habituation was measured by touching time, fixation time, and GSR frequency. GSR supplied the best measure of habituation. Results were consistent with the Sokolov's theory, suggesting that cortical models formed from one mode of sensory stimulation facilitate transfer and provide a basis for habituation to stimuli in another modality.

Implication

The present study will attempt to elucidate the factors involved in visual-auditory bisensory integration tasks and their relation to reading deficits. It will operationally separate the attentional variable by using physiological measures for its estimation. In most experimental designs which use a matching paradigm for visual-auditory integration investigation, the intrasensory comparative base is not well established. It is planned to provide an intrasensory experimental task which would provide meaningful parameters for interpreting the results of the intersensory experiments. The extensive series of studies reported by Senf and Freundl (1971) did not alter the order of the recall tasks, i.e., the visual stimulus had to be reported first. In the present study the effects of alteration in recall order will be studied.

The classification system for reading deficits which will be used in the present study will be considered next.

Classification of Reading Deficit Groups

Clearly indicated in studies of reading deficit groups is the need for a better scheme for classifying reading deficit. Rabinovitch (1954) reviewed the etiologies which can be used as a basis for a better classification of reading deficits. Fuller (1969) combined an instrument, Minnesota Percepto-Diagnostic Test (MPD) a measure of visual motor perception, with the Rabinovitch theoretical constructs to provide a method which classified reading deficit with an acceptable exactness and in which the results allowed for an etiological interpretation. Accordingly reading deficit is classified as primary, secondary, and organic as given by Rabinovitch (cited in Money, 1962).

Primary Reading Deficit (PRD): "The capacity to read is impaired without definite brain damage being suggested in the case history or upon neurological examination. The defect is in the ability to deal with letters and words as symbols with resultant diminished ability to integrate the meaningfulness of written material. The problem appears to reflect a basic disturbed pattern of neurological organization."

Secondary Reading Deficit (SRD): "The capacity to read is intact but is utilized insufficiently for the child to achieve a reading level appropriate to his intelligence. The causative agent is exogenous, the child having a normal reading potential that has been impaired by negativism, anxiety, depression, emotional block, psychoses, limited schooling opportunity, or other external influences."

Organic Reading Deficit (ORD): "The capacity to read is impaired by neurological deficit. The case history reveals the cause of brain injury as being anoxiar head injury, encephalitis, or prenatal toxicity."

Children classified as having organic reading deficits were excluded from the present study. The methodological demands were judged to be too much for them since one hour and fifteen minutes (1' 15") was required to complete the experimental session. Difficulties would also have been encountered in obtaining the required number of Ss in this classification due to the limited number in the local population.

The Minnesota Percepto-Diagnostic Test (Fuller, 1969) is used to classify the reading deficit groups into the three etiological categories established by Rabinovitch (1954). Perceptual motor stability is based on degree of rotation, which occurs when the subject reproduces Wertheimer designs (cited in Bender, 1939).

Two of Wertheimer's designs, used by Bender (1938) as Figures A and B appear in three different orientations each, i.e., vertically on diamond card, horizontally on diamond card, and vertically on oblong card. The subject is instructed to copy each of the six stimulus figures.

In the study reported by Fuller (1964) each figure drawn by S was measured for degrees of rotation from the original axis. The total rotation score for 6 cards was used for correlational and significance analysis for Ss classified by the methods listed above. For the whole group of Ss, 89% were correctly identified on the basis of their scores on the MPD.

In the work reported by Fuller (1964) the good reader rotated 12.62° and the primary 13.12°. The difference in means was not significant. The mean score of the secondary readers was 45.10° and that of the organics 72.10°. These scores were significantly different than those of normal readers and readers with primary deficits. Fuller (1964) recommends that good and primary readers rotate 25° or less, that secondary readers rotate 26° to 54°, and that organic more than 55°. The review also states that the MPD test is most successful in its prediction for those within the IQ range of 80 to 110.

In the revision of the MPD Test (Fuller, 1969) where raw scores were controlled for age and IQ and reported in T scores new cut-off scores were established for the reading disability groups as follows: primary reading disability 45-80, secondary disability 31-44, organic 0-30. Primary reading deficit groups appear to function as normal readers in that their visual integration is considered to be intact.

Summary and Analysis

Research on three topics germane to the study of children with reading deficits has been reviewed in this chapter. First, the evidence from the literature on sensory integration supports the view that deficit readers have a less efficient capacity to integrate information from auditory and visual channels than normal readers (Birch, 1962; Ford, 1967; Berry, 1967; Senf & Freundl, 1971; Shipley & Jones, 1969). Interpretations of findings from the studies in this area are diverse. They include the following: failure of dominant visual system (Birch, 1962); dominance of the auditory over visual modality (Senf & Freundl, 1971); deficit ability to reject auditory distraction with presentation of visual stimuli (Shipley & Jones, 1969).

An analysis of the experimental designs used in the above studies indicates that in the investigation of visual-auditory integration, the intrasensory comparative bases were not well established and also that an important alteration of the order of sensory modality (i.e., having auditory recalled first in the tasks) was not carried out. Experimental designs which do not have the shortcomings mentioned above should provide more meaningful data for interpreting results of intersensory experiments. As already noted, the conflicting evidence found in these studies, particularly between Senf and Freundl (1971) and Shipley and Jones (1969), may be due to difference in experimental design. However, a commonality which all the studies appear to share is the emergence of an attentional factor in the processing of information via auditory and visual modalities.

Since psychophysiology has provided the means to separate the attentional from other variables, the use of physiological measurements are suggested for an estimation of this factor. Sokolov's (1962, 1963) neurophysiological theory proposes that the physiological changes which occur with stimulus presentation are dependent upon the presence or absence of a cortical neuronal model of the stimulus parameters. The physiological responses of heart rate measures and galvanic skin responses (GSR) to stimulation have been the focus of a number of recent studies. Heart rate deceleration and increased GSR responsivity have been reported to occur during stimulus presentation Lacey _et al_., 1965 and, Kagan _et al_. (1963). Graham and Clifton (1966) reviewed the experimental evidence relating to heart rate change and concluded that heart rate deceleration occurs with presentation of non painful stimuli. Heart rate acceleration and GSR responsivity are also reported to occur in association with cognitive activity, such as solving mental arithmetic problems (Johnson & Campos, 1967; Steele & Lewis, 1968; Lacey, Kagan, Lacey & Moss, 1963). Specifically, these studies suggest that heart rate deceleration and GSR responsivity will occur during periods of stimulus presentation, whereas heart rate acceleration and GSR responsivity will occur during periods of recall or mental activity.

The research reviewed generally employed physiological measures with stimulus input directed at a single sensory modality, i.e., intrasensory. An exception is the work of Allen and Fitzgerald (1974) who used a habituation paradigm in a study of intrasensory and intersensory integration. An interesting question is whether the heart rate response generally found with intrasensory stimuli would be the same for intersensory stimuli. In an experimental design that uses intersensory and intrasensory stimuli with recall tasks, the attentional level demands of intersensory task would appear to exceed those of the intrasensory tasks particularly with auditory and visual stimuli. In such a case, a concomitant heart rate deceleration and GSR responsivity that exceeds that which occurs with intrasensory stimuli should be found for the intersensory stimuli.

The final issue considered in the review of sensory integration in children with reading deficits was a classification system for reading deficits. All the research reviewed used a construct of reading deficit based on a singular entity, akin to Stern's "IQ." In such an approach, all children with reading problems are destined to experience a singular process which includes symptoms of deficit visual perception, motor and laterality functions; impaired auditory discrimination; sensory inattention; writing abnormalities; impaired body schema; finger agnosia; dyscalculia; topographic disorder; speech disorders and least of all a reading problem (Belmont & Birch, 1962; Silver & Hagan, 1960;

Money, 1968; Rabinovitch, 1954; Critchley, 1964). Investigators who compare groups of "good" and "poor" readers or "learning disability" to normal control groups do not provide controls for the heterogeneity in groups of children with reading deficits. Recently, several psychometric studies have attempted to devise a systematic approach to the understanding of subgroups within reading deficits (Boder, 1973; Bannatyne, 1971; Smith, 1970). However, only a minority of experimental investigations are presently concerned with the heterogeneity within deficit reading groups.

Since this discussion of sensory integration in reading deficits focused on visual and auditory modalities, a classification scheme based on an etiology (Rabinovitch, 1954) which has been incorporated into a quantitative measure of visual-motor functioning (MPD, Fuller, 1969) was determined to be the best standardized system.

Briefly, three groups of reading deficits, Primary, Secondary and Organic are classified according to the number of degrees of rotation and distortions produced while drawing geometric designs (MPD Test). Primary readers, who score in the normal range, are considered to have adequate visual motor functions. According to Rabinovitch, a defect of basic neurological organization exists in the primary group and would account for their reading problems. Secondary readers produce a moderate degree of rotation on the MPD and experience defects in visual motor functions. The visual motor problem found in the secondary group are supposed to be derived from states of anxiety, tension, inattention and distractibility.

The third reading classification group, organic readers, appear to have severe problems in visual motor functions. Rotation and distortion scores are extremely high, well beyond that which would be expected for CA and IQ values. The organic group differs significantly from the primary and secondary groups on all measures of performance (Fuller, 1974). The capacity to read appears to be impaired by neurological damage. In view of the severity of the organic's performance, an experimental investigation would have to be designed specifically to fit their low tolerance level. Therefore Ss who are classified as organic readers will not be included in the present study and only primary and secondary groups will be used.

The overriding concern of this paper has been to elucidate the factors involved in visual-auditory integration and their relation to reading deficit. A fruitful approach appears to be one that incorporates the results from the three areas in the above discussion; visual-auditory integration in reading deficit group; physiological measures of attention and a reading classification system.

The experimental design used by Senf and his associates with intersensory auditory-visual stimuli is flexible enough to be expanded to include intrasensory stimuli and visual-auditory alteration within the recall tasks. Physiological measurement can be continuously recorded during the experiment to provide estimation of attentional levels in groups of Ss classified according to Rabinovitch's constructs of primary and secondary reading deficits and in a control group of normal readers.

Based on reported studies in literature summarized above, the experimental design of this study should measure differences in physiological responses and recall responses between a control group of normal readers and two groups of reading deficit Ss. The two reading deficit groups, primary and secondary, would also differ on the physiological and performance measures. Specifically, cardiac deceleration and GSR responsivity would be expected to occur during stimulus presentation in the normal reader group and conversely, acceleration and GSR responsivity would be predicted to also occur in the recall period. Between intersensory and intrasensory conditions heart rate deceleration and GSR responsivity is predicted to occur with intersensory conditions exceeding that in the intrasensory conditions in the normal readers group. However, within the intrasensory and intersensory conditions, physiological response should remain stable, e.g., deceleration occurs across all intersensory conditions, in the normal readers group.

Between the two reading deficits groups, primary and secondary, one would expect the primary deficit readers group to have physiological responses similar to those of normal readers with visual stimuli during stimulus presentation and recall. Therefore, the direction of autonomic changes predicted for normal readers should occur in primary readers group compared to secondary readers group in conditions which enhance the visual stimuli.

The recall performance of the both reading deficits group would further be expected to be inferior to the normal readers group under all experimental conditions. Table 1 summarizes the experimental hypotheses framed in terms of the above discussion.

TABLE 1.--A summary of experimental hypotheses.

Hypothesis Number	Autonomic Responses
1	Normal readers group (NR) will exhibit cardiac deceleration and GSR responsivity in the stimulus period.
2	Normal readers group (NR) will exhibit cardiac acceleration and GSR responsivity in the recall period.
3	Normal readers group (NR) will exhibit cardiac deceleration and GSR responsivity in the intersensory conditions exceeding those in the intrasensory condition in the stimulus period.
4	Within intersensory conditions and within intrasensory conditions no differences in autonomic responses will be observed in the normal readers group (NR).
5	Primary readers group (PRD) will exhibit cardiac deceleration and GSR responsivity with intrasensory conditions in the stimulus period.
6	Primary reading group (PRD) will exhibit cardiac deceleration and GSR responsivity with the intersensory conditions which cite the visual stimuli first in the stimulus period.
7	Primary reading group (PRD) will exhibit cardiac acceleration and GSR responsivity with the intrasensory and intersensory conditions which cite the visual stimuli first in the recall period.
	Performance Responses
8	Reading deficits groups will make more gross and other errors under all intersensory and intrasensory recall conditions than normal readers.

CHAPTER II

METHOD

The following is a description of the selection of Ss including the descriptive statistics of S populations as well as the criteria used to define reading deficits. A description of stimuli, apparatus and procedures by which the hypotheses presented in Chapter I were tested is given. This is followed by a description of physiological methods, experimental conditions and the design which includes the data analysis.

Subjects

A total of forty-eight[1] males ranging in age from nine years to thirteen years with a mean chronological age (CA) of eleven years served as Ss. Clinical reports of sex differences in reading deficit groups indicate a male to female ratio of 5:1 (Rice, 1970). In view of these findings only male Ss were used. Of the total sample, sixteen Ss

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[1]Testing was actually started with fifty Ss, but was discontinued for two reading deficit Ss. One S had symptoms of motion sickness with the onset of visual stimuli and the experiment was discontinued immediately. Another S was holding his breath at onset of stimulus and the testing was discontinued.

composed the control group of normal readers (NR) (n = 16, mean CA = 11 years, 3 months, mean IQ = 119). The remaining thirty-two were reading deficits Ss, of these, sixteen Ss met the criteria for primary readers group (PRD) (n = 16, mean CA = 11 years, 5 months, mean IQ = 106) and sixteen Ss met the criteria for secondary readers group (SRD) (n = 16, mean CA = 11 years, 0 months, mean IQ = 111.)

The reading deficit Ss were selected from two reading remedial programs conducted during the summer months. Of the thirty-two reading deficit Ss, ten were enrolled in Central Michigan University Reading Clinic located on the campus of the university. The remaining twenty-two Ss were enrolled in Fancher School Reading Clinic at Mt. Pleasant, Michigan. The Fancher Clinic is located in a public school, however, personnel from the Department of Education, Central Michigan University administer the program.

The control group of normal reading Ss were obtained through referrals from private individuals with whom personal contacts had been made. Parental permission was obtained directly without involvement of school officials. Testing was conducted outside the normal school day, e.g., weekends and summer months.

The total pool of Ss was white, attended public schools located in the surrounding areas of Mt. Pleasant, Michigan, and lived in urban and rural areas which have been characterized as middle class neighborhoods. Parental permission was obtained for all Ss. Feedback in form of psychological reports was given to reading clinicians who worked individually with reading deficit Ss and in some cases to parents of Ss in the control and reading deficit groups. Table 2 presents a statistical summary of the ages and IQ of the total sample.

TABLE 2.--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.

Reading Deficit Criteria

The following criteria were used to determine suitability for inclusion in the sample:

A reading level of one or more years below expected grade level.

Average range of intelligence as determined by the Wechsler Intelligence Scale for Children (Wechsler, 1949). The average range is defined as a Performance scale IQ of 90-110.

Normal general health was required with corrected visual or hearing defects as recorded in school records.

Two instruments were used in establishing reading deficit: (a) Wide Range Achievement Test, Reading subtest (Jastak & Jastak, 1965), (b) Wechsler Intelligence Scale for Children (Wechsler, 1949). Scores from both of these tests were used to determine the level of reading deficit.

Reading Deficit Definition

The extent of reading deficit was defined in the following way.

The measure of the actual reading level was taken as the grade level performance which corresponded with the scores of S on the Wide Range Achievement Test (Jastak & Jastak, 1965).

The expected reading level of S was taken as that given on the Wide Range Achievement Test (Jastak & Jastak, 1965) which corresponded with scores on the performance IQ of the Wechsler Intelligence Scale for Children (Wechsler, 1949). The non verbal IQ was used in order to minimize the extent to which the measure of potentiality and the reading deficit would be related by a common factor (Rabinovitch, 1954). Reading deficit was taken as the difference between the expected and actual reading grade level of S. To be considered for inclusion in this study S had to have a reading deficit in excess of one grade.

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.

Normal Reading Group

The normal reading control group was composed of Ss who were reading at grade level or above that expected for age and IQ with no past history of a reading lag.

Apparatus

A Bell and Howell Language Master (Model #711B) was used to present the auditory and visual stimuli. A shield with a 7.62 cm. (3 in.) high by 3.81 cm. (1 1/2 in.) wide window was placed between S and the stimulus allowing for display of only one visual stimulus at a time. Cardiac activity and GSR were continuously recorded on an E & M physiograph. A Lehigh Valley solid state programming system was used to trigger a signal to the E & M physiograph at stimulus onset.

Stimuli

The six stimuli were digits 1 through 9 randomly selected without replacement for each S with the restriction that the same digit was not used twice in a given trial. The visual stimuli were printed on Language Master cards in 0.64 cm. (1/4 in.) black type. The auditory stimuli came from the speaker of the Language Master via tape in a female voice.

Procedure

Thirty-two reading deficit Ss[2] were tested in a session prior to the experiment to determine suitability for inclusion in this study. During the initial session the performance scales of the Wechsler Intelligence Scale for Children (Wechsler, 1949), The Wide Range Achievement Test (Jastak & Jastak, 1965) and Minnesota Percepto-Diagnostic Test (Fuller, 1969) were administered. The performance scales of the Wechsler Intelligence Scale were also administered to sixteen Ss in normal reading group.

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[2]Thirty-seven reading deficit Ss were actually tested. As noted, experiment was discontinued with two Ss who exhibited negative reaction to the experimental conditions. Three other Ss were dropped from the study because their measured IQ was below criterion.

Each S in the reading deficit groups was escorted individually by the experimenter to the physiological psychology laboratory located in Rowe Hall at Central Michigan University from the classrooms of the respective reading clinics. Approximately fifteen minutes were used for transportation and to familiarize the child with the experimenter's assistant and the new surroundings. All the children in the reading clinics had met the experimenter during the initial testing session, therefore, the experimenter was familiar to Ss. The children in the normal reading group were escorted to the physiology laboratory by their parents or were escorted by experimenter from their home to the laboratory. Five of these children met the experimenter for the first time at the physiology laboratory. Psychometric data was gathered at a later date on these children. In all cases approximately fifteen minutes were used to familiarize S with the experimenter, the assistant and the surroundings. During the warm up period the children appeared familiar with heart rate readings taken on astronauts and did not appear apprehensive to take part in the experiment. After the experiment the children were escorted back to the reading clinics or home.

In the experiment proper, the child was asked to sit in front of the language master. Partitions which always remained in place were used to enclose the area and screen the physiograph equipment from the view of S. The stimulus display area and procedures were then described to S with the following instructions:

> You will see numbers through this opening and you will hear numbers from this speaker (both areas on language master were pointed out to S). Now I am going to place one of the electrodes on your wrist, one on your arm, one on your leg and one on your finger. These are like little microphones that listen to your heart beat.

Specific instructions, described in Figure 1 and 2, for performing the individual tasks were then given and the stimuli presented. The S was asked to perform the tasks by verbal recall until he understood what was required of him. After the practice trials (an average of 2 trials) the actual experimental series was given. All Ss participated in the same intrasensory and intersensory conditions. Two experimenters were present, at all times, one worked with Ss and the other monitored the output on the physiograph.

Physiological Methods

Heart rate was recorded from standard leads I, II, and III (active electrodes on left arm and right wrist and ground electrodes on left leg). All cardiotach electrodes were applied with sodium chloride electrode paste. EKG-R waves were used to trigger input signal to the cardiotach which measured the rate as the reciprocal of the average R-R time interval. The change in GSR during the experimental period was measured using the "Record AC" mode of the E & M physiograph preamplifier. A constant DC of 20 microamperes was applied across the electrodes and changes in resistance amplitude and frequency were recorded on a strip chart. A soft lead sensing electrode was strapped around the middle finger. The ground electrode was attached to the wrist with sodium chloride electrode paste. Responses of resistance change of 750 ohms or more were counted.

Experimental Conditions

Intersensory Tasks

Bisensory visual-auditory paired stimuli (digits 1 through 9) were presented simultaneously. Three pair of stimuli were presented two seconds apart. Four separate recall conditions were used.

Recall Order Conditions

1. Recall V_1 V_2 V_3
   A_1 A_2 A_3
   Pair recall (PR) i.e., V_1 A_1 V_2 A_2 V_3 A_3 citing the visual stimuli first.

2. Recall A_1 A_2 A_3
   V_1 V_2 V_3
   Pair recall (PR) i.e., A_1 V_1 A_2 V_2 A_3 V_3 citing the audio first.

3. Recall V_1 V_2 V_3
   A_1 A_2 A_3
   Linear recall (LR) i.e., V_1 V_2 V_3 A_1 A_2 A_3 citing the visual first.

4. Recall A_1 A_2 A_3
   V_1 V_2 V_3
   Linear recall (LR) i.e., A_1 A_2 A_3 V_1 V_2 V_3 citing the audio first.

Ten trials were performed in each task. The intertrial interval was an average of 20 seconds with range of 15 to 25 seconds and the intertask interval was an average of 60 seconds with range of 55 to 65 seconds. After completion of four tasks an average rest period of ten minutes was given. Since the same Ss were given all the eight tasks, any effects which might result from the order of presentation were balanced out by using a latin square design. Within the latin square design for order, 24 Ss were randomly assigned to intersensory conditions first and 24 Ss to intrasensory conditions first. Diagrammatic illustration of the four intersensory experimental condition are shown in Figure 1.

Intrasensory Visual Tasks

Three pairs of stimuli (digits 1 through 9) were presented two seconds apart. The two stimulus digits in each pair were placed in a vertical spatial relation, i.e., one above another separated by 0.32 cm (1/8 in.) blank space.

Recall Order Conditions

There were two separate recall tasks employed:

5. Linear recall (LR), i.e., the correct order was V_1 V_3 V_5 V_2 V_4 V_6

Intersensory Task Number	Presentation	Stimulus condition 6 second period	Recall condition 6 second period	Instructions
1	Simultaneous 10 trials	V 5 9 4 A 8 7 2 /----/ 2 seconds /--------------/ 6 seconds	V $5_{(1)}$ $9_{(3)}$ $4_{(5)}$ PR A $8_{(2)}$ $7_{(4)}$ $2_{(6)}$V1st	You will see & hear 3 prs. of nos. As soon as the 3rd pr. is finished tell me the 1st pr., 2nd pr., 3rd pr. starting with the no. you see in the pr.
2	Simultaneous 10 trials	V 6 7 1 A 2 4 5 /-----/ 2 seconds /-------------/ 6 seconds	A $2_{(1)}$ $4_{(3)}$ $5_{(5)}$ PR V $6_{(2)}$ $7_{(4)}$ $1_{(6)}$A1st	You will hear & see 3 prs. of nos. As soon as the 3rd pr. is finished tell me the 1st pr., 2nd pr., 3rd pr. starting with the no. you hear in the pr.
3	Simultaneous 10 trials	V 8 9 2 A 4 4 7 /-----/ 2 seconds /--------------/ 6 seconds	V $9_{(1)}$ $7_{(2)}$ $4_{(3)}$ LR A $5_{(4)}$ $3_{(5)}$ $1_{(6)}$V1st	You will see & hear 3 prs. of nos. As soon as the 3rd pr. is finished tell me all the nos. you see first then all the nos. you hear next.
4	Simultaneous 10 trials	V 7 8 6 A 3 2 4 /-----/ 2 seconds /-------------/ 6 seconds	A $3_{(1)}$ $2_{(2)}$ $4_{(3)}$ LR V $7_{(4)}$ $8_{(5)}$ $6_{(6)}$A1st	You will see & hear 3 prs. of nos. As soon as the 3rd pr. is finished tell me all the nos. you hear first then all the nos. you see next.

FIGURE 1.--DIAGRAMMATIC ILLUSTRATION OF FOUR INTERSENSORY EXPERIMENTAL CONDITIONS, V = VISUAL; A = ADUITORY; PR = PAIR RECALL; LR = LINEAR RECALL; SUBSCRIPT 1, 2, 3, 4, 5, 6 = ORDER OR RECALL IN LR AND PR.

6. Pair recall (PR), S was required to recall pairwise V_1 V_3 V_5

   V_2 V_4 V_6

   The correct order was V_1 V_2 V_3 V_4 V_5 V_6

Intrasensory Auditory Tasks

Three pairs of auditory stimuli (digits 1 through 9) were presented two seconds apart. The time interval between stimuli in a pair was one half second. The time interval in auditory intrasensory task was the following:

A_1	2 sec.	A_3	2 sec.	A_5	2 sec.
.5 sec.		.5 sec.		.5 sec.	
A_2		A_4		A_6	

Recall Order Conditions

The PR and LR recall tasks were the same as those employed in visual intrasensory recall order conditions:

7. Pair recall (PR), S was required to recall pairwise A_1 A_3 A_5

   A_2 A_4 A_6

   The correct order was A_1 A_2 A_3 A_4 A_5 A_6

8. Linear recall (LR), i.e., the correct order was A_1 A_3 A_5 A_2 A_4 A_6

Each S performed ten trials in each task condition. The intertrial and intertask intervals were the same as in the intersensory conditions. Diagrammatic illustration of the four intrasensory experimental conditions are shown in Figure 2.

Design

The experimental objectives provided that Ss be distributed into categories represented by variable (p). Assignment to conditions was necessarily a priori. Repeated measures on two of the independent variables [(q) and (r)] by each S was an integral part of the experiment. These considerations favored choosing a design based on multifactor analysis than on a multivariate design.

Independent Variables

Three independent variables were involved in the designs for all the experiments. Reading classification, p, consisted of three fixed levels, normal, primary and secondary. The tasks, four each for intersensory and intrasensory, were taken as an independent variable, q.

The third independent variable, r, for all the physiological measures, except heart rate (HR) deceleration and acceleration, consisted of the three six second intervals, preperiod, stimulus and recall periods. For the HR deceleration and acceleration measures the two intervals

Intrasensory Task Number	Presentation	Stimulus condition 6 second period	Recall condition 6 second period	Instructions
5	Simultaneous 10 trials	V 3 8 1 V 9 2 4 /-----/ 2 seconds /--------------/ 6 seconds	V $3_{(1)}$ $8_{(2)}$ $1_{(3)}$ LR V $9_{(4)}$ $2_{(5)}$ $4_{(6)}$ Top row 1st	You will only see 3 prs. of nos., one on top of the other. As soon as the 3rd pr. is finished tell me the top row of nos. first then the botton row of nos. next.
6	Simultaneous 10 trials	V 7 3 8 V 2 6 5 /-----/ 2 seconds /--------------/ 6 seconds	V $7_{(1)}$ $3_{(3)}$ $8_{(5)}$ PR V $2_{(2)}$ $6_{(4)}$ $5_{(6)}$	You will only see 3 prs. of nos., one on top of the other. As soon as the 3rd pr. is finished tell me the prs. of nos. starting with the 1st pr. then 2nd pr. & then the 3rd pr.
7	Alternating 10 trials	2 seconds /-----/ A 9 4 2 .5 seconds 3 6 1 /--------------/ 6 seconds	A $9_{(1)}$ $4_{(3)}$ $2_{(5)}$ PR A $3_{(2)}$ $6_{(4)}$ $1_{(6)}$	You will only hear 3 prs. of nos. As soon as the 3rd pr. is finished tell me the prs. of nos. you hear starting with the 1st pr., then 2nd pr. & then 3rd pr.
8	Alternating 10 trials	2 seconds /-----/ A 4 9 7 .5 seconds 6 3 1 /--------------/ 6 seconds	A $4_{(1)}$ $9_{(2)}$ $7_{(3)}$ LR A $6_{(4)}$ $8_{(5)}$ $1_{(6)}$ Top row 1st	You will only hear 3 prs. of nos. As soon as the 3rd pr. is finished tell me the first nos. in each pr. then the 2nd nos. for each pr. next.

FIGURE 2.--DIAGRAMMATIC ILLUSTRATION OF FOUR INTRASENSORY EXPERIMENTAL CONDITIONS, V = VISUAL; A = ADUITORY; PR = PAIR RECALL; LR = LINEAR RECALL; SUBSCRIPT 1, 2, 3, 4, 5, 6 = ORDER OF RECALL IN LR AND PR.

are the difference between the base in the preperiod and the subsequent stimulus and recall periods. For the performance measures, r, variable was taken as the gross, order and interchange error types for the intrasensory and total data. Gross auditory, gross visual, order auditory, order visual and interchange error types were used as, r, variable for the intersensory tasks.

Dependent Variables

All the physiological data and recall responses were taken at the same time for each S. Each of the eight tasks was presented ten times in a counterbalanced array. The different physiological measurements, and the recall errors made on the tasks were each taken as dependent variables for an analysis of variance.

Mean Heart Rate

For the three experimental intervals, preperiod (r_1), stimulus period (r_2) and recall period (r_3), the time of each interval was six seconds. The HR (bpm) for each six seconds was recorded. If more than one beat occurred within one second then the average beat was taken for that second. The mean HR over ten trials for S for each task in the r_1, r_2, r_3 periods was taken as the measure of dependent variable.

Heart Rate Variability

The variance of the six beats in a period was taken as a measure of HR variability in that period. The dependent variable was taken as the mean of the ten trials for a task by a S during a period (r_1, r_2, r_3).

Heart Rate Deceleration

The extent of the occurrence of HR deceleration was determined by taking the lowest of the six beats in the pre-period on each trial as a base for comparison with the lowest beat in the stimulus and recall periods for that trial. The mean differences over ten trials for each task for each S was used as the measure of dependent variable in the r_1, r_2 periods.

Heart Rate Acceleration

The extent of the occurrence of HR acceleration was determined by taking the highest of the six beats in the pre-period on each trial as a base for comparison with the highest beat in the stimulus and recall period for that trial. The mean differences over ten trials for each task for each S was used as the measure of dependent variable in the r_1, r_2 periods.

GSR

The GSR criterion was a change of 750 ohms from immediately preceding level. The dependent variable measure was taken as the frequency of GSR's over the ten trials for a single task during r_1, r_2, r_3 periods for S.

Errors

For the intrasensory tasks, the independent variables r_1, r_2, r_3 represent the three error types, gross, order and interchange. Gross error was scored for omissions of the correct digit or substitution by another digit. One point was given for each gross error. Order errors were scored for digits properly recalled but out of sequence. Therefore, only correct digits were scored for order error. One point was given for each digit out of order. Interchange errors were counted for pairs of digits properly recalled in which inversion occurred, i.e., in a VA pair, the auditory digit was recalled as a visual digit. One point was scored for each digit inverted. The measure of dependent variable is the mean of errors during recall for ten trials for each task for each S. 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.

Data Analysis

Analysis of Variance

A three variable multifactor design with repeated measures on two variables was chosen for all the experiments

(Winer, 1962, p. 319). Such a design assumed additive main effects and interactions which in this design were easily interpreted. A counterbalanced ordering of the task by a latin square arrangement of presentation was used to avoid non random sequencing effect. The correlation between pairs of experimental errors which was of concern in a repeated measures design of this type was treated by nesting the subject variance under the classification variable.

Simple Effects

If in the repeated measures analysis of variance significant two way interactions ($p < .05$) were found, then simple effects, single factor analyses of variance were carried out for the two interacting variables (Winer, 1971, p. 457 and 545).

One of the multifactor analyses of variance contained a significant three way interaction. Simple interaction analysis (Winer, 1962, p. 252) was then carried out on the three, two by two tables. Single factor simple, simple main effect analyses (Winer, 1962, p. 252) treatment were applied to those two way tables showing interaction significance ($p < .05$).

Newman-Keuls Comparisons of Means

Where means for a single factor were found to be significantly different either by a multifactor or simple effect ANOVA then pairwise comparisons by the Newman-Keuls method was carried out for "logical grouping" (Winer, 1962, p. 238).

t Test

Comparison of the means for errors during intrasensory tasks with those errors during intersensory tasks was carried out using the procedure of Welch and described in Winer (1962, p. 37).

Sign Test

For HR data, an estimate of deceleration was obtained by testing the number of decreases against chance for the means over the eight tasks using a one-tailed sign test (Siegel, 1956, p. 68). A similar analysis was applied to the acceleration data.

Wilcoxon Matched-Pairs Test

The eight tasks were assumed to be independent of each other. A comparison against random distribution of the differences of the means of the paired HR variability for each task was carried out for the normal reading-primary reading deficit and secondary reading deficit-primary reading deficit group. Since magnitude as well as direction was considered important a two-tailed Wilcoxon Matched-Pairs Test (Siegel, 1956, p. 75) was used in the analyses.

CHAPTER III

RESULTS

In this chapter, the analyses of the physiological and performance dependent measures which are the following: heart rate, heart rate variability, heart rate deceleration, GSR, and recall errors collected through procedures described in Chapter II are presented as evidence related to the hypotheses described in Chapter I. The analyses are described first for all 8 tasks followed by separate treatments of intersensory and intrasensory tasks. Significances had to reach the $p < .05$ level to be considered.

Heart Rate Measures

A summary of analysis of variance of the mean HR scores as a function of Reading Classification, Task and Period for all 8 tasks is given in Table 3. Significant interaction was obtained for Tasks X Periods ($F = 4.18$, $df = 14/630$, $p < .0005$). This interaction is shown graphically in Figure 3. Comparison of simple effects of the mean HR of the eight tasks for the preperiod, stimulus and recall periods revealed significant differences for the preperiod and stimulus periods ($F = 45.75$ and 21.55, $df = 7/630$,

TABLE 3.--A summary of the analysis of variance of the mean heart rate as a function of reading classification, task and period.

Source	*df*	*MS*	*F*	*p*
Between subjects				
Classification (c)	2	345.36	0.7181	ns
*S*s within group	45	480.91		
Within subjects				
Task (T)	7	15.152	1.50	ns
C X T	14	7.726	0.763	ns
T X *S*s within group	315	10.12		
Period (P)	2	5.293	1.50	ns
C X P	4	3.391	0.961	ns
P X *S*s within group	90	3.537		
T X P	14	3.219	4.18	<.0005
C X T X P	28	0.6771	0.882	ns
T P X *S*s within group	630	0.7676		

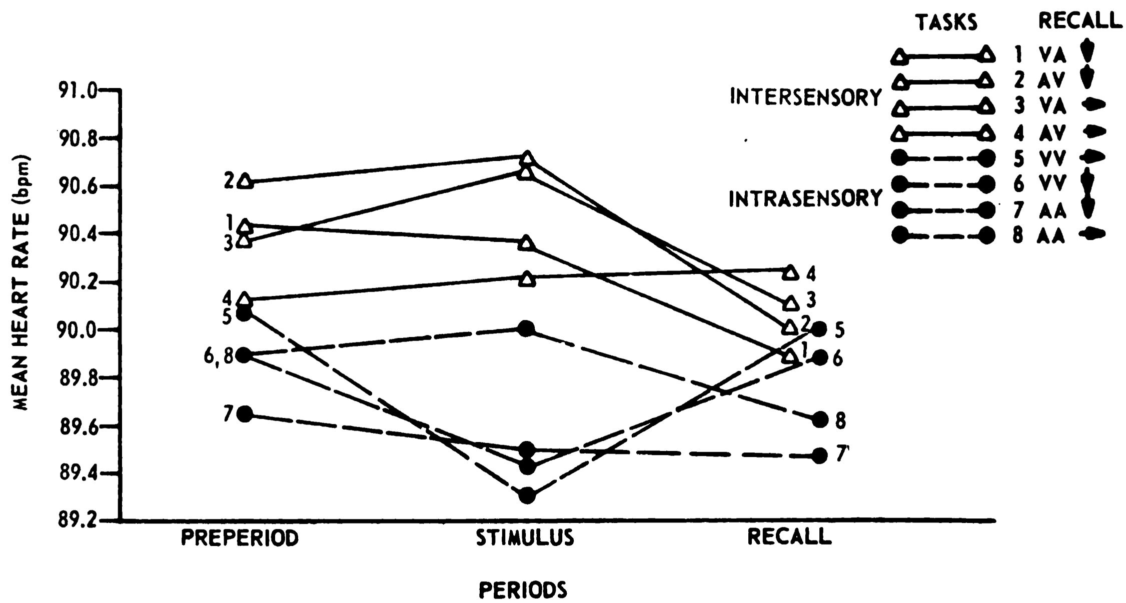

FIG. 3--MEAN HEART RATE FOR INTRASENSORY AND INTERSENSORY TASKS AS FUNCTION OF PERIODS FOR TOTAL SAMPLE

$p < .01$ respectively). Similar significance was not obtained for the means in the recall period. Consequently, the mean of the four intersensory tasks in the preperiod was compared with a Newman-Keuls test with that of the four intrasensory tasks and was found to be significant ($p < .01$). Similarly, for the stimulus period the mean of the four intersensory tasks exceeded that of the intrasensory ones as shown by a Newman-Keuls significance ($p < .01$).

The simple effects analyses for individual tasks across the three periods were also carried out. Simple effects for the mean HR of the first three intersensory tasks were significant (F = 3.86, 17.69, 3.62, df = 2/630, p < .05, .01, .05 respectively). Newman-Keuls indicated that the mean HR during the recall period for these three tasks decreased from the stimulus periods (p < .05, .01, .05 respectively).

For the first two intrasensory tasks (5, 6) which are visual, simple effect significances (F = 15.74, 6.11, df = 2/630, $p < .01$), were obtained. For both tasks, Newman-Keuls tests indicated that the mean HR decreased between the preperiod and stimulus periods, and increased for the stimulus and recall periods, ($p < .01$ for all cases). Similar results were not obtained for the two auditory, intrasensory tasks (7, 8).

Separate analyses of variance of intersensory and intrasensory tasks are summarized in Tables 4 and 5 respectively. Treatment of intersensory data did not yield significant results.

TABLE 4.--A summary of the analysis of variance of the mean heart rate as a function of reading classification, task and period for intersensory data.

Source	*df*	*MS*	*F*	*p*
Between subjects				
Classification (C)	2	172.31	0.661	ns
*S*s within group	45	260.71		
Within subjects				
Task (T)	3	2.240	0.548	ns
C X T	6	2.339	0.572	ns
T X *S*s within group	135	4.091		
Period (P)	2	7.904	2.91	.06
C X P	4	1.128	0.415	ns
P X *S*s within group	90	2.717		
T X P	6	1.239	1.861	ns
C X T X P	12	0.394	0.592	ns
T P X *S*s within group	270	0.666		

On the intrasensory tasks HR means in the preperiod, stimulus and recall periods were 89.95, 89.60, 89.77 respectively. The main effect of period was significant (F = 3.20, df = 2/90, p < .05, Table 5). However, a Newman-Keuls comparison did not indicate any meaningful differences between mean HR for the individual periods.

No significant effects for reading group were found in any of these analyses. The mean HR data are presented in

TABLE 5.--A summary of the analysis of variance of the mean heart rate as a function of reading classification, task and period for intrasensory data.

Source	df	MS	F	p
Between subjects				
Classification (c)	2	196.45	0.785	ns
Ss within group	45	250.13		
Within subjects				
Task (T)	3	2.788	0.291	ns
C X T	6	7.891	0.825	ns
T X Ss within group	135	9.564		
Period (P)	2	5.816	3.20	<.05
C X P	4	3.740	2.06	.09
P X Ss within group	90	1.829		
T X P	6	3.441	4.36	<.0005
C X T X P	12	0.6938	0.879	ns
T P X Ss within group	270	0.7888		

Tables 3, 4, 5 and in Figure 3. Consequently, these data do not support hypotheses 1, 2, 3, 5, 6, and 7 (given in Chapter I) all of which predicted differences in HR among the reading classification groups as a function of task and period.

Hypothesis 3 proposed HR deceleration in intersensory would exceed that in intrasensory tasks for normal reading group. The mean HR data do not support this prediction. The finding of a higher mean HR for the intersensory tasks in the preperiod and stimulus periods compared to intrasensory tasks was in the opposite direction to that expected.

[illegible]
[illegible] ratio as a function of [illegible]
Task and period for intrasensory data

Source	df	MS	F
Between subjects			
Classification (C)	2	108.45	[illegible]
Ss within groups	48	[illegible]	
Within subjects			
Task (T)	[illegible]	[illegible]	[illegible]
C x T	[illegible]	[illegible]	[illegible]
T x Ss within groups	[illegible]	[illegible]	
Period (P)	[illegible]	[illegible]	[illegible]
C x P	[illegible]	[illegible]	[illegible]
P x Ss within groups	[illegible]	[illegible]	
T x P	[illegible]	[illegible]	[illegible]
C x T x P	[illegible]	[illegible]	[illegible]
T x P x Ss within groups	[illegible]	[illegible]	

[illegible]

[illegible] tion. The finding of a higher mean HR for the intersensory tasks in the preperiod and stimulus periods compared to intrasensory tasks was in the opposite direction to that expected.

For the total sample, mean HR decreases in recall period from the stimulus period were found in the intersensory tasks 1, 2 and 3 and mean HR decreases occurred in intrasensory tasks 5 and 6 from preperiod to stimulus period followed by increases in recall period (Figure 3). These tasks, 1, 2, 3, 5 and 6, use visual stimuli with instructions for recall which require that the visual stimuli be given first or in paired recall with the auditory stimuli. Changes in mean HR across periods were not obtained for intrasensory auditory tasks 7 and 8 nor for the linear recall intersensory task 4 which requires that the auditory stimuli be cited first in recall. These results suggest that the modality characteristic of the task (auditory or visual) as well as the presentation (intersensory or intrasensory) produced a change in direction of mean HR as a function of periods.

Heart Rate Variability Measures

A summary of analysis of variance of the mean HR variability as a function of Reading Classification, Task and Period for both intrasensory and intersensory modes of presentation is given in Table 6.

No main effects reached statistical significance. However, the interaction of Classification X Task (F = 1.74, df = 14/315, p < .05) and Task X Period (F = 2.16, df = 14/630, p < .001) were significant. For the Classification

TABLE 6.--A summary of analysis of variance of the mean heart rate variability as a function of reading classification, task and period.

Source	df	MS	F	p
Between subjects				
Classification (C)	2	482.57	0.336	ns
Ss within group	45	1433.54		
Within subjects				
Task (T)	7	139.68	1.37	ns
C X T	14	176.95	1.74	<.05
T X Ss within group	315	101.54		
Period (P)	2	113.58	2.65	.10
C X P	4	82.37	1.92	ns
P X Ss within group	90	42.76		
T X P	14	59.14	2.16	<.001
C X T X P	28	29.39	1.07	ns
T P X Ss within group	630	27.30		

X Task interaction the mean HR variability is shown graphically in Figure 4. Simple effect significance was obtained for the intrasensory auditory pairing task (7) ($F = 13.75$, $df = 2/315$, $p < .01$) across the reading classifications.

The HR variability of the NR group was higher than those of the deficit reading groups, Newman-Keuls ($p < .05$), for this task (7). Significant simple effects were obtained for the NR group across the tasks ($F = 4.40$, $df = 7/315$, $p < .01$), but not for either of the deficit reading classifications.

For the Task X Period interaction, simple effects significance was obtained for the preperiod ($F = 3.93$,

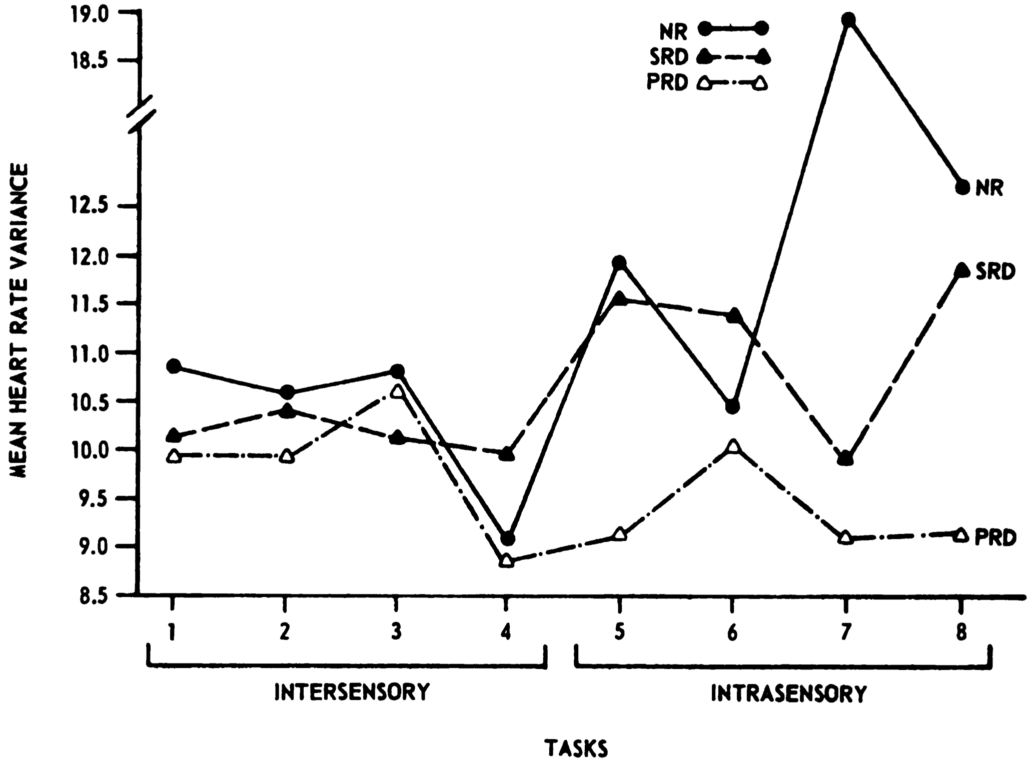

FIG. 4-- THE EFFECT OF TASKS ON THE MEAN HEART RATE VARIABILITY OF THE THREE READING CLASSIFICATIONS

df = 7/630, p < .05) across the tasks. Mean HR variability of tasks across periods is shown graphically in Figure 5.

Across the periods, simple effect significances were obtained for the intersensory linear task (3), (F = 3.22, df = 2/630, $p < .05$) and for the intrasensory auditory pairing task (7) (F = 5.92, df = 2/630, $p < .01$). The HR variability during recall period was higher than that of the stimulus period, Newman-Keuls ($p < .05$) for task (3). For task (7), the preperiod HR variability was higher than those of the stimulus and recall periods, Newman-Keuls ($p < .05$ and $p < .01$) respectively.

Separate analyses of variance were carried out for the intersensory and intrasensory tasks. For the

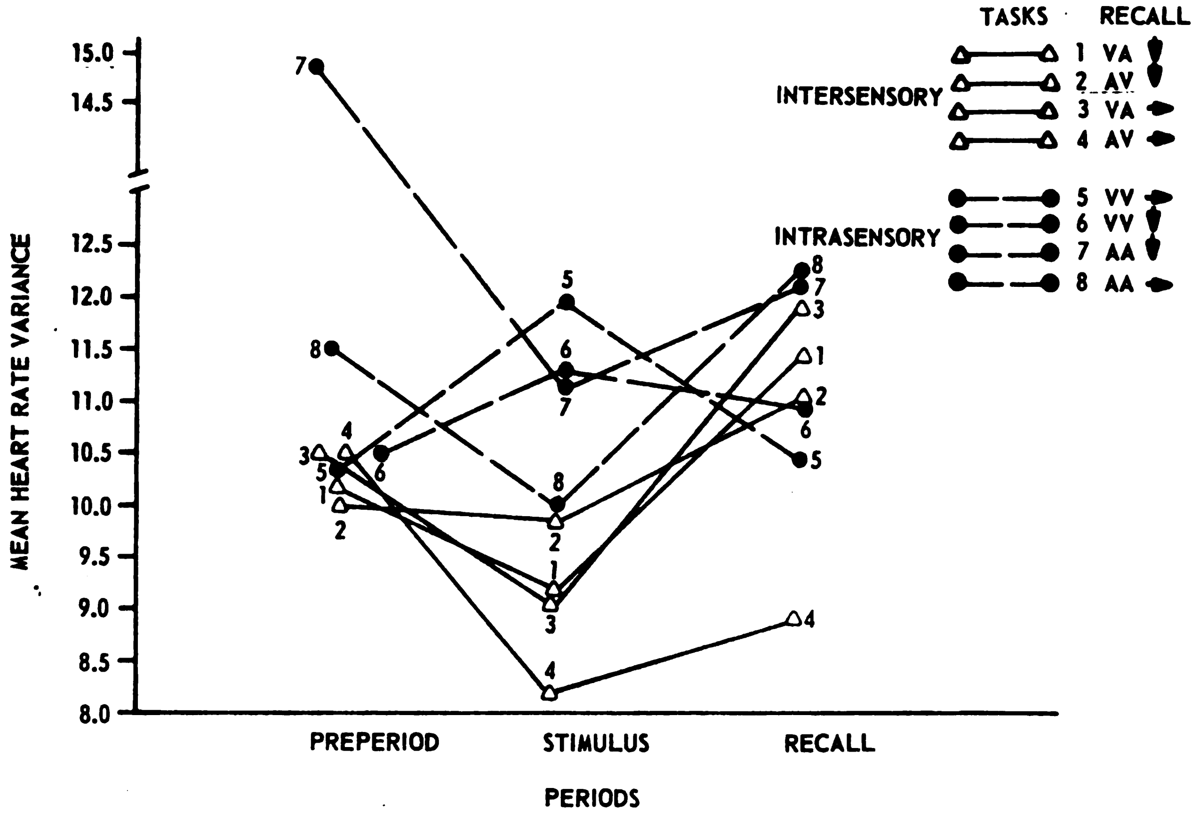

FIG. 5-- MEAN HEART RATE VARIABILITY FOR TASKS ACROSS PERIODS FOR TOTAL SAMPLE

intersensory data, significant main effects for Period with mean HR variabilities of 10.35, 9.12 and 10.82 for preperiod, stimulus and recall periods respectively, (F = 4.88, df = 2/90, $p < .01$, Table 7) were obtained. The summary of analysis of variance for intersensory data is shown in Table 7.

A Newman-Keuls comparison of pairs of means of HR variability for the reading classification across the three periods is given in Table 8. For the total population, the results indicated that the HR variability decreases between the preperiod and stimulus periods and then increases in the recall period (Newman-Keuls $p < .05$). However, similar results were obtained independently only for the SRD group

TABLE 7.--A summary of the analysis of variance on the mean heart rate variability as a function of reading classification, task and period for intersensory data.

Source	df	MS	F	p
Between subjects				
Classification (C)	2	12.08	0.019	ns
Ss within group	45	628.09		
Within subjects				
Task (T)	3	46.78	1.93	ns
C X T	6	7.801	0.322	ns
T x Ss within group	135	24.20		
Period (P)	2	147.53	4.88	<.01
C X P	4	56.52	1.87	ns
P X Ss within group	90	30.22		
T X P	6	29.18	1.64	ns
C X T X P	12	21.29	1.20	ns
T P X Ss within group	270	17.75		

Table 8.--Newman-Keuls comparisons of mean heart rate variability of reading classifications across periods for intersensory data.

Classification Groups	Periods				
	Pre	p*	Stim.	p*	Recall
Control	9.758	ns	9.060	0.01	11.975
Primary	10.448	ns	9.478	ns	9.504
Secondary	10.842	0.01	8.835	0.05	10.988
Total	10.349	0.05	9.124	0.05	10.832

*p represents significance between two periods on either side of the p column.

(Newman-Keuls *p* < .01 and *p* < .05 respectively). An increase in HR variability in recall period over stimulus period was found for the NR group (Newman-Keuls *p* < .01).

A summary of analysis of variance of the mean HR variability for intrasensory data is shown in Table 9. Only one interaction, Tasks X Periods, was significant (F = 2.53, *df* = 6/270, *p* < .02) for the intrasensory tasks (Table 9).

TABLE 9.--A summary of the analysis of variance on the mean heart rate variability as function of reading classification, task and period for intrasensory data.

Source	*df*	*MS*	*F*	*p*
Between subjects				
Classification (C)	2	784.29	0.819	ns
*S*s within group	45	956.47		
Within subjects				
Task (T)	3	116.94	0.720	ns
C X T	6	300.50	1.85	
T X *S*s within group	135	162.39		
Period (P)	2	25.08	0.558	ns
C X P	4	36.91	0.822	ns
P X *S*s within group	90	44.90		
T X P	6	89.16	2.53	<.05
C X T X P	12	43.62	1.23	ns
T P X *S*s within group	270	35.18		

Mean HR variability of intrasensory tasks across periods is depicted in Figure 6. Simple effect analysis showed significance for the intrasensory task (7) across the three periods (F = 4.60, df = 2/270, p < .01, Figure 6). For task 7, both the stimulus and recall variability decreased from the preperiod mean (Newman-Keuls p < .01, .05) respectively. Simple effect significance (F = 5.59, df = 3/270, p < .01) was obtained for the preperiod across the four intrasensory tasks. A comparison of the HR variability in preperiod for the two visual tasks (5, 6) indicated that it was lower than for the auditory tasks (7, 8) (Newman-Keuls p < .01). The HR variability means of task 7 and 8 were combined for the three periods and these new means compared across periods. A decrease and subsequent increase was obtained between preperiod and stimulus and stimulus and recall (Newman-Keuls p < .01, .05 respectively, Figure 6).

The HR variability data presented in Table 6 and Figure 4 support the finding that change in HR variability occurred in NR group across all eight tasks but not for the two deficit reading groups, PRD and SRD. Higher HR variability occurred for NR group for intrasensory auditory task 7. For the total sample change in HR variability as a function of periods was found for intersensory task 3 and intrasensory task 7. A common element which might account

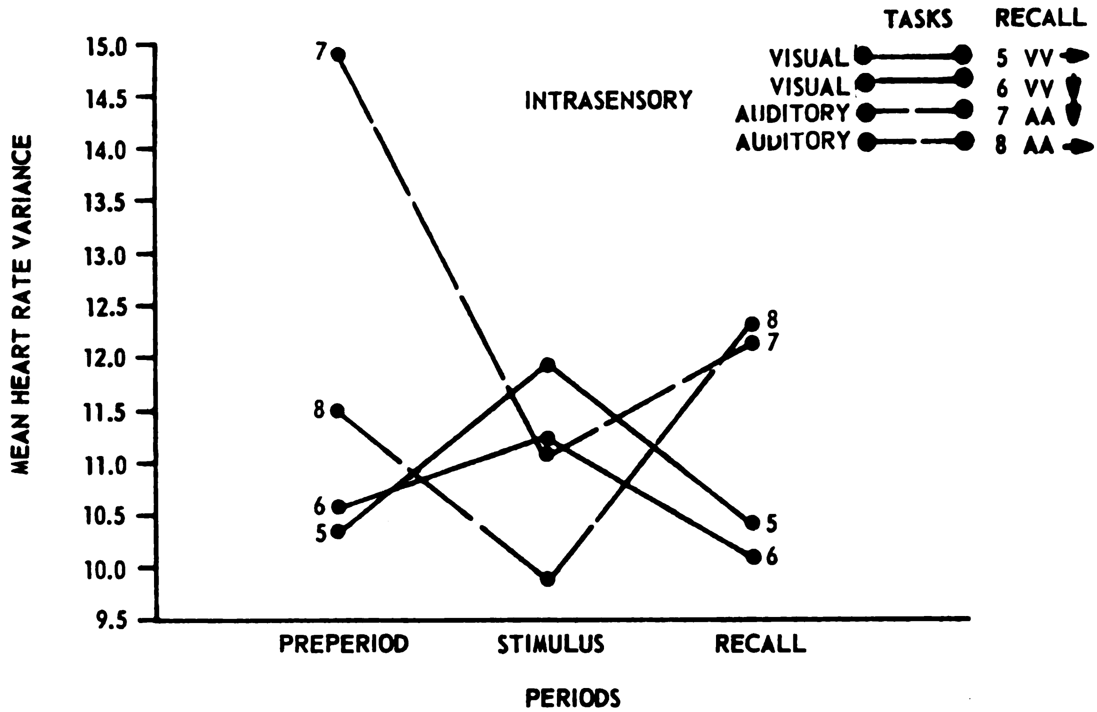

FIG. 6--MEAN HEART RATE VARIANCE FOR INTRASENSORY TASKS ACROSS PERIODS FOR TOTAL SAMPLE

for change in HR variability in both these tasks is unclear. However, the HR variability data on the tasks do differ; task 7, HR variability was higher in preperiod than in stimulus and recall periods, whereas, in task 3 the HR variability in recall period was higher than in stimulus period (Figure 5). The increase in HR variability in task 7 for the total sample may have resulted from the very high value, (14.75) for the NR group on this task 7 (Figure 5).

For the total sample, the HR variability decreased in the stimulus period from the preperiod followed by increase in recall period for intersensory tasks (Figure 5). For these tasks, the direction of change in HR variability was opposite to that found for direction of change in mean HR measure.

The intrasensory results presented in Figure 6 indicated that HR variability was related to modality characteristics of the tasks (auditory and visual). The combined HR variability of visual task 5 and 6 was lower than the combined means of auditory tasks in the preperiod. The combined, mean HR variability of auditory tasks,decreased in stimulus and subsequently increased in recall period.

Heart Rate Deceleration Measures

The summary of analysis of variance of HR deceleration as function of Reading Classification, Task and Period for all 8 Tasks is given in Table 10.

For each trial the lowest beat in preperiod was used as base for comparison with the lowest beat in each of the other periods. The mean difference over the 10 trials for each task was the dependent variable. Main effects significance was obtained for the reading classification groups with mean HR deceleration of -.60, +.17, and +.09 for NR, PRD and SRD respectively ($\underline{F} = 3.68$, $\underline{df} = 2/45$, $\underline{p} < .03$). Mean HR deceleration of reading classification groups is shown graphically in Figure 7. HR deceleration occurred for the NR group, but not for each of the deficit reading groups.

TABLE 10.--A summary of analysis of variance of heart rate deceleration as function of reading classification, task and period.

Source	df	MS	F	p
Between subjects				
Classification (C)	2	46.95	3.68	< .05
Ss within group	45	12.76		
Within subjects				
Task (T)	7	8.775	1.59	ns
C X T	14	4.397	0.799	ns
T X Ss within group	315	5.506		
Period (P)	1	15.58	2.55	ns
C X P	2	7.438	1.22	ns
P X Ss within group	45	6.116		
T X P	7	14.36	8.33	< .0005
C X T X P	14	1.423	0.825	ns
T P X Ss within group	315	1.725		

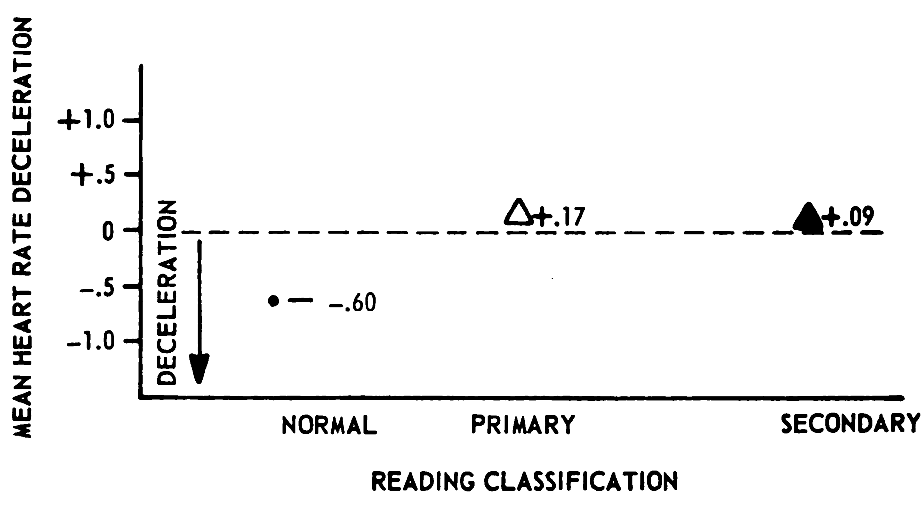

FIG. 7-- MEAN HEART RATE DECELERATION (FROM MINIMUM HR (bpm) IN PREPERIOD) FOR READING CLASSIFICATION GROUPS FOR TOTAL DATA (INTER AND INTRA)

The Task X Periods interaction was significant ($\underline{F}$ = 8.33, $\underline{df}$ = 7/315, $\underline{p}$ < .0005). Mean HR deceleration for tasks across period for total sample is depicted in Figure 8. Tests of simple effects showed HR deceleration for the intersensory tasks (1, 2, and 3) in the recall period ($\underline{F}$ = 12.57, 11.95, 12.44, $\underline{df}$ = 1/315, $\underline{p}$ < .01 respectively). The HR deceleration in the recall period for the three intersensory tasks was indicated relative to their respective stimulus periods as well (Newman-Keuls $\underline{p}$ < .01). For the two intrasensory visual tasks (5,6), HR deceleration during the stimulus periods was obtained ($\underline{F}$ = 10.45, 11.30, $\underline{df}$ = 1/315, $\underline{p}$ < .01 respectively). HR deceleration occurs for task 8 in

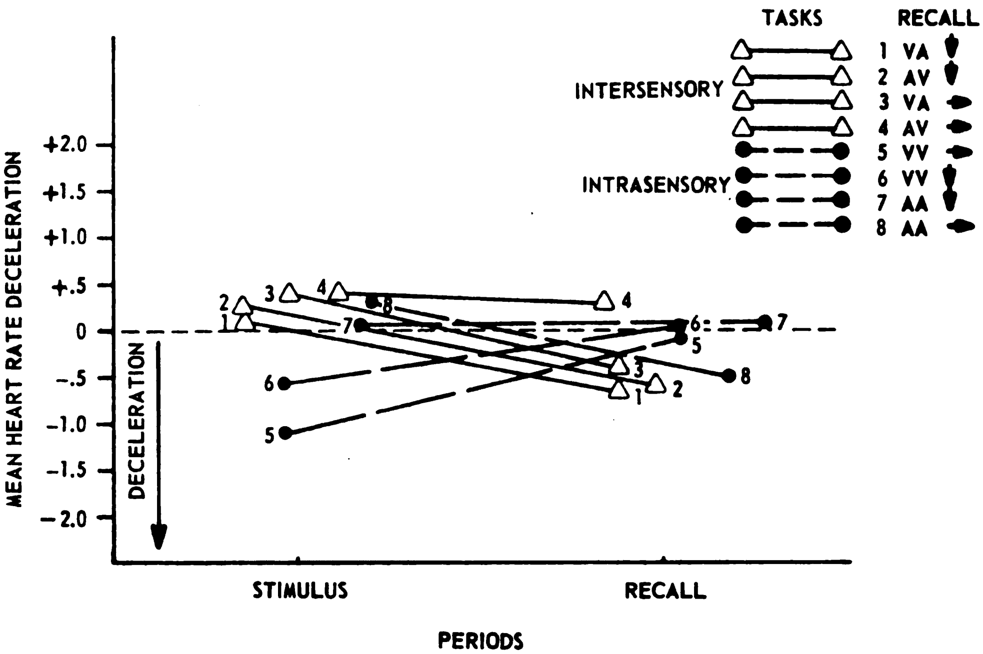

FIG. 8-- MEAN HEART RATE DECELERATION FOR INTERSENSORY AND INTRASENSORY TASKS ACROSS PERIODS FROM MINIMUM HR(bpm) IN PREPERIOD

recall period relative to the stimulus period ($F = 13.34$, $df = 1/315$, $p < .01$, Newman-Keuls $p < .01$, Figure 8).

A separate treatment of intersensory data is summarized in Table 11. A significant main effect for HR deceleration in the stimulus and recall periods with means of +.36 and -.37 respectively ($F = 10.38$, $df = 1/45$, $p < .002$) was obtained.

TABLE 11.--A summary of analysis of variance on mean heart rate deceleration as function of reading classification, task and period for intersensory data.

Source	df	MS	F	p
Between subjects				
Classification (C)	2	27.13	2.95	.06
Ss within group	45	9.178		
Within subjects				
Task (T)	3	8.608	1.50	ns
C X T	6	2.957	0.5187	ns
T X Ss within group	135	5.702		
Periods (P)	1	51.92	10.38	< .002
C X P	2	3.390	0.678	ns
P X Ss within group	45	4.998		
T X P	3	4.058	2.37	.07
C X T X P	6	1.497	0.877	ns
T P X Ss within group	135	1.706		

Treatment of intrasensory data is given in Table 12. A Task X Period interaction significance was obtained for the separate analysis of variance of the intrasensory tasks ($F = 9.39$, $df = 3/135$, $p < .0005$, Table 12). Mean HR

TABLE 12.--A summary of analysis of variance on mean heart rate deceleration as function of reading classification, task and period for intrasensory data.

Source	df	MS	F	p
Between subjects				
Classification (C)	2	25.82	2.45	.09
Ss within group	45	10.50		
Within subjects				
Task (T)	3	9.117	1.88	ns
C X T	6	5.302	1.09	ns
T X Ss within group	135	4.841		
Periods (P)	1	2.633	0.935	ns
C X P	2	7.145	2.53	.09
P X Ss within group	45	2.814		
T X P	3	16.46	9.39	< .0005
C X T X P	6	0.7898	0.450	ns
T P X Ss within group	135	1.752		

deceleration for intrasensory tasks across stimulus and recall periods is depicted in Figure 9.

A simple effects test supported the results obtained from the total data, i.e., for the two visual tasks (5, 6) HR decelerations were indicated in the stimulus period (F = 18.97, 6.45, df = 1/135, $p < .01$ respectively, Figure 9).

Since the lowest beat in the preperiod was taken as a base to compare with the lowest beat in the stimulus and in the recall periods, the number of decreases (independent of magnitude) for the means of the eight tasks was taken as a measure of the probability of deceleration. For the NR

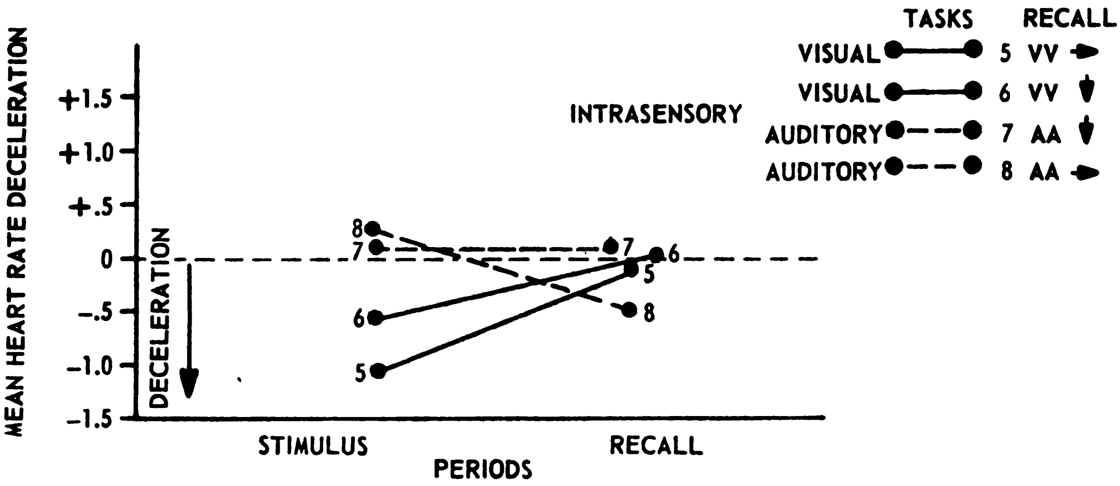

FIG. 9— MEAN HEART RATE DECELERATION FOR INTRASENSORY TASKS ACROSS STIMULUS AND RECALL PERIOD FOR TOTAL SAMPLE

group the combined (stimulus and recall) decreases for the eight tasks shows deceleration, n = 14, the decreases, n = 11, $\underline{p} < .02$ with a one tailed, Sign test.

Deceleration was not obtained for the PRD group, n = 16, the decreases, n = 5, being less than half the observed changes. Deceleration was indicated in the recall period, n = 8, the decreases n = 7, p < .03, by the Sign test, but not for stimulus or combined decreases for the SRD group. Similar Sign test analyses did not indicate that acceleration, based upon preperiod maximum HR as a base occurs for any of the groups or periods.

Hypothesis 1 predicted HR deceleration would occur in NR group with stimulus presentation. The data presented in Table 10 and Figure 7 indicated that HR deceleration occurred only in NR group. A Classification X Period Interaction was not found. Hypothesis 1 as stated would not be supported by the results. Hypotheses 5 and 6 predicted HR deceleration would occur in PRD group but not in SRD group with stimulus presentation of intrasensory and intersensory conditions which cite the visual stimuli first. The results do not support either of these hypotheses.

For the intersensory data, a main effect for Periods was observed (Table 11). HR deceleration occurred in recall period which was in direction opposite to initial expectations.

The analysis of direction of change in HR deceleration for tasks across periods indicated similar results for the intersensory tasks 1, 2, 3 and auditory, intrasensory task 8; intersensory task 4 and intrasensory, auditory task 7; intrasensory, visual tasks 5 and 6 (Figure 8). These results follow the data for mean HR except for task 8 where the change in mean HR across periods was not significant.

The analyses of the number of decreases independent of magnitude by the Sign test indicated that for NR group, HR deceleration occurred in combined stimulus and recall periods, HR deceleration was not observed for PRD group whereas, HR deceleration was found in recall period for

SRD group. The intrasensory visual tasks 5 and 6 were the only tasks in which HR deceleration was observed in stimulus period for total sample (Figure 9).

Heart Rate Acceleration Measures

The analysis of variance of HR acceleration in the stimulus and recall periods for all 8 tasks is given in Table 13.

TABLE 13.--A summary of analysis of variance for mean heart rate acceleration as a function of reading classification, task and period.

Source	df	MS	F	p
Between subjects				
Classification (C)	2	1.140	0.117	ns
Ss within group	45	9.768		
Within subjects				
Task (T)	7	1.952	0.974	ns
C X T	14	2.327	1.16	ns
T X Ss within group	315	2.003		
Period (P)	1	0.197	0.067	ns
C X P	2	3.348	1.13	ns
P X Ss within group	45	2.957		
T X P	7	1.628	2.60	$< .01$
C X T X P	14	0.654	1.04	ns
T P X Ss within group	315	0.627		

For each trial the highest beat in the preperiod was used as base for comparison with the highest beat in each of the other periods. The mean difference over the 10 trials for each task was the dependent variable. For HR acceleration from the preperiod maximum HR only a Task X Period interaction was significant (F = 2.60, df = 7/315, p < .01). Decreases which occurred were rejected since the criteria for acceleration was chosen to be an increase and therefore the obtained significance was meaningless.

A separate treatment of intersensory data yielded a significant Task X Period Interaction (F = 3.25 df = 3/135, p < .02). The direction of change (decrease) was not in accord with stated criteria for acceleration and therefore meaningless. An analysis of variance for the intrasensory tasks did not yield any significant results.

Hypothesis 2 predicted a HR acceleration would occur for NR group during the recall period. Data present in Table 13 as well as the separate treatment for intersensory and intrasensory tasks do not support the hypothesis. In hypothesis 7 HR acceleration in PRD group for intrasensory and intersensory tasks which cite the visual stimuli first was also predicted. No support for this hypothesis was found. The direction of change (decrease) in recall period for SRD that was obtained was not anticipated.

Galvanic Skin Response Measures

The summary of an analysis of variance of the mean GSR as a function of Reading Classifiction, Task and Period for all 8 tasks is given in Table 14.

Significance for the main effect, Period, was obtained (F = 27.14, df = 2/90, p < .01). The mean, 4.497,

TABLE 14.--A summary of analysis of variance on mean GSR as function of reading classification, task and period.

Source	df	MS	F	p
Between subjects				
Classification (C)	2	20.96	0.2309	ns
Ss within group	45	90.75		
Within subjects				
Task (T)	7	10.90	0.8955	ns
C X T	14	30.38	2.49	< .01
T X Ss within group	315	12.17		
Period (P)	2	418.15	27.14	< .01
C X P	4	10.05	0.6530	ns
P X Ss within group	90	15.40		
T X P	14	7.360	1.71	< .05
C X T X P	28	3.659	0.8522	ns
T P X Ss within group	630	4.293		

4.471 and 6.292 decreased from preperiod to stimulus period and then increased from stimulus period to recall period. An increase in mean GSR during the recall period compared to those in the pre and stimulus periods was indicated by the Newman-Keuls test, $p < .01$ for both.

A significant interaction was found for the Reading Classification X Task ($F = 2.49$, $df = 14/315$, $p < .002$). Mean GSR for reading classification across tasks is shown graphically in Figure 10. Only the two auditory intrasensory tasks (7, 8) showed simple effects significances across the three reading classifications ($F = 38.60, 3.05$, $df = 2/315$, $p < .01$ and $.05$ respectively). A Newman-Keuls comparison test, p < .01, indicated that in task (7) the mean GSR was higher for the NR group than for either of the deficit reading groups (Figure 10). For task (8) a simple effects significance was found across the reading classifications (F = 3.05, df = 2/315, p < .05). Newman-Keuls comparisons indicated that in the NR group the mean GSR for task (8) exceeded that of the SRD group, p < .01, and that of the PRD group, p < .05, and that the PRD group is higher than the SRD group (p < .05).

Task X Period interaction was significant (F = 1.71, df = 14/630, p < .05). For all the eight tasks simple effect significances were obtained across the experimental periods

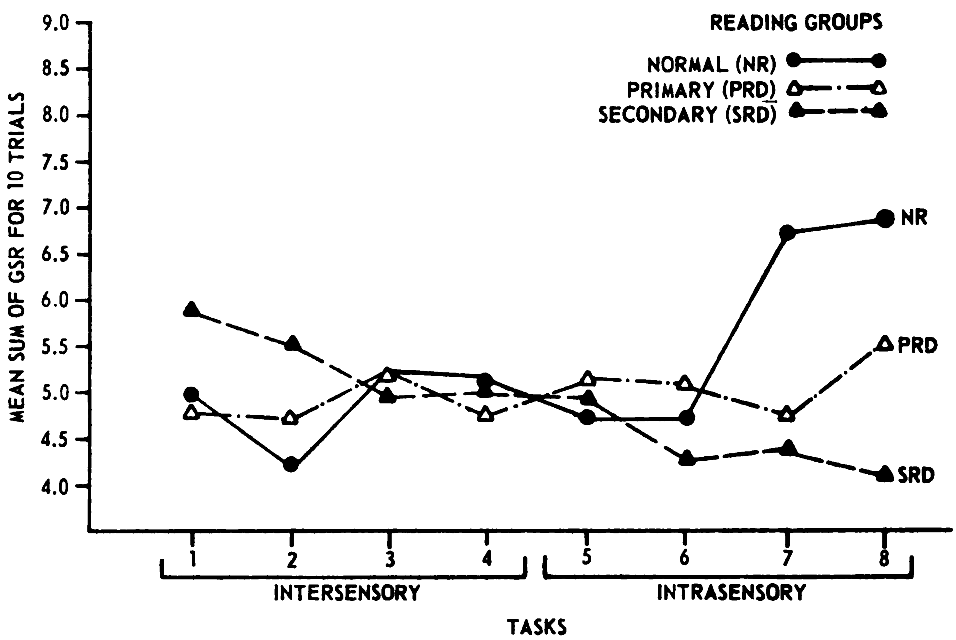

FIG. 10--MEAN GSR FOR READING CLASSIFICATION GROUPS ACROSS INTERSENSORY AND INTRASENSORY TASKS

at p < .01, (Figure 11), also for each task it was indicated that the recall GSR exceeded both the preperiod and stimulus periods at the Newman-Keuls, p < .01 level except for tasks 2 and 5 where the significances for comparison of recall and stimulus periods and of recall and preperiods were p < .05 respectively (Figure 11).

Separate treatments of the intrasensory and intersensory GSR measurements were carried out and are shown in Tables 15 and 16 respectively. In both cases significant main effects for Period were obtained (F = 17.10, 20.35, df = 2/90 respectively with p < .005 for both). The means are 4.729, 4.465 and 6.260 for the intrasensory tasks and

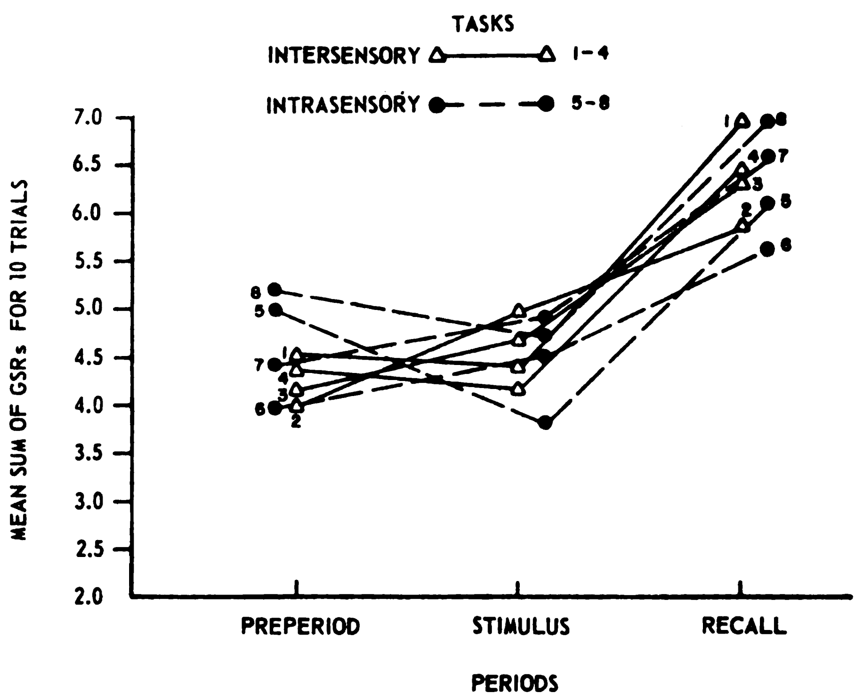

FIG. 11--MEAN GSR FOR INTRASENSORY AND INTERSENSORY TASKS OVER PREPERIOD, STIMULUS AND RECALL PERIODS FOR TOTAL SAMPLE

TABLE 15.--A summary of analysis of variance on mean GSR as function of reading classification, task and period for intrasensory data.

Source	*df*	*MS*	*F*	*p*
Between subjects				
Classification (C)	2	90.07	1.57	ns
*S*s within group	45	57.32		
Within subjects				
Task (T)	3	20.09	1.82	ns
C X T	6	34.36	3.11	< .01
T X *S*s within group	135	11.03		
Period (P)	2	180.60	17.19	< .0005
C X P	4	4.075	0.387	ns
P X *S*s within group	90	10.50		
T X P	6	8.780	2.34	< .05
C X T X P	12	4.128	1.10	ns
T P X *S*s within group	270	3.745		

TABLE 16.--A summary of analysis of variance on mean GSR as function of reading classification, task and period for intersensory data.

Source	*df*	*MS*	*F*	*p*
Between subjects				
Classification (C)	2	18.61	0.287	ns
*S*s within group	45	64.78		
Within subjects				
Task (T)	3	3.761	0.543	ns
C X T	6	7.310	1.06	ns
T X *S*s within group	135	6.923		
Period (P)	2	245.68	20.35	< .0005
C X P	4	9.234	0.765	ns
P X *S*s within group	90	12.07		
T X P	6	5.681	1.46	ns
C X T X P	12	3.326	0.857	ns
T P X *S*s within group	270	3.881		

4.266, 4.479 and 6.323 for the intersensory tasks during the pre, stimulus and recall periods respectively. These results are congruent with the overall analysis. No other effects were significant for intersensory data.

For intrasensory tasks, significance was obtained for the Reading Classification X Task interaction ($\underline{F}$ = 3.11, $\underline{df}$ = 6/135, $\underline{p}$ < .007, Figure 12). Simple effects significance was only found for task 8 across the reading classification. However, a Newman-Keuls test indicated that in the NR group the mean for the two visual tasks (5, 6), 4.740 was less than that of the two auditory tasks (7, 8), 6.928 ($\underline{p}$ < .01).

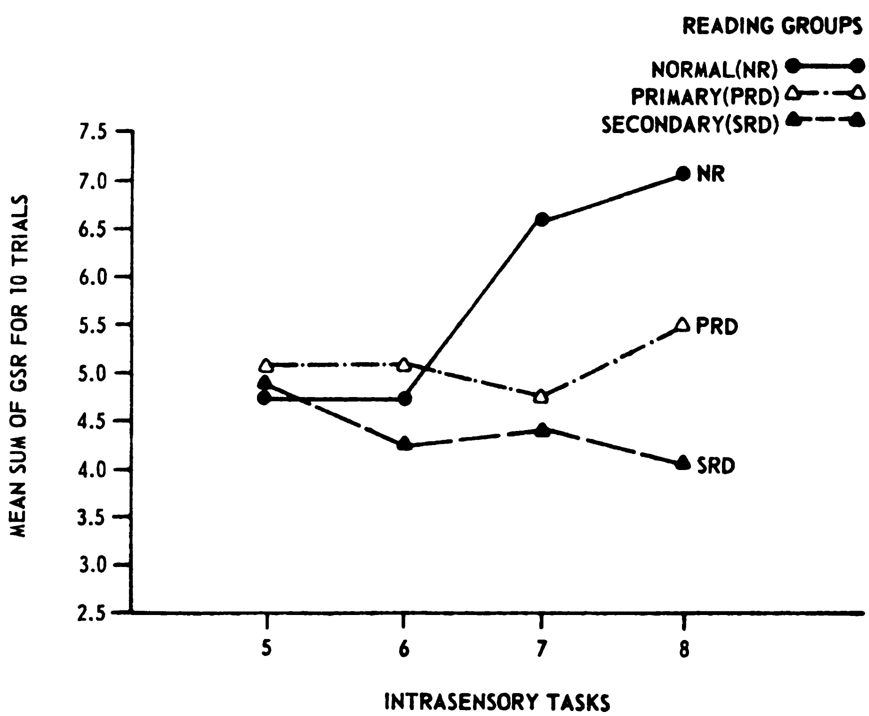

FIG. 12-- MEAN GSR FOR READING CLASSIFICATION ACROSS INTRASENSORY TASKS

Interaction significance was also obtained for Task X Period (F = 2.34, df = 6/270, p < .03). Simple effect significances were found for the three periods, preperiod, stimulus and recall (F = 3.92, 2.93, 3.33, df = 3/270, with p < .01, .05 respectively (Figure 13). For each of the tasks (5, 6, 7, 8) simple effect significances were obtained (F = 17.05, 8.64, 15.08, 14.65, df = 2/270 respectively with p < .01 for all). Newman-Keuls comparisons indicated an increase in GSRs for all of the tasks during recall period over the respective stimulus and preperiod values at the p < .01 level. For the task (5) a significant decrease between preperiod and stimulus period was found (Newman-Keuls, p < .01).

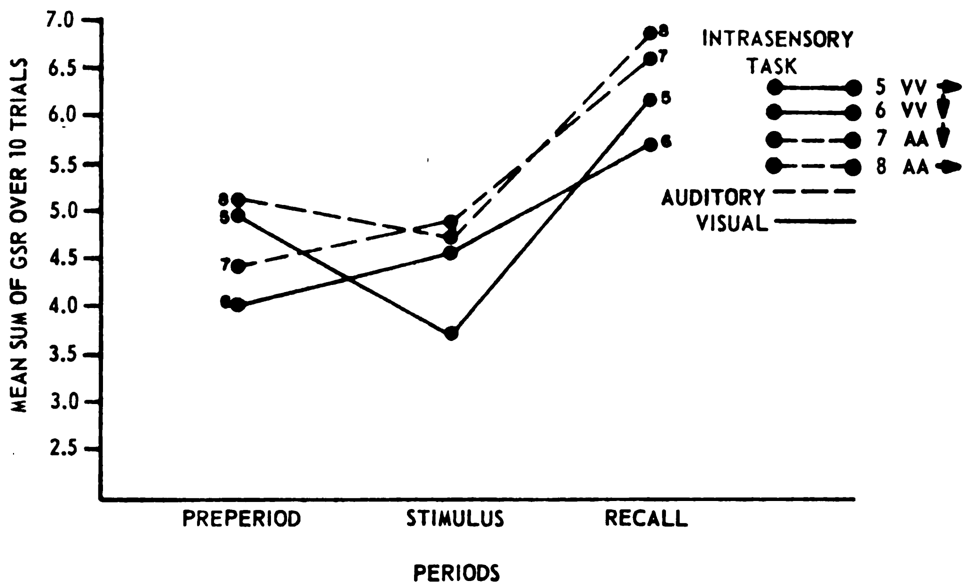

FIG. 13--MEAN GSR FOR INTRASENSORY TASKS OVER PREPERIOD, STIMULUS AND RECALL PERIODS

Hypothesis 1 predicted GSR responsivity for NR group with stimulus presentation and hypothesis 2 predicted GSR responsivity for NR group in the recall period. Neither hypothesis was supported by the data.

An increase in GSR responsivity was found in recall period across all eight tasks for total sample (Figure 11). GSR responsivity was greater in NR group only for intrasensory auditory tasks 7 and 8. This evidence did not support hypothesis 3 which predicted GSR responsivity in intersensory tasks would exceed that in intrasensory tasks for NR group. GSR responsivity was also found to be greater for PRD group than SRD in task 8 (Figure 10). These results were the only evidence to suggest differences between the deficit reading groups in GSR responsivity. Therefore hypotheses 5, 6 and 7 all of which predicted GSR responsivity in PRD group were not supported. Evidence was presented in Figure 12 which indicated differential GSR responsivity among intrasensory tasks for NR group. Mean GSR for the intrasensory visual tasks 5 and 6 was lower than mean of intrasensory aduitory tasks 7 and 8. This evidence would not support hypothesis 4 which predicted no difference in autonomic responses would be observed within intrasensory and within intersensory tasks in NR group.

Performance Measures

The dependent variable was taken as the number of errors on recall. A summary of analysis of variance on mean errors as function of Reading Classification, Task and Error Type for all 8 tasks is given in Table 17.

Main effect significances were found for Reading Classification, Task and Error Type, (F = 17.14, df = 2/45, F = 23.77, df = 7/315, F = 95.56, df = 2/90 respectively, with all p < .0005). The means for the variables are shown in Table 18. As predicted, a comparison of the means for the reading classification groups indicated that the mean errors for the SRD group exceeded those of the NR and PRD groups (Newman-Keuls p < .01, .05 respectively) and the mean errors of the PRD group exceeded those of the NR group (Newman-Keuls p < .05).

TABLE 17.--A summary of analysis of variance on mean errors as function of reading classification, task and error type.

Source	df	MS	F	p
Between subjects				
Classification (C)	2	33.32	17.14	< .0005
Ss within group	45	1.944		
Within subjects				
Task (T)	7	4.983	23.77	< .0005
C X T	14	0.2264	1.08	ns
T X Ss within group	315	0.2097		
Error type (ET)	2	74.84	95.56	< .0005
C X E T	4	6.579	8.40	< .0005
E T X Ss within group	90	0.7831		
T X E T	14	1.454	10.06	< .0005
C X T X E T	28	0.1617	1.12	ns
T E T X Ss within group	630	0.1445		

TABLE 18.--Mean errors for reading classification, task and error type.

Reading Classification	Task		Error Type
0.310 (1)	1	0.404	0.899 (1)
0.613 (2)	2	0.403	0.833 (2)
0.899 (3)	3	0.262	0.099 (3)
	4	0.232	
	5	0.778	
	6	0.616	
	7	0.399	
	8	0.896	

Reading classification: (1) Control, (2) Primary readers, (3) Secondary readers.

Task: (1-4) Intersensory (5-8) Intrasensory.

Error Type: (1) Gross, (2) Order, (3) Interchange.

Significant interactions were obtained for Reading Classification X Error Type (F = 8.40, df = 4/90, p < .0005) and Task X Error Type (F = 10.06, df = 14/630, p < .0005, Table 17).

Mean errors for reading classification group across error types is shown graphically in Figure 14. Simple effect significances were obtained for both the gross errors (F = 3.79, df = 2/90, p < .05) and order error (F = 3.63, df = 2/90, p < .05) means across the three reading classifications. Newman-Keuls comparisons indicated that for both the gross and order errors the SRD group made more errors than the NR group, p < .05 for both cases. The mean errors for each of the reading deficit groups were not significantly different between the gross and order error types.

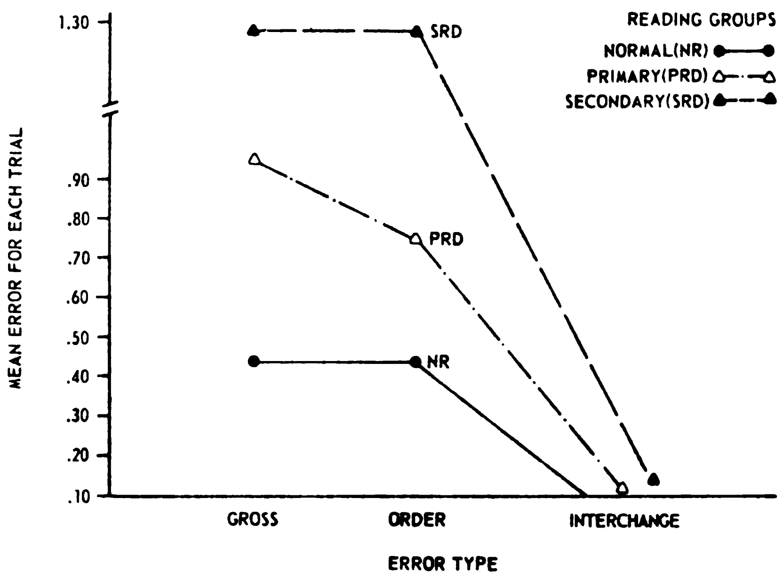

FIG. 14-- MEAN ERRORS OF READING CLASSIFICATION GROUPS ACROSS ERROR TYPES (GROSS ORDER AND INTERCHANGE)

Treatment of the Task X Error Type interaction is depicted in Figure 15. For the three error types, gross, order and interchange, simple effect significances were found across the eight tasks, (F = 28.44, 23.69, and 4.29, df = 7/630, p < .01 respectively, Figure 15). Task 5, visual intrasensory, showed a significant decrease in order over gross errors (Newman-Keuls, p < .01). For the remaining tasks the gross and order means were not significantly different.

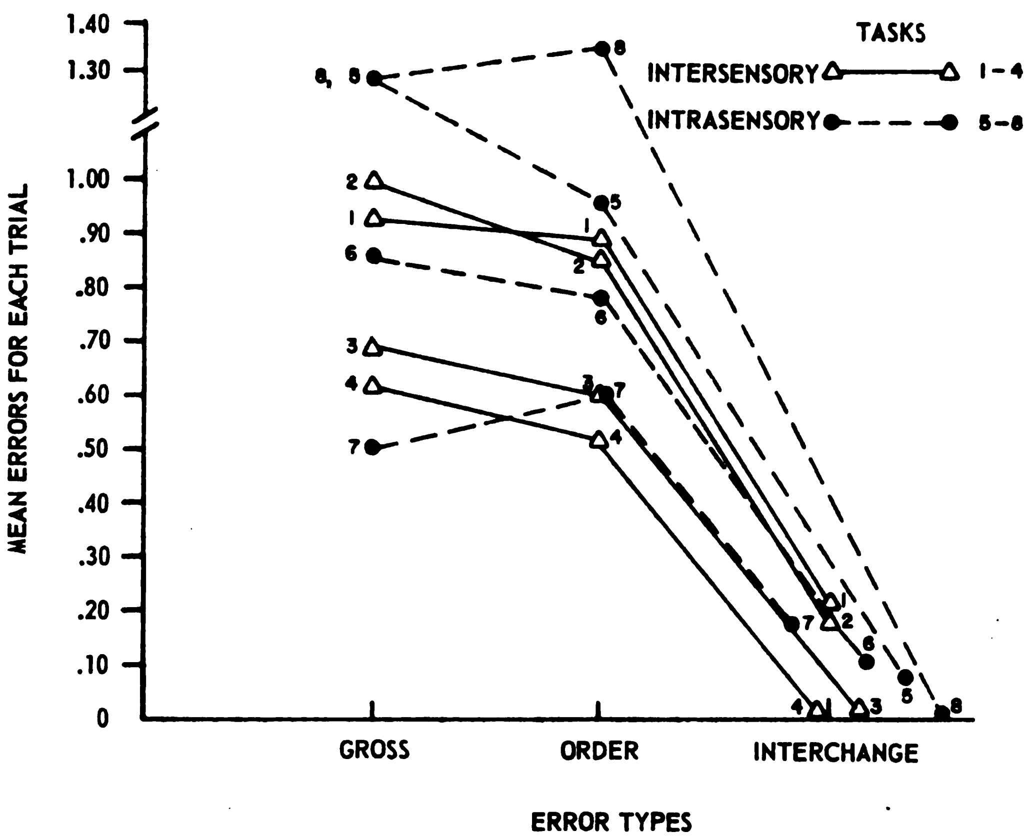

FIG. 15--MEAN ERROR FOR INTERSENSORY AND INTRASENSORY TASKS ACROSS ERROR TYPES (GROSS, ORDER AND INTERCHANGE)

A summary of the analysis of variance on the intrasensory data is given in Table 19. Main effect significances, *p* < .0005, were obtained for Reading Classification, (*F* = 14.23, *df* = 2/45, Task (*F* = 31.99, *df* = 3/135) and Error Type (*F* = 85.55, *df* = 2/90) and the means are listed in Table 20. A Newman-Keuls comparison of the classification means indicated that the SRD group made more errors than the NR group (*p* < .01). The means for the gross and order error types were not significantly different.

TABLE 19.--A summary of analysis of variance on mean errors as a function of reading classification, task and error type for intrasensory data.

Source	*df*	*MS*	*F*	*p*
Between subjects				
Classification (C)	2	19.31	14.23	< .0005
*S*s within group	45	1.356		
Within subjects				
Task (T)	3	6.669	31.99	< .0005
C X T	6	0.2083	0.9998	ns
T X Ss within group	135	0.2084		
Error Type (ET)	2	47.72	85.55	< .0005
C X ET	4	3.618	6.486	< .0005
ET X *S*s within group	90	0.5578		
T X ET	6	2.8611	18.02	< .0005
C X T X ET	12	0.1078	0.6791	ns
T ET X *S*s within group	270	0.1587		

TABLE 20.--Mean errors for reading classification, task and error type for intrasensory data.

Reading Classification		Task		Error Type	
1	0.356	5	0.778	1	0.992
2	0.670	6	0.616	2	0.927
3	0.991	7	0.399	3	0.098
		8	0.896		

Reading Classification: (1) Control, (2) Primary, (3) Secondary

Task: (5) & (6) Visual, (7) & (8) Auditory.

Error Type: (1) Gross, (2) Order, (3) Interchange

For the intrasensory data, significant interactions were found for Reading Classification X Error Type interaction (F = 6.49, df = 4/90, $p < .0005$). Mean errors for reading classification groups in intersensory and intrasensory tasks across error types (gross, order and inter) are shown graphically in Figure 16. Intersensory tasks are included to allow for diagrammatic comparison, however, the following findings are based on analyses of intrasensory data.

Simple effect significances for reading classification across error types were found for the PRD group (F = 7.13, df = 2/90, $p < .01$) and for the SRD group (F = 15.23, df = 2/90, $p < .01$), but not for the NR group. For the gross error type, simple effect significance was found (F = 4.50, df = 2/90, $p < .05$) and for the order error type

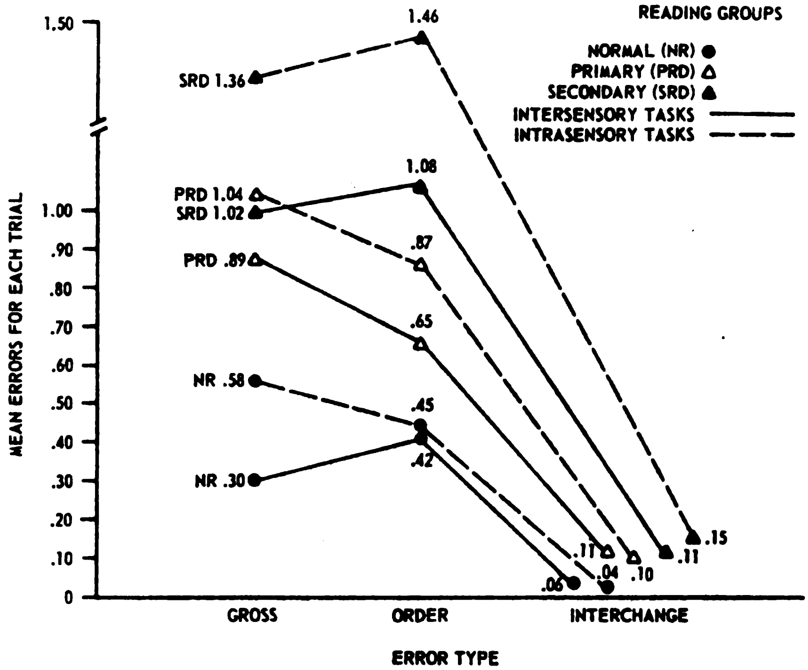

FIG. 16--MEAN ERRORS FOR READING CLASSIFICATION GROUPS IN INTERSENSORY AND INTRASENSORY TASKS ACROSS ERROR TYPES (GROSS, ORDER AND INTER)

(F = 7.35, df = 2/90, $p < .01$). Newman-Keuls comparisons indicated that for both types of errors (gross and order), the errors in SRD group were higher than those of the NR group ($p < .01$). Differences between deficit reading groups for gross and error types were not found.

For the Task X Error Type interaction for intrasensory data (F = 18.02, df = 7/630, $p < .0005$, Table 19), simple effect significances for all tasks (5, 6, 7 and 8) were obtained (F = 119.12, 41.26, 21.80, and 171.59, df = 2/270, $p < .01$, respectively). A Newman-Keuls comparison of the mean of tasks (6, 7), pairing responses, with the mean of tasks (5, 8) linear responses, indicated that more gross and order errors were made on the linear than on the pairing responses.

The mean of the gross errors of the intrasensory tasks was significantly higher than those of the intersensory tasks ($\underline{t}$ = 3.00, $\underline{df}$ = 197, $\underline{p}$ < .005). Similarly, the order error mean of the intrasensory tasks was higher than that of the intersensory tasks ($\underline{t}$ = 2.90, $\underline{df}$ = 282, $\underline{p}$ < .005).

For the following analyses of intersensory data, the error types, gross and order, were scored separately for the auditory and visual modalities. Therefore, the error types for intersensory data were analyzed as follows: ET 1 (gross auditory); ET 2 (gross visual); ET 3 (order auditory); ET 4 (order visual) and ET 5 (interchange).

An analysis of variance for the intersensory data is summarized in Table 21. Main effect significance was found for Reading Classifications, ($\underline{F}$ = 15.52, $\underline{df}$ = 2/45, $\underline{p}$ < .0005), Task ($\underline{F}$ = 19.41, $\underline{df}$ = 3/135, $\underline{p}$ < .0005), Error Type ($\underline{F}$ = 34.40, $\underline{df}$ = 4/180, $\underline{p}$ < .0005). Means are listed in Table 22.

Newman-Keuls comparisons of the classification means indicate that the intersensory errors were higher for the SRD group than those of the NR group, $\underline{p}$ < .01 and those of the PRD group $\underline{p}$ < .05, and that the PRD group, errors exceeded the NR group ($\underline{p}$ < .05). Significant differences between any

TABLE 21.--A summary of analysis of variance on mean errors as a function of reading classification, task and error type for intersensory data.

Source	df	MS	F	p
Between subjects				
Classification (C)	2	8.529	15.52	< .0005
Ss within group	45	0.5495		
Within subjects				
Task (T)	3	1.993	19.41	< .0005
C X T	6	0.1492	1.45	ns
T X Ss within group	135	0.1027		
Error type (ET)	4	3.752	34.40	< .0005
C X ET	8	0.5859	5.372	< .0005
E T X Ss within group	180	0.1091		
T X ET	12	0.9955	17.70	< .0005
C X T X ET	24	0.1333	2.37	< .0005
T ET X Ss within group	540	0.0562		

TABLE 22.--Mean errors for reading classification, task and error type on intersensory data.

Reading Classification		Task		Error Type	
1	0.264	1	0.404	1	0.322
2	0.555	2	0.403	2	0.483
3	0.807	3	0.262	3	0.371
		4	0.232	4	0.348
				5	0.101

Reading Classification: (1) Control, (2) Primary (3) Secondary.

Task: Intersensory tasks, (1) & (2); Directed pairing, (3) & (4); Linear.

Error Type: (1) Gross auditory, (2) Gross visual, (3) Order auditory, (4) Order visual, (5) Interchange.

of the first, four error type means were not found. The first two tasks (1, 2) required paired responses and the last two (3, 4) were linear. The mean of the former pair was compared with that of the latter. A Newman-Keuls test indicated that the errors of the pairing responses were higher than that of the linear (p < .01).

For the Reading Classification X Error Type interaction the means errors are shown graphically in Figure 17.

Simple effect significances were obtained for the PRD group (F = 3.05, df = 4/180, p < .05) and SRD group (F = 7.61, df = 4/180, p < .01), but not for the NR group. For the error types across reading classification, significances

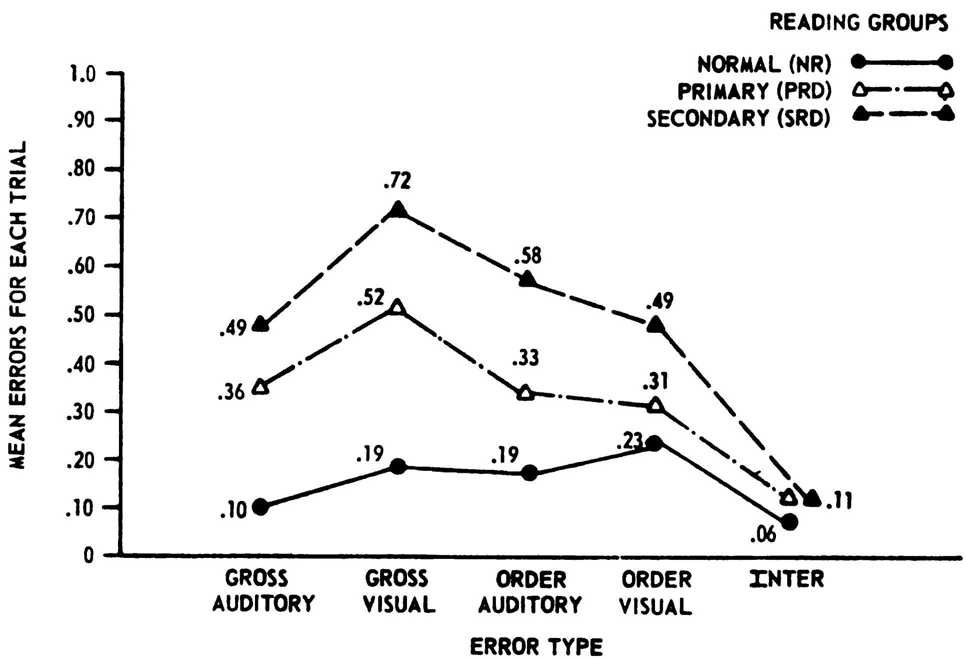

FIG. 17--MEAN ERRORS OF READING CLASSIFICATION GROUPS ACROSS ERROR TYPES IN INTERSENSORY TASKS

were obtained for the ET 1, ET 2, ET 3 and ET 4 ($\underline{F}$ = 5.74, 10.67, 5.82, and 21.16, $\underline{df}$ = 2/180, $\underline{p}$ < .01 respectively). Newman-Keuls comparisons, $\underline{p}$ < .05, were found for error types: ET 1 (gross auditory, NR < PRD, SRD); ET 2 (gross visual, NR < PRD, SRD); ET 3 (order auditory, NR < SRD, PRD < SRD); ET 4 (order visual, NR < SRD).

For the Task X Error Type interaction a summary of mean errors is shown graphically in Figure 18.

Significant simple effects were obtained for tasks 1, 2, 3 and 4 across the error types ($\underline{F}$ = 14.74, 21.54, 11.20, 54.65, $\underline{df}$ = 4/540, $\underline{p}$ < .01 respectively). For all

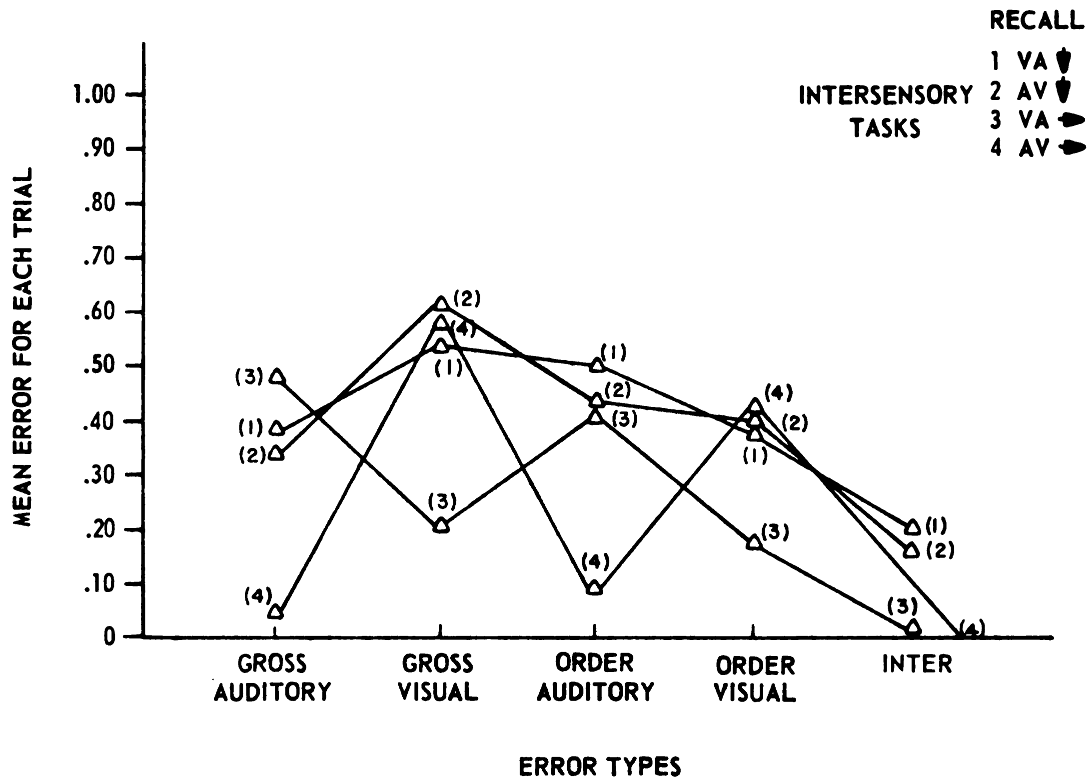

FIG. 18-- MEAN ERRORS FOR INTERSENSORY TASKS ACROSS ERROR TYPES FOR TOTAL SAMPLE

the error types across tasks simple effect significances were found (F = 9.44, 9.78, 9.53, 3.69, and 3.14, df = 3/54, p < .01. .01, .05, .05 and .05 for error types; 1, 2, 3, 4, and 5 respectively). Simple effect analyses for total sample are summarized in Table 23.

A significant (F = 2.37, df = 24/540, p < .0005) three way interaction, Reading Classification X Task X Error Type was also obtained for the intersensory data (Table 21). Simple Task X Error Type interaction analyses were subsequently carried out for the NR, PRD, and SRD groups. Interaction significances were found for the PRD group (F = 62.62, df = 12/540, p < .01) and SRD group (F = 14.29, df = 12/540, p < .01). Similar significance was not obtained for the NR group. The mean errors for the deficit reading groups across error types are shown graphically in Figure 19.

For all the tasks across the error types in the PRD and SRD group, simple effect significances were found at p < .01. For error types 1, 2, 3, 4 and 5 simple effect significances across the tasks were found at the p < .01 level, in the SRD group. For error type 1, 2, 3 simple effects significance across tasks were found at the p < .01 and for error type 4 and 5 at p < .05 in the PRD group.

The data presented in above tables and figures supported hypothesis 8 which predicted that deficit reading groups would make more errors under all bisensory recall

TABLE 23.--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

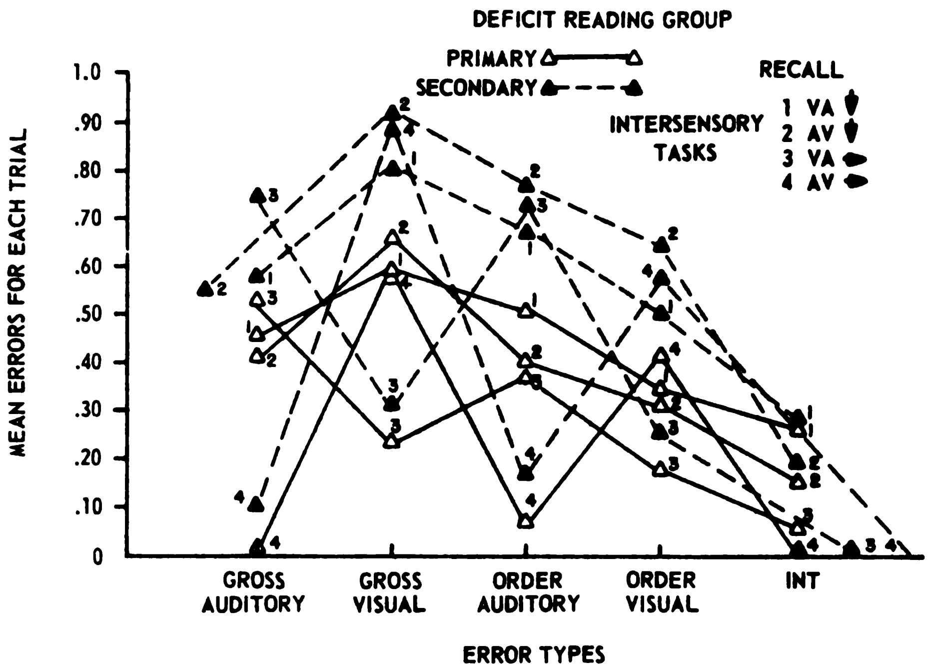

FIG. 19--MEAN ERRORS FOR DEFICIT READING GROUPS (PRIMARY AND SECONDARY) ACROSS ERROR TYPES ON INTERSENSORY TASKS

conditions than NR group. The mean total errors of SRD group exceeded that of PRD group and the mean total errors of both deficit reading groups exceeded that of NR group (Figure 14). The mean error of the reading classification groups did not differ on the interchange error type. The mean errors of the gross and order error types were not different for the deficit reading groups on the total data analyses. Across the eight tasks, only in intrasensory task 5 were more gross than order errors found for total sample.

The analyses of the intrasensory data across error types indicated that more gross and order errors were made on tasks 5 and 8, which require linear responses than on task 6 and 7, the pairing tasks. In contrast, for intersensory conditions, more errors were found in pairing responses for task 1 and 2 than on linear responses for tasks 3 and 4.

The mean error of gross and order error types on intrasensory conditions was found to exceed the mean error for gross and order error types on intersensory conditions for total sample.

In the treatment of intersensory tasks, the error types, gross and order were analyzed for modality (auditory and visual) type. The results supported hypothesis 8 since mean errors of SRD exceeded PRD and NR groups and PRD group exceeded NR group (Table 22). For the Classification X Error Type interaction, the results were consistent with previous finding except for ET 4 (order visual) in which mean errors in NR group were found to be less than only the SRD group and for ET 3 (order auditory) for which the mean error in NR group was not less than PRD group (Figure 17).

The data in Table 23 indicate that in linear, intersensory tasks 3 and 4, a "primacy effect" for modality recall across the error types occurred, i.e., the mean error of ET 1 (gross auditory) was highest in linear task 3 which required that visual stimuli be recalled first before the audio stimuli.

For the total sample, the gross, visual errors exceeded that of the gross, auditory errors. Examination of pairing tasks, 1 and 2, indicated that in task 1 where the visual stimuli was cited first in recall, auditory order errors exceeded those found in order visual. In task 2, however, which had auditory responses first, order visual errors did not exceed the order auditory. These results suggest that visual stimuli was dominant, i.e., they effected auditory responses.

Analyses of Reading Classification X Task X Error Type interaction indicated no significance for NR group, whereas, significances were found for both deficit reading groups.

For the three error types (gross, order and interchange) more errors were found for the pairing tasks than linear ones in the intersensory conditions. However, for the intrasensory conditions more errors were made in the linear than pairing tasks for the total sample (Figure 15). The mean errors of the intersensory and intrasensory pairing conditions for the reading classification groups is shown graphically in Figure 20 and for the linear conditions in Figure 21.

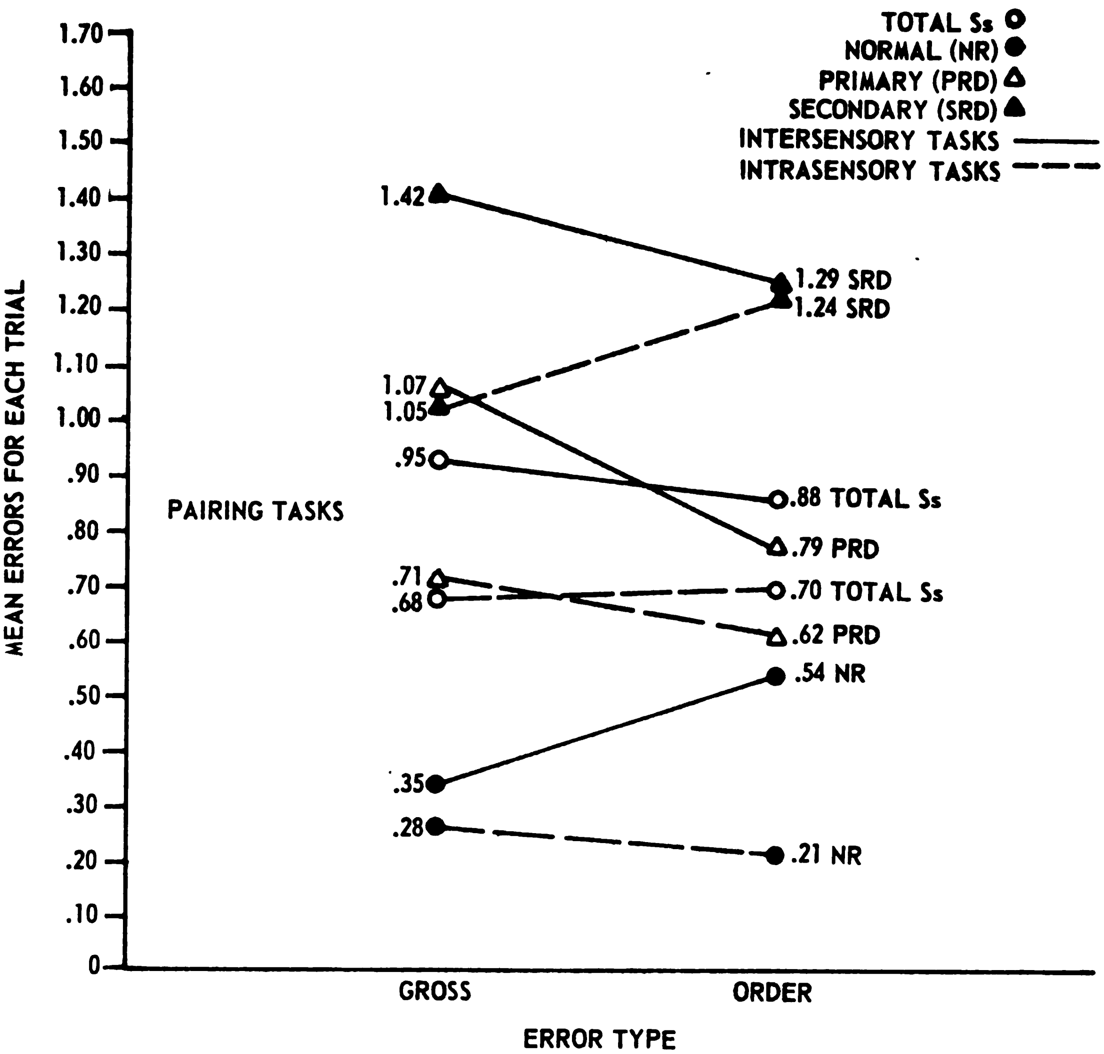

FIG. 20-- MEAN ERROR TYPES FOR READING CLASSIFICATION GROUPS AND TOTAL SAMPLE ON INTERSENSORY AND INTRASENSORY PAIRING TASKS

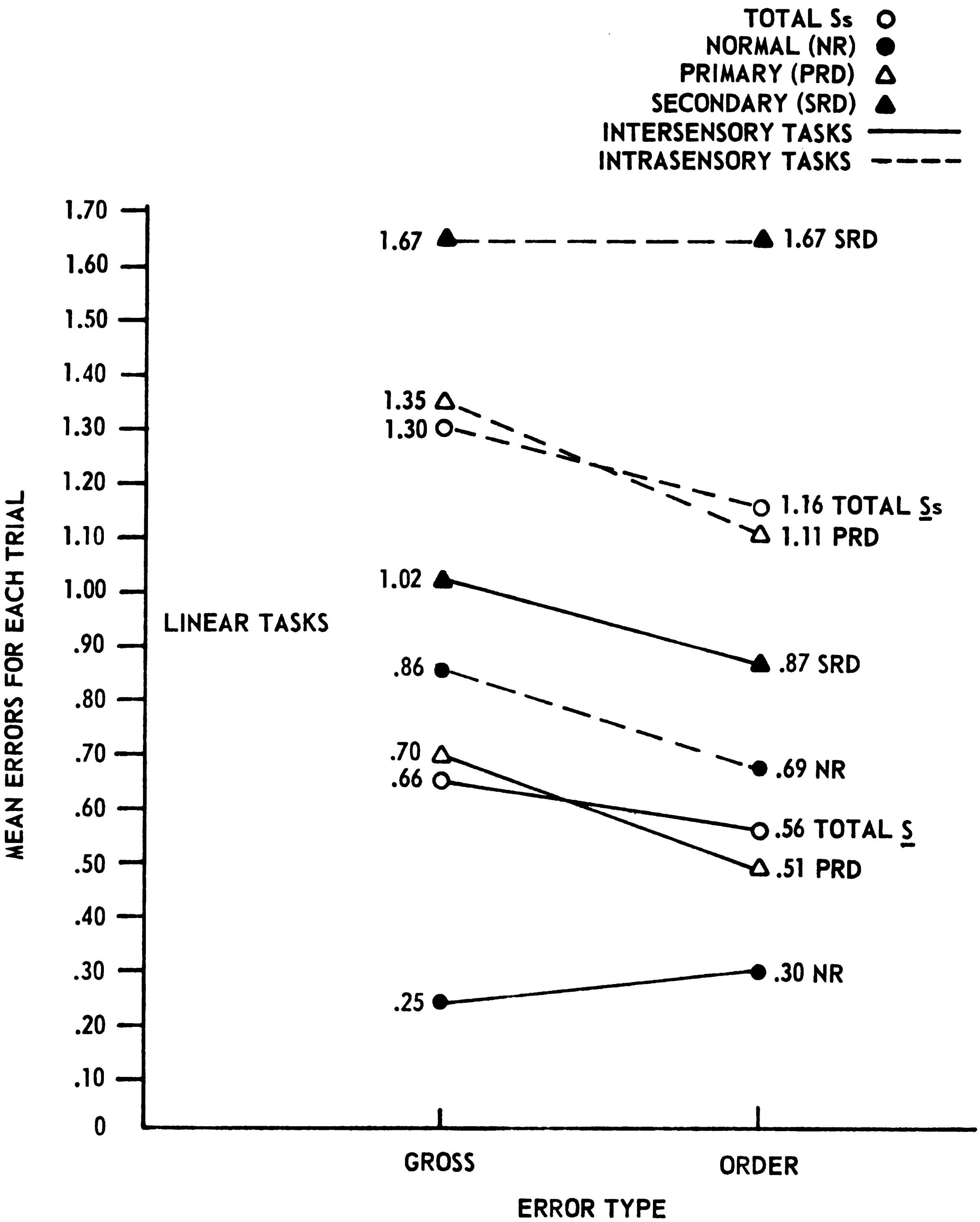

FIG. 21--MEAN ERROR TYPES FOR READING CLASSIFICATION GROUPS AND TOTAL SAMPLE ON INTERSENSORY AND INTRASENSORY LINEAR TASKS

CHAPTER IV

DISCUSSION

One of the two basic hypotheses of this study was that physiological changes which occur with the simultaneous presentation of a pair of intersensory or intrasensory auditory and visual stimuli and during recall tasks involving those stimuli would be different for a sample of *S*s from the normal reading population than those from deficit reading groups. Furthermore, the physiological measures would also differ for the two classified groups of reading deficit children and be a function of the modality parameters of the stimuli. The second major hypothesis predicted was that children with reading deficits would make more errors on all the recall tasks than normal readers.

In testing the specific experimental predictions derived from these major hypotheses, differences among the physiological measures employed; the interactions of the modality characteristics of the tasks (auditory or visual) and the intersensory and intrasensory parameters, were observed in a set of eight experimental conditions.

Discussion of Physiological Responses

The hypothesis predicting differences in heart rate among the reading classification groups was not supported by data on 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 Ss which were observed with the heart rate deceleration measure.

For the total sample, 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.

A decrease in mean heart rate occurred in recall period for the intersensory tasks 1, 2 and 3 (Figure 3). No significant change in mean heart rate was found for the tasks 4, 7 and 8. The latter two were pure auditory and task 4 was linear intersensory with auditory recall 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. Campos and Johnson (1966, 1967) have proposed that the verbalization demands of visual tasks produces heart rate acceleration with visual stimuli whereas heart rate deceleration occurs only under conditions which do not require verbalization in the processing of visual stimuli. These authors noted that the heart rate decelerations were generally non-significant. Campos and Johnson suggested that, "rather simple instructional or set variables can influence physiological responses and clearly override factors as modality, affective tone and complexity of stimulus, and direction of attention." The Campos and Johnson hypothesis that the verbalization requirements of a task accounted for differences in cardiac responses was not supported by the findings in the present study. Evidence was found to suggest that other task requirements may mediate the heart rate response. 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 S (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 instructions in intersensory tasks produced anticipatory stress; instructions requiring auditory response first, or solely auditory response, resulted in no significant cardiac change, whereas instructions requiring visual responses produced decreases in stimulus period with no apparent mediation from the mental set.

Support for the variability of heart rate being an indicator of attention has been reported by a number of studies (Porges, 1972; Porges & Raskin, 1969; Porges, Arnold & Forbes, 1973). Uniformly, it was found that a decrease in mean heart rate variability accompanied an increase in attention. These findings have been replicated in the present study. A main effect significance showed that a decrease in mean heart rate variability occurred for total sample during attention to intersensory stimuli, (expected to require greater attention than intrasensory), followed by an increase in mean heart rate variability during recall period (Table 7). Similar significant mean heart rate variability was not obtained for intrasensory data alone (Table 9). For the intrasensory data, an analysis of Task X Period interaction indicated that the preperiod mean heart rate variability was higher for auditory than for the other intrasensory tasks which indicated a lower level of anticipatory attention for the pairing auditory task 7. Apparently the linear requirement of the auditory task 8 tended to increase attentivity.

It appeared 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 4, 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.

The mean heart rate variability of primary reading deficit group was lower than that of normals on each of the eight tasks. These results have a $\underline{p} < .01$ 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 secondary reading deficit group. The lower heart rate variabilities found in primary reading deficit than in secondary reading deficit group on each of the remaining seven tasks were better than random, $\underline{p} < .02$ (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 period.

Consideration of heart rate variability results in association with the characteristics of the reading classification groups indicates that attentional factors conflict with cognitive processing. It was assumed that mental or cognitive activity would occur during the recall period. The primary reading deficit group, which maintained a stable level of heart rate variability in the three periods does not sufficiently adjust the attentivity (heart rate variability doesn't increase for intersensory recall) to allow effective cognitive processing to occur in the recall period. The normal reading group whose heart rate variability increased in recall can apparently "switch off" the attentivity factor to pursue cognition without the disturbing effect of attentivity.

The secondary reading deficit group apparently over-attended during stimulus presentation as shown by decreased heart rate variability. The secondary reading deficit group, whose etiology contains an element of emotional distress, overact to the stimulus presentation when compared to the other two groups who are considered less prone to emotional stress. The secondary reading deficit group can relax the "attentivity" during recall period. However, the excessive attention during the stimulus presentation may prevent the early (in stimulus period) initiation of cognitive processing, consequently the stimulus cues are not adequately processed. The normal reading group can maintain a moderate and apparently adequate attentional level during stimulus presentation and initiate cognitive activity during this period. These Ss then relax the attentional elements during recall for more effective, final cognitive processing.

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 (Figure 7). These results for 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 $\underline{p} < .02$) 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 $\underline{p} < .03$). The heart rate deceleration as operationally defined here is analytically a function of the heart rate variability and the mean heart rate and would be expected to reflect the causative factors for both measures. The heart rate decelerations found in normal reading group and secondary reading deficit group during recall should be considered in the light of the increased heart rate variability found in the recall period for both groups.

The heart rate deceleration data support the hypothetical model of attention proposed for the reading deficit groups. This measure provides evidence of defective attentional mechansims in the deficit reading groups. The magnitude and frequency of heart rate deceleration differs for the three reading groups. Greater magnitude and more frequent occurrences of heart rate deceleration occurred in stimulus and recall periods for 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 occurrences 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.

For the total sample, the role of the stimulus parameters of the tasks in mediating heart rate deceleration parallels the results found in the mean heart rate. Heart rate deceleration occurred in the stimulus periods for intrasensory visual tasks 5 and 6, whereas heart rate deceleration was found in the recall periods for intersensory tasks 1, 2, and 3 with no change occurring for intersensory task 4 and auditory task 7. A deceleration occurred in the recall period for task 8. These results appear to indicate that the processing of intrasensory, visual stimuli require higher levels of attentivity in the initial stages than for auditory or intersensory information. As previously indicated, this response may be a function of the reduced anticipation of the level of task requirements or that the heart rate deceleration response may be specific to intrasensory, visual stimuli. Graham and Clifton (1966) have pointed out that acceleratory heart rate responses found in a number of studies may be modality specific.

The results of heart rate deceleration data did not indicate support for the hypotheses which predicted heart rate deceleration would be observed in primary reading deficit group with presentation of visual tasks. However, it should be noted that the only heart rate decelerations (magnitude was non-significant) to be observed for the reading deficit groups during stimulus period occurred with intrasensory visual tasks 5 and 6.

A common assumption throughout many of the hypotheses postulated for testing by this study was that S would exhibit stress as well as cognitive activity during the recall periods. Such stress should be observed by an increase in the mean heart rate which has been established as a measure of increased anxiety. However, during the recall period heart rate deceleration was found to be the dominant cardiac response for normal reading group and secondary reading deficit group. An increase in heart rate variability was also found for both these groups. For normal reading group and secondary reading deficit groups it would appear that the heart rate deceleration was associated with a reduced stress which may be related to the reduced attentivity. An increase in heart rate variability could result in a deceleration which is measured from the lowest beat in the recall period relative to the lowest beat in the preperiod. Thus the evidence is interpreted to indicate that attentivity which may have an associated stress factor is reduced during recall for the normal reading group and secondary reading deficit groups but not for the primary reading deficit group.

Stress or increased cognitive activity are both interpreted to result in GSR responsivity. Increased GSR activity was obtained for each task during the recall period, but not for the stimulus period (Figure 11). Main effects significances for periods are obtained for both intersensory and intrasensory data (Table 15 and 16). These results considered with those of no heart rate acceleration during recall periods suggests that the increased GSR may be due to cognitive activity rather than stress during the recall period. The conclusions are supported by the findings of Lacey, Kagan, Lacey and Moss (1963) and Johnson and Campos (1967) who reported an increased GSR responsivity in situations soliciting cognitive activity. Thus the expected increased cognitive activity was found for all Ss in recall. A change in the level of attentivity during the recall period was found for normal reading group and secondary reading deficit group but not for primary reading deficit group.

Again the greater capacity for normal reading group to adjust levels of physiological activity was observed in the greater GSR responsivity for intrasensory, auditory tasks than for the intrasensory, visual ones (Figure 12). Similar adjustment capability was not indicated for the deficit reading groups.

Discussion of Performance Measures

As expected, the level of recall errors was related to the reading classification groups (Table 17), in support of the view that reading ability is dependent upon a set of attentional and cognitive skills.

Mean, total, recall errors observed for the secondary reading deficit group exceeds that of primary reading deficit group and mean, recall errors of both reading deficit groups exceed that of normal reading group (Figure 14). Examination of the data for error types showed that for the deficit reading groups gross and order errors did not differ significantly across the eight experimental conditions. The interchange (reversal of pairs of digits) error type was unusually low and did not differ for reading classification groups. Analysis of Task X Error Type interaction showed that only in the intrasensory, visual task 5 were order errors less than gross errors. For the remaining tasks no differences were found between gross and order means. These results support the validity of the reading classification system (Rabinovitch, 1954) for differentiating groups of deficit readers.

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. These results do not necessarily contradict the frequently reported finding in the literature that the performance of deficit readers is inferior on intersensory tasks since most of the studies reviewed (Birch et al., 1964; Ford, 1964; Berry, 1967) did not incorporate an intrasensory, comparative base in the experimental designs.

One of the important goals of the present experimental design is the study of sensory interaction and its relation to reading ability. The use of linear and pairing tasks in the intersensory and intrasensory conditions provided design features to deal with this objective.

Although linear tasks are inherently more difficult, as shown by the intrasensory results, a higher level of confounding occurs for pairing tasks which is sufficient to cause more errors than for the corresponding linear, intersensory tasks. Figures 20 and 21 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 deficit groups and for gross error type in secondary reading deficit group. However, for the latter, the intersensory and intrasensory, order errors on 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 20, 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 intrasensory and intersensory experimental conditions. 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 21 where the secondary reading deficit made the same number of gross and order errors for intrasensory tasks, whereas, the other groups made fewer order than gross errors.

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

One of the four factors cited by Senf and Freudl (1971) as possible basis for reading déficits 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 Freudl postulated the auditory dominance hypothesis based on a preference exhibited by the learning disabled S 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 with present study argue against an auditory dominance hypothesis and suggest that Senf and Freundl's conclusions may be a specific consequence of their experimental design.

For the total sample, Intersensory Task X Error Type data, Table 23, the gross visual errors exceeded the gross auditory. In task 1 where the recall of visual stimuli is first in the paired response, order errors in auditory exceed those found in the visual and implies that the visual mode is "dominant" and effects the auditory performance. The results on task 2, which has the auditory response first, support this view since order errors in auditory do not significantly exceed those in the visual. For the linear responses, tasks 3 and 4, any "dominance" effects are blanked by the obvious results in which fewer errors are made in the modality where the first responses are required. The data shown in Figure 19 for the primary and secondary reading deficit groups are analogous to those found for the total sample.

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 normal reading group the confounding or 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, ($\underline{t}$ = 3.56, $\underline{df}$ = 56, $\underline{p}$ < .005) and supports the view that in linear tasks less errors are made in the first recalled modality.

Senf's finding 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 modality recall occurred in experimental conditions which alternate the instructions and that visual processing "dominates" over the auditory.

The analysis of reading classification across error type indicate that the normal reading group make fewer errors than both reading deficit group across all error types except for visual and auditory order errors of ET 4 and ET 3, where difference was not observed between normal reading and primary reading deficit groups. From these results it appears that the primary reading deficit and normal reading groups have a more efficient processing of visual information than the secondary reading deficit group.

The results of the present study 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 deficit readers. The reading problems of Ss with primary reading deficits appear to be primarily caused by lacking sufficient "attentivity" for the initial processing steps. Major problems for Ss with secondary reading deficits appear to be derived from an inability to relax the attentivity factor which apparently interfers with reaching the proper cognitive level for optimum performance on a step in the processing chain. These Ss also appear to have more deficient capability for processing visual information and sequential recall of auditory and visual stimuli. Whether these are separate independent factors or are related to the quality of attentivity-cognitive interaction has not been determined in the present study.

LIST OF REFERENCES

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Allen, I. W., & Fitzgerald, H. E. Habituation as an index of intrasensory and intersensory integration of form. Journal of Genetic Psychology, 1974, 124, 131-144.

Bakker, D. J. Sensory dominance in normal and backward readers. Perceptual and Motor Skills, 1966, 23, 1055-1058.

Bannatyne, A. Language, Reading and Learning Disabilities: Psychology, Neuropsychology, Diagnosis and Remediation. Springfield, Ill.: Charles C. Thomas, 1971.

Belmont, L., & Birch, H. G. Lateral dominance, lateral awareness and reading disability. Child Development, 1965, 36, 57-71.

Bender, L. A visual motor gestalt test and its clinical use. American Orthopsychiatry Association Research, Monograph, 1938, No. 3.

Berry, J. W. Matching of auditory and visual stimuli by average and retarded readers. Child Development, 1967, 38, 827-833.

Birch, H. G. Dyslexia and the maturation of visual function. In J. Money (Ed.) Reading Disability. Baltimore: Johns Hopkins Press, 1962, 161-169.

Birch, H. G., & Belmont, L. Auditory-visual integration in normal and retarded readers. American Journal of Orthopsychiatry, 1964, 34, 852-861.

Birch, H. G., & Belmont, L. Auditory-visual integration, intelligence and reading ability in school children. Perceptual and Motor Skills, 1965, 20, 295-305.

Blank, M., & Bridger, W. H. Crossmodal transfer in nursery school children. Journal of Comparative Physiological Psychology, 1964, 58, 277-282.

Boder, E. Developmental dyslexia: Prevailing diagnostic concepts and a new diagnostic approach. Bulletin of the Orton Society, 1973, 23, 106-118.

Broadbent, D. E. Perception and Communication, New York: Pergamon, 1958.

Campos, J. J., & Johnson, H. J. The effects of verbalization instructions and visual attention on heart rate and skin conductance. Psychophysiology, 1966, 2, 305-310.

Campos, J. J., & Johnson, H. J. The effects of affect and verbalization instructions on directional fractionation of autonomic response. Psychophysiology, 1967, 3, 285-290.

Connolly, K., & Jones, B. A developmental study of afferent-reafferent integration. British Journal of Psychology, 1970, 61, 259-266.

Critchley, M. Developmental Dyslexia, London: Heinemann, 1964.

Doehring, D. G. Patterns of Impairment of Specific Reading Disability: Bloomington, Ill.: Indiana University Press, 1968.

Ford, M. P. Auditory-visual and tactual integration in relation to reading ability. Perceptual and Motor Skills, 1967, 24, 831-841.

Fuller, G. B. Perceptual consideration in children with reading disability. Psychology in the Schools, 1964, 1, 314-317.

Fuller, G. B. The Minnesota Percepto-Diagnostic Test (Rev.). Journal of Clinical Psychology, Monograph Supplement, No. 28, 1969.

Fuller, G. B. Three diagnostic patterns for children with reading disabilities. Paper presented at the International Conference of the Association for Children with Learning Disabilities, Houston, Texas, 1974.

Graham, F. K., & Clifton, R. K. Heart rate change as a component of the orienting response. Psychological Bulletin, 1966, 65, 305-320.

Hancock, J., Moore, W., & Smith, W. I. Note on two-channel transmission of information. Perceptual and Motor Skills, 1969, 28, 269-270.

Horowitz, A. B. Effect of stimulus presentation modes on children's recall and clustering. Psychonomic Science, 1969, 14, 297-298.

Jastak, J. G., & Jastak, S. R. The Wide Range Achievement Test (Rev.), Wilmington, Delaware: Guidance Associates, 1965.

Johnson, H. J., & Campos, J. J. The effect of cognitive tasks and verbalization instructions on heart rate and skin conductance. Psychophysiology, 1967, 4, 143-150.

Jones, J. P. A study of the relationship among intersensory transfer, intersensory perceptual shifting, modal preference, and reading achievement at the third grade level. Dissertation Abstracts International, 1971, 3 (8-A), 4038.

Kagan, J., Moss, H. A., & Siegel, I. E. Psychological significance of styles of conceptualization. Monographs of the Society for Research in Child Development, 1963, 28, 73-112.

Kagan, J., & Rosman, B. L. Cardiac and respiratory correlates of attention and an analytic attitude. Journal of Experimental Child Psychology, 1964, 1 (1), 50-63.

Lacey, J. I. Psychophysiological approaches to the evolution of psychotherapeutic process and outcome. In E. A. Rubenstein and M. B. Parloff (Eds.), Research in Psychotherapy, Washington, D. C.: Johns Hopkins Press, 1959.

Lacey, J. I., Kagan, J., Lacey, B. C., & Moss, H. A. The visceral level: Situational determinants and behavioral correlates of autonomic response pattern. In P. H. Knapp (Ed.), Expression of the Emotions in Man, New York: International University Press, 1963.

Lee, C. L., Kagan, J., & Robson, A. Influence of a preference for analytic categorization upon concept acquisition. Child Development, 1963, 34, 433-442.

Levine, M., & Fuller, G. Psychological, neuropsychological and educational correlates of reading deficit. Journal of Learning Disabilities, 1972, 5, 50-58.

Lewis, M., Kagan, J., Campbell, H., & Kalafat, J. The cardiac response as a correlate of attention in infants. Child Development, 1966, 37 (1), 63-71.

Lewis, M., & Wilson, C. D. The cardiac response to a perceptual cognitive task in the young child. Psychophysiology, 1970, 6, 411-419.

Madsen, M. C., Rollins, H. A., & Senf, G. M. Variables affecting immediate memory for bisensory stimuli: Eye-ear analogue studies of dichotic listening. Journal of Experimental Psychology, 1970, 83, (3, pt. 2).

Majarov, M. R. Development of visual and kinesthetic discrimination and integration in elementary school children. Dissertation Abstracts International, 1971, 32 (1-B), 565.

Money, J. Reading Disability: Progress and Research Needs in Dyslexia. Baltimore: Johns Hopkins Press, 1962.

Nelson, J. B. The effect of visual-auditory modality preference on learning mode preference in first grade children. Dissertation Abstracts International, 1970, 31 (5-A), 2219-2220.

Pick, H. L., Pick, A. D., & Klein, R. E. Perceptual integration in children. In L. P. Lipsitt and C. C. Spiker (Eds.) Advances in Child Development and Behavior, London: Academic Press, 1967, Vol. 3.

Porges, S. W. Heart rate variability and deceleration as indexes of reaction time. Journal of Experimental Psychology, 1972, 92, 103-110.

Porges, S. W., Arnold, W. R., & Forbes, E. J. Heart rate variability: An index of attentional responsivity in human newborns. Developmental Psychology, 1973, 8, 85-92.

Porges, W. W., & Raskin, D. C. Respiratory and heart rate components of attention. Journal of Experimental Psychology, 1969, 81, 497-503.

Rabinovitch, R. D., Drew, A. L., Dejong, R. N., Ingram, W., & Withey, L. A. Research approach to reading retardation. Research Publication in Nervous and Mental Diseases, 1954, 34, 363-396.

Rasof, B. Sensory preference and intersensory functioning in children. Dissertation Abstracts, 1969, 29 (9-B), 3514-3515.

Rice, D. B. Learning disabilities: An investigation in two parts. Journal of Learning Disabilities, 1970, 3, 149-155.

Rubenstein, L., & Gruenberg, E. M. Intramodal and cross-modal sensory transfer of visual and auditory temporal patterns. Perception and Psychophysics. 1971, 9, 385-390.

Rudel, R. G., & Teuber, H. L. Crossmodal transfer of shape discrimination by children. Neuropsychologia, 1964, 2, 1-18.

Senf, G. M., Rollins, H. A., & Madsen, M. C. Recall order of dual-channel input as a function of induced recall strategy and stimulus rate. Proceeding of the 75th Annual Convention of the American Psychological Association, 1967, 2, 57-58.

Senf, G. M. Development of immediate memory for bisensory stimuli in normal children and children with learning disorders. Developmental Psychology, 1969, 1 (6 pt. 2).

Senf, G. M., & Feshbach, S. Development of bisensory memory in culturally deprived, dyslexic, and normal readers. Journal of Educational Psychology, 1970, 61, 461-470.

Senf, G. M., & Freundl, P. C. Memory and attention factors in specific learning disabilities. Journal of Learning Disabilities, 1971, 4, 36-48.

Shipley, T. Auditory flutter-driving of visual flicker. Science, 1964, 145, 1328-1330.

Shipley, T., & Jones, R. W. Initial observations on sensory interaction and the theory of dyslexia. Journal of Communication Disorders, 1969, 2, 295-311.

Siegel, S. Nonparametric Statistics for the Behavioral Sciences. New York: McGraw-Hill Co., 1956.

Siller, H. The relationship of auditory-visual integration to reading disability in adolescents. Dissertation Abstracts International, 1969, 30, (1-B), 392.

Silver, A. A., & Hagin, R. Specific reading disability: Delineation of the syndrome and relationship to cerebral dominance. Comprehensive Psychiatry, 1, 126-134.

Smith, M. Patterns of intellectual abilities in educationally handicapped children. Unpublished Doctoral Dissertation, Claremont, California, Claremont College Graduate School, 1970.

Sokolov, E. N. Neuronal model and the orienting reflex. In M. A. B. Brazier (Ed.), The Central Nervous System and Behavior, New York: Josiah Macey Foundaation, 1960.

Sokolov, E. N. Perception and the Conditioned Reflex. New York: Macmillan, 1963.

Steele, W. G., & Lewis, M. A longitudinal study of the cardiac response during a problem solving task and its relationship to general cognitive function, Psychonomic Science, 1968, 11, 275-276.

Wechsler, D. Manual for the Wechsler Intelligence Scale for Children. New York: Psychological Corporation, 1949.

Wertheimer, W. Studies in the theory of gestalt psychology Psycholog. Forsch., 4, 1923, Cited in Bender, L. A. Visual motor gestalt test and its clinical use. American Orthopsychiatry Association Research Monograph, 1938, No. 3.

Winer, B. J. Statistical Principles in Experimental Design. New York: McGraw-Hill Co., 1962.

Winer, B. J. Statistical Principles in Experimental Design (Second Edition). New York: McGraw-Hill, 1971.

Zeaman, D., & House, B. J. The role of attention in retardate discrimination learning. In N. R. Ellis (Ed.) Handbook of Mental Deficiency. New York: McGraw-Hill, 1963.