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AUDITORY-VISUAL AND SPATIAL-TEMPORAL INTEGRATION ABILITIES OF ABOVE AVERAGE AND BELOW AVERAGE READERS

BY

MALCOLM FREDERICK MARSHALL
B.A., University of Otago, 1966
M.A. (Hons), University of Otago, 1968

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Department of Educational Psychology

The University of British Columbia
2075 Wesbrook Place
Vancouver, Canada
V6T 1W5

Date 23/4/79

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ABSTRACT

Research Supervisor: Dr. R. F. Jarman

The need was presented for further research of reading abilities in their early development, with emphasis on the information processing characteristics of the reader. The approach used was investigation of the sensory integration and cognitive processing abilities of above average and below average readers as inferred from cross-modal and intramodal matching of visual, auditory, spatial and temporal information.

The tasks required that a stimulus pattern presented in one modality dimension be compared with a second pattern in either the same or a different modality dimension. Subjects were required to classify pairs of stimuli (standard and comparison) as same or different. With three modality dimensions, namely auditory temporal (AT), visual temporal (VT), and visual spatial (VS), there were nine combinations of paired stimuli. These were AT-AT, AT-VT, AT-VS, VT-AT, VT-VT, VT-VS, VS-AT, VS-VT, and VS-VS.

To present these stimuli for matching, in a precise and consistent manner, nine cassette tapes and two electronic circuits were constructed. Stimulus patterns were series of dots (slides), auditory beeps or flashes of a light bulb. Each task contained 30 pairs of items randomly arranged for sameness or difference.

Subjects were 72 boys and 72 girls from 24 grade three classes in eight North Delta Schools. Half of each sex group were above average readers (high) and half were below average (low). All four groups were matched for non-verbal intelligence. The mean reading grade level for low readers was 3.2 and for high readers 5.8. Mean I.Q. for all groups was 94. Subjects in small groups received the nine tasks in a counterbalanced order of presentation over a period of 10 weeks.

Analysis of variance results showed a significant main effect for reading with high readers superior on all matching tasks. A very strong main effect was found for the standard stimulus due mainly to the (easy) VS patterns and to the greater difficulty of VT standards. A strong main effect was also found for the comparison stimuli due to easier VS comparisons. A significant standard X comparison interaction indicated that VT standards made AT comparisons more difficult than with AT standards, while the reverse held for VT comparisons. A significant comparison X reading interaction showed the same disordinal interaction of AT and VT stimuli, particularly for low readers.

As there was no significant main effect for sex, data were pooled across sex and factor analysed by principal components solution with varimax rotation. Different factor loadings for high and low readers indicated that different cognitive processes were involved in the integration of auditory, visual, spatial and temporal information by these two groups. Tasks loaded on spatial and temporal factors rather than visual and auditory.

Inspection showed that purely spatial tasks were easiest while purely temporal tasks were most difficult. Pairwise comparisons showed that cross-modal matches were significantly more difficult than intramodal only for low readers. Similarly, processing temporal information in the visual modality was significantly more difficult than processing spatial information, only for low readers.

An item analysis examined the discriminatory power of items within the tasks in terms of point biserial correlations and item structure. Kuder-Richardson formula 20 reliabilities showed the tasks to be of adequate reliability.

Findings were discussed in relation to the modality-specific view of sensory functioning which appeared to apply only to low readers. Findings were also discussed in terms of the writing of Luria, deriving from studies of brain-behaviour relationships, and the paradigm of simultaneous and successive processing arising out of Luria's work.

Implications of the findings for reading were drawn and some suggestions as to how the findings might be applied to remedial practices were made.

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DEDICATION

TO THE MEMORY OF THE LATE PROFESSOR PHILIP ASHTON SMITHELLS

PIONEER EDUCATIONALIST

INSPIRER OF STUDENTS

CHAPTER I

INTRODUCTION

> And so to completely analyse what we do when we read would almost be the acme of a psychologist's achievements, for it would be to describe very many of the most intricate workings of the human mind, as well as to unravel the tangled story of the most remarkable specific performance that civilization has learned in all its history.
>
> E. B. Huey (p. 6)

Inspite of a wealth of research, there continues to be a poverty of systematic knowledge about the processes by which children learn to read. Failure to learn to read ranks among the most serious educational problems facing us today (McGrady & Olson, 1970; Tower, 1973). Although incidence varies from country to country it has been estimated that in the United States of America, some 10 to 30 percent of school children do not read well enough to meet the requirements of school and society (Bond & Tinker, 1973; Gibson & Levin, 1975; Karlin, 1975). A similar trend could be expected for Canada. Besides being a problem to himself, the problem reader in time develops problems with his peers, at school and at home (Wilson, 1972). It would be easy to justify further research in reading and reading disabilities on these grounds alone. However, the very complexity of the processes of learning to read and the lack of unequivocal research findings on what processes lead to effective or ineffective reading, demand that ongoing research into reading and reading disorders be sustained and developed.

Numerous approaches to the study of reading have been taken but the success of any particular approach in facilitating the acquisition of reading skills has not been outstanding (Belmont, 1974). Curriculum research in reading has dominated the scene since 1920 without consumers being able to say that any one method of teaching reading is better than another. Although curriculum research continues, theory based research on how children read is again coming into its own (Gibson & Levin, 1975).

Theory-based research, in contrast to addressing the outcomes of methods of teaching reading, is concerned with the processes involved, guided by theories of reading, perceptual learning and cognitive functioning. As with curriculum research, however, theory-based research cannot claim much success in contributing to reduction of reading failure. One of the main reasons for this is that approaches are often based upon untested hypothetical generalizations rather than detailed analysis of learning tasks and perceptive competencies involved in reading (Belmont, 1974).

Analysis of the reading process has taken many forms (Gibson, 1969), including language, psychological, psycholinguistic and physiological approaches. Definitions of reading have ranged from complex perceptual discriminations to verbally mediated comprehension of meaning. The psychological processes involved in reading are numerous and complex, and vary at different stages of learning to read (Huey, 1968; MacGinitie, 1969; Vernon, 1971). The bulk of research appears to support a general schema involving perception of graphic stimuli, transfer of this information through a mediating process involving organization and modification of sensory data, culminating in a perceptual response which varies with the maturity and ability of the individual reader (Chester, 1974; Huey, 1968). It is in the context of such schema that this study finds its orientation.

Gibson and Levin (1975) suggest that although reading ultimately amounts to extracting meaning and information from written text, reading as psychological-perceptual processes needs to be further explored. The foundations for later mature reading for meaning lie in the perceptually based skills and strategies of the first few years of learning to read.

Closely associated with the perceptual approach to reading has been research concerned with sensory dynamics (Silverston & Deichmann, 1975). Any survey of factors which appear to interact with development of early reading competence clearly identifies visual and auditory abilities (Robinson, 1972). Modality research has largely centered around the relative importance of these two single modalities and analyses of the relationship between the two modalities. Such investigations, with their bases in sensory perception, have by the same token been deeply rooted in cognitive theory which concerns itself with perceptual experience data, information storage and information retrieval (Silverston & Deichmann, 1975). Cognitive theory places particular emphasis on central brain functioning in its application to learning tasks such as reading. This emphasis is expressed in a number of approaches to theories of reading, one of which is known as the strategy approach (Silverston & Deichmann, 1975).

The strategy approach can be expressed in terms of adaptive rules or strategies, created by the cognitive functioning of the individual, which motivate and enhance perceptual performance in reading. Modality dynamics enter into the process of developing adaptive strategies. The close link and developmental relationship between peripheral sensory processes and central processes in controlling perception is emphasized by Elkind (1967), for example, in applying Piaget's theory of perceptual development to reading.

The principles of perceptual learning are sufficiently specific that when inadequately incorporated into the cognitive functioning of developing children, such children will have difficulty in learning to read (Gredler, 1972). Wepman too, (1968) stressed the necessity of establishing perceptual bases of conceptual learning. While the danger exists of attempting to "explain" reading disability on the basis of a particular bias or viewpoint, Gredler (1972) considers that to explain adequately the differential functioning of good and poor readers, specific study of processes such as intersensory integration need to be directly investigated.

Huey (1968) considered that in studying reading, attention should first be focussed on the perceptual functioning of the reader, then upon the perceptual aspects of the processed material, and finally upon the higher-level cognitive operations by which the psychological results of the first two stages are translated into meaning. Sawyer (1974), like Huey, suggests that future efforts should focus on learning more about the learner, attending less to content and more to process. She considers that the future concerns of remedial programs must range far beyond the mastery of reading skills:

> We must begin to appreciate the human child as a highly complex processor of information - more complex, indeed, than the most sophisticated computer one might imagine. So complex that the finest minds of our time are collectively unable to comprehend how he learns what he learns as rapidly as he learns. (p. 561)

In summary, the need is presented for further research of reading abilities in their early development. At this stage, perceptual development and the integration of auditory and visual information is particularly important. One approach to the study of early reading abilities is to investigate cognitive processing as inferred from ability to integrate information within and between visual and auditory modalities. A technique of studying such auditory-visual integration is known as cross-modal and intramodal matching of auditory and visual stimulus patterns. A stimulus pattern presented in one modality is followed by a comparison pattern in a second modality, the subject being required to judge the equivalence of the two patterns. Matching of patterns in the same modality is designated intramodal matching. For two patterns presented in different modalities a cross-modal match is called for.

A further consideration is involved when visual stimuli can be presented in both a spatial and a temporal dimension. Modality matching may thus be viewed as requiring integrations within and between auditory and visual, spatial and temporal dimensions.

This study attempts to clarify the role of some of the perceptually based skills and strategies involved in reading by comparing the cross-modal, intramodal, spatial and temporal matching abilities of above average and below average boy and girl readers at the third grade level. Differential functioning of good and poor readers at such sensory integrations permits examination of inferred cognitive processing characteristics and investigation of the interaction of stimulus elements as integration requirements change from task to task. An attempt is also made to improve upon some of the weaknesses of previous research, evident in the reviewed literature.

CHAPTER II

REVIEW OF RELATED LITERATURE

> For the large majority of children, proficiency in visual and auditory perception and the integration of these two modalities are essential to achievement in reading.
>
> Ruth Strang (p. 139)

Sensory Modalities and Reading

Considerable research in recent years has examined the place of sensory systems in children's reading (Doehring, 1968; Freides, 1974; Hammill & Larsen, 1974; McNinch, 1971; Robinson, 1972; Silverston & Deichmann, 1975). Problems have largely centered around the relative importance of either visual or auditory modalities, and the relationship of inter-sensory and intrasensory integration to reading ability. This study proposes to investigate the latter aspect, namely the characteristics of intramodal and inter-modal integration abilities of good and poor readers. The term integration is used in the sense that perceived stimulus information from one sense modality is applied to a second stimulus situation either in the same or a different modality, the information being used relationally to the degree required by the cognitive task involved.

Cross-modal research has come a long way since Cole, Chorover and Ettlinger (1961) first stated that they found no evidence for auditory-visual cross-modal matching in man. Sensory integration can be regarded as a starting point for investigation of the processes of perceptual organization and conceptualization at different levels and for different cognitive tasks (Bannatyne, 1968; Birch & Bitterman, 1949). Birch and Belmont (1965) cite a growing body of evidence that integration of information from different sensory modalities is a basic mechanism subserving all adaptive functioning. Birch and Bitterman (1951) considered that sensory integration or intersensory liaison is foundational to judgement of stimulus equivalence and of cross-modal and intramodal matching, and thus is basic to the process of reading (Pollack, 1976).

Integration between the modalities involved in pre-reading perceptual growth requires the relating of speech (auditory temporal) patterns to spatially ordered visual patterns (Birch & Belmont, 1964). The act of reading is initiated by the matching or transferring of visual spatial patterns to auditory temporal information (Bannatyne, 1968; Beery, 1967; Birch & Belmont, 1965; McGrady & Olson, 1970; Muehl & Kremenak, 1966). Analysis of the early reading process thus shows that several kinds of integrations among the auditory and visual modalities are called for. Integrations within modality (intramodal) involve auditory temporal to auditory temporal (AT-AT) and visual spatial to visual spatial (VS-VS) liaison. In view of the sequential nature of reading along a line of print, integration of a temporal element is also involved for the visual modality (Doehring, 1968; Rudnick, Martin & Sterritt, 1972; Sterritt, Martin & Rudnick, 1971). This requires visual temporal to visual temporal integration (VT-VT). Between modality (cross-modal) integrations require the organization and inter-relating of spatial and temporal, visual information with auditory temporal input. This encompasses six further combinations of inter-sensory integrations: visual spatial to visual temporal (VS-VT) and the reverse (VT-VS), visual spatial to auditory temporal (VS-AT) and the reverse (AT-VS), and visual temporal to auditory temporal (VS-AT) with its complement (AT-VS) (Rudnick et al., 1972; Sterritt et al., 1971).

Historically the divergent views on the essential contributions of audition and vision to processing information could be represented by 1. a modal specific view whereby each modality has specific and distinct patterns of transduction, specific neural location and functions and characteristic sensory and perceptual qualities, and 2. an opposing amodal, supramodal or nonmodal view where a unitary modal-processing of information occurs with unique modal qualities overlooked (Ettlinger, 1967; Freides, 1974). Although some elements of both views appear in literature on cross-modal function, the main approach taken by modality matching research infers a basically modal specific view with some degree of rapprochement in the area of sensory integration. Ettlinger (1967) presents something of these opposing positions in writing that it is not known for certain whether a single process of recognition takes place in the one neural system regardless of sensory input mode, or if recognition takes place in a specific modality for specific stimuli.

It is this lack of certainty together with clear necessity for integration of sensory information in the process of reading that has contributed to the considerable amount of research in the area. Thus study of intra- and intersensory functioning for the auditory and visual channels is of significant value for the study of learning disorders and in particular in the understanding, classification and remediation of children with reading disorders (Beery, 1967; McGrady & Olson, 1970).

Modality Matching and Reading

One approach to the study of integration of auditory and visual modalities in reading has been to compare the sensory integration abilities of normal and retarded readers. Birch and Belmont (1964) were among the first to examine intersensory integration in this way, using analogous visual spatial and auditory temporal stimuli calling for cross-modal matching of the stimulus patterns.

Modality matching involves the presentation of a stimulus or standard pattern in one modality followed by a comparison pattern in a second modality, the subject being required to judge the equivalence or match of the two patterns. Matching of patterns in the same modality is designated intramodal matching (IMM). For two patterns presented in different modalities a cross-modal match (CMM) is called for. In that judging equivalence is a requirement of the task, the subject is aware that a relationship exists between the stimulus patterns.

Cross-modal matching (CMM) is not to be confused with cross-modal transfer (CMT) which involves transfer of a learned principle from original to concurrent or subsequent tasks (Balter & Fogarty, 1971; Ettlinger, 1967; Goodnow, 1971a, 1971b; O'Conner & Hermelin, 1971). In CMT as distinct from CMM the subject is not made explicitly aware of any equivalence between the two tasks. While a considerable time interval may separate the two stimulus presentations in CMT, for CMM the time interval is rarely longer than a few seconds.

Another confusion among the results of CMM studies has also arisen due to lack of intramodal controls (Bryant, 1968; Holloway, 1971; Jones, 1970; Milner & Bryant, 1970; Rae, 1977; Rubinstein & Gruenberg, 1971; von Wright, 1970). Exclusion of information on intramodal performance is critical in cross-modal integration research since there is no way of knowing if poor performance is due to failure to integrate information or failure to discriminate relevant stimulus aspects in either or both of the modalities concerned. Lack of intramodal controls is also crucial if development of cross-modal integration with age is being considered. In such a case, age changes in integration cannot be separated from improvements due to developing ability to discriminate in the modalities concerned.

Intramodal data in conjunction with cross-modal data permit some analysis of the performance of good and poor readers. Differences in scanning, coding, or memory of the initial stimuli are taken into account by intramodal and cross-modal data comparisons. It is also possible to assess the relative difficulty of the various integration tasks if the standard and comparison stimuli are identical in each matching situation. Such an assessment requires that all subjects perform all tasks.

Recent modality matching research permits some degree of coming together of the views that emphasize either receptor mechanism (modal specific) or higher cortical processes (nonmodal). The findings of Freides (1974) are foreshadowed in Goodnow's (1971a) suggestion that adjudged equivalence depends on the extent of the correspondence between sets of properties sampled on the two occasions, and that superiority of any integration method will depend upon the degree to which it highlights essential properties. Freides (1974) concludes that the nonmodal position is relevant for simpler information loads while the modal specific view holds largely true for the processing of complex pattern information.

The implication for reading seems to be that the more easily the sight-sound or sound-sight correspondence is attained, the more adequate the reading performance will be. If integration ability for complex information can be demonstrated by poor readers, it suggests that some other interference in establishing the correspondence of the visual and auditory stimuli in the reading task may lie at the base of poor reading performance.

If the poor reader can integrate the simpler information but not the more complex, it suggests that the child may be bound by initial stimulus characteristics or lack a mediational facility or rule for establishing correspondence of cross-modal stimuli. If a strength in one of the modalities is indicated, the effect of this strength as the initial or standard stimulus modality or as the comparison modality may be investigated by analysis of interaction effects. This raises the question of spatial and temporal conditions of presentation as well as the place of memory in mediating the two conditions.

Research to clarify some of these areas of partial understanding has been steady if not voluminous over the past decade and a half but due to methodological variations and inadequacies, a number of the key variables have not been examined systematically or controlled adequately enough to clarify some of the major issues arising from sensory modality integration research (Silverston & Deichmann, 1975). Chalfant and Scheffelin (1969) have supplied a tabulation that includes many of the variables that need to be considered in designing intramodal and cross-modal matching studies (see Table 1). Consideration of these variables serves to narrow the focus of the present review since the majority of the "organism" variables are controlled by selection of the subjects (sex, age, organic involvement) while the majority of the remaining variables are controlled by the research design or have been sufficiently examined by recent research. Since Birch and Belmont's (1964) original study has set the scene and has highlighted a number of major areas of contention, their study serves to introduce some factors which directly influence the design and purpose of this study.

Table 1

Variables to be Considered in Modality Matching Research

Mode of Stimuli	Organism	Mode of Response
Intramodal	Sex	Intermodal
Intermodal	CA	Intramodal
Simultaneous presentation	MA	Symbolic a. motor b. vocal
Successive presentation	I.Q.	Nonsymbolic a. motor b. vocal
Symbolic stimuli	Organic involvement	Production a. latency of response b. duration of response c. frequency of response d. intensity of response
Nonsymbolic stimuli	Prior experience or training	Imitative response
Intensity		Judgemental response a. same b. different c. recognition d. recall e. equivalence f. correspondence g. recoding to a rule
Number of units		
Rate		
Duration		
Interval		
Instructions		
Order		
Complexity		
Distortion		

The matching of analogous auditory temporal (AT) and visual spatial (VS) stimuli which Birch and Belmont (1964) employed has become known as the Birch and Belmont test (see Figure 1)

	AUDITORY TAP PATTERNS	VISUAL STIMULI		
		EXAMPLES		
A	• •	••	• •	•••
B	• ••	•••	• ••	•• •
C	•• •	•••	• ••	•• •
		TEST ITEMS		
1	•• ••	• •••	• •• •	•• ••
2	• •••	••••	• •••	••• •
3	••• ••	•••••	•• •••	••• ••
4	• •• •	• •• •	•••••	•• ••
5	••• •• •	••• •• •	•• ••• •	• ••• ••
6	•• •••	••• ••	•• •••	•••• •
7	•• •• ••	•• •• ••	•••• ••	••• • ••
8	••• ••• •	•• ••• ••	••• •• ••	••• ••• •
9	•• • •••	•• •• ••	•• • •••	•• ••• •
10	• ••• ••	• •• •••	• ••• ••	•• • •••

Figure 1. Test stimuli used by Birch and Belmont.

Auditory patterns were tapped on a table top in the subject's view after which the subject chose the matching visual dot pattern from among three alternatives presented on cards. For nine and ten-year-old boys, good readers made significantly fewer errors than retarded readers, suggesting that they dealt more effectively with tasks requiring auditory-visual matching of stimuli. Within the two reading groups there were also significant differences in reading ability between those who were high and low on the A-V ability test. The relationship between intelligence, A-V integration and reading, and the place of memory, which they also studied, will be discussed in later sections of this review. They concluded that one of the contributing factors of reading difficulties was poor development of intersensory integration.

A number of weaknesses were apparent in their study and subsequent studies have attempted to remove those weaknesses, unfortunately in the process adding further variables or variations which have made finding consensus difficult. Among the major weaknesses, together with later studies which replicated those weaknesses, are the following: (a) low ceiling of the test (Birch & Belmont, 1965; Holloway, 1971; Klapper & Birch, 1971; Muehl & Kremenak, 1966; Reilly, 1971), (b) lack of control of visual cues during the tapping patterns, thus confusing auditory and visual stimuli and intramodal with cross-modal matching (Birch & Belmont, 1965; Holloway, 1971; Reilly, 1971; Rudnick, Sterritt & Flax, 1967; Sterritt & Rudnick, 1966); (c) imprecision and variation in presentation of the AT stimuli (Becker & Sabatino, 1971; Birch & Belmont, 1965; Ford, 1967; Goodnow, 1971a; Kahn & Birch, 1968; Reilly, 1971; Rudnick, Sterritt & Flax, 1967; Sterritt & Rudnick, 1966); (d) unrepresentative samples (Birch & Belmont, 1965; Rudnick, Sterritt & Flax, 1967; Sterritt & Rudnick, 1966); (e) lack of data on the reliability of the test, particularly in the light of the small number of items (six to ten) (Beery, 1967; Birch & Belmont, 1965; Kuhlman & Wolking, 1972; Muehl & Kremenak, 1966; Rudnick, Sterritt & Flax, 1967; Sterritt & Rudnick, 1966); (f) no consideration of the visual to auditory aspect of reading (Ford, 1967; Jones, 1970; Kahn & Birch, 1968; Rae, 1977; Reilly, 1971; Rudnick, Sterritt & Flax, 1967; Sterritt & Rudnick, 1966). In addition, a number of studies have confused the temporal-spatial aspects of perception via the visual modality. These weaknesses, together with some of the attempts made to control them, and major variables to be considered (after Chalfant & Scheffelin, 1969) will be summarized later in this review.

Not all of the many studies on CMM and IMM have related sensory integration to reading processes or difficulties. Those studies which did include consideration of the relation of AVI to reading, did so in a variety of manners. The original Birch and Belmont (1964) study used previously selected groups of good and poor readers as subjects for comparison. This method was also used by Beery (1967), Bryden (1972) and Vande Voort, Senf and Benton (1972). A second type of approach was to test the children for reading abilities before, (Birch & Belmont, 1965; Muehl & Kremenak, 1966; Rudnick, Sterritt & Flax, 1967), after, (Ford, 1967; Kahn & Birch, 1968; Sterritt & Rudnick, 1966) or sometime (Rae, 1977; Reilly, 1971) in relation to the AVI testing, treating reading ability as a continuum rather than dividing subjects into groups. Other major studies did not assess reading abilities.

Of the studies which assessed reading, a variety of aspects and standardized tests were used. Birch and Belmont (1964) used measures of word knowledge, word discrimination and oral reading. Beery (1967) divided subjects on the basis of oral reading but compared groups on AVI ability. Birch and Belmont (1965) used available reading readiness measures for grade one children and whatever measures were available for some of the older subjects. AVI ability was correlated with reading and reading readiness. Sterritt and Rudnick (1966) and Rudnick et al. (1967) related AVI to reading comprehension, Kahn and Birch (1968) to word knowledge and comprehension, and Muehl and Kremenak (1966) to pre-reading readiness subtests and reading achievement a year later. Ford (1967) related integration to paragraph reading and words in isolation while Vande

Voort and Senf (1973) used only the words in isolation. Some ten or more different tests were used, giving a wide variety of measures, the most commonly used being the Gates MacGinitie Reading Tests.

In addition to the variations in the reading measures, the ages of subjects varied from pre-schoolers to adults, with the most common groups as follows (numbers of studies in parentheses): K, K-2, K-3, K-4, K-6(2), grade 1 (2), 1-4, 2-6, 3, 3-4, 3-7(2), 4 (3) and 5. At least seven of the major studies used boys as subjects while in twelve or more the subjects were boys and girls. A number of different socio-economic groups were included and a number of I.Q. ranges. For several studies the mean I.Q. was 120 or above. Thus it is difficult to interpret the results as far as developing a clear picture of the contribution of sensory integration to reading performance. While the general relationship between AVI and reading is fairly well established, a breakdown of the relationship of the components of cross-modal and intramodal integration with skills of reading still needs further research.

The major findings of those studies which related sensory integration to reading are summarized as follows:

1. Cross-modal matching ability was higher for better readers (Birch & Belmont, 1964, 1965; Beery, 1967; Bryden, 1972; Ford, 1967; Jones, 1970; Kahn and Birch, 1967; Muehl & Kremenak, 1966; Rae, 1977; Reilly, 1971; Rudnick et al., 1967; Sharan & Calfee, 1977; Sterritt & Rudnick, 1966; Vande Voort et al., (1972). With the exception of Birch and Belmont (1965) the various studies showed that this relationship held for all grades up to grade six. The decline of significant relationship for higher grades in Birch and Belmont (1965) is questionable since ceiling effects reduced variance of scores and thus decreased the correlations. Findings of other studies also opposed Birch and Belmont's conclusion.

2. While some studies related integration to reading in general, Birch and Belmont specified the significant relationship of integration with word knowledge, word discrimination and oral reading. Kahn and Birch (1968) studied the relationship of sensory integration with word knowledge and comprehension, Ford (1967) with two measures each of vocabulary and oral reading, Muehl and Kremenak (1966) with comprehension, Rae (1977) with comprehension, Jones (1970) and Reilly (1972) with vocabulary and comprehension, Vande Voort et al. (1972) with words in isolation, and Bryden (1972) with a composite of vocabulary, speed and accuracy and comprehension.

3. With the effects of intelligence taken into account or adequately controlled, auditory-visual integration is independently significantly related to reading (Birch & Belmont, 1964; Beery, 1967; Muehl & Kremenak, 1966; Rudnick et al., 1967; Sterrit & Rudnick, 1966). Ford (1967) found the relationship lost significance with intelligence controlled. Jones (1970) and Kahn and Birch (1968) found that word knowledge and AVI were still significantly related with intelligence controlled but that comprehension and AVI correlations tended to lose their significance. Jorgensen and Hyde (1974) found AVI correlated significantly with vocabulary but not comprehension for grade one and two children. Bryden (1972) with I.Q. constant, found partial correlations between reading and matching, with values of .14 for good readers and .60 for poor readers, concluding that the relation of reading to modality matching was non-linear.

4. Various cross-modal matching tasks are significant predictors of reading performance. These include A-VS, accounting for 11 and 23 percent of reading variance respectively, in Rudnick et al (1967) and Sterritt and Rudnick (1966). In the Rudnick et al. (1967) study, VT-VS accounted for 14 percent of the reading variance. Muehl and Kremenak (1966) found that

only VS-A and A-VS contributed as significant predictors of grade one reading. For reading readiness they found only letter naming was a significant predictor of later reading, and VS-A and A-VS correlated significantly with letter naming. Beery (1967) found that VS-A matching discriminated between good and poor readers. She also concluded that either VS-A or A-VS was equally useful in discriminating between good and poor readers since the lower A-VS scores might have been due to unequal opportunities for guessing when tests had unequal numbers of patterns to choose from in the comparison conditions. Bryden (1972) concluded that although good readers are superior on all nine combinations of matching tasks, only A-A, VT-A, VT-VS, and VS-VT give significant differences between good and poor readers.

In examining the influence of the dominant parietal cortex on A-VS CMM tasks and VS-VS and A-A intramodal matching, Butters and Brody (1968) found specific localizations in the dominant hemisphere for cross-modal and intramodal integrations and concluded that AVI capacities serve as prerequisites for attainment of reading skills. Although there is a clear relationship of sensory integration and reading, many aspects of the relationship still need to be further explored.

Test Ceiling and Low Reliability

Although significant relationships were found among the variables studied (Birch & Belmont, 1964, 1965; Klapper & Birch, 1971; Muehl & Kremenak, 1966; Reilly, 1971), low ceiling effects make some of the results questionable. Levelling-off effects of AVI abilities with increasing age were particularly influenced by predominance of easy items. Easy items also caused skewed results and reduced variability of scores, with resulting implications for inferential statistics. Beery (1967), Ford (1967) and Kahn and Birch (1968) increased the number of items in the Birch and Belmont test from 10 to 20 in order to give greater ceiling and reliability. Subsequently, Bryden (1972), Rae (1977), Reilly (1971), Sharan and Calfee (1977), and Vande Voort, Senf and Benton (1972) employed 20 items in their modality matching studies. Becker and Sabatino (1971), Rudnick, Martin and Sterritt (1972) and Sterritt, Martin and Rudnick (1971) added two items to extend either the ceiling, or in the case of Becker and Sabatino the floor, of the tests. The most obvious effect of increased numbers of items was to raise the asymptote found by Birch and Belmont (1964) at the Grade 5 level. Kahn and Birch (1967) using a 20 item extension of the AVI test with unseen tapping of the AT pattern obtained test-retest reliabilities after 10 days of .76 and .90 for third grade and fifth grade boys respectively.

While few other studies have reported reliability data for the AVI test, Becker and Sabatino (1971) concluded that the Birch and Belmont AVI test could provide reliable information as early as grade 1 in a group testing setting and with the tapping action concealed from subjects' view. For ages five, six, seven and eight the test-retest reliability coefficients were respectively .34, .90, .92, .75. Rae (1977) with nine and ten year olds in small group settings used a modified version of the Birch and Belmont test extended to twenty items. He obtained a reliability coefficient of .82 using the Kuder-Richardson twenty formula. Ford (1967) pointed out the continuing need not only for more clear cross-modal tasks, but also for attention to be given to "... the more mundane psychometric criteria of reliability and sample sizes" (p. 840).

Presentation of Auditory Temporal Stimuli

The original method of tapping the auditory pattern in full view of the subjects added a visual component which later studies tried to remove. Ford (1967), Goodnow (1971a), Kahn and Birch (1968) and Becker and Sabatino (1971) employed an unseen tapping system, under the table with arm and shoulder movements concealed. As early as 1966 Sterritt and Rudnick introduced taped auditory tone beeps of 1000 Hz, via headphones, as the auditory stimuli to be matched. Beery (1967) also systematized presentation of auditory stimuli using a Bell and Howell Language Master and louspeaker connection to a soundproof room. The tones were 500 cycles per second. Vande Voort, Senf and Benton (1972) also used the Language Master with 1000 Hz tones. Muehl and Kremenak (1966) removed the visual element by using a telegraph key, still manually operated. This method was later used by Bryden (1972), Klapper and Birch (1971), and Kuhlman and Wolking (1972).

The technique employed by Sterritt et al. (1971) and Rudnick et al. (1972) presented 1000 Hz and 1200 Hz tones via headphones, the two frequencies being used to separate the standard and comparison stimuli. Finally Jarman (1977a, 1977b, 1978) and Rae (1977) used tape recorded tones of 1000 Hz and 800 Hz respectively.

While a variety of stimuli lengths and interval durations were used, the majority used a beep duration of about .15 to .25 secs, a short interval of .35 to .5 secs and a long interval of 1 to 1.35 secs. The times between pairs of stimuli have usually ranged from one to two seconds, with longer periods in studies specifically testing for memory effects. While it is difficult to know the significance of such practical differences, the methodology variability and confusion of visual and auditory input have, by these methods, been more adequately controlled.

The confusion of spatial and temporal dimensions in the earlier studies occurred in the matching of VS and AT patterns, thus calling for two types of integration, auditory to visual and temporal to spatial. The Rudnick et al. (1972) and Sterritt et al. (1971) studies represented the first attempt to differentiate these factors in modality matching. A number of studies including Rubinstein and Gruenberg (1971) had observed the need for control of spatial-temporal transformations and also the need for study of the complement of A-V integration (V-A) and of the intramodal pairings, A-A and V-V. To make valid comparisons between intramodal and cross-modal matches, all possible combinations would need to be included.

Muehl and Kremenak (1966) had added intramodal controls, the V-A complement, and changed the response mode from choice of one among three possible matches to a two choice, same/different format. At the same time they used different sets of stimulus items for each task, thus including a possible task difference factor. The cross-modal task still involved the spatial-temporal confusion.

Rubinstein and Gruenberg (1971) changed all the patterns to include the same number of elements, including all temporal combinations, the only identification required being the location of the long interval among the stimuli. They used fast and slow presentations, with adult subjects, for the four combinations, AT-AT, VT-VT, AT-VT, VT-AT. They found VT patterns more difficult to match than AT and cross-modal matches as easy as intramodal for a slow rate of presentation. For a fast rate of presentation cross-modal matches were more difficult. Symmetric standard patterns were easier to match than asymmetric.

Thus the Rudnick et al. (1972) and Sterritt et al. (1971) studies marked a significant step in generating all nine possible combinations of stimulus and response patterns, covering all dimensions of integration. Using headphones, lamps, printed dots and a same/different response format, they included AT-VS, VS-AT, AT-VT, VT-AT, VT-VS, VS-VT, AT-AT, VS-VS and VT-VT matchings. They found the AV and TS integrations were similar in difficulty to respective intramodal integrations. Easiest tasks were visual spatial matchings, more difficult were mixed visual spatial and temporal matchings and most difficult were purely temporal matchings. Visual and auditory modality roles appeared to be of little significance for indicating individual differences compared to the temporal-spatial dimension. A plausible conclusion could be that poor CMM performance in previous studies may have been due to the temporal-spatial variable rather than visual-auditory. The Goodnow (1971a) and Kläpper and Birch (1971) studies produced similar findings.

The question raised by the modality specific view is raised again in considering whether space is best approached by vision and temporal perception best served by audition. O'Connor and Hermelin (1971, 1972) concluded that the input modality determines the conceptual organization of space rather than the physical. Their 1972 study showed the visual items were organized spatially and auditory items organized temporally. When spatial and temporal stimuli were presented simultaneously the modality of input determined the perceptual organization. Kuhlman and Wolking (1972) drew much the same conclusion in saying the IMM and CMM tasks were not significantly different when both begin with the same modality. This points the need for further interaction effect studies of standard and comparison conditions for visual and auditory modalities.

The Rudnick et al. (1972) and Sterritt et al. (1971) studies raised issues since subjects were impoverished black and chicano kindergarten and first grade children. Questions raised include the possible influence of poor language skills on mediation in matching or in temporal discrimination.

Mediation in Modality Matching

Birch and Belmont's originally propounded view that modality characteristics mediated sensory matching was rejected by Blank and Bridger (1964) in favour of higher order processes. As indicated from the Rudnick et al. (1972) and Sterritt et al. (1971) studies, the role of language appears to be a significant consideration in understanding modality matching. The role of language is likely to vary from task to task and adequate verbalization is probably not a sufficient condition for CMM to occur (Blank & Bridger, 1964; O'Connor & Hermelin, 1971). Ettlinger (1967) points out that CMM may occur with or without the aid of verbalization and may take place at a perceptual level without verbal mediation. The question seems not to be whether language is necessary for modality matching ability but rather, in what ways it may be used to facilitate performance (von Wright, 1970). Jones and Robinson (1973) considered that in CMM, subjects may be forced to use verbal coding as mediation between modalities, which helps to account for visual-visual tasks being easiest.

Blank and Bridger (1966) attempted to separate the role of language from cognitive development in transfer of cross-modal learning, using the deaf to control for language. They concluded that the deaf performed as well as the hearing because they had number concepts which could be expressed kinaesthetically if not in language. In a further attempt to control for language, Belmont, Birch and Belmont (1968) used brain damaged patients with and without language aphasia. They found no support for the view that CMM was dependent on verbal mediation, supporting the Blank and

Bridger conclusion that language may be a hindrance to processing some types of sensory information.

Kahn and Birch (1968) proposed that factors such as visual or auditory discrimination, auditory memory or verbal labels for stimuli could be possible mediators between AVI and reading. They employed a post-hoc questionnaire on the strategy used by the grade two to grade six subjects in an extended item AVI test. They employed the following categories (with percentage of use in subjects' responses in parentheses):

(1) counting variations (48%) (a) counting with pauses (b) grouping (c) grouping with a word for pauses

(2) attempts to visualize the pattern before comparison (15%)

(3) instinctive gestalt-proprioceptive feeling (5%)

(4) no known technique (32%).

Ability to apply labels did not influence AVI in a positive way. The use of counting procedures showed lowest AVI scores while attempted visualization tended to produce high AVI scores. Having no apparent method produced comparable results to use of verbalized methods.

This finding that visualized schematization of temporal patterns mediates matching better than any other method, while surprising, is consistent with discussion arising out of the confusion of spatial and temporal elements and dealt with by Rudnick et al. (1972) and Sterrit et al. (1971). These studies concluded that auditory-visual and temporal-spatial integrations were <u>not</u> higher order abilities. Children who visualized auditory patterns had a ready schema for comparison in the spatial modality aspect of matching and thus had virtually made the match before the presentation of the VS stimuli. This was not so for those who used a numerical coding system. Numerical coding was found to be increasingly used in relation to length of stimulus patterns and intervals within patterns, with increasing age (Lehman & Goodnow, 1972). Age changes were also reflected by changes in information selected for coding. The simplification of coding for memory purposes was especially useful in temporal sequences. This seems to tie in with the process visualization and a simplification in the coding-mediation requirements. This notion has significant implications for the visual-auditory and temporal-spatial integrations involved in early reading tasks. In the words of Bannatyne (1968):

> In learning to read, children learn to associate sound-labels with visual-labels (and vice versa) on both a gestalt whole-word basis and on a phoneme-grapheme analytic-synthetic basis. (p.14)

It may be that visualization and verbalization are best used selectively and interchangeably as the integration task changes in terms of the modality of presentation of the initial stimulus and the complexity of the stimuli, as Friedes (1974) suggests.

The factor of meaningfulness of the stimulus material might possibly be of influence. Groenendaal and Bakker (1971) investigated the role of mediation in retention of temporal sequence and found that good verbal mediators perceived and retained temporal sequences of meaningful figures better than non-mediators with the groups being equal for meaningless figures. The same differentiation applied to good and poor readers (Bakker, 1967), with good readers able to retain meaningful figure sequences better. Results led to the conclusion that such data on mediation and retention apply to the mechanical reading process at earlier stages of reading. If meaningfulness of material aids in perception of temporal order this supports the idea of mediation for simplification of temporal order matching. The simplicity of symmetrical temporal patterns may account for easier matching (Rubinstein & Gruenberg, 1971). Thus for poor readers, adequate language does not help them in modality matching, when a difficulty in handling temporally and sequentially ordered information is the main difficulty for such readers (Bryden, 1972; Doehring, 1968; Leong, 1976, Note 1).

Memory in Modality Matching

A number of references have been made to the place of memory. Birch and Belmont's original study found that children with low and high AVI scores were not significantly different in memory ability as tested by the Digit Span subtest of the Wechsler Intelligence Scale for Children (WISC). Ford (1967) and Kahn and Birch (1968) obtained similar results using WISC Digit Span scores. Using the Auditory and Visual Sequential Memory subtests of the Illinois Test of Psycholinguistic Abilities (ITPA), Jorgensen and Hyde (1974) found no significant relationship to AVI for auditory memory but a tentative significant relationship between visual sequential memory and AVI for grade two boys. Goodnow (1971a) controlled for memory effects by including checks on memory for the original series and by providing a no-memory test, with the pattern always available. She found that matching difficulty could not be accounted for by memory weakness since children with reading problems had difficulties in matching both when the original stimulus had to be remembered and when it remained present. Milner and Bryant (1970) found that increasing the delay of the matching stimulus presentation added a memory factor after delays of more than five seconds. Vande Voort and Senf (1973) in comparing AVI for normal and retarded readers using VS-VS, VT-VT, AT-AT, and AT-VS found that only

VS-VS and AT-AT tasks discriminated good and poor readers. Although they concluded that poor memory or perceptual factors may be alternatives to account for reading deficits, Vande Voort, Senf and Benton (1972) had earlier found no main effect for interstimulus interval, thus concluding that it was not possible to ascertain whether poor memory differentiates retarded readers from normal readers. The consensus of research appears to be that given an adequate memory threshold other factors than memory are required to account for poor sensory integration of poor readers.

Developmental Trends and Matching Difficulty

As has already been indicated, modality matching has been researched heavily over the grades K to 6. The early Birch and Belmont studies indicated increasing AVI ability with age, the growth being most rapid at younger ages. The asymptotic effects were later shown to be ceiling effects and improvement in AVI appears to continue at least until grade six. Limitations of test instruments make data on the developmental trend of cross-modal matching ability somewhat tenuous. Both IMM and CMM appear to follow a similar developmental trend which is fairly well established and replicable (Goodnow, 1971a, 1971b). The question of when and how these abilities are related to reading is less clear. The range of studies indicate them to be significantly related from K to grade six with the suggestion that after grade four the significance changes. This change may be related to the mastery of perceptual and mechanical aspects of reading from about grade four onwards for normal readers and to the relative maturation of visual and auditory perceptual abilities by this stage.

On the matter of the relative difficulty of IMM and CMM tasks, the expectation has been that cross-modal integration by its essential nature would be more difficult. Some studies have shown this to be true (Goodnow, 1971b) while some have found the reverse (Muehl & Kremenak, 1966) or equal difficulty (Sterritt et al., 1971). Kuhlman and Wolking (1972) would add that IMM and CMM are not significantly different only when both begin with the same modality. Some degree of confusion of findings can be attributed to variations of methodology, instrumentation and research design. In spite of these inconsistencies there are some general trends that can be distinguished. The Rudnick et al. (1972) and Sterritt et al. (1971) studies and Jarman (1977b) concur with the Muehl and Kremenak (1966) findings at a greater degree of detail. Muehl and Kremenak found V-V to be easiest, A-V and V-A intermediate and A-A hardest in difficulty. The Rudnick and Sterritt studies found VS-VS easiest, VS-A, A-VS, VS-VT, VT-VS intermediate and A-VT, VT-A, VT-VT, and A-A most difficult. Thus pure spatial matching was easiest, mixed temporal and spatial intermediate and pure temporal matching was hardest. Increasing stimulus length made all tests involving audition more difficult.

On the matter of relative task difficulty Bryden (1972) has some strong conclusions though data were collapsed across sexes, and he employed a mixed condition presentation format for the matching tasks rather than blocks of similar standard to comparison matches. He found that if the first pattern is a spatial one (VS) the task is easy. If the first task is a temporal one (A or VT) the matching is harder. The same trend applied to the comparison conditions with the proviso that VS patterns are easier to remember and thus to compare. In answering the question whether cross-modal matches are harder than intramodal matches, or whether temporal presentation makes the difference, Bryden concluded that cross-modal matches are more difficult, shifts of timing more difficult than shifts across modality and that adding a cross-modal shift to a temporal shift does not automatically make the matching task more difficult.

Sex and SES Effects

In collapsing data across sexes, Bryden re-introduced the question of sex differences. There are unquestionable sex differences in reading ability (Dwyer, 1973; Ford, 1967). The position with regard to AVI however is not so clear. Although Jorgensen and Hyde (1974), Muehl and Kremenak (1966), Rae (1977), Reilly (1971) and Sharan and Calfee (1977) found no sex differences in AVI ability, Reilly and Jorgensen and Hyde did find sex differences in the relationship of AVI to reading. None of the five studies mentioned, however, used more than four of the nine possible modality matching combinations, and two of the studies used the Birch and Belmont method of tapped (and thus, seen) auditory patterns. Only Jarman (in press) and Bryden (1972) used all nine combinations and both of these studies found no sex differences in AVI ability. Several of the previously mentioned studies had ceiling effects which may have masked sex differences. In these studies there were also differences in age, race and the content of the tests. Three of the five studies used subjects from different social class groupings.

Although not included in Chalfant and Scheffelin's table of variables, SES appears to be a significant independent variable to consider in modality matching studies. Jorgensen and Hyde (1974) concluded that SES did make a significant contribution to AVI performance of lower-class children and should be considered when interpreting AVI research.

Sharan and Calfee (1977) with second, third and fourth grade Israeli children found significant interaction between AVI ability and SES. Lower class and younger children found non-verbal stimuli more difficult to match than middle class and older children. Since SES is well known to have significant relationship to measured intelligence, it appears to be an important factor in reading and AVI research.

Intelligence and Modality Matching

Although measured intelligence played an important part in the findings of Birch and Belmont's original study (1964), and has been included as a variable in most later studies, its effects have not always been controlled-for in relating modality matching to reading. Birch and Belmont (1964) found that children with low AVI scores had lower mean I.Q.'s regardless of whether they were good or poor readers. The differences in mean I.Q. for low and high AVI groups was significant for both good and poor readers. Poor readers with high AVI scores had similar I.Q.'s to normal readers with low AVI scores. AVI was shown to be significantly related to reading over and above shared intelligence.

With methodological improvements, later studies found correlations of I.Q. with AVI ranging from .34 (Ford, 1967) to .53 (Sterritt and Rudnick, 1966). Later studies of course included more cross-modal and intramodal combinations for correlation with intelligence. The Ford (1967) and Kahn and Birch (1968) studies with intelligence controlled produced opposing findings. Ford found no AVI differences for good and poor readers while Kahn and Birch found AVI and word knowledge (and comprehension at some grades) to be still significantly related. Jarman (1977b, 1978) found that A-VS matching discriminated most strongly among three intelligence groups at four grade levels, compared to VS-VS, A-A, VS-A and a group of other perceptual and memory tests. Factor analyses showed clearly different strategies on modality matching tasks for the three I.Q. groups.

Jorgensen and Hyde (1974) using correlational techniques found no significant correlations between intelligence and AVI but results were probably confounded by SES factors. After partialing for intelligence, AVI and vocabulary retained a significant relationship. Rae (1977) found that intersensory integration correlated significantly with both nonverbal I.Q. and reading achievement (.68 and .56 respectively). With intelligence controlled, AVI remained significantly correlated with reading but accounted for only 4 percent of reading variance.

From these tests it is clear that the relationship of modality matching to reading and intelligence is complicated and differences in findings may result from design variations and test differences. It is clear from the Jarman studies that more qualitative analysis of cognitive and intellective strategies in modality matching tasks is necessary, together with the full range of modality matching combinations, and the combination of these refinements to be applied to performance of good and poor readers.

Summary and Conclusions

It is the view of Robinson (1976) that too few studies use continuing study of a topic and that problems in reading will never be solved by "one shot" studies (p. 14). Among the advantages of continuing to investigate the same topic are the opportunity to verify, to extend, to improve on weaknesses and avoid pitfalls, and to include use of new techniques for investigation.

The position is taken by this study that further research is essential for understanding, preventing and remediating difficulties in reading experienced by so many children, especially boys, beginning in the early grades. Reading ability underlies success in most areas of study and vocation, with major implications in the communication of knowledge and as a leisure pastime. Understanding of the reading process is of central importance for teaching methods, diagnosis of difficulty and for intervention in cases of inadequate performance.

The position is taken that the early stages of learning to read are heavily dependent on perceptual aspects of the stimulus materials and organization of the information received from visual and auditory modalities. Early reading is seen as involving integration of visual, spatial, auditory and temporal information and involving a matching of visual and sound labels for both whole word and part word stimulus elements. The sensory and intersensory integration approach to the study of reading, by observing the cross-modal and intramodal matching abilities of good and poor readers is considered to be a valid and necessary area for research (Jones, 1970; Jorgensen & Hyde, 1974). All evidence suggests that there is a continuing need for early identification of children deficient in ability to integrate auditory and visual information (Muehl & Kremenak, 1966). Since A-VS integration tests appear useful in both predicting reading difficulty and discriminating normal and poor readers, even with intelligence controlled, further research would seem to be productive (Beery, 1967).

Lack of standardized instruments and variations in methodology, sample selection and research foci have led to conflicting findings in modality research related to reading (Silverston & Deichmann, 1975). Ceiling effects produced by too few and too easy items in matching tasks have contributed to equivocal findings and reduced confidence in conclusions of those studies. At the same time, reliability of sensory integration measures based on as few as six or ten items has been inadequate. Confounding of the spatial and temporal aspects of visual stimuli in matching tasks has further contributed to confused findings. Only in some of the more recent studies have all combinations of intramodal and cross-modal matching been included and in some of these other limitations were not removed. Some of these include small samples, mixed sex groups, inadequately counterbalanced or confused orders of presentation of stimuli, and non assignment of all subjects to all conditions. Bryden (1972) in the only major Canadian study to examine modality matching and reading by including all nine conditions of stimulus presentation did not avoid a number of these latter weaknesses. In particular, interaction effects need to be more adequately investigated for the temporal, spatial, visual and auditory elements of the standard and comparison conditions. The method of stimulus presentation in the Bryden study appears to have confused this aspect of modality matching.

Although the broad factors of intelligence and auditory-visual integration are clearly related to reading ability, more detailed and qualitative analyses of intellective strategies and interaction effects of auditory, temporal, visual and spatial stimulus orderings as they relate to reading ability is considered to be necessary.

> There have been claims that the human being is primarily a visual animal just as some theories equate human information processing with verbal thinking. These are one-sided views. Human beings are both visual and auditory, spatial and temporal, integrating

> and differentiating. It follows that research designs should include specification or control of the information to be processed, the adeptness of the input modality for dealing with the information, and the modality response biases of the individual. (Freides, 1974, p. 303)

This study investigates the auditory and visual, intramodal and cross-modal integration abilities of above average and below average readers, taking into account a number of the requirements and weaknesses expressed in this review of the literature.

CHAPTER III

PROBLEM

> ..... the process of investigation, and therefore
> the growth of knowledge, never ends.
>
> L. J. Cronbach (p. 503)

Statement of the Problem

From the foregoing review it was considered necessary to further study the relationship of visual, auditory, spatial and temporal integration to reading. A useful method of doing this is to compare the sensory integration characteristics of above average and below average readers. Sensory integration abilities could thus be expressed in terms of ability at spatial and temporal, cross-modal and intramodal, matching tasks. The problem centers around three fundamental questions which arise from the reviewed literature.

1. Are above average and below average readers characterized by differing levels of performance on tasks requiring the integration of cross-modal, intramodal, spatial and temporal information?
2. For above average and below average readers, what are the relative difficulty levels of sensory integrations in terms of auditory and visual, spatial and temporal elements and their order of presentation?
3. Are above average and below average readers characterized by differing cognitive processes in the integration of cross-modal, intramodal, spatial and temporal information?

Rationale

The rationale for examination of the sensory integration abilities of good and poor readers arises out of two main considerations. The first is that reading disability is of major concern for anyone involved in the process of education, with ramifications that influence all walks and stages of life. Many of the difficulties involved in establishing the causes of reading disability arise from incomplete knowledge of the processes of reading. In order for more adequate understanding, prevention, diagnosis and remediation of reading disabilities, continued research into the early foundations and processes of reading is vitally important. The second consideration is that sensory integration appears to be intrinsically foundational to the process of learning to read.

The more recent studies (Bryden, 1972; Freides, 1974, 1975; Jarman, in press, 1977b, 1978; Rae, 1977; Rudnick, Martin & Sterritt, 1972; Sharan & Calfee, 1977; Silverston & Deichmann, 1975) have begun to draw out some of the intricacies of sensory modality dynamics which are involved in visual and auditory, spatial and temporal integrations in modality matching tasks. Qualitative differences in the ways children process the same, visual, auditory, spatial and temporal information can be viewed not simply as abilities but more possibly as cognitive strategies or adeptness in applying the most effective sensory integration performance as required by the nature of the stimulus characteristics and task demands. Using this kind of approach the various elements of tasks eg. combinations of visual, spatial, auditory and temporal integrations, may be viewed as controlled experimental situations for the observation of differing expertise and strategy as called for by the content of the task. The recent studies have begun to approach modality matching research from these kinds of theoretical bases which carry with them, implications for methodological review or modification.

Inherent in the foregoing, and carrying over into research design is the question of the confounding of spatial and temporal dimensions and the question of intramodal adeptness. It is clearly essential to assess cross-modal integration from the baseline of intramodal functioning. It is also clearly necessary to include all possible combinations of auditory, visual, spatial and temporal, intramodal and cross-modal sensory integrations in order to make adequate observations of the cognitive processes and intellectual functioning of the subjects. To do so with a priori sub groupings is also desirable (Freides, 1974).

That such steps were not taken consistently has been shown in the reviewed literature. When reliability was improved by increasing the number of items, not all combinations of matching tasks were used (Beery, 1967; Kahn & Birch, 1968). When the complement of A-VS was used plus intramodal controls, the number of items was decreased to six but spatial and temporal dimensions were confounded (Muehl & Kremenak, 1966). When all nine combinations were used the study was not related to reading and few items were included in each task (Rudnick, Martin & Sterritt, 1972).

Although several studies report no sex differences in development of perceptual modalities and matching performance (Bryden, 1972; Rae, 1977; Snyder & Pope, 1972), there are well recognized sex differences in reading ability (Bentzen, 1963; Dwyer, 1973; Johnson, 1973; Norfleet, 1973; Wallbrown, Wallbrown, Engin & Blaha, 1975). Because of methodological differences in matching studies which report no sex differences, it was decided to study the reading and modality matching of boys and girls at the third grade level. Third grade subjects were chosen for three main reasons. (1) Several of the studies with methodological inadequacies studied children of this age, (2) it seems likely that by the end of grade three, perceptual aspects of reading start to give place to more comprehension-centered reading for meaning (Bond & Tinker, 1973), and (3) there is evidence to suggest that optimal perceptual development occurs by the age of eight years (Buktenica, 1970).

Thus as was indicated in the literature review, variations in instrumentation, in control of stimulus presentation, in subject variables (sex, age, sample size, I.Q. ranges etc.), in research design and foci, have left doubts as to the generalizability of the findings. It was with this rationale that this study was undertaken.

Hypotheses

From the literature review and the three fundamental questions which introduced the rationale for the study, the following hypotheses presented themselves.

Question 1

Are above average and below average readers characterized by differing levels of performance on tasks requiring the integration of cross-modal, intramodal, spatial and temporal information?

Hypothesis 1

Above average readers will be significantly superior to below average readers in performance on spatial, temporal, auditory and visual matching tasks.

Question 2

For above average and below average readers, what are the relative difficulty levels of sensory integrations in terms of auditory and visual, spatial and temporal elements and their order of presentation?

Hypothesis 2.1

There will be significant differences in relative task difficulty among the matching tasks within reading ability levels.

Hypothesis 2.2

There will be significant interaction effects involving reading level and the visual, auditory, spatial and temporal elements for different orders of presentation in the standard and comparison positions.

Question 3

Are above average and below average readers characterized by differing cognitive processes in the integration of spatial, temporal, cross-modal and intramodal information?

Hypothesis 3

Different cognitive processing will be found for above average and below average readers as inferred from different factor loadings in exploratory factor analyses of performance scores on the matching tasks.

CHAPTER IV

METHOD

Subjects

The population from which the four groups of readers were selected comprised some 550 boys and girls in 24 grade three classes, from eight schools. These schools were located in the compact North Delta area of the Delta School District, B.C. The community in which the schools are set is considered to be of fairly homogeneous middle-class socio-economic status.

All 24 grade three classes were tested for reading ability (Gates-MacGinitie Reading Tests; Gates & MacGinitie, 1965) and intelligence (Lorge-Thorndike Non-verbal battery; Lorge, Thorndike & Hagen, 1967), as the bases for group selection. Children with known learning, neurological or emotional disabilities or with uncorrected hearing or vision difficulties were then excluded, together with those for whom English was a second language. About 25 children were thus excluded. The reading tests were administered at the mid grade three (3.5) stage of the year. Grade placement scores ranged from 1.4 to 7.1 with a mean of 4.82. Equal numbers of boys and girls from the lowest and highest reading ability levels were then selected, who could be matched for intelligence, and which would give the largest groupings of above average and below average readers with regard to the grade three population tested. Seven of the boys selected were excluded due to failure to obtain parental permission to take part in the study.

The final sample thus consisted of two groups of 36 boys and two groups of 36 girls, matched for intelligence and representing above average and below average readers for this sub-population (see Table 2).

Table 2

Characteristics of Reading Groups

	Below Average Readers				Above Average Readers			
	Boys		Girls		Boys		Girls	
	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD
Age (mos)	105.97	5.74	104.78	5.49	104.23	3.30	104.71	3.86
Non-verbal I.Q.	94.22	9.77	94.08	9.63	94.00	10.21	94.89	8.21
Reading (raw scores)								
Vocabulary	31.64	5.37	29.03	6.62	45.72	2.36	45.44	2.61
Comprehension	22.75	6.85	24.06	7.07	42.47	3.28	40.94	3.31
Reading Total	54.39	9.62	53.08	12.46	88.19	4.66	86.36	4.99
Grade Level	3.18	.54	3.17	.67	5.92	.57	5.72	.56

The standardized reading test appeared to give inflated scores such that the mean reading grade level was 4.82. Thus some 33 percent of boys and 25 percent of girls classified as below average readers scored above their actual grade placement level. The mean grade level scores of the below average (boys 3.18, girls 3.17) and above average readers (boys 5.92, girls 5.72) were thus 1.6 and 1.0 grades respectively below and above the sub-population mean of 4.82. Within the below average readers (hereafter referred to as low), the grade scores ranged from 1.7 to 4.2, while for the above average readers (referred to as high) the range was from 4.8 to 7.1.

Instruments and Scoring Procedures

Test instruments used, fall into two categories - those used in selection of subjects and which gave the intelligence and reading measures, and those used with the four groups thus selected, namely the modality matching tests of sensory integration.

Selection Instruments

Gates MacGinitie Reading Tests, Level C, Form 2.

This test has been the most commonly used reading measure in past modality matching studies. In addition it was about to become part of the regular testing program of the Delta School District. While the test has some limitations (Buros, 1972; Farr & Anastasiow, 1971), the technical manual reports the following reliabilities (Gates & MacGinitie, 1972)

Table 3

Reliability Data

Reliability study	Reading measure	Alternate form reliability	Split half reliability
1964-65	Vocabulary	.85	.89
	Comprehension	.87	.91
1971-72	Vocabulary	.88	.90
	Comprehension	.85	.91

Validity information is limited to one doctoral dissertation study in 1968 which found concurrent validity with four other standardized reading tests to give median coefficients of .84 for vocabulary and .79 for comprehension. Form 2 of Level C was selected in view of the possibility that Form 1 had already been administered at the beginning of the school year.

Canadian Lorge-Thorndike Intelligence Test (non-verbal battery). Although the Lorge-Thorndike Intelligence Test was frequently used in earlier studies, only one of the published studies used the Canadian version. In a survey of intellective tests used in elementary schools in Alberta, Ogston (1973) conducted a review of associated research literature on empirically determined reliability and validity estimates. The Canadian Lorge-Thorndike was the most frequently used test at the grade three level. Ogston writes that "... the Lorge-Thorndike has been subjected to the most complete evaluation of reliability with only a stability estimate not reported" (p. 274). Reliability estimates were .76 to .90 for equivalent forms, .88 to .94 (Spearman-Brown) and .87 to .91 (Kuder-Richardson). The Technical Supplement (Lorge, Thorndike & Hagen, 1972) reports odd-even reliability for the non-verbal battery of Level A as .93, a K-R 20 reliability of .93 and a standard error of measurement ranging from 3.6 to 4.8 deviation I.Q. points. In a study conducted by the Greater Victoria School Board, the stability coefficient over one year, four months was .64 at the grade three level.

Validity coefficients are reported with Canadian Test of Basic Skills at grade 6 for vocabulary (.56), reading (.62) and composite (.71). Data on an Edmonton study at grade three gave correlations of .50 with reading. Correlations with Otis and Henmon-Nelson group intelligence tests were .48 and .61 (Otis) and .69. The correlation with Stanford-Binet at grade six was .78 and with WISC Full Scale, .53. The Technical Supplement states that the non-verbal battery permits assessment of "... abstract intelligence which is not influenced by specific disability in reading" (p. 4).

Modality Matching Tests

The instruments for the modality matching tasks comprised three elements. Visual spatial (VS) stimuli were presented as dot patterns on 35 mm slide transparencies, the projector being controlled by inaudible impulses on one track of the instruction cassette tape. Auditory temporal (AT) stimuli were presented on the verbal instruction track of the tapes. These auditory stimuli were also used to cue and control the presentation of the visual temporal stimuli (VT) which were flashing light patterns.

For each of these three elements there were two sets of stimulus patterns, one for presentation in the initial or standard position and one for presentation in the final or comparison position. The three elements were combined in nine pairs of presentations with each element appearing three times as the standard stimulus and three times as the comparison stimulus:

AT-AT	VT-AT	VS-AT
AT-VT	VT-VT	VS-VT
AT-VS	VT-VS	VS-VS

Visual spatial stimuli. Stimulus patterns (Jarman, 1977a, 1978) consisted of from three to seven dots arranged in varying sized groups with short and long gaps. If a dot is represented as one unit in diameter, a short gap was .80 units and a long gap was 7.17 units. A series of visual patterns consisted of 38 slide transparencies: three examples, five practice items and 30 test items. Two series of slides were required (one standard and one comparison) with two copies of each series, (one for VS as standard, one for VS as comparison and two for VS-VS as both standard and comparison condition). All slides were tinted pale blue to avoid screen glare.

Standard and comparison pairs of stimuli had equal numbers of dots, varying in arrangement, sometimes being the same and sometimes different. The order of same or different items was randomized to avoid memory or systematic response set effects. Pairs of items were grouped in blocks of eight patterns having the same number of dots. Dots increased in number from four to seven over four blocks (see Appendix A for diagram). As the items increased in complexity, the duration of presentation increased from one second for the easiest to three seconds for the longest. After a short trial period of slide presentation times ranging from two to four seconds on the original tapes, it appeared that a ceiling effect was likely for the VS-VS condition. Times were accordingly reduced to range from one to three seconds. Since it was not possible to re-cue the tapes to the reduced times, the original pulses were used to present the VS stimuli and a card, timed by stopwatch, was used to cut off the projection image at the appropriate time. The accuracy of this procedure was found to be comparable to the original cued timing.

Auditory temporal stimuli. The basis for these stimulus patterns were groups of tone bursts or beeps recorded on cassette tapes and identical in array to the dot patterns for the standard and comparison conditions. Tapes originally made by Jarman (1977a) were modified for this study (see Appendix C). All beeps were .15 sec. in duration. Short pauses were .35 sec. and long pauses were 1.35 sec. Overall length of the patterns of beeps ranged from 1.15 seconds to 8.15 seconds over the three examples, five trials and 30 test items.

Visual temporal stimuli. Tone bursts or beeps from the auditory temporal patterns became the triggering and controlling mechanism for the visual temporal patterns of flashes of light (Jarman, Marshall & Moore, Note 2; see Appendix C). The exact timing and spacing of the auditory beeps was thus reproduced in the flashing of a small incandescent lamp.

"Ready"	spatial standard 1.0 to 3.0 sec.	"and"	spatial comparison 1.0 to 3.0 sec.
	or		or
	1.5 to 8.15 sec. temporal standard		1.15 to 8.15 sec. temporal comparison

Figure 2. Arrangement of spatial and temporal elements in matching tasks.

Visual, spatial, auditory and temporal combinations. Four original cassette tapes were converted by transferring them to reel-to-reel tapes, where 1000 Hz sync-pulse cues were added to control the presentation times of the visual spatial (slides) stimuli (see Appendix B). Reel-to-reel tapes were then copied onto cassettes. Five new copies of tapes were made and modified so that the tone bursts or beeps could control the light flashes and not be audible. Thus all nine combinations were accounted for and controlled by the nine cassette tapes played on a Wollensak 3M tape recorder, modified to pick up the 500 Hz tone bursts which controlled the light flashes (see Appendix C).

Due to the addition of five integration combinations, the original taped introductory instructions were discarded in favour of manually presented example and trial items, working from standard scripts. A 1000 Hz solid-tone tape with breaker switch permitted presentation of auditory beeps. Similarly a manual switch circuit permitted the light to be flashed manually. When the introductory section was completed the tape-controlled sequences for the 30 matching items presented the various integration combinations. Slides were projected from a standard distance using an auto-focus Kodak 760H carousel projector. The flashing lamp was placed at the bottom of the projection screen.

Scoring Procedures

Raw scores were used from the Gates-MacGinitie Test since the procedure described in the manual for the construction of standard scores appeared somewhat irregular. Grade scores were calculated according to the test norms. Lorge-Thorndike scores were converted into deviation IQ equivalents using test norms also. Each of the matching tasks were scored for the number of errors on the thirty items with no correction for guessing. The response required from the subject after the comparison condition was a choice of whether the two patterns were the same or different. Immediate feedback on correctness of response was given during the trial items for the matching tasks but no indication as to correctness of choice was given thereafter.

Materials

Two sets of scripts were drawn up for standardization of introductory instructions. Nine in the first set were used for the initial presentation in each of the nine orders of presentation. The second set of nine scripts was used on subsequent matching sessions, being somewhat simplified to avoid redundancy as subjects became familiar with procedures. Nine response forms were constructed, one for each of the integration tasks, with the words same .... different printed for each of the 35 items. The subject was thus required only to circle the word for the chosen response.

Apart from the tape recorder and sync-cued projector the only additional pieces of apparatus were the electronic circuits and cued tapes constructed at the U.B.C. Instructional Media Centre. Manual switching systems for the instructional phase of each matching session were also constructed at the Instructional Media Centre.

Procedure

Approval for conducting the study was obtained from the Superintendent of the Delta School Board. Principals in the North Delta group of schools were notified by the Board office that approval of a research study had been granted.

In early February, 1978, the Principals were contacted by phone to arrange interviews to explain the purpose and nature of the study. In those interviews, Principals received a printed outline of the procedures to be followed, indicating what would be required of the school by the project. At the same time, the teachers of the grade three classes were given the reading test materials and administration manual, together with some guidelines in order to make the administration of the reading tests by classroom teachers as standard as possible. During this visit a schedule was made for administration of the Lorge-Thorndike Intelligence Test by the investigator. Three schools chose not to take part in the study. Testing was begun in the third week of February and completed by the first week of April. Scoring of all the reading and intelligence tests was carried out and double checked by the investigator.

Students' reading vocabulary and comprehension scores were used to establish the overall sub-population parameters, and the two groups of above and below average readers were separated. Approximately 36 boys and 36 girls in each category were selected and matched for IQ and age, and checked by the teachers according to the limitations set concerning freedom from disabilities. A letter was sent home to the parents of the children selected, outlining the purpose of the study and containing a tear-off slip to be returned to the school, giving or withholding permission for their child to take part in the study. Several schools invited parents to evening meetings to ask questions about the study before responding to the request letter. Following the parents' response and the IQ matching procedure, 36 boys and 36 girls from each reading ability level became the subjects of the study.

Each child in each group was then randomly assigned a number from one to nine which determined the order in which they would do each of the matching tasks. Equal numbers from each group were assigned to each order of presentation. The nine orders of presentation were selected on the basis of the tables of complete sets of orthogonal Latin Squares (Fisher & Yates, 1963) which gave an approximately counterbalanced order (see Figure 3).

1	2	3	4	5	6	7	8	9
2	3	1	5	6	4	8	9	7
3	1	2	6	4	5	9	7	8
4	5	6	7	8	9	1	2	3
5	6	4	8	9	7	2	3	1
6	4	5	9	7	8	3	1	2
7	8	9	1	2	3	4	5	6
8	9	7	2	3	1	5	6	4
9	7	8	3	1	2	6	4	5

Figure 3. Orders of presentation of the matching tasks for each of the groups numbered one to nine.

A schedule was then drawn up in order to carry out the testing in small groups according to location of the students and the orders of presentation. Each matching task required approximately 20 minutes of actual testing time with whatever administration time was required to settle the children and establish working rapport. Testing was carried out in a variety of relatively undisturbed rooms with groups of one to six students. In the first session time was taken to explain the purpose of the study and to encourage cooperation. In four of the five testing sessions, two matching tasks were administered consecutively, requiring 45 minutes, with a small break between tasks in addition to the standard rest periods controlled by the tapes. Each successive round of tests took place every eight to ten days, thus requiring three months to completion in early June. The timetable of testing was arranged so that each child was tested at a different time of the day on each of the five testing occasions.

CHAPTER V

RESULTS

> When the interaction is significant, F ratios are not very helpful in answering the questions that are raised. What should be done? Let us follow Cox's (1958, p. 133) advice: "In the majority of cases ...intelligent ...plotting of the results is the most important step ..."
>
> A. Lubin (p.811)

Subject Classifications

From the summary data in Table 2 it can be seen that the four groups of subjects were virtually undifferentiable on the basis of age and non-verbal I.Q. Similarly, the groups of boys and girls for the total sample showed no significant sex differences in mean vocabulary and comprehension scores. In comparing mean scores for the reading ability sub-groups, the only significant sex difference was for the high boys' higher comprehension scores ($t = 1.96$, $p < .05$). The comparisons of matching task performance of the various groupings of subjects were made against these bases of equivalence.

The I.Q. matching process together with the limitations set on reading in subject selection had the effect of removing some of the extremes of reading and intellectual ability. Thus the I.Q. scores, which ranged from 76 to 122 (mean = 94.3, S.D. = 9.39), were a little below the figures for the grade three sub-population (mean = 100.25, S.D. = 15.48). The relationships among the reading measures, and between reading measures and I.Q. can be seen in Table 4. While vocabulary and comprehension were significantly correlated for both sexes and for all reading groups except low boys, the correlations of I.Q. and reading measures indicated some sex and reading ability differences.

Table 4

Correlations of Reading and I.Q. Measures

	Boys	Girls	Boys and Girls
Grade 3 Sub-population			
Vocabulary/Comprehension	.34***	.23**	.22**
Vocabulary/I.Q.	.18**	.44***	.22**
Comprehension/I.Q.	.45***	.13*	.23**
	N=234	N=252	N=486
Reading Groups[a]			
High Readers			
Vocabulary/Comprehension	.35*	.40*	
Vocabulary/I.Q.	.31	.63***	
Comprehension/I.Q.	.40*	.56***	
Low Readers			
Vocabulary/Comprehension	.23	.66***	
Vocabulary/I.Q.	.10	.10	
Comprehension/I.Q.	.19	.13	

[a] N = 36

* $p < .05$

** $p < .01$

*** $p < .001$

While I.Q. and reading measures were generally significantly related for the grade three sub-population and for the high girls, none of the correlations was significant for either group of low readers. The only other significant correlation was for high boys between I.Q. and comprehension. Correlations for the reading groups were affected by restriction of range as compared with correlations for the sub-population. The restriction was explicit for the reading measures since average readers and some from the extremes were excluded. There was thus an implicit restriction of range in the I.Q. data, augmented by exclusion of extremes of intelligence in the matching for I.Q. process. Accordingly there was an implicit limitation on the range of the matching task data with effects which influenced the analyses based on the matching task data.

Matching Tasks and Classification Variables

The relationship of the error scores for modality matching tasks with reading vocabulary and comprehension scores of the four reading groups can be seen in Tables 5 and 6.

Table 5

Correlations of Modality Matching and Reading Measures: Boys

Tasks	Vocabulary		Comprehension		Reading Total	
	Low	High	Low	High	Low	High
AT-AT	-.16	-.29	-.03	-.18	-.11	-.28
AT-VT	-.07	-.11	-.15	-.03	-.15	-.08
AT-VS	-.23	-.15	-.17	-.14	-.25	-.18
VT-AT	-.14	-.24	-.27	-.03	-.27	-.14
VT-VT	-.08	-.16	-.31	-.05	-.18	-.12
VT-VS	-.19	-.33*	-.33*	-.15	-.34*	-.27
VS-AT	-.19	-.13	-.16	-.01	-.22	-.07
VS-VT	-.23	-.34*	-.34*	-.23	-.37*	-.33*
VS-VS	-.21	-.14	-.38*	-.09	-.39*	-.14

Note. Negative correlations are due to use of error scores.

*$p < .05$

**$p < .01$

The VT-VS task was significantly correlated with vocabulary for high reading boys and with comprehension for low readers. The converse task, VS-VT, showed the same pattern. It is of interest that the spatial-temporal integration tasks within vision were significantly related to different aspects of reading for the two levels of reading ability. The VS-VS task was significantly related to comprehension for low boys. Thus none of the tasks was significantly correlated with word recognition for low reading boys, and none with comprehension for high readers.

Table 6

Correlations of Modality Matching and Reading Measures: Girls

Tasks	Vocabulary		Comprehension		Reading Total	
	Low	High	Low	High	Low	High
AT-AT	-.16	-.25	-.32*	-.21	-.26	-.28
AT-VT	-.02	-.30	-.14	-.15	-.09	-.27
AT-VS	-.31	-.13	-.48**	-.04	-.43**	-.10
VT-AT	-.22	-.25	-.20	-.19	-.23	-.26
VT-VT	-.06	-.26	-.11	-.21	-.03	-.28
VT-VS	-.09	-.27	-.28	-.29	-.21	-.33*
VS-AT	-.10	-.22	-.25	-.10	-.19	-.19
VS-VT	-.02	-.33*	-.01	-.23	-.01	-.33*
VS-VS	-.34*	-.27	-.31	-.28	-.36*	-.34*

Note. Negative correlations are due to use of error scores.

*$p < .05$

**$p < .01$

Patterns of correlation for girl readers showed some similarities and some differences when compared to the boys. For low girls, two tasks with

AT standards (AT-AT and AT-VS) were significantly correlated with comprehension. There was a tendency for both vocabulary and comprehension to be more highly correlated with VS-VS scores though only for low girls' vocabulary was this significant, together with total reading scores for both groups of girls. VS-VT was significantly correlated with vocabulary for high girls, as it was for high boys. Again there were no significant correlations of matching tasks with comprehension for high readers. Only the one task (VS-VS) was significantly correlated with word recognition for low reading girls. Again the spatial-temporal integration tasks within vision were more highly correlated with vocabulary for high readers. It would appear that cross-modal and intramodal integration abilities are differentially related to reading skills for the different levels of reading ability, together with some sex differences.

Although no hypotheses were formulated about the relationship of intelligence and integration abilities, the nature of this relationship has been of importance in reviewed literature. Since all groups were matched for intelligence, the only source of data on the relationship of matching and intelligence was in the correlations between these two measures for the reading groups (see Table 7).

The only correlations for the low reading groups with any noteworthy significance were for the low boys on the VT-AT and VS-VT tasks. For the high readers, significant correlations occurred for high girls on AT-AT, VT-AT and VT-VS tasks, the latter being the only task with a significant correlation for high boys. Significant correlations for high reading girls occurred on three tasks with temporal standards, two of which involved AT comparisons. The only task which was correlated with I.Q. for both boy and girl high readers involved a temporal to spatial shift within the visual modality (VT-VS). For low boys the task most highly correlated with I.Q. involved a spatial to temporal shift within the visual modality (VS-VT). The most direct observations were that intelligence and matching abilities were positively correlated for all subjects, with different patterns of relationships occurring for the different reading ability and sex groups.

Table 7

Correlations of Matching Tasks and Non-Verbal I.Q.

Tasks	Low Readers' I.Q.			High Readers' I.Q.		
	Boys	Girls	All	Boys	Girls	All
AT-AT	-.25	-.02	-.13	-.16	-.34*	-.24*
AT-VT	-.28	-.12	-.20	-.04	-.26	-.13
AT-VS	-.26	-.25	-.25*	-.19	-.10	-.15
VT-AT	-.34*	-.08	-.23	-.07	-.34*	-.15
VT-VT	-.29	-.08	-.18	-.04	-.29	-.13
VT-VS	-.21	-.06	-.14	-.34*	-.41**	-.37**
VS-AT	-.16	-.22	-.19	-.15	-.22	-.18
VS-VT	-.41**	-.15	-.28*	-.23	-.25	-.24*
VS-VS	-.28	-.14	-.22	-.09	-.31	-.11

Note. Negative correlations are due to use of error scores.

* $p < .05$

** $p < .01$

Matching Task Reliability

From the literature review, reliability of the tasks used for modality matching was noted as frequently questionable due to the small number of items used, and to ceiling effects. Consequently, Kuder-Richardson formula 20 reliabilities were calculated for the nine tasks, each containing 30 items for the two reading levels. These are reported in Table 8.

Table 8

Reliability Coefficients for Matching Tasks[a]

Task	Low Readers	High Readers
AT-AT	.582	.653
AT-VT	.702	.717
AT-VS	.734	.682
VT-AT	.469	.710
VT-VT	.566	.690
VT-VS	.707	.688
VS-AT	.832	.669
VS-VT	.731	.690
VS-VS	.756	.711

[a]Kuder-Richardson formula 20

The range and level of reliability measures were moderate and similar for both reading levels, being particularly even for high readers. The three lowest reliabilities for low readers were on the purely temporal tasks with the highest error rates. With a two choice response format and 100 items the estimated reliability should be about .74 (Ebel, 1969). Thus to have obtained reliabilities averaging .675 and .690 for low and high readers respectively, for 30 item tasks, appearsto be a reasonable result. Ebel (1969) estimated that to expect a reliability of .90 on a two-choices-per-item test would require 270 items. Since the pooled item reliability for the nine tests of 30 items (270 items in total) for both groups was .875, the reliability of the nine matching tasks was considered to be acceptable. Ebel also pointed out that estimates of reliability are raised above the expected level if test items are high in quality and if the test is particularly homogeneous in content. Since the obtained reliabilities for 30 items were close to those expected for a 100 item test, and since the content of tasks was homogeneous it was assumed that the quality of the items was of an acceptable standard.

Table 9

Mean Errors on Matching Tasks

	Low Readers				High Readers			
	Boys		Girls		Boys		Girls	
Tasks	$\bar{X}$	S.D.	$\bar{X}$	S.D.	$\bar{X}$	S.D.	$\bar{X}$	S.D.
AT-AT	9.14	3.45	10.58	4.02	7.83	3.93	7.64	3.65
AT-VT	10.25	4.61	11.00	4.35	7.55	4.35	9.17	4.09
AT-VS	9.97	5.08	9.92	4.16	6.72	3.79	7.25	3.64
VT-AT	11.58	4.09	12.19	3.02	8.08	4.39	9.17	4.19
VT-VT	11.33	3.74	11.58	4.04	7.36	3.97	9.75	3.92
VT-VS	9.89	4.85	9.72	4.10	7.42	4.46	7.11	3.22
VS-AT	7.14	5.27	5.69	4.66	3.14	2.84	3.08	2.66
VS-VT	5.50	3.92	6.11	4.00	3.30	2.91	3.53	3.04
VS-VS	3.58	3.79	2.36	1.88	1.72	1.89	2.83	2.96

Mean Task Performance

Question one was addressed to the nature of the relationship between reading ability and modality matching. Mean error scores on the nine matching tasks for the four reading groups can be seen in Table 9. Error scores were analyzed by a four way analysis of variance, with sex and reading as between-subject variables, and with standard and comparison stimuli as within-subject variables. A strong main effect was found for reading, with the high readers superior on the matching tasks, $\underline{F}$ (1,140) = 28.49, $\underline{p} < .001$. The greatest difference in mean error scores for the two reading levels occurred where (a) integration of both auditory with visual and temporal with spatial stimuli were involved (AT-VS and VS-AT), (b) the integration was visual to auditory for temporal stimuli (VT-AT) i.e. cross-modal within the temporal dimension, and (c) the integration was intramodal to vision, and temporal (VT-VT) (see Figure 4). Although high readers were superior to low readers on the VS-VS task, the difference was not significant (t = 1.49, $\underline{p} < .13$).

Hypothesis 1. It was hypothesized that above average readers would be significantly superior to below average readers in sensory integration as measured by performance on modality matching tasks. As a result of the significant main effect involving reading level and modality matching, Hypothesis 1 was considered to be supported. Additional support was gained from the patterns of significant correlations of matching tasks with reading subskills. Significant differences were evident in the auditory, visual, spatial and temporal integration abilities of third grade boys and girls who were above average readers, when compared with below average readers.

Task Difficulty in Cross-modal and Intramodal Matching

Question 2 was concerned with the relative difficulty of matching tasks in terms of the visual, auditory, spatial and temporal elements and their combinations. These relationships were investigated in a number of ways.

The first and simplest estimate of difficulty level was comparison of mean error scores on the matching tasks (see Table 9 and Figure 4). The

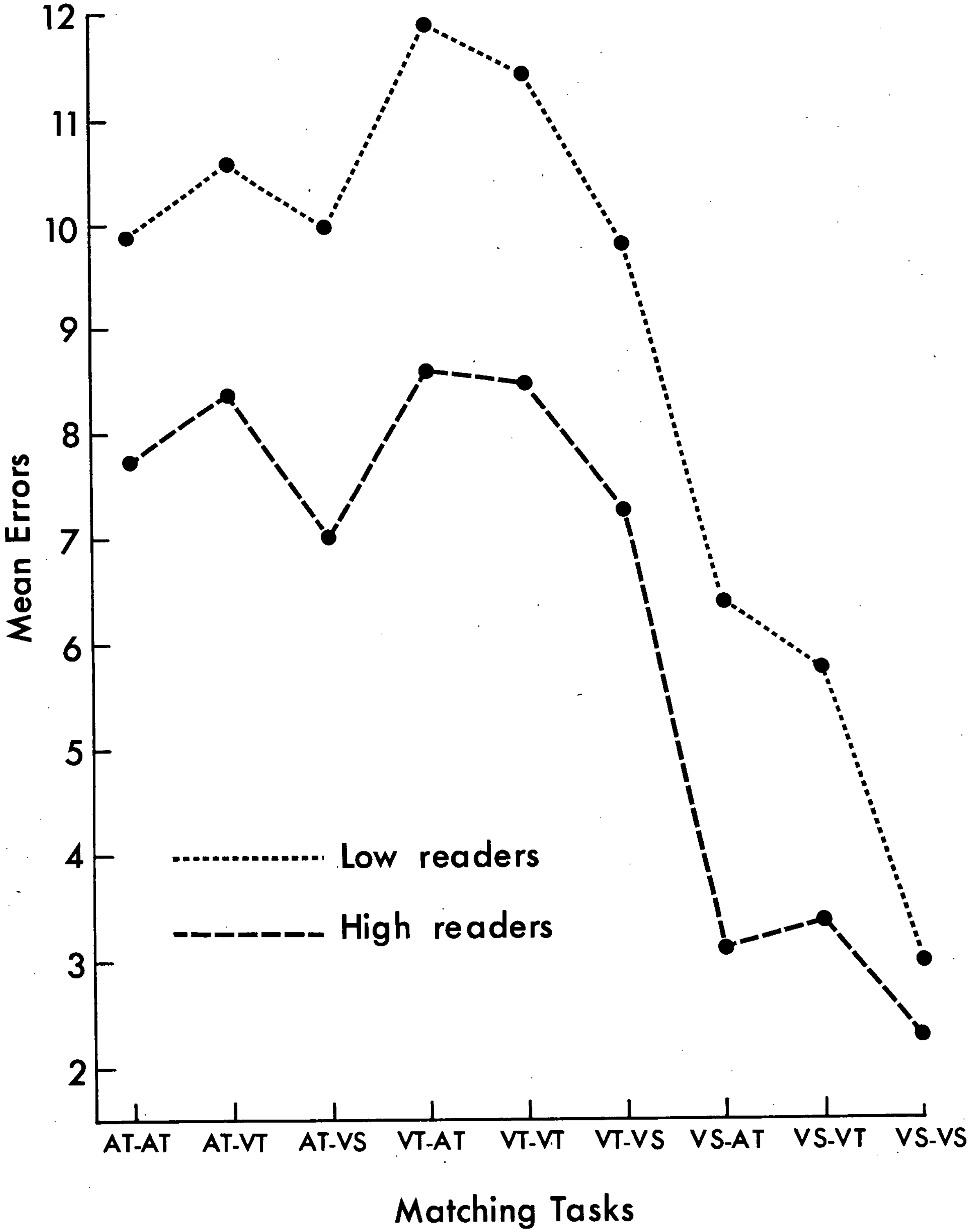

Figure 4. Sources of main effect for reading.

four most difficult tasks for both reading levels were the purely temporal tasks, AT-VT, VT-AT, VT-VT and AT-AT. With an AT standard, a VT comparison gave relatively high error rates for both groups of readers. Error rates increased when both standard and comparison elements were VT, especially for low readers. These error rates however, were surpassed by the error rates for AT comparisons with VT initial stimuli. This was especially so for low readers.

Next in difficulty for both reading levels, and almost comparable in error rates with the first four mentioned, were tasks with a temporal standard and a VS comparison, namely AT-VS and VT-VS. While these VS comparisons gave relatively high and approximately equal error rates within reading levels, VS standards reduced the error rate for all comparisons for both reading levels. Of the tasks with a VS standard, VS-AT was most difficult for low readers while VS-VT was slightly more difficult for high readers. Appearance of the VS element in any position in matching tasks contributed to lower error rates.

The second set of relationships was seen for the analysis of variance, in the nature of the main effects for the standard and comparison stimulus portions of the matching tasks for the different reading levels. A strong main effect was found for the standard stimulus, $F\ (2,280) = 422.68$, $p < .001$ and a less strong but significant main effect for the comparison element, $F\ (2,280) = 45.89$, $p < .001$. Figure 5 shows the nature and source of the main effects for the standard and comparison elements. The very high significance of the standard main effect was due to the presence of VS stimuli making the tasks much easier, combined with the greater difficulty of matches where the standard stimulus was visual and temporal. The same contributory factors influenced the comparison main effect, but to a

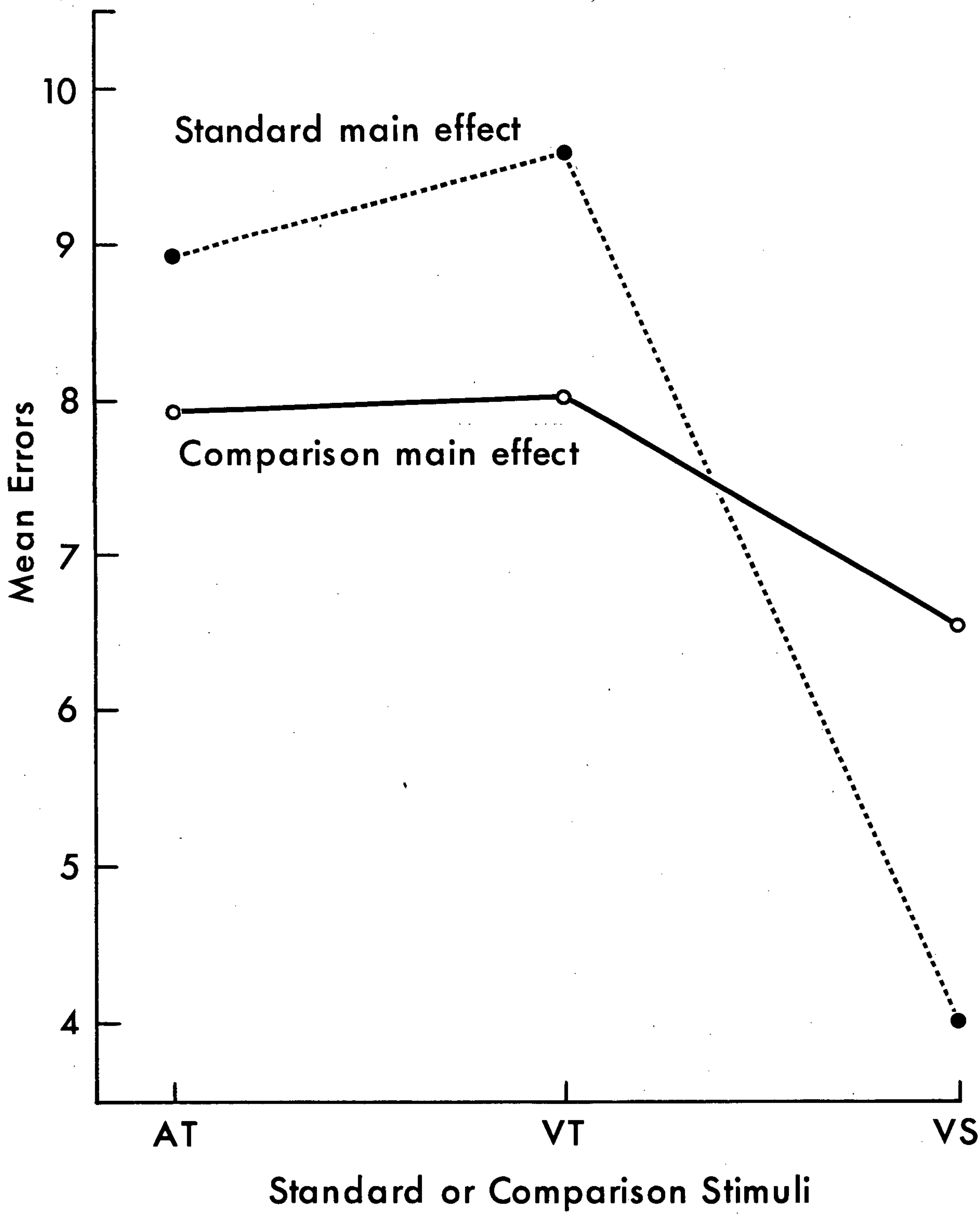

Figure 5. Sources of main effects for standard and comparison stimuli.

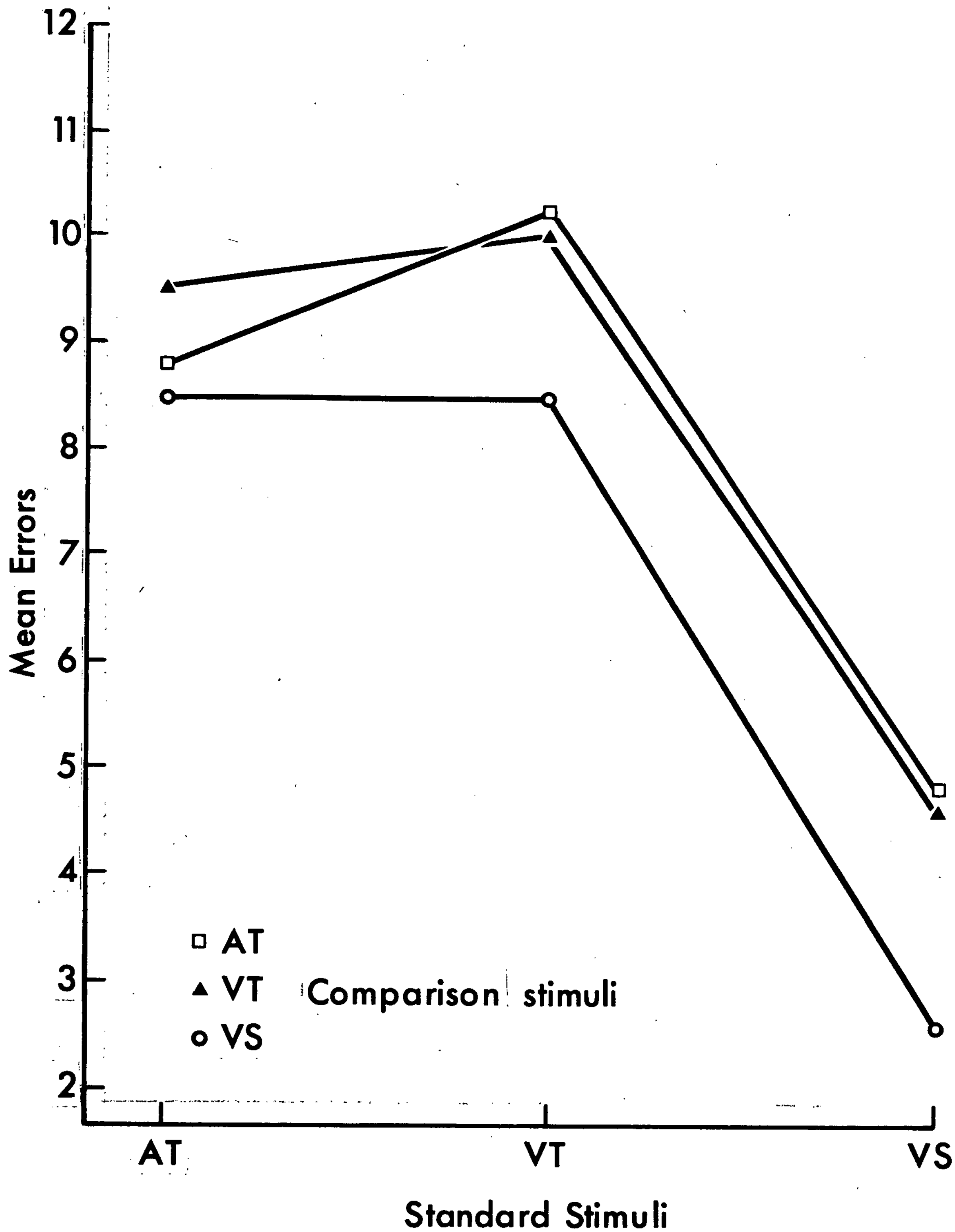

Figure 6. Sources of standard X comparison interaction.

lesser extent.

The standard X comparison interaction was significant, F (4,560) = 4.10, $p < .003$ (see Figure 6). The interaction was due to two influences. The lesser of these was a slight increase of error rate for VT comparisons with a VT standard as compared to an AT standard. The main influence was due to a greater increase in error rate for AT comparisons with a VT standard compared to AT comparisons with AT standard. Since the main effect for the standard stimulus was very strong, the indication is that it is the presence of a VT standard which contributes most to the increasing difficulty of VT-VT and VT-AT tasks. The remaining combinations of task elements showed almost no variation in the relationship trends.

There were no significant double interactions of standard or comparison with reading, though the latter approached significance, F (2,280) = 2.37, $p < .06$. This was due to the greater relative decrease in error rate for low readers for VT and VS comparisons. The lack of significant interaction between the standard stimulus and reading indicated that the characteristics of the initial stimulus in matching contributed to a consistently higher performance by high readers.

The triple interaction of standard X comparison X reading was significant, F (4,560) = 3.45, $p < .01$ (see Figure 7). The sources of this interaction showed some of the same influences that were evident in the stimulus X comparison interaction but modified by the high reader and low reader differences. The disordinal interaction of AT and VT elements was again evident with the increase in difficulty of the VT-AT task over the AT-AT task being more marked for low readers than high readers. A second source was due to the increase in difficulty of the tasks with VT comparisons as the standard changed from AT to VT for low readers. Task

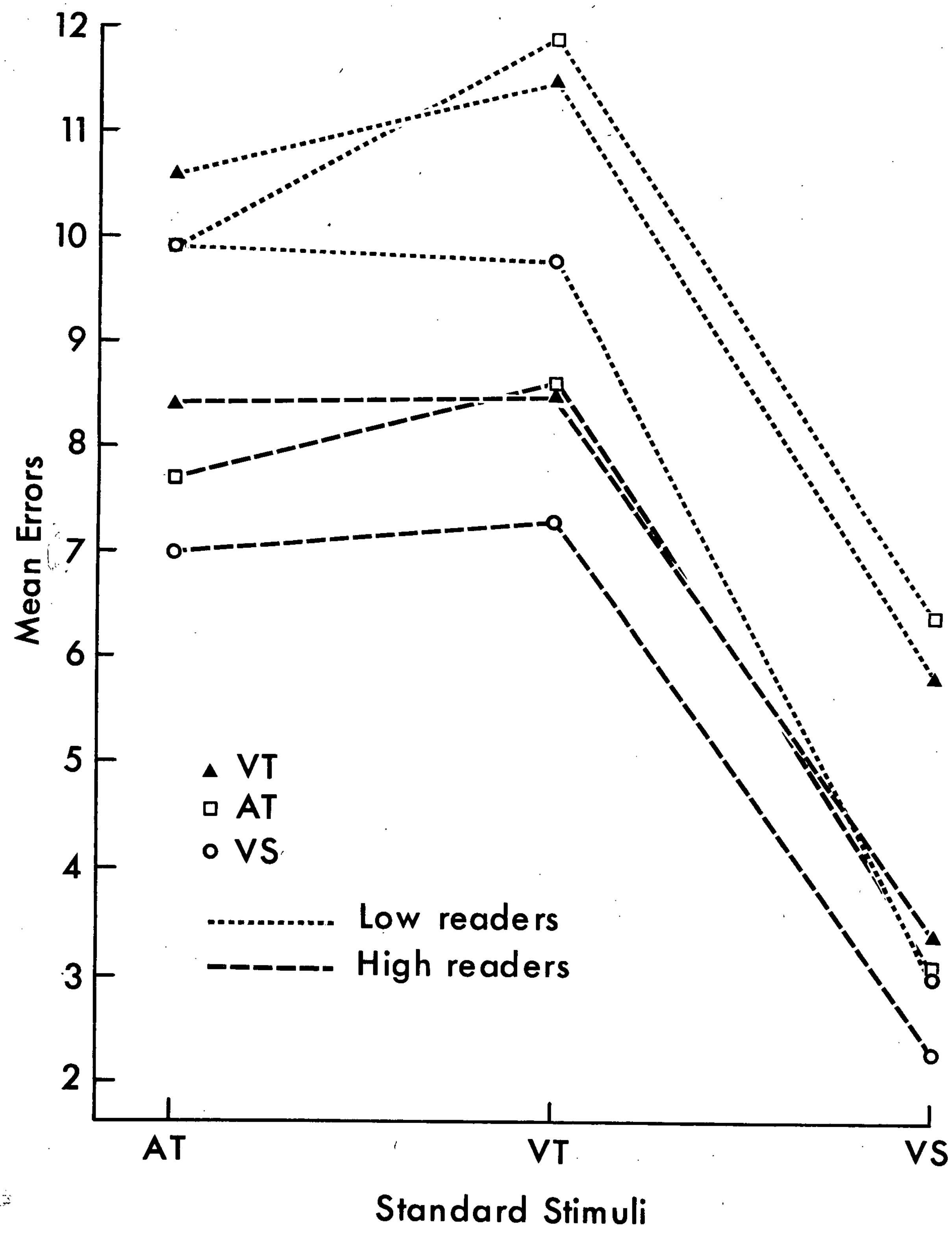

Figure 7. Sources of the standard X comparison X reading interaction.

difficulty did not increase for high readers. A further source arose out the influence of VS as the comparison stimulus which contributed to the triple interaction though it did not to the double interaction. Relative to the difficulty of the AT-VS task for both groups, the error rate for VS comparisons with VT standards was lower for low readers but higher for high readers. Similarly for VS comparisons with VS standards, the relative decrease in error rate for low readers was greater than for high readers. The increase in difficulty of temporal comparisons with VS standards compared to VS-VS task difficulty was greater for low readers than high readers.

Two further trends contributed to the interaction. A slight disordinal tendency was noticeable for temporal comparisons with VT and VS standards for the high readers but not for low readers. Here AT comparisons were more difficult with VT standards and VT comparisons more difficult with VS standards. There was an increasing difference in mean error scores between AT and VS comparisons as the initial stimulus changed from AT to VT to VS, for low readers. This was due to the higher difficulty of AT comparisons with VT standards and the sharper decrease in error rate for low readers when both comparison and standard stimuli were visual and spatial. The opposite trends were seen for high readers.

As has already been indicated there was no main effect for sex in the analysis of variance, nor was there a significant interaction of reading and sex. However, as Kirk (1968) points out, whenever a significant interaction occurs it indicates the need for interpretation and qualification of the main effects in the light of differences among specific means at specific levels. Although the majority of interactions involving sex were not significant, a significant double interaction suggested that some comments be made.

Reference to Figure 8 shows that girls made more errors on purely temporal tasks than did boys, this being especially so for high reading girls. Low reading girls made slightly lower error scores on VS-VS tasks than high reading girls while low boys made more errors on VS-AT tasks compared to the other three groups.

Though the double interaction of standard stimulus with sex was not significant, the comparison X sex interaction was significant, $\underline{F}$ (2,280) = 4.33, $\underline{p} < .01$. This effect was due to VT patterns as comparisons being more difficult for girls than boys. There were almost no sex differences for AT and VS comparisons. Thus the presence of a VT comparison stimulus in matching tasks was a significant discriminator between male and female readers.

Of the triple interactions involving sex none was significant. Similar trends were apparent in the data however, for in the standard X reading X sex and the comparison X reading X sex interactions girls had higher error rates than boys for VT comparisons, low girls having more errors than low boys with VT standard stimuli, and low girls having lower error rates than low boys with VS in both the standard and comparison conditions.

The final and quadruple interaction of standard X comparison X reading X sex was significant, $\underline{F}$ (4,560) = 2.48, $\underline{p} < .04$. While specific analysis of the sources, and interpretation of the meaning, of the interaction do not appear to be easy or warranted, inspection shows that a number of the features of relationship and interaction already mentioned are present and contributory.

In order to further examine the significance of, and specific effects within, the standard X comparison X reading interaction, a number of

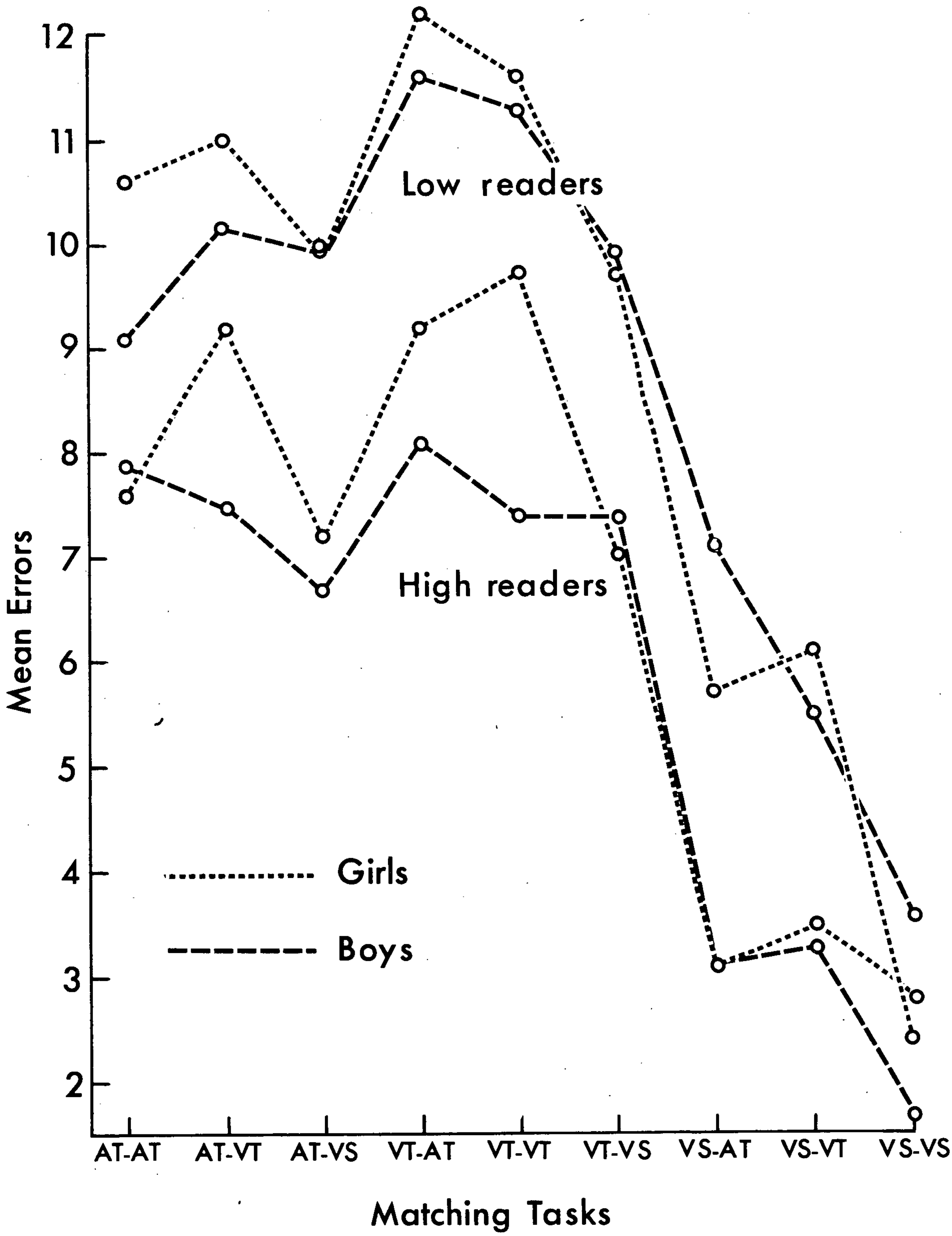

Figure 8. Matching task error scores for reading groups.

pairwise comparisons were made of differences in mean error rates, using Dunn's multiple comparison procedure (Kirk, 1968). This procedure permits both orthogonal and non-orthogonal comparisons among differences in means for repeated measures designs. The α = .01 level of significance was split up evenly among the planned comparisons to give a conservative test of the differences between mean error scores.

In the literature review, reference was made to the modal specific view of sensory functioning which attributes specific locations and types of information processing to each modality. From the theory of modal specificity it would be expected that the processing of temporal information in the visual modality would produce the highest error rate. This was investigated by comparing the difference in mean error rates for those tasks where temporal information was processed in the visual modality in contrast to the auditory modality. In comparing the AT-AT and VT-VT tasks the only difference is the modality used for temporal processing. The same holds for comparisons of the AT-VS and VT-VS tasks and of the VS-AT and VS-VT tasks. Error rate differences for these pairs of tasks were tested by pairwise comparisons. The results of these comparisons can be seen in Table 10.

Similarly, from the reviewed literature, some investigators held that cross-modal integrations were hierarchically more difficult than intramodal integrations. This view was examined by comparing the error rate differences to see if cross-modal integrations would produce higher mean error scores (see Table 10). Thus AT intramodal errors were compared with the two temporal and cross-modal task error rates (AT-AT vs AT-VT and AT-AT vs VT-AT), and similarly for the VT intramodal task (VT-VT vs VT-AT and VT-VT vs AT-VT). Since VS-VS intramodal tasks were obviously easier than cross-modal tasks with temporal standards, only cross-modal tasks with VS standards were compared with the VS-VS intramodal tasks (VS-VS vs VS-AT and VS-VS vs VS-VT).

Table 10

Differences Between Means for Pairwise Comparisons

	Low Readers	High Readers
Temporal Comparisons between Visual and Auditory		
	Difference	Difference
AT-AT : VT-VT	-1.6*	-0.8
AT-VS : VT-VS	0.1	-0.3
VS-AT : VS-VT	0.6	-0.3
Cross-modal and Intramodal Comparisons		
AT-AT : AT-VT	-0.8	-0.6
AT-AT : VT-AT	-2.0*	-0.9
VT-VT : VT-AT	-0.4	-0.1
VT-VT : AT-VT	0.8	0.2
VS-VS : VS-AT	-3.4*	-0.8
VS-VS : VS-VT	-2.1*	-1.1

$p < .01$

For sixteen planned comparisons a difference in mean error rate of 1.6 would be required for significance at $\alpha = .01$ with 560 degrees of freedom and with a MS error value of 8.15. Results showed that the only significant differences were for low readers in comparing AT-AT with VT-VT, AT-AT with VT-AT and for the two comparisons with VS-VS tasks. While the first of these significant differences indicates that processing temporal information in the visual modality is indeed more difficult than in the auditory modality, (thus supporting the modal-specific view), this held true only for low readers. The other VT against AT differences for low readers showed small and insignificant trends opposing the modal specific view, with lower error score differences favouring the VT element. For high readers all differences were small and insignificant with VT tasks more difficult than AT.

For the intramodal and cross-modal difficulty comparisons, the visual to auditory (cross-modal) integration within the temporal dimension (VT-AT) was significantly more difficult than AT-AT (intramodal) integration, but again only for low readers. A similar trend for high readers did not approach significance. The cross-modal match VT-AT was also slightly but not significantly more difficult that VT-VT (intramodal), for both groups of readers. The complementary temporal cross-modal integration AT-VT when compared to AT-AT and VT-VT (intramodal) integrations, showed cross-modal to be easier than intramodal in the visual modality and more difficult than intramodal in the auditory modality. Neither of the differences was significant.

Spatial to temporal integrations were more difficult than VS intramodal integrations, but only significantly so for low readers. Spatial to temporal shifts within the visual modality were less difficult than spatial to temporal shifts which also involved visual to auditory integration.

Item Analyses

The final method of examining the relative difficulty of matching tasks consisted of analyses of item characteristics within sub-tasks for the total sample of readers, based on the point biserial correlations of the items with the nine tasks. Since the matching tasks were good discriminators between above average and below average readers it was reasoned that items which discriminated well between individuals of the total sample, within each task, would also be good discriminators between high and low readers. Such items would be those with the highest point biserial correlations for the total sample. These items could then be further analyzed and classified in terms of organizational main effects for standard and comparison conditions and in terms of structure of items and the types of integration involved. Twenty-six items attained a point biserial correlation of .40 and above for one or more of the nine tasks (see Table 11.) When plotted in a frequency distribution, point biserial correlations of .40 and above represented the upper 33 percent of the 270 correlations. These items were anlayzed according to a number of criteria.

Item complexity. Table 11 shows the structure of the paired items. While the more complex items with five, six or seven structural units (i.e. dot, beep, or light flash) might be expected to be more often the discriminating items, it was the requirements of the integration task rather than simply the number of units in the stimulus patterns that enhanced or diminished the final discriminating power of an item within a particular task. Items which were good discriminators in one task were sometimes not good discriminators on other tasks. Thus half of the four-unit items were strong discriminators in at least three, or in as many as eight of the tasks, while six of the six and seven-unit items were good discriminators in only one of the tasks.

Item structure. Of the 26 items chosen, 15 matches were 'different' and 11 were 'same'. None of the discriminating items had the location of the point difference solely at the beginning of the standard and

Table 11

Point Biserial Correlations for Discriminating Items

Item	Stimuli	AT-AT	AT-VT	AT-VS	VT-AT	VT-VT	VT-VS	VS-AT	VS-VT	VS-VS
6	.... a .... b									.41
8	. ...		.48	.54	.43	.45	.57		.51	
9	... .	.43	.41	.43		.43	.43	.43		
10	. . ..		.42		.47				.42	
11	. .. .							.50	.40	
12	.. . .									.45
13	. . ..		.43	.58	.43	.46	.40	.64	.45	.41
14	. ...			.40			.40	.51		
15	.. ..			.44			.54	.43		.47
16	. ...	.51		.46	.42		.40	.46	.40	
17	... .		.42		.52			.40		
18	.. ..		.43				.52	.42		
19	. . . .		.53			.43		.40		
21	.. . .							.49		.50
22	.. ..	.43		.55			.42			

Item	Stimuli	AT-AT	AT-VT	AT-VS	VT-AT	VT-VT	VT-VS	VS-AT	VS-VT	VS-VS
23	....						.43			
24	. .. .	.40			.40			.47	.42	.43
25	.. . .			.48				.58	.47	.40
26	. . . .	.42	.50	.43		.40		.43		
27	.. . .							.48		
29	.. . .							.45		
30	....			.43					.44	.46
31	... .		.43					.46	.44	
33	. ...								.46	
34	.. . .									.43
35	. . ..		.41							

[a]Standard stimulus

[b]Comparison stimulus

comparison stimuli. In two items the difference was at both the beginning and middle of the items (e.g. item 21), for three items it was at both the beginning and end (e.g. item 22). In one item the point of difference was at the middle (item 33), in two items it was at the end (e.g. item 16), and in seven items it was at both middle and end (e.g. item 19). In all

11 of the 'same' items the subject had to wait until the comparison pattern was completed before being able to make a match. Thus in the bulk of discriminating items the middle and end of the stimuli were the key points where correct or erroneous judgements could be made. Of the nine items which were discriminating in the VS-VS task, where the structural units were viewed simultaneously, seven had the point of difference concentrated at the end or middle and end. Fifteen out of 17 items which contained clumps of three or four units appeared among the discriminating items.

Items within tasks. Three of the purely temporal tasks (which had the highest error rates) namely VT-VT, AT-AT and VT-AT, had the smallest number of discriminating items (five, five, and six respectively). The VS-AT task, which required integrations both from visual to auditory and spatial to temporal, had the greatest number of discriminating items (16). The remainder of tasks had either nine or ten items. The implication is that the easier and more difficult items are not the best discriminators by virtue of the larger numbers of subjects succeeding or failing on these items.

By comparing point biserial correlations for each reading level with those of the total sample for each task it was possible to determine if the items were equally discriminating for both low and high readers. The general pattern was for the purely temporal presentations of items to be less discriminating but equally so for high and low readers. A middle group with visual comparisons were equally discriminating for both reading levels or slightly more discriminating for low readers. Presentations of items with a VS standard were either equally discriminating for both reading levels or discriminating only for low readers.

The final block of most complex (7 unit) items when presented in the VT standard condition produced no discriminating items, suggesting that the difficulty of these items made them no longer good discriminators.

Visual, auditory, spatial and temporal integrations. Discriminating items were also classified in terms of the elements involved in the integration and the nature of the integrations thus produced. Of the 80 item by task appearances, items with temporal standards occurred 45 times and items with temporal comparisons appeared 52 times. These items with temporal standards comprised 25 items with AT standards and 20 with VT standards. Items with temporal comparisons were evenly divided between AT and VT. Items with VS standards numbered 35 while 28 had VS comparisons. If the known difficulty of VT standard patterns and ease of VS standard stimuli is applied to these findings the suggestion is that the smaller number of items with VT standards as discriminating items is due to the greater difficulty level. The occurrence of items containing VS elements similarly reflects the relative ease of matches with VS standards and slightly increased difficulty of matches with VS comparisons.

Twenty six items involved double integrations (auditory with visual and spatial with temporal) and the same number of items required spatial to temporal integrations. Temporal to spatial integrations occurred in 19 of the items while auditory to visual integrations and the converse occurred in 20 and 22 items respectively.

Thus it would appear that for those items which best discriminate between good and poor readers, frequency of occurrence of an element is a measure of discriminating power while infrequency of occurrence is a measure of the item's difficulty or non-difficulty. Accordingly, matches involving two integrations are of similar discrimination power to those requiring only a spatial to temporal integration. Temporal to spatial integrations would be less discriminating and more difficult. Items with VT standards are more difficult and less useful discriminators than AT standards while AT and VT comparisons are approximately equal in difficulty and discrimination power. Of the intramodal matches, integrations within AT and within VT dimensions are equally more difficult and less discriminating than matches within the VS dimension.

This analysis of the data suggests that cross-modal matches are not intrinsically more difficult than intramodal matches, the difficulty level depending more upon the temporal-spatial dimensions than upon the modalities themselves.

By virtue of the number of discriminating items in the VS-AT task, this would appear to be one of the best tasks to discriminate between above average and below average readers, if a single auditory visual integration task were to be used for that purpose.

Hypotheses 2.1 and 2.2. The hypotheses arising from Question two dealt with the qualitative differences between above average and below average readers in terms of difficulty levels in the processing of specific types of information intrinsic to the integration tasks. Quantitative and qualitative differences were found between the two reading levels on specific tasks, specific types of integration and with specific elements of integration tasks. Significant interactions occurred between elements of the integration tasks, their order of presentation and reading level. Consequently Hypotheses 2.1 and 2.2 were considered to be supported.

Cognitive Processes

Question three was concerned with different cognitive processes employed by good and poor readers on modality matching tasks, as inferred from the factor structure and loadings produced by exploratory factor analyses. Since there was no significant main effect for sex in the analysis of variance, the matching scores were collapsed across sex within reading levels. Pooled error scores for the matching tasks were intercorrelated separately for each reading level (see Table 12).

Table 12

Intercorrelations of Matching Tasks for Low and High Readers

Tasks	AT-AT	AT-VT	AT-VS	VT-AT	VT-VT	VT-VS	VS-AT	VS-VT	VS-VS
AT-AT		.585	.499	.603	.640	.579	.442	.603	.340
AT-VT	.474		.553	.551	.692	.450	.358	.265	.271
AT-VS	.546	.580		.517	.519	.517	.438	.284	.217
VT-AT	.472	.634	.512		.588	.485	.464	.350	.404
VT-VT	.405	.317	.242	.387		.444	.468	.308	.365
VT-VS	.585	.519	.544	.417	.429		.467	.457	.287
VS-AT	.401	.386	.666	.288	.263	.610		.320	.466
VS-VT	.611	.459	.563	.409	.533	.614	.504		.367
VS-VS	.264	.489	.401	.314	.277	.483	.569	.510	

Note. High readers are above the diagonal, low readers below.

Inspection of the matrices showed some interesting differences between the two reading groups in the patterns of intercorrelations. For those intercorrelations where the standard stimulus was VS the coefficients were generally higher for low readers than high readers except for the VS-AT tasks. When VS-AT was intercorrelated with the purely temporal tasks with VT standards for low readers, the coefficients were considerably lower than for high readers. When VS-AT was intercorrelated with any task with a VS comparison the coefficients for low readers were considerably higher than for high readers. On all these task intercorrelations for high readers, the coefficients were consistently even. When the VT-VT task was intercorrelated with the other purely temporal tasks plus AT-VS and VS-AT, the coefficients for the high readers were considerably higher than for low readers. The remaining intercorrelations were relatively similar for both groups of readers.

The matrices were factor analyzed by principal components analysis with unities in the diagonal, followed by a varimax rotation of the factor loading matrix. The criterion adopted for retention of factors was the Kaiser-Guttman criterion of eigenvalues greater than unity. Although the principal components solution with orthogonal rotation was considered to be the most appropriate form of analysis (Hakstian & Bay, 1973; Timm, 1975), other combinations of common-factor solutions (maximum likelihood procedure) and principal components solutions, with both orthogonal (varimax) and oblique (Harris-Kaiser) rotations were carried out as a check on the original analyses. Since these alternative analyses produced very similar results, the original principal components solutions with varimax rotation were retained.

Analysis for the low readers gave only one eigenvalue greater than 1 (4.75) with the next highest being 0.99. Consequently this second factor was retained. Results for the low readers are given in Table 13.

The first factor had its heaviest loadings from those tasks which include a VS element. The second factor had its main loadings from tasks

Table 13

Principal Components Analysis with Varimax Rotation:

Low Readers

Task	Factor I	Factor II
AT-AT	.328	.715
AT-VT	.451	.607
AT-VS	.689	.424
VT-AT	.197	.758
VT-VT	.067	.741
VT-VS	.634	.506
VS-AT	.885	.137
VS-VT	.530	.606
VS-VS	.772	.151
Component Variance	2.893	2.849
% Component Variance	50.38	49.62

with temporal elements. The only two tasks with an initial temporal stimulus element which did not weight the second factor more highly were those where the comparison stimulus was VS (AT-VS and VT-VS). In both these cases the loadings on the first (VS) factor were higher, which suggested that where visual spatial and temporal integrations are involved for low readers the VS element plays a predominant part, even if it is not the initial stimulus. Something of this influence of VS stimuli as comparisons was evident in the patterns of intercorrelations already mentioned. It is clear that the alignment of factors was on the spatial-temporal dimension rather than the visual and auditory modalities. If it had been the modality of presentation of the initial stimulus which loaded the factors the tasks with VT standards would have loaded the same factor as the tasks with VS standards, which was not the case. A further irregularity showed the VS-VT task to load slightly more heavily on the temporal factor. A possible reason for this was that VT as a comparison stimulus was clearly a powerful element in the analysis of variance. Both of the factors contributed equally to the common variance of the analysis.

Factors for the high readers are shown in Table 14. Eigenvalues for high readers were 4.65 and 1.01, and thus two factors were retained.

Table 14

Principal Components Analysis with Varimax Rotation:

High Readers

Task	Factor I	Factor II
AT-AT	.656	.515
AT-VT	.854	.101
AT-VS	.775	.149
VT-AT	.684	.387
VT-VT	.798	.256
VT-VS	.559	.473
VS-AT	.408	.588
VS-VT	.177	.767
VS-VS	.109	.775
Component Variance	3.387	2.273
% Component Variance	59.84	40.16

In contrast to the low readers, Factor I for high readers has its loadings primarily from the temporal element, and particularly the temporal element in the initial or standard position. The three tasks with VS as the initial stimulus have the highest loadings on Factor II. This also was the opposite for low readers. In further contrast to the low readers, where VS and AT integrations occur for high readers, if VS is in the comparison position it does not load more heavily on the VS factor. It is of interest that the temporal factor for low readers appears to be loaded heavily by tasks with the temporal element also in the comparison position, while for high readers the loadings are more from the temporal element in the standard position. The factors in the analysis for high readers contributed differently to the common variance than the factors for low readers, with the temporal factor (Factor I) contributing approximately 20% more variance than Factor II.

Comparison of the analyses for the two reading levels indicated differences in the processing of temporal and spatial information and in the part played by the initial stimulus in integration tasks. For competent readers the nature of the initial stimulus in terms of its temporal or spatial qualities, dictated which factor was loaded by the task. For these readers there appeared to be little distinction between visual and auditory modalities in dealing with the temporal dimension. Whether the initial temporal stimulus was visual (VT) or auditory (AT), or was followed by a cross-modal or intramodal match, all tasks had similar high loadings on the temporal factor.

Less able readers, on the other hand appeared to be more influenced in the processing of temporal information by the presence of the visual spatial element. When temporal standard stimuli (AT and VT) were matched with a VS comparison, the loading was highest on the VS factor. Similarly, in those tasks requiring integration of temporal and spatial elements within the visual modality (VT-VS and VS-VT), the factor loadings were almost equal with the slightly higher loading on the element occurring as the comparison stimulus rather than the initial stimulus.

Thus for low readers the visual modality appeared to play a different and less versatile role, its function being somewhat modal-specific, with a greater facility for the processing of spatial information. The above average readers in contrast seemed to process temporal information equally well in both the auditory and visual modalities. In both of the analyses the intramodal and cross-modal tasks AT-AT, VT-VT, AT-VT and VT-AT loaded similarly and highest on the temporal factor. This appeared to indicate that similar cognitive processing occurs for both types of integration, with cross-modal integration not a higher order process than integration within modality.

Hypothesis 3. Results of the exploratory factor analyses indicated different factor structure of the intercorrelation matrices for above average and below average readers. Loadings on the factors in terms of the influence of the visual spatial element was also different for the two groups. As a consequence, Hypothesis 3 was considered to be supported. The cognitive processing of spatial, temporal, visual and auditory information is different for above average and below average readers.

CHAPTER VI

DISCUSSION

> The greatest usefulness of research may not be in the construction of specific remedial techniques, but in the contribution which it makes to the cataloging and proper description of the variety of human abilities.
>
> J. Torgesen (p.433)

The purpose of this study was to investigate the sensory integration abilities of above average and below average readers at the third grade level, as measured by cross-modal and intramodal matching tasks. The aim was to understand more about the process of learning to read through learning more about the characteristics of good and poor readers in the integration of visual, auditory, spatial and temporal information. An integral aim was to rectify some of the weaknesses evident in previous research on modality matching.

Of particular emphasis in the latter regard was the need to avoid the confounding of temporal and spatial elements of visual stimuli in matching tasks by including all nine combinations of auditory, visual, spatial and temporal elements of integration, presented in as precise, consistent and objective a manner as possible. Other such emphases were to increase reliability and prevent ceiling effects for the matching tasks, to control for intelligence differences in the groups being compared, and to relate the modality matching tasks specifically to reading at an age where decoding skills have generally been mastered, and where perceptual development has reached an asymptote. A further emphasis was to make a more specific and detailed analysis of the relationship to reading ability of the auditory, visual, spatial and temporal elements of integration in terms of their combinations in the matching tasks.

Reading, Modality Matching and Intelligence

Reading ability was assessed by an instrument which placed the average reading level for over 500 grade three students at approximately one year above actual grade placement. It was from above and below this average that the reading groups were selected. The limited size of the grade three population available and the constraints of matching for intelligence, accounted for the inclusion of some below average readers who were reading above their grade placement level. This fact was somewhat mitigated by the widely held view in the lower mainland of British Columbia that the reading tests in question give inflated reading measures of up to one year above grade placement. In spite of these limitations the two reading ability levels were significantly different in matching ability.

Within the limitations of group intelligence tests, and with the further constraint that only the non-verbal battery was administered, the four groups were matched for intelligence. It is likely that good readers would have performed relatively better on a verbal intelligence test with the converse for poor readers. Similarly, the poorer readers may possibly have performed relatively better on the non-verbal test in relation to the good readers (Hage & Stroud, 1959). In addition, while the mean I.Q. and standard deviation for the grade three population were almost identical with the Canadian standardization figures, these data for the selected groups were a little below the population figures, due largely to the exclusion of more of the above average readers and more highly intelligent students by the matching process.

While the correlations for the grade three population were generally in keeping with the moderate, positive correlation commonly found between intelligence and reading (Chester, 1974), the relationship clearly varied for the selected groups of readers and for sex groups. It must be kept in mind that restriction of range due to selection of reading groups influenced the correlations of measures based on these groupings. Although matched for intelligence, poorer readers differed from good readers in the relationship of I.Q. to the reading skills of word recognition and comprehension. Correlations for high readers were essentially all significant, especially for girls. None of the correlations for the low readers approached significance. This was in spite of the greater variability of scores for low readers. Few of the reviewed research articles provided comparable information. In the most comparable study Bryden (1972) found approximately equal correlations of .35 and .37, for good and poor readers respectively, between the Cattell IPAT intelligence test and total scores on the Gates MacGinitie Reading Tests. There was no breakdown into reading subskills. Bryden's subjects had mean I.Q.s approximately 15 points higher than the children of this study.

For the children of the present study it would appear that intelligence was less closely related to word recognition than to comprehension for boys, especially for low reading boys. The same held for low reading girls. This would be in keeping with the findings of those studies where controlling for intelligence affected the correlation of matching with comprehension but not matching with word recognition. If word recognition is more heavily grounded in perceptual discrimination than is comprehension, this is not a surprising finding. One would expect factors other than perceptual decoding and intelligence to influence comprehension, among which are a number of factors considered to contribute to sex differences in reading. The low relationship of I.Q. to reading for low readers suggests that some other intervening factors cause interference. Among these must be sensory integration, which brings both unique and common variance to the tripartite relationship.

In spite of some contradictory results in studies investigating the relationship between sensory integration and intelligence, the consensus of findings supports a significant relationship of I.Q. and modality matching, and between modality matching and reading over and above the influence of intelligence (Beery, 1967; Birch & Belmont, 1964, 1965; Muehl & Kremenak, 1966; Kahn & Birch, 1968). Some studies also found that controlling for intelligence had the effect of reducing the significance of the correlation between auditory visual integration and comprehension, while the significance of the correlation between integration and word recognition remained high (Beery, 1967; Jones, 1970; Kahn & Birch, 1968; Muehl & Kremenak, 1966; Rudnick et al., 1967; Sterritt & Rudnick, 1966). Bryden (1972) found overall matching scores of low readers significantly correlated with I.Q. and almost no correlation for high readers. Representing reading and matching by one composite score obviously leads to loss of descriptive detail. It must be remembered that Bryden's subjects were considerably higher in mean I.Q. It is clear that the relationship of modality matching and intelligence for different reading ability levels is a very complex one, and influenced by contributing factors in an interactive fashion.

This complex relationship is even more evident when the separate tasks are correlated with I.Q. None of the reviewed studies reported these data. There were sex differences as well as reading level differences in the patterns of correlations in the present study. None of the tasks was significantly correlated with I.Q. for low reading girls and only one for high boys. On seven of the nine tasks low reading boys and high girls had the highest correlations, a number of which were significant and near significant, suggesting that the abilities of these groups were more similar. In addition, observation of the reading group profiles on the matching tasks shows that the high girls' profile is more similar to the low boys than the high boys. In view of these facts and the high boys' significantly higher comprehension scores, it may be that able girl readers and low readers are more tied to perceptual aspects of the reading process, and to visual spatial rather than visual temporal aspects, as evidenced by the high error rates on tasks with VT elements.

It is of interest that those matching tasks which were significantly correlated with both I.Q. and reading for high readers include the AT-AT task and the two tasks requiring spatial-temporal shifts within vision (VT-VS and VS-VT). These tasks are three of the four on which Bryden (1972) found significant differences between good and poor readers. For low readers the only task significantly correlated with I.Q. and both reading measures was AT-VS, a double integration task which seems to have importance in discriminating between good and poor readers. These close relationships support the notion that poorer readers find temporal processing easier in the auditory than the visual modality and are most at ease with visual spatial stimuli.

The present findings suggest that a further area of study could be in examining more closely, the three-way relationships using sub-components of intelligence and more varied reading measures, while retaining the nine integration tasks. Using sub-tests of the Wechsler Intelligence Scale for Children or one of the re-categorizations of sub-tests would be a possibility. In particular the apparent similarity between the profiles of low reading boys and high girls might be further investigated. Comparison of low, medium and high intelligence levels in relation to matching and reading would also be valuable.

Sex Differences in Reading and Modality Matching

From the foregoing discussion there have been indications of sex differences in some aspects of modality matching and reading level. It is not a simple matter to explain the absence of sex difference in reading for the grade three population, though a similar trend was found by Reilly (1971). Of the major explanations usually given for sex differences in reading (Dwyer, 1973), namely differential maturation, reader content, negative treatment of boys by female teachers or cultural expectations for the male role, none appears to be isolable in this instance. It may be that a high quality of reading instruction in a compact community deals with the latter three explanations, especially if culturally based influences are most important, as Dwyer (1973) and Johnson (1973) suggest.

Bentzen (1963) suggested that sex differences in reading result from the interaction of stress from cultural expectations and the maturational development of the reader. If in fact these stresses are minimized for the children of this study, and if as Buktenica (1970) proposes, the optimal perceptual development has been achieved by 8 years of age, these factors could indeed account for the absence of any significant sex differences in reading.

The interaction of variables, previously mentioned, does seem to apply in the matter of sex differences observed in the matching task performance. Although no main effect was found for reading nor any interaction of sex and reading level, significant specific differences did occur at certain points. Both Jorgensen and Hyde (1974) and Reilly (1971) suggested that sensory integration and reading achievement are related in a complex manner involving sex differences. From the performance on the matching tasks by the four groups it is clear that girls appear to handle VT stimuli less easily than boys when there is no VS element involved in the match, i.e. when the integrations are either intramodal or cross-modal within the temporal dimension. Expressed in another way, and taking into account the significant interaction of comparison stimulus and sex, girls have more difficulty in matching when the second portion of the match is visual and temporal. When the VS element is matched with VT stimuli sex differences drop practically to zero.

The temporal intramodal match within audition (AT-AT) showed no difference between high boys and girls but a considerable difference for low readers. While this could represent an intramodal auditory deficit, the general difficulty of AT-AT tasks for all groups, and the patterns of scores involving the auditory element in cross-modal matches for both reading levels, suggest that this is not the case. The practical significance for reading competence of the girls' VT weakness is not readily apparent since boys and girls within reading levels read equally well. Similarly, for low readers, the practical significance of a weakness in AT-AT integration for girls is not obvious. These girls may simply be less attentive to auditory stimuli of this nature. On the other hand it may reflect once more the complex interaction of integration abilities, sex, intelligence and reading, as well as the nature of the task.

The other aspect of sex difference of note was for integrations involving VS elements, especially for low boys on VS-AT, which is a double integration task. A weakness on this task may be a peculiarity of this group of subjects since data from two other studies show the VS-AT task to be less difficult than the VS-VT task. Low boys here showed the opposite trend. While low girls scored better than high girls on the VS-VS task and low boys scored not much worse than high girls, this relative strength for low readers does not appear to be related to better reading performance. On the contrary it appears from parts of the data analysis that poorer readers may over-dwell on VS aspects of stimulus input to the detriment of reading performance - an overcompensation. While this feature could be interpreted as evidence of modal specificity it could equally be a developed incompetence in the over-use of the spatial adeptness of the visual modality.

Modality Matching and Reading

Earlier studies used a variety of methods, tasks, numbers and types of items, ages, and sex groupings. Although the majority of studies found a significant relationship between sensory integration and reading, some studies questioned the existence of such a relationship. Of the reviewed studies which included all nine combinations of visual spatial, visual temporal and auditory temporal elements of sensory integration, only one related intramodal and cross-modal abilities to reading abilities. In that study Bryden (1972) did find a significant main effect for reading with good readers superior on all tasks. Although superior on all tasks, only on the tasks AT-AT, VT-AT, VT-VS, and VS-VT were good readers significantly superior. In the present study the good readers were significantly superior on all tasks except VS-VS, in all cases the probability being less than .001.

Bryden (1972) suggested a non linear relationship between matching and reading, with the correlation dropping to zero once a moderate level of reading was achieved. It appears that Bryden's view is too simple. It did not take into account the elements of the integration tasks, particularly the spatial and temporal dimensions, nor did it take into account more specific sex differences. The necessary minimal level for adequate reading performance may vary with different combinations of the contributory factors.

The plotted patterns of matching scores for Bryden (1972) and the present study bear some resemblance but they also diverge at certain points. Bryden's method of data analysis did not include a breakdown into standard and comparison elements which meant that the interaction of these elements with reading could not be found. In addition, Bryden's subjects were few and of above average intelligence. The items used were fewer and simpler than in the present study, which made for much smaller differences in task error scores. The VS-VS task showed evidence of a ceiling effect with a mean error rate of 0.5 for good readers. In addition, by using randomly mixed matching tasks within testing sessions it is likely that poor readers were adversely affected by their known difficulty with intersensory perceptual shifts in cross-modal integrations (Derevensky, 1978).

Thus, in the Bryden (1972) study, while performance on AT-AT, AT-VT, VT-VS, VS-AT, VS-VT and VS-VS are comparable in difficulty trend to the present study, the trends of scores on the two purely temporal tasks with VT standard stimuli show some differences. The difficulty level of these tasks did not show a marked increase in errors in the Bryden study as compared to the present study. Bryden's data showed decreasing error rates for these tasks except for poor readers on the VT-AT task which had a slightly higher error rate. Similarly, the good readers' error rate on the AT-VS task does not drop in the Bryden study, though it did for Bryden's poor readers and did so characteristically for all groups in the present study.

The studies by Sterritt et al. (1971) and Rudnick et al. (1972) provide further comparisons though they used younger, black and chicano children, not all of whom did all tasks. Their studies were not applied to reading. They generally supported the increasing and high error rate for the two temporal tasks with VT standards. They also showed the step in the profile of task scores where a lower error rate for the VS-AT task is followed by increased errors on the VS-VT task. Seven out of eight groups plotted, showed this feature indicating that spatial to temporal integrations within vision are more difficult than spatial to temporal integrations which also involve a shift from visual to auditory. Bryden's different results may reflect higher intelligence of subjects, easier tasks or the different method of presentation of the tasks. Given these differences, it would appear that the present study presents a more realistic picture of the difficulty of the purely temporal tasks with VT standards than does the Bryden study.

Stimulus Elements and Matching Task Performance

The nature of the initial stimulus would appear to be of key importance for sensory integration. O'Connor and Hermelin (1972) demonstrated that the modality of input was a determining factor in whether information was organized or encoded spatially or temporally. There can be no question that spatial information is best organized visually and that poor readers have a visual spatial strength. The very significant main effect for standard stimulus in the present study was due largely to the much lower error scores of tasks with VS initial stimuli, combined with higher error scores for tasks with VT standards. However, when the task calls for visual temporal performance with initial temporal stimuli in the visual modality, it is the task demand rather than the modality of input that determines whether the information is encoded temporally or spatially. Thus it is the spatial or temporal encoding facility of the visual modality that is invoked by the nature of the initial stimuli in the matching task. High reading boys were equally able at temporal processing in both visual and auditory modalities. High girls had more difficulty with VT stimuli but were still more able than low readers. There was a slight tendency for purely temporal matching tasks to be easier with initial AT stimuli than with initial VT stimuli. With AT comparison stimuli half the tasks were easier than with VT comparisons and half were more difficult. AT and VT standards with VS comparisons were approximately equal in difficulty.

Results of the factor analyses showed that tasks loaded on the spatial and temporal dimensions rather than visual and auditory modalities, with high readers more versatile at processing temporal information in the visual modality. Thus it seems that while the visual modality as the modality of input may be predisposed to processing information spatially, it has a strong capacity for processing information temporally. However when the initial stimulus is visual and temporal, the poor reader seems more bound by the spatial processing tendency than the good reader.

Bryden (1972) suggested that an initial VS stimulus gave higher matching scores, not simply because they are easier to match, but because they are easier to remember or to organize conceptually. Likewise, initial temporal stimuli (especially VT) gave lower matching scores because temporal organization was more difficult and the visual modality less adept at temporal organization. It seems fair to add that this reflects the nature of temporality rather than a modality deficit, and that facility for appropriate use of these two capacities of the visual modality, as required by the task, also contributes to better matching performance.

Thus part of the problem of relative task performance is bound up in the modality of input, part in the spatial or temporal dimension in which the visual modality is operating, as set by the initial stimuli, and part in these same factors for the comparison stimuli. If for all the studies using nine tasks, the tasks are given rank order of difficulty, the following order is found. Easiest are those with VS standards, first VS-VS then VS-AT and then VS-VT. Next and equal in difficulty are the two remaining tasks with VS comparisons, AT-VS and VT-VS. The next two most difficult are AT-AT and then AT-VT, two tasks with AT standards, the cross-modal VT comparison being more difficult than the intramodal match. Next most difficult is VT-VT, an intramodal match within the temporal dimension, and most difficult is the cross-modal match from visual to auditory within the temporal dimension, VT-AT.

Thus the two intramodal matches within vision stand almost at the two extremes of difficulty, representing a spatial-temporal dichotomy. The first and third most difficult tasks are cross-modal matches within the temporal dimension, with VT standards more difficult than AT. The three most difficult tasks are integrations within the temporal dimension. Tasks requiring two integrations fall in the group of easier tasks with VS standards being easier than AT standards. These composite results contradict or qualify Bryden's (1972) findings that cross-modal shifts are more difficult, and that spatial-temporal integrations within vision are more difficult than cross-modal integrations within the temporal dimension. Cross-modal shifts are more difficult only for the purely temporal tasks. Thereafter they are of equivalent difficulty or the intramodal matches are more difficult. Conversely to Bryden's findings, spatial-temporal shifts within vision are easier than cross-modal integrations. The findings lend support to the Kuhlman and Wolking (1972) view that cross-modal and intramodal matches are similar in difficulty if both begin with the same modality element.

These conclusions were supported and further qualified by the pairwise comparisons made to examine the assumptions of the modal-specific view of sensory functioning. Friedes (1974) reinterpreted the modal-specific view in terms of information complexity. The modal-specific view must be qualified also in terms of the characteristics of the information processor. Processing temporal information in the visual modality was only significantly more difficult for poorer readers. Similarly cross-modal integration in the temporal dimension was only significantly more difficult for low readers. Other cross-modal matches were insignificantly more or less difficult than intramodal matches. Thus, there was no support for the view that cross-modal integration is a higher order process of sensory integration. Results of the factor analyses for both reading groups added support to this refutation.

It appears also that Friedes' (1974) reinterpretation with regard to stimulus complexity also needs further qualification. Friedes concluded that the modality specific view held for the processing of complex pattern information. However if the stimulus patterns of the present study are regarded as complex, and if the modality specific view only appears to hold true for low readers, then Friedes' view needs modification since good readers process temporal information effectively in the visual modality. Alternatively, if Friedes' conclusion that simple tasks call for non-modal processing and complex tasks call for modality specific processing, there could be a switch of processing style called for in the middle of a test where item complexity progressed from simple to complex. Poorer readers may begin with one perceptual set, e.g. spatial, and when complex patterns call for temporal processing, they may have difficulty making the switch. This would correspond with poor readers' difficulty with intersensory perceptual shifts. It would also be a plausible explanation of why poor readers often are good at decoding initial word parts (spatial) but have difficulty with mid and end word parts (temporal).

Thus the direction of focus indicated by this study is more to the processing of information as determined by the adeptness of the input modality, in inter-action with the spatial and temporal characteristics of the input stimuli which set the requirements of the task. The exploratory factor analyses investigated the cognitive processing characteristics of good and poor readers. The results indicated that for good readers, temporal stimulus input is processed similarly by visual or auditory modalities depending on the task requirements. Poorer readers on the other hand appear to demonstrate lack of adeptness, or confusion in the processing of temporal information where the visual modality is involved.

The introductory items of each of the matching tasks established the task requirements in terms of visual, auditory, spatial and temporal integration. The order of presentation of the stimulus elements determined the type of integration or processing required. Then the developed adeptness of the input modality of the individual processor determined how well the task was performed. From the factor analyses and the pairwise comparisons, poorer readers appeared to be less adept at processing temporal information in the visual modality, particularly in the absence of a VS task element. Poorer readers appeared to be bound by the spatial encoding facility of the visual modality. Not only did this facility appear to override temporal processing requirements in terms of modality function as indicated by the initial stimulus, but also it appeared to over-ride the temporal processing requirements of the task itself, by over-emphasis on spatial aspects of the task, even if they occurred as the comparison stimuli. In the factor analysis for low readers, the two tasks with temporal standards which loaded the spatial factor were those with VS comparisons.

Attention is thus drawn to the link between temporal and spatial stimulus elements and their relative position in the matching tasks. The strong main effect for the standard stimulus was due to the combined influence of the VT and VS elements. The main effect for the comparison stimuli was due solely to the influence of the VS element. The implication seems to be that the VT or sequential element is of particular influence as an initial stimulus in sensory integration. Differential abilities at processing VT stimuli distinguish between good and poor readers whereas ability at processing VS stimuli does not. Matching tasks which called for spatial and temporal integration within vision were significantly correlated with reading measures for high readers, especially for word recognition. For low readers it was the VS-VS task that was significantly correlated with word recognition. The implication is that temporal-spatial shifts within the visual modality are particularly called for in the reading process, and that more able readers demonstrate a greater facility in making those shifts, especially in word recognition. The fact that AT-AT integration and vocabulary were highly correlated for high readers suggests that auditory attention and sequencing are important for word recognition, and tends to support the view that temporal rather than spatial abilities are more closely associated with adequacy at decoding. Poorer readers, who have a spatial strength, are weak at decoding.

O'Connor and Hermelin (1972) highlighted the capacity of the input modality to induce a temporal or spatial set for the processing of the information. It would seem that for poorer readers, when the input modality is visual but the task requirement set by the standard stimulus is temporal processing, an inappropriate set for spatial encoding may occur. In Friedes' (1974) terminology, information input for the less adept temporal aspect of visual processing is translated into the code of the most adept spatial aspect of the visual modality. This could well be classed as a "compensatory enhancement" (Friedes, 1974, p.285) of the spatial processing strength of the visual modality for poorer readers. This may also be the explanation why visual to auditory switches for poorer readers are more difficult than auditory to visual, as found in this study and in other studies (Estes & Huizinga, 1974; Vande Voort, Senf & Benton, 1972).

This VS processing characteristic of poorer readers may contribute to an effect which was evident in the item analysis data. That part of the most discriminating items where the choice point (and thus the error point in matching) occurred, was predominantly at the middle and end of the stimulus patterns. This demonstrated a type of recency effect in the concentration of errors. A visual-spatial strength favours primacy (Friedes, 1974). Very few of the items were discriminating where the point of difference was at the beginning of the stimulus patterns. This tendency could be explored further by future studies. A further area of research could also be the relating of modal preference and other measures of modality strength to performance of good and poor readers on integration tasks.

Emphasis on the processing characteristics of the individual reader inevitably takes one further away from the symptoms towards the etiology. There is a temptation to view the discussed findings in the light of neuropsychological literature such as that dealing with hemispheric function of the brain (Dimond & Beaumont, 1974; Kimura, 1963; Milner, 1971), particularly hemispheric involvement in verbal and visuo-spatial function or in simultaneous and successive processing (Cohen, 1973). Butters and Brody (1968) were among the few researchers to relate specific cortical lesions to modality matching, finding that cross-modal matching loss was particularly related to the dominant parietal lobe, while frontal-temporal lesions did not impair intramodal or cross-modal matching. Even with specific neurological information, application of findings is limited. Without specific neurological data on the subjects this would be a futile exercise.

In compromise there does seem to be a justification however for viewing the discussion in the light of theoretical views of those working in the field of brain science and brain-behaviour relationships which are pertinent to modal-specificity and information processing and which are applicable to differences in reading ability. The theories of Luria (1966, 1973) appear to be most relevant in this regard. Working from studies of cortical lesions, Luria rejects both the idea of the undifferentiated functioning of the brain and that of the narrow localization of function. He postulates three basic co-operating zones of the brain, each with different cortical function and relationship to sensory modalities. The three zones are organized on a hierarchical basis in terms of neural development and diminishing modal specificty. The primary areas of the upper brain stem and reticular formation are involved with arousal, motivation, information reception and analysis. They are most modality specific. The secondary areas (occipital, parietal and temporal regions) subserve sensory input, visual and auditory analysis and coding and storage of information, being highly modality specific. The tertiary block includes the large area of the frontal lobes subserving the most complex behaviours, the function being non-modality specific.

All three of the areas identified by Luria work together to subserve perception and the development of abilities resulting from educational experiences. Thus poor reading performance and sensory integration performance which is more tied to modality specifics can be seen in the developmental hierarchy put forward. Whether or not it is neurological impairment, a maturational lag, or inadequate learning experience which is responsible for the poorer performance is not so relevant as the degree of functioning developed. It would be wrong to consider all poor readers with cross-modal inadequacies as having dominant parietal lobe weaknesses. It seems more acceptable to view an inadequacy of sensory integration by poorer readers as placing them somewhere on a continuum of developed expertise in information processing. It is on the establishing of this status that remediation can be based.

Closely related to the modality matching approach and arising out of the work of Luria is the approach of simultaneous and successive syntheses in information processing. Simultaneous processing involves integration of sensory stimuli into essentially spatial groupings, being subserved by the secondary area of the cortex. This processing deals with global and relational concepts. Simultaneous synthesis is also involved in comparative, spatial and logical relationship concepts as expressed in language (Cummins & Das, 1977). Successive processing, linked to the tertiary area of the cortex, subserves integration of stimuli into temporal series as in automatic sequential skills. Studies using the simultaneous and successive syntheses paradigm in relation to reading, and using a variety of meaningful content and memory tasks, suggest that among children who are likely to experience difficulty in reading, successive processing is highly related to reading ability, while better reading is more related to simultaneous processing (Cummins & Das, 1977; Doehring, 1968). Kirby and Das (1977) added the emphasis that both forms of processing were important for superior performance on complex tasks such as reading.

In summarizing a great deal of research on the cognitive functioning of disabled readers, Kirby and Das (1977) present a case for the applicability of simultaneous and successive processing to research in reading difficulties. Since VS stimuli in matching tasks are simultaneous in presentation, while all temporal stimuli are successive, there is a clear overlap between these two approaches. In view of (a) the 25-study review by Rugel (1974) which found that disabled readers are strong in visual-spatial skills, (b) the heavy emphasis on the VS element which is a feature of poor readers' matching task performance in the present study, (c) the modality-specific nature of the secondary zone function which subserves simulteaneous synthesis and visuo-spatial relationships, the value of these approaches to the study of reading difficulties appears to be well established. Kirby and Das (1977) concuded that "it is only on the basis of this type of research into the underlying processing deficits of disabled readers that rationally-based remediation procedures can be implemented" (p. 569).

Implications for Reading

Several studies drew attention to the difficulty of temporal integrations in the visual modality. The present study indicated clearly that poorer readers are significantly less able at such integrations than good readers. The spatial-temporal integration abilities of poorer readers are clearly impaired (Doehring, 1968; Leong, Note 1; Rugel, 1974). What are the implications of these findings on modality integration for remediation? While this study was not intended to extend into program development it would be hoped that it has clarified some of the issues in the relationship of sensory integration to reading. Can this relationship be further expressed in terms of direct remedial principles?

Reading clearly involves a mixture of sensory integrations. Spatially perceived units (whole or part words or phrases) are integrated with other spatially organized units in a sequential (visual and temporal) manner. Spatially and temporally perceived (visual) units are also integrated with phonic or phonetic units as graphic symbols become associated with oral-auditory vocabulary. Thus flexibility in the full variety of sensory integrations is called-for in proficient reading. This flexibility would also extend to selective use of appropriate integrations as the requirements of the task change. In Friedes' (1974) terms this could be expressed as the utilization of the most adept aspect of modality function in terms of the complexity of the information processing required by the task. It seems clear that processing needs change as reading skills develop (Doehring, 1976), and also clear that good readers use both the global VS and sequential VT adeptness of the visual modality more flexibly and appropriately (Gibson, 1970). In learning or decoding stages, the integration demands of the visual modality could call upon its temporal adeptness more heavily. As words become known or as larger units are synthesized more readily, a more automatic, global, visual spatial adeptness in integration would be more appropriate.

Looking at the processing characteristics of good readers it is apparent that they have strong VS abilities. They are also able to integrate visual temporal and auditory temporal information equally well as called-for by the stage of difficulty of the task. VT integrations are still more difficult but when they are called-for this adeptness is brought to bear on the task. Poorer readers on the other hand appear to be more bound by the VS adeptness of the visual modality and process information inappropriately by over-use or over-compensation in this aspect of modal function, being locked into modal-specific aspects of cortical functioning. This could be explained in terms of neurological damage or slower maturational development. It could be due to inadequate experience in language, in perceptual motor skills or in general perceptual organization which is demanding of sequential relating and processing of information.

Whatever the explanation, the child's needs would be the same - planned, progressive and broadly based rich experience in developmental language and reading activities. This would not mean perceptual training exercises such as matching patterns of light flashes, beeps and dots, but perceptual training that is intrinsic to oral and written language and to the teaching of reading and writing, as sequential steps within these activities.

If the integration weaknesses of poor readers, highlighted by the findings of this study, are translated into enrichment practices, some examples could include judging the equivalence or difference of written and spoken, spatially and temporally presented words and word elements. Using timed presentation techniques, letters or syllables could be matched and subsequently pronounced. This would utilize VS skills, observing distinctive characteristics etc., but calling for integration, and adding sound association (cross-modal integration) to the spatial integration. Further stages would call for matching larger units of whole words or phrases, followed by pronunciation.

In parallel could be presentation of sequences of syllables, increasing in number and complexity, first calling for matching and then blending. Again in parallel could be the cross-modal matching of visual elements (syllables, words) both spatially and sequentially with heard syllables or words, calling for simple matching and then vocalizing. Similarly the auditory elements could precede the visual-spatial and visual-sequential elements or be followed by matching auditory elements. Part of the process could require anticipation or visualization of what the equivalent match would be, followed by actual presentation of the comparison stimulus. These practices would lead naturally to writing and spelling as the standard or comparison part of the matching process. They would be aimed at increasing the flexibility of the child at handling both intramodal and inter-modal aspects of integration. For remediating more basic difficulties the same principles could be used with pictorial or alphabetic materials as stimuli to be matched.

The practices would be aimed at facilitating and developing the neuronal connections to gradually decrease inappropriate modal-specific functioning and to increase the ability of vision to handle both spatial and temporal stimuli. This would be in the context of meaningful pictorial, oral and verbal materials. Bakker's writing (1967) would support the naming and retention of temporal sequences as a training program for children with reading difficulties. It is a salutory reminder that children rated low in reading and perception made significantly greater gains in word recognition after listening to taped stories and discussing them, than did children who received specific training in visual perception using non-verbal materials (Buckland & Balow, 1973).

It seems clear that poor readers include those who have either auditory-temporal or visual spatial difficulties, and those who have both (Doehring, 1968). The present study would include those with visual-temporal weakness. Friedes (1974) would add a fourth group to include those for whom none of the forementioned conditions apply. Likewise Torgesen (1975) suggests that research indicates that the relationship between reading ability and perceptual functioning is the result of deficits in specific subsets of perceptual functioning. It would seem that a remedial program based on the principles outlined would have a wide spectrum of influence in view of such a wide range of integration difficulties. A further area of research could be to use the suggested principles in a remedial program and to conduct an experimental study on the efficacy of the program in improving reading.

Appropriate use of the modality functions in blending visually and auditorily perceived phonemes, graphemes and larger units, would presumably help in preventing over-compensatory use of VS adeptness. This would place each of the phonic and sight word approaches to reading in dynamic balance. A dominantly VS approach to reading would place undue emphasis on the primacy effect (Friedes, 1974). From various aspects of the data analysis (factor loadings, stimulus main effect, item analysis) a bias towards primacy appears to be a characteristic of the poorer readers. The visual input of VS patterns is slower than for VT patterns. The poorer reader often dwells too long on the elements of words. These characteristics may accentuate some of the inappropriate use of the visual modality by under-use of the temporal processing capacity of this modality. The skilled reader on the other hand is less bound by the VS element in word recognition (Smith, 1971).

The dynamic balance would thus be not only between visual and auditory, but also between spatial and temporal integration experience. A general aim would be to reduce the degree of modality specific processing of information by giving experience in flexible use of modalities in interaction. The complementary nature of the integrations would call for both working from print to auditory production and moving from audition to vision through matching, pronouncing, writing and spelling. It is possible that modal preference would play a part, and the importance of such a bias would need to be examined in further research. The presence of a preferential bias would not reduce the need for rich experience in sequential activities, in order to develop at each step of the learning to read process, the network of neuronal connections necessary for integration of all the sensory channels.

If as Hardy, Stennett and Smythe (1973) suggest, the syllable rather than the phoneme is the more natural perceptual unit in beginning reading, this would seem to reinforce the idea of attaining a balance between analytical spatial and synthetic sequential use of modalities. Such a balance would draw upon both the integrative and differentiative functions of modalities in processing the information. While better reading performance would demonstrate processing of larger manageable units of print, undue emphasis would not be placed upon the global VS element. In attaining the balance, extreme over-analysis of words into excessively small spatial units would also be avoided.

It was in the establishing of some of the characteristic weaknesses of poor readers in the integration of sensory information and of their status in terms of modality adeptness that this study had its aims. Effective remediation of reading difficulties depends upon understanding more of the contributing variables. Attention was not given to variables such as anxiety, motivation, verbal facility, specific memory abilities or ability to concentrate attention on learning tasks, in the present study, but the writer does not consider these to be unimportant influences to take into account. While these factors generally operate together in varying degrees of contributory importance, each one which influenced a specific, poor reading performance would need to be dealt with by specific remedial measures. If, and to what degree, sensory integration inadequacies limit reading performance, they must be increasingly more specifically delineated and related to the body of existent knowledge of psychological and neuropsychological theory, and of the reading process. Such was the intent of this study.

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APPENDIX A

MATCHING TASK STIMULUS PATTERNS

ITEM NUMBER	STIMULUS	COMPARISON	SAME (S)/ DIFFERENT(D)
EXAMPLES			
1	●●●	●●●	S
2	●●●	● ●●	D
3	●● ●	● ●●	D
4	● ● ●	● ● ●	S
5	● ● ●	● ●●	D
TEST ITEMS			
6	●●●●	●●●●	S
7	●●●●	● ●●●	D
8	● ●●●	●● ●●	D
9	●●● ●	●●● ●	S
10	● ● ●●	● ●● ●	D
11	● ●● ●	● ●● ●	S
12	●● ● ●	●● ● ●	S
13	● ● ●●	● ● ● ●	D
14	● ●●●●	● ●●●●	S
15	●● ●●●	●● ●●●	S
	REST	REST	
16	● ●●●●	● ●●● ●	D
17	●●● ●●	●●●● ●	D
18	●● ●● ●	●● ●● ●	S
19	● ● ● ●●	● ● ●● ●	D
20	● ●● ● ●	● ●● ● ●	S

ITEM NUMBER	STIMULUS	COMPARISON	SAME (S)/ DIFFERENT(D)
21	•• • • •	• •• • •	D
22	•• ••••	••• •••	D
23	•••• • •	•••• • •	S
24	• •• •••	• ••• ••	D
25	•• • •••	•• •• ••	D
	REST	REST	
26	• • • •••	• • •• ••	D
27	•• • • ••	•• • •• •	D
28	• • •• • •	• •• • • •	D
29	•• • • • •	•• • • • •	S
30	•••• •••	•••• •••	S
31	••• •• ••	••• ••• •	D
32	• •••• ••	•• ••• ••	D
33	• ••• • ••	• •• •• ••	D
34	•• • •• • •	• •• •• • •	D
35	• • •• • • •	• • •• • • •	S

Figure 9. Matching task stimulus patterns.

APPENDIX B

SLIDE DURATION TIMING

Slide Duration Timing

Using the original cassette tapes, the lengths of the blank spaces which represented all the visual-spatial stimulus presentations were timed and recorded. From the tone and pause dimensions the total duration of the auditory patterns were calculated and recorded. These durations were then converted proportionately to fit the range of two to four seconds which was set as the duration for slide presentation on the basis of the literature and previous research (Jarman, 1978). These times (time available on the tape and time required for presentation) were entered into a detailed script of the tape.

The next stage was to convert the tapes for use in a slide-sync audio-visual system. This system is usually comprised of a two track tape recorder and slide projector. One track of the recorder is used for the audible information, in this case verbal instructions and tone bursts (beeps). The other or cue track is used for advancing the projector by means of programmed inaudible tone bursts.

The original verbal instructions and tones (1000 Hz) were transferred to one track of a variable speed, reel-to-reel two track tape recorder, set at the highest speed, 7½ ips. The tape was then played back at 1 7/8 ips (one quarter speed), during which time the cue tones for advancing the projector were recorded on the other track. The duration time was multiplied by four and the tones were manually keyed using a signal generator (set at 250 Hz) and an electronic stopwatch. A 0.8 sec. constant was added to the period between the cue change tones for each slide to compensate for the response time of the final playback machinery.

This final recording was then transferred at the original speed onto a two track audio cassette, slide-sync tape recorder. The cue track, being transferred at four times its recorded speed, showed a slide duration error of no greater than ± 0.2 sec. The inaudible cue tones transferred at 1000 Hz (four times the original recorded frequency) which fitted the design of the final playback machinery.

APPENDIX C

VISUAL-TEMPORAL TEST CONSTRUCTION

Visual-Temporal Test Construction

For construction of the VT stimulus patterns, a Wollensak 3M 2551 AV slide/sync cassette tape recorder was used. In addition, two electronic circuits (a tone decoder and a binary divider) were required.

The VT condition required that a small incandescent lamp be flashed for the same duration and pattern as the audible tone bursts which were recorded at 1000 Hz. The tones to flash the lamp could not be directly selected from the audible track as this was still required and as 1000 Hz tones were inherent in the verbal instructions on that track. The tones could not be directly transferred on to the cue track as this track already contained inaudible 1000 Hz tones for slide change cues. To overcome these problems, two electronic circuits were built.

Tone decoder: The first of these was a tone decoder circuit, comprising an amplifier, tone decoder and lamp driver. This was connected directly to the cue track record-playback tape head. Signals from the head were amplified and sent to the tone decoder which was programmed to respond to 500 Hz tones (± 10 Hz for tape speed variation). The response of the decoder signalled the lamp driver to turn on a small 12 volt, 100 milliamp incandescent lamp for the duration of the 500 Hz tone bursts.

The decoder was coupled to the tape recorder by a 2-conductor shielded cable and the "sync out" of the recorder was connected to the "sync in" of the decoder. An extension cord to the lamp was plugged into a socket on the top of the decoder. Power to the decoder was controlled by a switch on the decoder box and power was indicated by the L.E.D. (light emitting diode). A press-button switch on top of the decoder permitted testing and manual control of the lamp.

Binary divider: The second circuit was a binary divider circuit. The original, audible 1000 Hz tone bursts were played back through this circuit and divided to 500 Hz. These 500 Hz tone bursts were simultaneously re-recorded onto the inaudible cue track. The slide changer thus responded only to the 1000 Hz tones.

The speaker output from the recorder was connected via a Y cord to an auxilliary speaker and to the divider input of the decoder. The volume control was set so that approximately 4.5 volts p-p (peak to peak) AC was fed to the divider input. This was the value required for the divider to operate properly.

For tones recorded on the Wollensak 2551 AV recorder at 0 VU (100% modulation), an oscilloscope was placed on the divider output and the volume control turned up until a stable square wave output of 500 Hz showed on the oscilloscope. An audible distortion was then evident on the auxilliary speaker.

The output of the divider was fed into the sync input of the recorder via a shielded 1-conductor cable. The output gain was controlled via the out gain on the decoder. This was set for 1 volt AC nominal. Too large a signal caused the projector to advance, while too small a signal did not light the lamp properly.

Completion of Tapes for all Conditions

Construction of the five new tapes for the addition of the visual-temporal element was thus achieved by dividing the 1000 Hz audible sound patterns on copies of the three original tapes which contained the auditory element, and simultaneously re-recording them on the cue track. Once the transfer was made, the original audible tone bursts were erased from the audio-track. The AT-AT test thus became VT-VT, and the AT-VS test and its converse became the VT-VS test and its converse. When the AT-AT test had the initial stimuli altered it became VT-AT, and when the comparison half was altered this became AT-VT. Thus all nine combinations of cross-modal and intramodal tasks were accounted for and presented in an accurate and consistent manner, with stimuli identical within the standard and comparison conditions, and across the visual and auditory temporal dimensions.

Circuit Descriptions

Power supply: The power supply provided ± 15 volts DC and + 5 volts DC. The line level AC was transformed and rectified (D1 - D4: see Figure 10) and filtered (C17, C18). This voltage, ± 35 volts DC, was then regulated to + 15 volts DC by IC6 and to -15 volts DC by IC7. A +5 volts source was obtained by IC5.

Divider section: The AC signal from the tape recorder speaker was fed through C11 (see Figure 11) to a low pass filter (C12, C13, R12, R13) to eliminate any high frequency component from affecting the divider. The signal was then fed to half of IC3, a dual binary divider. The divider output was fed to a unity gain Op. Amp. IC4 and the output, controlled by R15, was fed back to the tape recorder sync input.

Tone decoder: The signal from the sync head was AC coupled via C1, C2 to a differential amplifier IC1. The common mode rejection ration (R4), was adjuted for minimum hum at 60 Hz. The output of IC1 was AC coupled to a tone decoder IC2. This decoder's free running frequency was adjusted

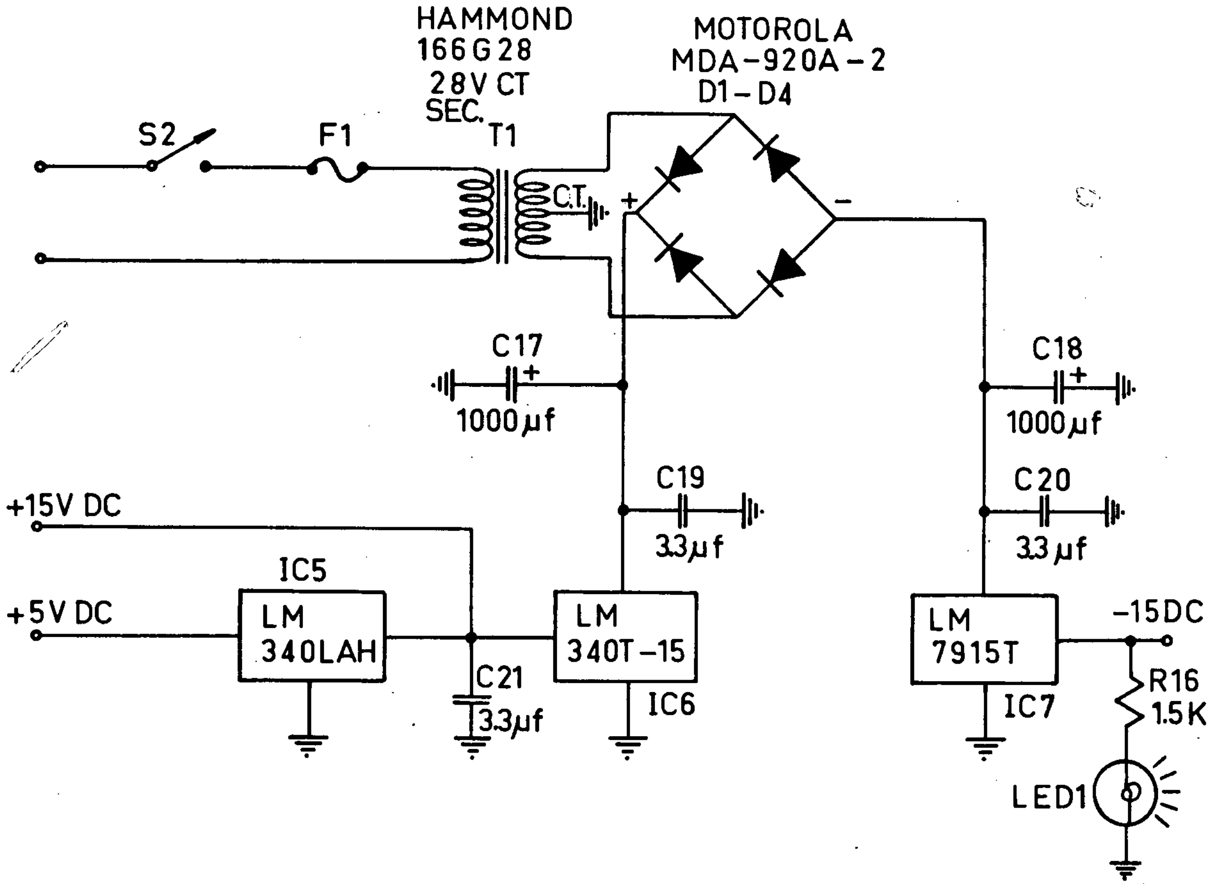

Figure 10. Power supply.

by C6 and R6 (set to 500 Hz), the decoding section being set by the two loop filters C7 and C8. The output of the decoder was inverted by Q1 and fed to Q2 which acted as an inverter and lamp driver. The filter, C9, prevented superfluous oscillations. Switch SW1 was for manual operation of the lamp (see Figure 12).

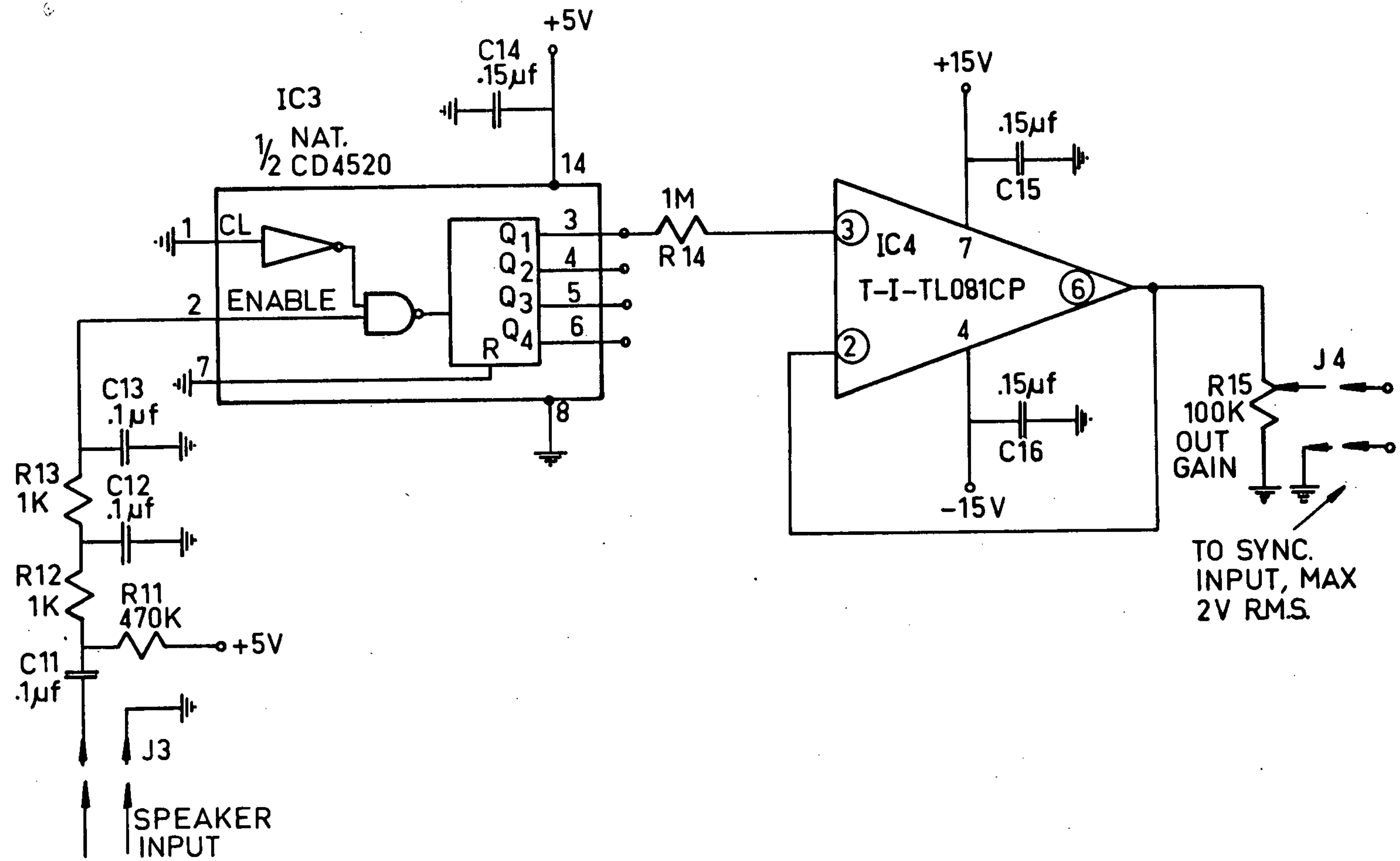

Figure 11. Divider section.

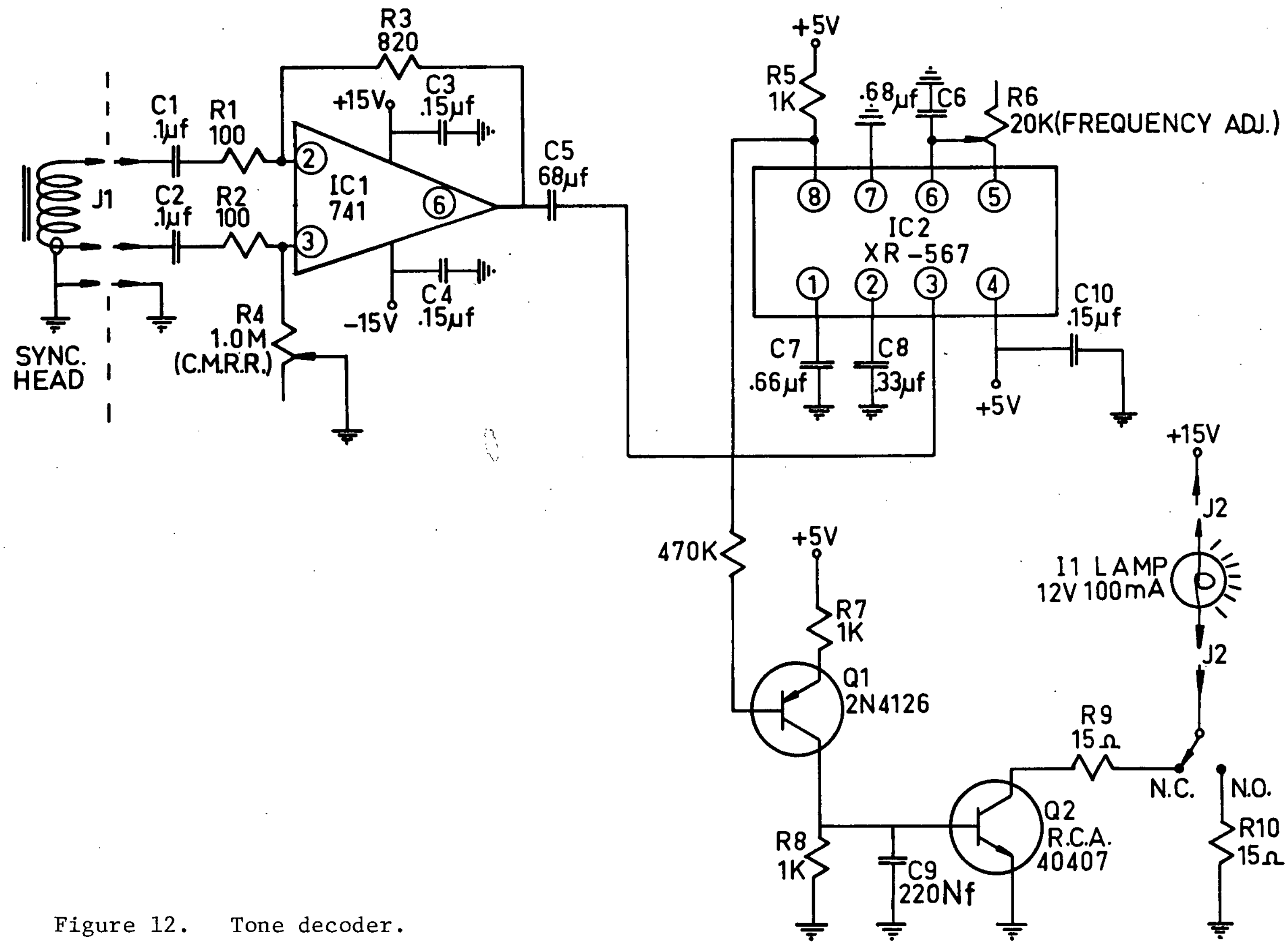

Figure 12. Tone decoder.

APPENDIX D

REVISED SLIDE PRESENTATION TIMES

Table A

Revised Slide Presentation Times

Item	Time	Item	Time	Item	Time
6.	1.1 sec.	16.	1.6 sec.	26.	2.25 sec.
7.	1.1	17.	1.6	27.	2.25
8.	1.5	18.	1.8	28.	2.5
9.	1.5	19.	2.2	29.	2.5
10.	1.75	20.	2.2	30.	1.8
11.	1.75	21.	2.2	31.	2.1
12.	1.75	22.	1.75	32.	2.1
13.	1.75	23.	2.0	33.	2.5
14.	1.6	24.	2.0	34.	2.75
15.	1.6	25.	2.0	35.	3.0

APPENDIX E

SCRIPT FOR INTRODUCTION OF THE MATCHING TASKS

An Example of Scripts Used for Introducing Matching Tasks

Test 8. Dots - lights, VS-VT.

Today we are going to look at some pictures. We are also going to look at some flashing lights. All of the pictures will be little dots. All of the lights will be flashes of a light bulb. We are going to play a kind of game with these pictures and lights. We are going to see if some of the lights are the same as some of the dots. We will also see if some of the lights are different from some of the dots. Let's look carefully at this picture (...). Now let's look at these flashes of light (. ..). Did you notice that the lights were not the same as the dots? Let's look at them both again. Ready for the dots (...) and now the lights (. ..). The lights were not the same as the dots were they? They were different from each other.

Let's compare some dots and lights that are the same as each other. Ready, (...) and (...). Those were the same as each other weren't they? How can we write on paper that the last one was the same as the first one or was different from the first one? On the paper in front of you the words <u>same</u> and <u>different</u> are written down for each set of dots and lights that we will compare. Let's look at some more dots and lights and see how we would write down the answer. Ready, (...) (...). They were the same, weren't they? If we look at No. 1 on the page, the word <u>same</u> has a circle around it to show that the dots and lights were the same as each other. Let's look at the dots and lights for No. 2. Ready, (...) and (. ..). The lights were different from the dots, weren't they? If we look at No. 2 on the page, a circle has been drawn round the word <u>different</u> to show that they were different. Let's look at the dots and lights for No. 3. Ready,

(.. .) and (. ..). They were different, weren't they? So a circle has been drawn around the word <u>different</u> for No. 3.

Now, would you like to try some? Use the pencil to circle the right word after you have seen the dots and lights. Let's do No. 4. Ready, (. . .) and (. . .). (Pause for answer). Did you circle the word <u>same</u> for No. 4? That is the right answer. Let's try another one - No. 5. Ready, (. . .) and (. ..). (Pause) Did you circle the word different for No. 5? That is the right answer.

Now we will do some more of these using the tape recorder to give the instructions. After each group of dots and lights, circle the right answer on your paper to show if they were the same or if they were different. After the word <u>ready</u>, be sure to watch and listen carefully so as not to miss the dots or lights.

APPENDIX F

PARTICIPATING SCHOOLS

Annieville Elementary School

9240 - 112th Street, Delta

Brooke Elementary School

8781 Delwood Drive, Delta

Chalmers Elementary School

11315 - 75th Avenue, Delta

Devon Gardens Elementary School

8884 Russell Drive, Delta

Gibson Elementary School

11451 - 90th Avenue, Delta

Gray Elementary School

10855 - 80th Avenue, Delta

Hellings Elementary School

11655 - 86th Avenue, Delta

Sunshine Hills Elementary School

11285 Bond Boulevard, Delta