THE UNIVERSITY OF MANITOBA

EARLY VISUAL INFORMATION PROCESSING AS A FUNCTION OF AGE AND OF READING ABILITY

BY

JOHN L. ARNETT

A DISSERTATION

SUBMITTED TO THE FACULTY OF GRADUATE STUDIES

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF

DOCTOR OF PHILOSOPHY

DEPARTMENT OF PSYCHOLOGY

WINNIPEG, MANITOBA

JULY, 1977

EARLY VISUAL INFORMATION PROCESSING AS A FUNCTION OF AGE AND READING ABILITY

BY

JOHN L. ARNETT

A dissertation submitted to the Faculty of Graduate Studies of the University of Manitoba in partial fulfillment of the requirements of the degree of

DOCTOR OF PHILOSOPHY

Abstract

Temporal integration and backward masking tasks were performed by 7, 9, 11, and 13 year old good and poor readers in order to assess the relationship between reading difficulties and temporal aspects of visual information processing. Earlier research (Stanley and Hall, 1973) suggested that poor readers had longer sensory persistence and a slower rate of visual information processing than normal-reading control children. However, methodological considerations concerning the possibility of response-criterion confounding cast uncertainty on the conclusions drawn from this earlier work. In the present experiment, temporal integration and backward masking tasks, designed to avoid this possible confounding, were employed to assess sensory persistence duration and processing rate, respectively.

The results revealed no differences between the experimental and control subjects at any age level on either experimental task although performance under backward masking conditions showed significant improvement with increasing chronological age in both groups. This suggests that while the rate of visual information processing was unrelated to reading proficiency at any age level studied, the processing rate did increase significantly with age. Conversely, however, the absence of any age-related differences in temporal integration indicates that the duration of sensory persistence was independent of both chronological age and reading competency.

The present results fail to support earlier research indicating differences between good and poor readers in sensory persistence duration and processing rate. This discrepancy in findings is believed to

be related to the confounding effects of response bias in the earlier work which was avoided here by forced-choice methodology. The present findings argue for future research involving good and poor readers being directed at higher levels of information processing than those presently investigated.

Acknowledgement

I wish to thank the members of my advisory committee, Drs. R. de von Flindt, T. P. Hogan, J. McIntyre, and M. W. Wright, for their constructive advice and help throughout the various stages of the research. I would also like to express a deep sense of gratitude and appreciation to the Chairman of my dissertation committee, Dr. Vincent DiLollo. His constant support, enthusiasm and extraordinary generosity with both his time and effort were instrumental in the successful completion of this project.

Throughout the research, I have had the opportunity to explore ideas and receive valuable feedback from two particularly able colleagues, Drs. Dan Harper and Garry Hawryluk. The discussions with Garry and Dan have contributed significantly to improving the final product and I sincerely wish to thank them.

I would also like to express my appreciation to Mr. Bob Scarth of the Fort Garry School Division and to the school principals who carefully screened and recommended potential subjects for the study. Messrs. T. Angus, D. Biggs, B. Hasker, F. Olsen, and D. Wilson were particularly helpful in this respect.

My wife, Anne, has contributed an unusual amount of time, effort, and support both in the preparation of this work and throughout my graduate education. I cannot thank her enough for this and for her consistent encouragement and faith in me.

I also wish to thank Mrs. Carol Dueck for her very helpful technical advice on preparing the dissertation.

Finally, I would like to express my appreciation to Dr. Robert Martin who, although on sabbatical in Scotland, took time to read the manuscript and provided a great deal of encouragement throughout the research.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

INTRODUCTION

Selected History and Theories of Reading Disabilities

The study of reading disabilities has been approached from a variety of perspectives over the last eighty years and yet many of the fundamental issues outlined very early in research appear to be the same issues persisting today. While significant progress in understanding the reading process has been made, the richness and diversity of what encompasses reading and the multitude of factors which appear to influence its acquisition and functional integrity have mitigated against any single comprehensive explanation of the process. The intention of this section is to review a representative sample of the literature in order to elucidate the fundamental issues and the basic findings.

James Hinshelwood (1895), an opthalmologist, was among the earliest workers to publish an account of reading disability without any clear neurological abnormality in one of his patients and he entitled this work "Word-Blindness and Visual Memory". This account drew the attention of Pringle Morgan (1896), a general practitioner, and prompted him to report in detail the case of a fourteen year old boy who appeared incapable of learning to read despite at least average intelligence, good health and coming from an adequate family and educational background. The boy's disability was limited to reading rather than generalized across all academic areas and it was believed by his teachers that his school performance would have been exceptional were instruction entirely oral. Because of the lack of any history of brain injury or neurological illness, Morgan concluded that this must indeed have been a case of "congenital word blindness". He further believed that the fundamental basis of the disability was most probably due to defective development of the left angular gyrus, disease of which often results in reading difficulties in adults.

Further evidence of specific reading disability in otherwise healthy and intelligent children was presented by Kerr (1897) who stressed the finding that reading problems were not the sole province of the "dull" but also affected the "mentally exceptional" as well. Later Hinshelwood (1917) published his now classic monograph which summarized several years of research and follow-up on children manifesting reading retardation. In this work, he provided a detailed description of symptomatology and noted the close parallel between these symptoms and those found in cases where the deficits were the result of brain damage. Hinshelwood, like Morgan, concluded that the condition was caused by some developmental agenesis in the left angular gyrus rather than the result of brain damage or disease.

Around this period of time, many similar observations of disability were made by other investigators and their conclusions appear to have formed the basis for the later development of a variety of theories of causation of reading disorders. For example, Stephenson (1907) observed and reported reading disabilities in several members of one family over three generations which led him to conclude that an hereditary component was involved in dyslexia. Fisher (1910), on the other hand, believed that "word-blindness" was the result of brain damage and suggested that birth trauma might have been the causal factor. Claiborne (1906) similarly believed that reading disability was due to brain damage in which the lesion was of congenital origin and probably consisted of imperfect development and tardy reaction of the "word and letter memory cells".

An overview of this early literature relating brain processes and reading disabilities appears to suggest general agreement with respect to an organic basis of one sort or another for the condition as well as some degree of agreement regarding the involvement of the left angular gyrus in reading disabilities. Another interesting and fundamental point worthy of consideration involves the apparent line of reasoning employed by these early workers in the formulation of their hypotheses concerning an organic basis for reading retardation. They suggested that it was appropriate to speculate about the causation of reading disorders by drawing an analogy between those who failed to acquire the ability to read and those who lost this ability through injury or disease. Indeed, Naidoo (1972) pointed out that this analogy continues to lead many researchers to the investigation of neurological anomalies in children with serious difficulties in learning to read. While this strategy is not necessarily inappropriate, it appears important to note that this approach may quite easily lead to the questionable assumption of a unitary and homogeneous cause for all reading difficulties.

Thompson (1966) noted that many psychologists were also among the early contributors in studying the reading process although they did not tend to focus on reading disabilities per se. Such individuals as

Wundt, Cattell, Javal, Erdmann and Dodge conducted more basic research relating to the eye and to the mechanics of the reading process. However, by the early 1900's many of the educational psychologists had become interested in studying reading disabilities. As might be expected on the basis of their differing training and responsibilities, the focus of their work was in several respects more diversified than that of the early medical investigators, with most attention paid to reading tests, methods of teaching, eye movements and the psychology of reading. The diversity of interest and those factors believed to influence reading were exemplified by Gray (1921) in a paper in which he proposed several potential causes of reading disabilities. Among those factors he noted were irregular school attendance, poor physical health, malnutrition, psychological disorders, nationality, inappropriate methods of instruction, visual, vocal, and auditory deficits, as well as brain damage. In addition, he proposed another series of causes which he referred to as"psychological" in nature which included general mental incapacity, inadequate attention to meaning, limited eye-voice span, inability to remember new words and an inability to analyze and pronounce words.

Another psychologist, Augusta Bronner (1917), who was associated with the first child guidance clinic, studied the reading process and reading disabilities extensively and concluded that acquired brain damage was not characteristic of the majority of reading disabled children. She stressed the importance of various perceptual and cognitive factors in reading such as (a) perception and discrimination of forms and sounds, (b) associating sounds with visually perceived letters, names with groups of symbols, and meanings with groups of words, (c) memory, motor, visual and auditory factors, and (d) the motor processes used in inner speech and reading aloud. She thought that reading performance was dependent on some synthetic process uniting all these separate elements and advocated an analysis of the mental processes on an individual level in dealing with those unable to learn to read.

Gibson and Levin (1975) observed that the focus of psychological research on reading changed significantly after around 1920 as the research emphasis shifted from fundamental investigations of the reading process itself to comparisons of the relative values of different methodological approaches to teaching reading. They described this period as the beginning of the dabate on the "phonics" versus "whole-word" approach to teaching reading and noted that curriculum research, in contrast to more basic research, still characterizes much of the work by educational psychologists studying reading.

In this regard, Gibson and Levin noted that teaching methods per se have often been considered by both professionals and lay people alike as the primary cause of many reading disabilities suffered by children. Quite frequently the debate has centered on whether phonics, which stresses the mastery of word elements, is more or less effective in learning to read than a whole-word method, emphasizing a "look and see" sight vocabulary approach. The struggle has gone on with varying degrees of intensity and with different approaches appearing to dominate for periods of time. However, Gibson and Levin concluded that after over forty years of intensive research into the most effective method of instruction very little has been clarified and for every series of studies proposing the superiority of one approach over another there seem to be an equal number of contradictory studies. Gray's (1957) conclusion that not all children and adults learn equally well by any given method is worthy of noting here. He maintained that this very fact indicated the significant involvement of other factors in learning to read which were perhaps just as important as the method of instruction itself. He suggested the importance of such factors as the personal characteristics of the teacher, the home and the school environment as well as the varying abilities and other unique characteristics of the learners themselves.

Another series of factors bearing some degree of relationship to and most likely interacting with educational factors involve the conditions of cultural and communicative-emotional deprivation (Gibson and Levin, 1975). Under these circumstances the lack of proper and adequate stimulation for language acquisition in the early social environment is believed to be a significant cause of language disability. For example, the existence of a poor mother-child relationship due perhaps to anger, disinterest or frequent absence on the part of the mother, might well result in poor and inadequate verbal communication between parent and child. A study by Bannatyne (1971) demonstrated that early deprivation of communication between a mother and child could result in the child's failure to acquire and develop good language skills. It was also suggested that this type of communicative breakdown resulted in deficits in the child's motivation to learn language-related tasks which further predisposed him to developing reading difficulties later.

In this regard, the work of Pringle (1965) indicated that partial or complete separation of the child from his parents in early childhood had a profound effect on the child's emotional stability and linguistic development. More specifically, those children who were removed from their parents at an early age and who had little or no contact with them were more retarded in intellectual and linguistic development and in reading achievement than were those children who were removed later and hence were less seriously deprived of parental contacts. In addition, reading comprehension was more seriously affected than word recognition suggesting that the more advanced processes of reading were more seriously affected than the earlier stages. One general impression that emerged from this work was that the motivation to attend and to concentrate and work both purposefully and energetically was impaired rather than the basic capacity to learn to read.

A culturally deprived environment has also been regarded as a serious and primary cause of reading disabilities. Basically, it is thought that such an environment fails to provide the child with the proper stimulation and pre-reading experiences which are prerequisites for acquiring those skills in early schooling which, in turn, are necessary for learning to read later. The study by Bannatyne (1971) referred to earlier indicated that an impoverished environment often differed from one more culturally privileged in its lack of talk containing references to logical relationships, which are important in learning in the school situation. Thus, children from a culturally deprived environment often appeared to be unprepared to learn many abstractions that are typically required in the academic sphere. This problem would be further compounded if the child attended schools which did not provide adequate enriching or remedial attention or which tended to gear their instruction to the culturally more privileged child (Gibson and Levin, 1975).

Another factor with both cultural and educational implications relates to the potential effect of the lack of an appropriate model in the classroom with whom the child may identify. In this view, modeling is believed to be an important element in encouraging the child to learn to read and a teacher of a different sex, race, social status, etc., relative to the child, may seriously diminish the teacher's effectiveness as a role model. Gibson and Levin (1975) argued that this factor was responsible for the large number of reading deficient boys relative to girls in the United States. They wrote, "it appears to be the case that the high ratio of dyslexic boys to girls in the schools of the United States is mainly the result of a high ratio of female to male teachers in the primary grades" (p. 489). While this suggestion appears to represent both an oversimplification of the problem and an overstatement of the effect of the predominance of female teachers, it does stress the emphasis placed on cultural factors in reading retardation.

Another cultural factor often regarded as being of crucial importance in subsequent reading achievement concerns the accessibility of books and other reading materials in the home as well as the observation of someone in the home actually reading. Morris (1966) showed that significant differences existed between good and poor readers and the number of adult books and magazines in the home as well as the frequency of parental membership in public libraries.

In addition to the potentially detrimental effects of a parent-child communicative disruption and educational deficiencies, Thompson (1966) observed that emotional blocks and inhibitions are frequently seen as the fundamental factors underlying language disabilities. From a psychoanalytic viewpoint, Pearson and English (1937) expressed the view that reading difficulties were an attempt on the part of the child to solve psychic conflicts. They maintained that reading might have been one subject stressed by a "hated parent" and in which the child, unable to express his antagonism to the parent openly and consciously, did so indirectly through refusal to learn to read. An alternative hypothesis noted that reading involved the acquisition of knowledge through looking and postulated that if a child had been severely "inhibited" in his "peeping activities", all acquisition of knowledge through looking might have come under the "ban of the child's superego". The basic problem was not viewed as the inability of the child to learn to read as such but rather involved his fear to use his vision to acquire knowledge. The treatment of choice thus involved psychotherapeutic intervention aimed at treating the basic neurosis of which the reading disability was only a symptom. From the same perspective, Phyllis Blanchard (1946) suggested that reading disabilities in children were associated with the child's difficulty in handling the "aggression" involved in learning or looking into things "with a piercing eye". This "aggression" was believed to result in a considerable degree of guilt for which the child unconsciously sought punishment. The reading disability represented the symptom for which the punishment followed in the form of scorn both at school and at home.

Macdonald Critchley (1970) pointed out that by 1925 the study of reading disabilities was clearly no longer the unique responsibility of medicine and that psychologists and sociologists had entered the field. In addition, the hypothesis that reading retardation was fundamentally due to brain damage or structural maldevelopment was yielding under increasing pressure. Samuel Orton (1925), a psychiatrist and neurologist, published a paper which specifically disagreed with the view of Hinshelwood, mentioned earlier, that reading retardation was due to localized agenesis in the brain by stating simply that there was no solid evidence for such an hypothesis. Although he acknowledged that brain damage or maldevelopment certainly could result in reading deficiencies, the vast majority of poor-reading children he saw showed no conclusive evidence of brain damage in either their history or neurological examinations. Orton observed that the children shared many common symptoms (see J. L. Orton, 1957), among which he stressed the particular importance of two: confusion when attempting to remember whole-word patterns as well as confusion regarding the orientation of letters. To describe this syndrome, he coined the term "strephosymbolia".

In subsequent papers, Orton (1928; 1937) proposed to explain these symptoms and reading difficulties in general on the basis of the same fundamental principle. He maintained that each cerebral hemisphere contained "engrams" which were mirrored copies of those in the other hemisphere and that a failure in the "establishment of the normal physiological habit of using exclusively those of one hemisphere might easily result in a confusion in orientation which would exhibit itself as a tendency toward an alternate sinistrad and dextrad direction in reading and in lack of prompt recognition of the differences between pairs of words which can be spelled backwards and forwards such as was and saw, not and ton, or on and no, etc." (p. 715). Further, he believed that one outstanding characteristic of the cerebral patterns underlying language in the normal adult was that of the much greater physiological importance of one hemisphere than the other in language which he referred to as the phenomenon of "unilateral cerebral dominance". Orton went on to describe the failure to establish such dominance in reading-retarded children as evidence of a developmental lag rather than as a neuropathological or acquired disorder. He further maintained that such developmental delays or deficits might have genetic and hereditary components as underlying correlates.

Lauretta Bender (1958), who is generally credited with laying the groundwork for the view of reading disabilities as a slowed or delayed developmental phenomenon, followed up and elaborated on Orton's concept of developmental lag and described it as follows:

> It is based on a concept of functional areas of the brain and of personality which mature according to a recognized pattern longitudinal-wise. A maturational lag signifies a slow differentiation in this pattern. It does not indicate a structural defect, deficiency or loss. There is not necessarily a limitation in the potentialities and at variable levels maturation may tend to accelerate, but often unevenly. Again one has to use the concept of plasticity in the way the embryologists use the term, being as yet unformed, but capable of being formed, being impressionable and responsive to patterning and carrying within itself the potentialities of patterns which have not become fixed. This is also characteristic of a primitive state. It is this particular characteristic of developmental lags that effect such a variety of symptoms that defy classification and make it possible for each investigator to emphasize those factors that best fit his experience and theories (p. 227).

Vernon (1971) observed that the maturational lag theory has perhaps become the most commonly held causal theory of reading retardation with the majority of poor readers believed to be suffering from a failure in the normal maturation of certain functions of the cerebral cortex. It also carried with it the implication that primitive perceptual and cognitive processes which had disappeared in normal readers at a comparatively early age might persist until a later age in poor readers but then might finally fade away in them also.

Like earlier researchers, Satz and Sparrow (1970) noted that the behavioral pattern of deficits observed in poor-reading children was quite similar to that of adults who had sustained damage to the left cerebral hemisphere. They observed that this pattern often included right-left confusion, finger agnosia, writing difficulty, visuo-constructional impairment and depressed performance on verbal intelligence tests. However, they too noted the typical finding of an absence of brain damage or structural alteration in poor readers following extensive neurological assessment. Thus the analogy between patients with left hemisphere damage manifesting similar symptoms to poor readers ran into trouble. However, the utility of the analogy associated with a similar symptom pattern across both groups could be reconciled if the assumption were made that a delay in lateral hemispheric development might have affected the <u>acquisition</u> (in poor readers) rather than the <u>loss</u> (in those brain damaged) of those skills which required the abilities of right-left discrimination, finger differentiation, auditory-visual integration, etc. Thus, Satz and Sparrow proposed that poor readers suffered from delayed development involving the central nervous system and specifically the left cerebral hemisphere. They noted Lennenberg's (1967) neuroanatomic studies of the cerebral cortex indicating that the growth of the brain undergoes enormous structural, electrophysiological and biochemical changes during the first two years of life and that this growth pattern does not come to a close until around puberty. Further, these growth phases tend to correlate with developmental milestones in motor, somatosensory and language function. Reference was also made to Geschwind's (1968) paper relating brain maturation and ontogenic development in which he stated that the early myelinating zones include all the classic motor cortex and the primary somesthetic, visual and auditory cortices. Satz and Sparrow noted that these early myelinating zones have the most efferent and afferent connections with subcortical structures and the fewest long connections with other cortical areas. By contrast, the zones which myelinate latest, the "terminal" zones (i.e., the left angular gyrus), have prominent intercortical connections which are necessary in the mediation of more complex language and cross-modal integration skills.

The Satz and Sparrow theoretical position maintained that the maturational process in normal children is essentially an age-linked process with the maturation level being a function of chronological age. On this basis, a maturational lag was regarded as slow or delayed development of those brain areas which mediate the acquisition of developmental skills which are fundamentally age-linked. Thus, the deficit pattern seen in reading-retarded children, rather than representing a unique syndrome of disturbance, should more typically resemble the behavioural pattern characteristic of chronologically younger normal children who have not yet acquired mastery of skills which develop ontogenetically later. As such, the level of brain maturation in both younger normal and older poor readers was seen as less mature and differentiated. Therefore, the pattern of deficits within poor-reading groups would be expected to vary as a function of the age at which certain skills were undergoing primary development. As visual-motor skills are established ontogenetically earlier (age 7-8 years) (Piaget and Inhelder, 1969), a pattern of difficulty in this domain might be expected in the younger poor-reading children whereas difficulties in those functions such as language which develop ontogenetically later (Piaget and Inhelder, 1969) might be expected in older poor-reading children (age 11-12 years) who are assumed to be maturationally delayed.

Satz, Rardin and Ross (1971) conducted an experiment based on the above theoretical position. More specifically, they hypothesized that skills which develop ontogenetically earlier (e.g., visual-motor and auditory-visual integration) would be more delayed, relative to age-matched controls, in younger poor-reading children (age 7-8 years) while skills which develop later (e.g. language skills and formal operations) would be more delayed, again relative to age-matched controls, in older poor-reading children (age 11-12 years). The results, using reading disabled and control children matched at two different age levels (7-8 and 11-12 years), were found to be basically in agreement with the a priori hypotheses and the general theoretical position outlined by Satz and Sparrow (1970).

Critchley (1966), another proponent of the maturational lag viewpoint, regarded reading retardation as a manifestation of a genetically determined constitutional delay in maturation. As a neurologist, he did not accept the idea that a mild or minimal degree of structural brain damage was primarily responsible for the condition and regarded the "soft" neurological signs (e.g. visuo-spatial deficits, lack of established cerebral dominance, right-left confusion, etc.) as evidence of cerebral immaturity. In his paper, Critchley raised the important and interesting question as to why, if reading retardation was due to a delay in maturation, it did not simply correct itself over time. He responded to this question by suggesting the possibility that there existed critical learning periods for some of the processes involved in reading or, alternatively, that viable opportunities for learning to read may pass quickly. Di Lollo (Note 1) offered an alternative conceptualization. He suggested that a reading-retarded child may have developed a particular strategy of reading which, while perhaps both inefficient and relatively ineffective, may, nevertheless, have been the best approach available at the time, given his maturational state. Later, following maturation and the availability of more efficient strategies, the child may have continued to utilize the less efficient and less productive strategy out of habit rather than necessity.

Before concluding this selected presentation of historical trends and theories of causation of reading disabilities, it is necessary to note the genetic and minimal brain dysfunction perspectives. As mentioned earlier, Stephenson (1907) felt strongly that hereditary factors were of considerable significance in reading disabilities. More recently, Hallgren (1950) presented data on a study of over 200 poor-reading children and their families in which he showed a relatively high degree of concordance between reading disabilities in the children and disabilities in parents, siblings or other relatives. Further, Doehring (1968) found that 40 per cent of the parents of a reading-retarded group of children had themselves experienced reading problems as compared to a 10 per cent rate of similar problems among the parents of a control group of normal-reading children. Citing Hallgren's (1950) data, Hermann (1959) argued that an hereditary component was suggested on the basis of the differing rates of occurance of reading retardation between monozygotic and dizygotic twins. He noted that out of three sets of monozygotic twins, all six children were poor readers whereas out of another three sets of dizygotic twins in only one pair were both children found to be reading-retarded. In a more recent and comprehensive study, Bakwin (1973) presented additional support for Hermann's contention. After studying 338 pairs of twins, it was found that monozygotic twins were alike in reading disability in 84 per cent of the cases while dizygotic twins were similar in this respect in only 29 per cent of the cases.

While the above data are consistent with genetic involvement, there appears to be little general agreement concerning the specifics of genetic transmission other than that a polygenetic mode is probably involved. In this regard, Critchley (1970) suggested that reading retardation was possibly a sex-linked genetic disturbance because of the high incidence of reading disabilities in males. However, Gibson and Levin (1975) presented data on the cross-cultural incidence of reading disabilities which suggested that Critchley's interpretation should be regarded with caution. They noted that while reading disabilities were much more common in males than in females in North America, France and Japan, the reverse appeared to be the case in Germany, Nigeria and India.

Another commonly mentioned cause of reading disabilities is Minimal Brain Dysfunction (MBD) which implies an alteration in the functioning of the central nervous system without specifying its location or nature and which is not necessarily the result of injury (Wender, 1971). In general, the symptoms typically noted in defining the syndrome consist of perceptual deficits, motor incoordination and other "soft" neurological signs. By and large, most of the symptoms of Minimal Brain Dysfunction have been observed and reported before within the context of other more specific theories of causation of reading disorders (e.g. Satz and Sparrow, 1970; J. L. Orton, 1957). The fact that this is so in addition to the relatively vague definition of Minimal Brain Dysfunction in terms of etiology raises some question as to whether or not the perspective represents a distinct theoretical position providing a unique viewpoint or advantage.

Not infrequently, the terms minimal brain <u>dysfunction</u> and minimal brain <u>damage</u> are used interchangeably. The minimal brain damage position maintains that some degree of cerebral damage does indeed exist and is responsible for a variety of learning disabilities. However, the damage is held to be subtle and often very difficult if not impossible to detect by standard testing procedures. Further, the hypothesis frequently cites the previously noted "soft" neurological signs as evidence of its existence. This position has been criticized a number of times (e.g., see Critchley, 1966) primarily on the basis that careful neurological tests have failed to provide any evidence of even slight brain damage. However, the counter argument typically questions the sensitivity as well as the nature of the usual neurological testing approach, often suggesting that it is too gross to detect minimal brain damage which may have significant, although perhaps subtle, cognitive manifestations without yielding any "hard" neurological signs. The important point here is that while minimal brain damage may well represent a sufficient condition for reading retardation, it is not, in all probability, a necessary condition.

Overview of the Literature on Causation of Reading Disabilities

Perhaps the most striking initial impression concerning the above literature on causation of reading disabilities is the large number of causes proposed by various investigators to be of primary significance as explanatory concepts. In general, most of the proposed causes may be differentiated as either "intrinsic" or "extrinsic" on the basis of the perceived origin of the difficulty (Applebee, 1971). In this regard, extrinsic causes are conceived of as being basically external to the individual and generally include such factors as the home environment, educational opportunities, cultural environment, etc. On the other hand, the intrinsic factors relate specifically to the individual and represent his own unique talents, abilities, and limitations. By way of example, intrinsic factors include such considerations as the unique genetic, neurological, developmental, intellectual, etc., status of the individual. In general, the fact that reasonable evidence exists in support of both these general positions appears to mitigate against the attribution of all reading disabilities to any unitary cause, be it cultural, educational, psychological or organic (including structural and developmental causes).

It is evident that several of the theories of causation are not necessarily mutually exclusive and that a conceptual approach capable of providing a unifying view in the area of reading disabilities would be desirable. With this in mind, it does not appear unreasonable to conceptualize deficiencies in the reading process outlined by the various theories of causation within the context of an information processing viewpoint. In this regard, Geyer (1972) outlined a number of information processing models of the reading process. This position does not imply a unitary cause for such disabilities and, in fact, such a framework appears tenable on the basis of a number of causation theories. For example, the processing of orthographic structure could be slowed or prevented entirely on the basis of inadequate maturation of the required mediating processes or structures. Cerebral agenesis or damage might result in similar effects by assuming the absence or structural alteration of the analogous mediating structures. Further, cultural and educational deprivation (extrinsic factors) may result in delayed processing characteristics in deprived children relative to non-deprived children perhaps on the basis of differences in familiarity and experience in recognizing the significance of and abstracting the meaning from orthographic material. Further, such alteration of information processing could conceivably occur at any number of different stages or levels of processing such that in some cases information processing might be disrupted at very early stages of visual input while in other cases processing might be affected later on in the sequence of events. This viewpoint is not an attempt to provide another cause of reading disabilities but rather to provide a broad framework within which reading disabilities might be systematically explored.

Current Status and Methodological Considerations

There exists today general agreement among the various professional disciplines dealing with reading disabilities that these difficulties represent a significant problem with serious personal, social, educational, and economic consequences. Indeed, Park (1968) noted that reading difficulties have been *the* major cause of school retardation with more children failing grade one than any other grade, and with most of the difficulties due to reading problems. Estimates of the actual incidence of disabilities cover a wide span but appear, on average, to range from about 10 per cent (Bateman, 1966) to 25 per cent (Gibson and Levin, 1975). As has been shown, the history of research in reading disabilities represents an extensive and diverse collection of work by researchers with widely different theoretical orientations, training and interests. However, the fundamental conceptual and methodological issues transcend the specific problems and interests of the various disciplines and the discussion will now focus on some of those issues.

Certainly, one of the most basic issues in reading concerns precisely what is meant by the term itself. Applebee (1971) noted that there are several aspects to reading such as oral reading, silent reading comprehension, and reading speed and that they show only a moderate degree of correlation with one another, suggesting that different processes may underlie each of these separate aspects of reading. Thus, in any reading-related study, it is important to specify the particular process or processes under investigation and to outline the means by which a disability is to be defined.

Applebee (1971) pointed out that the specific means of defining reading disabilities have varied somewhat depending on professional discipline with educators, physicians, and psychologists providing somewhat different emphases. Educators have most frequently focused their definition of reading retardation on an individual's level of achievement with respect to his actual grade placement with a "serious" reading disability constituting achievement approximately two or more years below grade level. Generally, the achievement level itself has been determined by performance on local or national reading tests or by the student's ability to adequately handle graded material presented in the classroom or by some combination of both procedures. Physicians, in addition to generally adopting the educational definition in principle, have also tended to focus on the "soft" neurological signs as a more or less unified collection of symptoms presumably due to a more fundamental underlying cause requiring treatment. Psychologists have drawn from both educators and physicians and have tended to specify reading disabilities in terms of the number of years behind while also focusing on symptom syndromes of an emotional, intellectual and physiological nature. In practice, the most commonly employed approach to defining reading disabilities has been to focus on the number of years a student's achievement level is behind his actual grade placement level or the degree to which performance is below the performance of classmates.

Irrespective of theoretical and professional orientation, Applebee (1971) pointed out that there has been a remarkable degree of consistency in the general methodological approach to studying reading disabilities. Most typically, the research paradigm has consisted of a sample of retarded readers to be contrasted with a sample of normal readers in an effort to determine whether or not significant differences exist between the groups. In the course of research, a considerable number of variables have been found relevant to reading performance (e.g., age, sex, I.Q., presence of serious psychopathology, neurological and sensory status, cultural background, instruction opportunities) and Eisenberg (1966), in an attempt to provide an adequate definition of the research population, recommended that specific reading disability be operationally defined as the failure to learn to read with normal proficiency despite conventional instruction, a culturally adequate home, proper motivation, intact senses, normal intelligence and freedom from gross neurological defect.

In addition to those factors noted above, a wide variety of additional variables have been studied with researchers usually employing one of two general experimental control procedures to deal with the known or suspected relevant variables. One form of experimental control employed in an attempt to achieve sample homogeneity has been to apply stringent standards for admission to the research populations from which the subjects were to be drawn. Following this approach, those with sensory, neurological, intellectual and other deficits have frequently been excluded from participating as subjects in reading research unless those specific variables were under study. The alternative general approach to control has involved an attempt to take into account the known or suspected relevant variables in the process of defining "expected" reading achievement, thus modifying the reading criterion itself. Applebee (1971) noted that either approach to control was legitimate as long as it was remembered that those variables which were controlled were not intrinsically of less importance in understanding reading retardation than those which were not controlled. Furthermore, the fact that not all researchers have controlled the same variables has resulted in a somewhat constantly shifting definition of the research population, thus complicating comparisons among studies of reading retardation.

A Model of Visual Information Processing and Reading

The fact that the very early stages of reading appear to be primarily visual in nature raises a question concerning the relationship between early visual information processing and reading disabilities. In fact, the suggestion that many reading disabilities have a basis in deficient visual information processing is a frequent hypothesis in the reading disabilities literature (e.g., Gilbert, 1959; Lyle and Goyen, 1975; Stanley and Hall, 1973). However, this does not, of course, imply that all detected reading problems have such a basis or that a unitary cause underlies all such deficiencies.

Viewing reading from a visual information processing perspective highlights the desirability of a general theoretical model within which the relatively early stages of the reading process might be broadly conceptualized. Di Lollo (1977) presented such a general framework in the form of a two-state visual information processing model which outlined the sequence of events and the manner in which the visual system deals with or processes incoming information.

The model assumes that perception of form occurs over time and emerges from a number of information processing operations on the visual display. The operations involved are broadly categorized into two successive phases of sensory coding (recruiting or "feature encoding" and interpreting or "meaning encoding") with the primary function of each phase being to produce a new level of sensory coding of the stimulus display. Ultimately, the purpose of the processing sequence is to reach a level of coding which permits comparison between the newly encoded stimulus and other long-term memories.

The first stage of coding (processing) is concerned with a feature abstraction process in which precategorical features such as dots, bars, edges, curves and angles emerge but remain unidentified. In this first stage, it is held that all parts of the visual display are processed simultaneously in parallel and that by the completion of this stage these parts have been feature-encoded. It is further maintained that only in this initial stage are the parts of the display, which are simply feature-encoded, subject to the "erasure" effects of a masking stimulus.

By the completion of the first processing stage, the feature-encoded parts of the display become available to the second stage of information processing where the operations of identification and categorization are postulated to take place. Processing in stage two is believed to be serial rather than parallel with those parts at the extremeties of the display taking precedence to those in the middle.

By the end of stage two, it is held that the display parts are meaning-encoded and that they are potentially available for more permanent forms of memory storage. Further, those display elements which have been meaning-encoded are not believed to be subject to masking.

Di Lollo (1977) observed that his proposed processing model basically agreed with other two-stage models of short-term visual memory (e.g., Sperling, 1963; Neisser, 1967) except with respect to the role of sensory persistence. It has been commonly assumed in visual information processing models that a visual representation of a presented stimulus display remained perceptually available (or persisted) for a brief period of time beyond the actual physical duration of the stimulus. This iconic or brief visual storage process has generally constituted the initial stage of information processing in most theoretical models and presumably permitted additional time for the processing of stimuli which might otherwise have been too brief to have been acted upon by the visual system (Di Lollo, 1977).

The fundamental point of departure between Di Lollo's model and other models concerns the nature of the mechanisms and processes underlying sensory persistence. The typical view has assumed that sensory persistence began at the <u>termination</u> of the presented stimulus and faded relatively rapidly thereafter while Di Lollo maintained that sensory persistence began at the <u>onset</u> of the stimulus presentation and continued for a limited duration and only outlasted the stimulus display if the display was less than a given maximum duration (about 100 msec) measured from stimulus onset. Further, Di Lollo viewed sensory persistence as being produced by the activity of sensory mechanisms engaged during the initial phase of information processing with persistence continuing while the mechanisms were active and ceasing as soon as the stimuli had been feature-encoded at the end of this initial phase. In this regard, he noted that the most significant departure of his model from iconic storage models was "in the assertion that sensory persistence should be identified with the activity of sensory coding mechanisms within the visual system and not with the contents of a static sensory store" (Di Lollo, 1977, p. 24).

Considering the Di Lollo model, it is conceivable that reading disabilities may result from deficiencies in those operations associated with either level of sensory coding and that it is theoretically possible to assess the level at which such deficits do in fact occur in the individual. In this view, for example, disability may originate in some cases at the feature-encoding level while in other cases it may occur at the level of meaning abstraction.

Visual Information Processing and Backward Masking

Since the present study in part involves assessing the rate of visual information processing, it is necessary to briefly review the fundamental principles of backward visual masking by visual noise. The relevance of this type of visual masking in the present work relates to the fact that this procedure has been widely regarded as a tool for the analysis of temporal parameters of visual information processing (Haber & Hershenson, 1973).

In his review of the literature in visual backward masking, Scheerer (1973) noted that the perception of a briefly presented visual test stimulus (TS) is impaired if a second visual stimulus (masking stimulus, MS) follows the TS in close temporal contiguity. This experimental situation is referred to as backward masking. In the typical backward masking by visual noise experimental paradigm, a TS composed of a number of elements (e.g., letters) is presented and then followed by a pattern of random contours which are evenly distributed over the exposure field (visual noise). The temporal delay between the TS and MS is varied and accuracy of observer performance as a function of the MS onset delay is measured. The delay between the TS and MS is often specified in terms of the stimulus onset asynchrony (SOA) which indicates the temporal interval between the onset of the TS and onset of the MS. However, the delay is also frequently reported in terms of the interstimulus interval (ISI) which represents the temporal delay between the TS offset and the MS onset. The results of this type of study typically show a monotonic rise in accuracy as SOA increases (Sperling, 1963) with accuracy rising steeply for SOAs up to 75 msec and levelling off for longer SOAs, reaching a no mask control level between 150 and 400 msec, depending on experimental conditions (Spencer, 1969).

Regarding the nature of the mechanisms underlying backward masking, two general theoretical approaches have been advanced. Sperling (1963) proposed an interruption theory of backward masking by visual noise which fundamentally postulated that when the TS is followed closely in time by the MS, the MS replaces the TS in the visual short-term store thus interrupting the processing of the TS. Therefore, the sensory persistence and thus the time available for processing the TS is limited to the SOA between the TS and MS. This position assumes that the central representation of the TS is fully developed when the MS arrives and thus the only effect of the MS is to limit the time that the TS representation is available for processing. The alternative approach attempting to explain backward masking by visual noise is integration theory which was first put forward by Kinsbourne and Warrington (1962). It basically maintains that the central representation of the TS is degraded and thus rendered difficult to clearly perceive as the TS and MS become integrated into a composite percept due to the overlap between the contours in the TS and those in the MS.

Scheerer noted that much of the past literature in backward masking by visual noise had been conducted on the belief that the masking effects should be explained by a single premise across the whole range of SOAs. However, he argued that a careful analysis of the literature made appropriate the adoption of a dualistic explanation such as the two-factor theory outlined by Spencer (1969) and Spencer and Shuntich (1970).

Spencer's two-factor theory maintained that at relatively short SOAs backward masking was caused by integration and consequent TS degradation while with longer SOAs a backward MS produced its effect by interrupting TS processing. However, the "critical" SOA where integration gives way to interruption is lacking and may be expected to vary with both exposure conditions (contrast and energy of TS and MS) and with processing load (e.g., the number of elements in the TS). In this regard, Bachmann and Allik (1976) also noted that the temporal boundary between the two components of backward masking by visual noise is specified differently by different authors and ranges from about 30 to 150 msec and more.

In assessing visual processing rate, the interruption model has been heavily relied upon to theoretically justify the use of visual backward making with visual noise as a technique for controlling the time available for processing the TS. For example, from an iconic processing model viewpoint, the elements composing the TS are generally thought to be abstracted wholistically by a parallel process and maintained in the visual short-term store (or icon) as a virtual copy of the distal stimulus. Then, over time, the information in the relatively large capacity but short-lived visual short-term store is transferred (read out) into a more durable but smaller capacity store called the short term memory. The short term memory is believed to be capable of being strengthened by rehearsal processes and endures long enough for subsequent decision-making and responding (Gummerman & Gray, 1972). In this view, the amount of information reported by subjects in backward masking experiments represents an index of the amount of information transferred from the visual short-term store to the short term memory prior to the fading (or disruption by a MS) of the visual short-term store. However, since information is believed to be read into short term memory from the visual short-term store, it is possible that equivalent performance might occur in individuals who possessed either long visual short-term store duration combined with a slow transfer rate or brief visual short-term store duration with a very rapid transfer of information to short term memory. Therefore, in order to make an inference concerning the rate of information transfer (i.e., processing rate) it is necessary to hold the visual short-term store or icon duration constant via backward masking and then measure the amount of information transferred from the visual short-term store to the short term memory.

The Di Lollo (1977) model of processing outlined earlier does not maintain that a lasting visual representation of the TS is necessary in order to provide additional time for the visual system to act upon it. In fact, the model holds that a feature-encoded stimulus may be available for further processing despite its iconic representation having faded. However, it is believed that the processing of a TS can be disrupted by the presentation of a MS prior to the TS being meaning-encoded and hence a backward masking paradigm may be similarly employed in assessing the rate at which this occurs.

Reading and Information Processing

In their description of the skilled reader, Gibson and Levin (1975) observed the complexities and the multiplicity of processes involved in reading. They noted that the skilled reader is very selective, sometimes skimming, sometimes skipping, and at other times concentrating intensely. Further, he plans a strategy ahead of time, suiting it to his interests, to the material and to his purpose. Thus, the process as a whole does not only involve the stages of decoding and comprehending but also involves thinking, remembering, and relating what his eye is fixating on to what came before, what will come next and to his own experience.

While keeping this in mind, it is also important to consider that at the initial level of analysis in the reading process, the individual approaches a line of text by making a series of discrete eye fixations (which vary in pause duration on the order of between 120-

250 msec) on different parts of the line. The area of text falling on the fovea of the eye is seen most clearly during any given fixation and this area extends over about seven to ten letter spaces with a considerable reduction in acuity of the more peripheral areas (Gibson and Levin, 1975). Movement from one fixation point to another is generally by very rapid ballistic-like saccadic eye movements. Typically, these saccadic eye movements are from one novel part of text to another but often interspersed between them are so-called regressive saccades which are fixations back over areas of text previously perused.

Given this operational process in reading and considering the information processing and masking literature outlined above, it appears reasonable to question what might happen to the reading process if the rate of information processing were slowed or deficient. In this situation, information from fixations which had not yet been processed to a level immune to masking would be subject to disruption by the information taken in during subsequent fixations. Thus, the information from successive eye fixations might "erase" part or even most of the information abstracted from previous fixations, resulting at best in a fragmentary comprehension of the text. This description of events is consistent with a view of reading as a process involving abstracting and interpreting information derived from a number of fixations over time in the development of an overall understanding of a written passage. This does not necessarily mean, of course, that all information from previous fixations would be masked, as it is quite possible that at least some aspects from the text would be meaning encoded prior to the subsequent fixations. Clinical support for such a contention follows from the observation that poor readers are frequently able to report various details from a passage without possessing an overall understanding of it. It is also clear, from the temporal range of fixation pauses (about 120-250 msec), that such an explanation is tenable as visual backward masking clearly occurs within the general time framework of up to and in excess of 250 msec following a stimulus display.

The above line of reasoning relating reading, information processing and visual masking appears to have been first suggested as a possibility by Gilbert (1959). He maintained that "the fixation pause must be long enough in duration to allow time not only to see but also time to process the visual stimuli" (p. 11). He further suggested that individual differences in information processing might be a significant variable in reading and noted that "some readers may use part of their fixation time to avoid interference from a new stimulus during the period they need free for processing the visual stimulus. In other words, part of the fixation time may be preventive in nature" (p. 12).

This approach does not represent an attempt to provide a comprehensive unitary explanation for all reading disabilities on the basis of processes involving only the early stages of visual information processing. Nor is it minimizing the importance of possible deficits in other phases of information processing such as, for example, mislabelling in oral encoding as suggested by Vellutino, Steger and Kandel (1972). On the other hand, however, it would appear that deficiencies at the early stages of visual information processing might well set the limit on the information available to other later phases of information processing pertinent to reading.

Detailed research following this specific conceptual approach is comparatively recent with the most directly relevant work to the present study having been reported by Gordon Stanley and his associates in Australia. Stanley and Hall (1973) noted the relevance of information processing concepts in the study of reading disabilities and explored possible differences in functioning between poor readers and normal-reading children at the early stages of visual information processing. The principal concern of their work focused on the properties of the visual short-term store and the transfer of information into short term memory.

Stanley and Hall studied 66 children between the ages of eight and twelve years with 33 being poor readers (mean age 10.88 years) and 33 serving as controls (mean age 10.52 years). The children came from four different schools in the Melbourne area with each school having a remedial reading teacher who selected the poor readers based on four criteria: (1) specific reading disability of 2.5 years or greater; (2) average or better functioning in other school subjects; (3) no gross behavioural problems and (4) no evidence of organicity. The controls were selected by their class teachers as being "average to bright" students who were performing in school at least equal to grade placement in reading.

The researchers first attempted to measure the visual short-term store duration (as a measure of sensory persistence) in the good and poor readers by employing a two-part stimulus integration task. The stimuli (Appendix A, Figure 1) were of two parts, consisting of the letters N and O, the two halves of a cross and a cross surrounded by a square. The procedure involved sequentially presenting the display on the left, first, for 20 msec, followed at various interstimulus intervals (ISIs) by the display on the right. The two parts of the stimuli were spatially adjacent or superimposed so that at brief intervals between their presentations the N and O were perceived as a composite, as were the components forming the cross and the cross surrounded by the square. The ISI between the stimulus presentations commenced at 20 msec and increased in 20 msec steps until the response criterion was reached. The two dependent variables (response measures) were (1) the ISI at which the subjects <u>first</u> reported the display as not consisting of a composite figure and (2) the ISI at which the subject correctly identified the two parts of the display on three successive presentations. The first criterion response measure was taken as a measure of the visual short-term store duration. Thus, if the duration of sensory persistence was indeed longer in one group, it would be expected that the appearance of separation would occur at longer ISIs in that group as the sensory image of the display presented first would be perceptually available for a longer duration. In this sense, that group would be better able to "bridge" the gap (ISI) between the successive display presentations.

The results indicated significant performance differences between the groups with respect to both the separation and identification tasks. The poor readers as a group were found to have an approximately 30-50 msec longer visual short-term store duration than the controls. Further, the fact that the poor readers took almost twice as long in terms of mean identification ISI suggested to the authors that their scan and retrieval processes were slower than those processes in the controls.

However, acknowledging that the identification task was not a particularly satisfactory measure of transfer and processing rate, Stanley and Hall adopted a backward visual masking paradigm as a means of studying the possible differences in the relative visual information processing rates between the two groups of children. Two backward masking tasks were employed. In the first task, dots arranged to form the consonants C, F, H, J, K, M, R and S were presented on a cathode ray oscilloscope screen for 20 msec and then followed by a dot mask pattern also of 20 msec duration. In the second task, the vowels U and O were similarly presented for 20 msec individually and were also followed by the 20 msec duration dot mask pattern. In both tasks, the ISI between the TS and MS commenced at 20 msec and was incremented in 20 msec steps until a criterion of three correct letter identifications at a given ISI was reached. The children were informed that a letter would be presented on the oscilloscope screen and would then be covered by dots and that their task was to report what the letter was.

The results of this part of the study indicated that, with both the consonant and vowel tasks, the poor readers mean ISI for correct identification was significantly longer than that of the controls. Thus, it was concluded that the reading-deficient children's rate of information processing was relatively slower than that of the controls.

Evidence that the impairment found in the poor readers studied by Stanley and Hall (1973) was not general across perceptual-cognitive tasks (at the original testing time) was reported by Stanley, Kaplan and Poole (1975). They compared the two groups of children on tasks involving visual matching with spatial transformation, tactual serial matching, auditory sequential memory, and visual sequential memory, the last two measures being subtests from the revised Illinois Test of Psycholinguistic Ability. All the children were tested individually and the order in which the tests were given was counterbalanced. Analysis of the data revealed that the poor readers performed as well as the controls on the visual matching with spatial transformation test and no differences between the groups on the tactual sequential matching test were found. However, both the visual and auditory sequential memory tests revealed significantly poorer performance in the reading-deficient group.

In a review of the above work, Stanley (1975) concluded that the evidence was consistent with the view that poor readers suffered from limitations at the early stages of visual information processing which specifically included longer visual short-term store duration and relatively slower processing rates than normal-reading controls. He also added that their "confusions may result from eye movements feeding new information into the visual system before the old information has been processed or masked. Thus there may be some overlap of visual information in storage" (p. 297). However, he cautioned that while his results were encouraging, more research was necessary to substantiate and clarify the deficits in visual information processing in poor readers suggested by his data.

While the above research suggesting differences between poor and normal readers in both sensory persistence and information processing rate is encouraging, the criterion response methodology employed raises some questions concerning interpretation of the findings. As has been noted, the measure adopted as indicative of the visual short-term store duration was the ISI at which the children first reported the display as not consisting of a composite figure. Similarly, in the masking tasks, thought to provide a measure of the relative rates of information processing, the dependent variable was the ISI between the TS and MS at which the children correctly reported three letter identifications consecutively. The interpretive difficulty relates to the possibility that the poor readers, quite probably exposed to the negative effects of failure in the past, could have adopted a more conservative response criterion than the controls. If this were the case, they might have waited longer until they felt more assured about the correctness of their answers before responding in the separation and masking tasks. This situation would have tended to artificially inflate both the separation ISI and the ISI between the TS and MS in the masking paradigm required to meet the criterion, quite possibly irrespective of the maximum performance capabilities of the children.

It would seem that a forced-choice experimental paradigm would be more appropriate in assessing the performance capabilities per se of the subjects. That such a methodological question may be an important consideration is suggested in a subsequent study by Stanley (1976). Again using a backward visual masking paradigm, he compared two groups of poor readers and a control group of normal-reading children in their rates of processing single digits. The two experimental groups (ranging in age from 8-10 years and from 9-12 years, respectively) and one control group (ranging in age from 9-12 years) were selected basically according to the criteria outlined earlier by Stanley and Hall (1973). The stimuli consisted of ten digits from zero to nine which were composed of single dot elements from a 5 x 7 element matrix with the mask consisting of a 35 element dot matrix which was spatially superimposed on the digit at varying ISIs. The design involved displaying a digit on an oscilloscope screen for 20 msec followed by the mask for 20 msec at ISIs of 8, 16, 24, 32, or 40 msec. In the procedure, the children were individually tested and provided with 10 response buttons, each of which was labelled with one digit ranging from zero to nine. They were instructed to press the appropriate button to indicate which number appeared on the screen. The children were further instructed to guess if they were not sure which number was presented with the provision that they were not to press the same button each time they guessed.

The results of the experiment showed that while the two experimental groups did not differ significantly from each other, they both performed at a higher level than the normal-reading control subjects. Thus, the results suggested that poor readers do not process single digits at a slower rate than controls. Therefore, despite the strong similarities between the Stanley and Hall (1973) and Stanley (1976) studies (except for a forced-choice versus response criterion methodology) they arrived at opposite conclusions regarding the information processing rate in poor and normal-reading control children.

In addition, the Stanley and Hall (1973) work indicating a difference in visual short-term store duration between poor readers and controls was called into question by a more recent study by Stanley and Molloy (1975).

They employed a retinal painting task in which a narrow slit is made to oscillate in front of a stationary outline drawing, thus permitting only a narrow segment of the figure to be presented to the eye at any given time. At an appropriate rate of oscillation the whole figure appears to be present at once. However, if the sweep rate is too slow, part of the stimulus will no longer be perceptually available when the other part appears and hence a complete percept will not occur. In this sense, successive slices of the stimulus are "painted out" across the retina as the slit sweeps across the stationary form. It is held that the rate of the slit for which the whole percept is obtained is a direct measure of the visual short-term store duration. In the experiment, 30 poor readers and 30 control children (aged 8-12 years) were selected to participate as subjects according to the criteria outlined by Stanley and Hall (1973). The dependent variable in the study was the mean sweep rate required for the wholistic perception of the stimulus object which, in the present case, was a drawing of a camel. The results of the study revealed that the poor readers and controls did not differ on this measure of visual short-term store duration. In the discussion of their results Stanley and Molloy maintained that "retinal painting involves a different persistence effect to that commonly used as a measure of visual short-term storage" (p. 288), apparently, in part, on the basis of their failure to replicate the work of Stanley and Hall (1973). Stanley and Molloy further noted in the discussion, however, that using the same subjects in a two-part stimulus integration task, Stanley (1975a) was able to replicate the differences in visual short-term store duration between poor and control readers reported by Stanley and Hall (1973).

These apparently contradictory findings point out the desirability of additional research aimed at clarifying the situation with respect to the status of both sensory persistence and relative information processing rate in poor and normal readers. The importance of clarification in this regard has associated with it a considerable degree of practical potential as well as theoretical significance. If consistent differences between poor and normal readers do indeed exist at the early stages of visual information processing, and if they can be reliably detected by appropriate experimental procedures, it is not unreasonable to suggest that potentially powerful tools for early detection and possibly prediction of reading disabilities as well as for monitoring them over time would be available. Further, it is also conceivable that such a finding would have significant treatment implications as, for example, presenting text at a carefully controlled rate consistent with the individual's unique capacity to deal with such information.

Thus, the present research is ultimately aimed at meeting two of Applebee's (1971) three important goals in reading research. Namely, it is an attempt to determine the feasibility of the development of techniques capable of being employed to predict in advance which students will have difficulty learning to read and, second, in possibly being able to develop a model for remediation involving the individual student.

Before focusing direct attention on the general outline and expected findings of the present study, however, it is necessary to present an overview of the manner in which sensory persistence and processing rate vary as a function of age in children.

Developmental Aspects of Sensory Persistence and Processing Rate

Several studies have indicated that the variables under consideration in the present investigation (sensory persistence and processing rate) vary developmentally in children.

Pollock (1965) utilized a metacontrast masking paradigm to study the visual processing rate as a function of both chronological age and intelligence in normal children aged 7, 8, 9, and 10 years. The procedure involved presenting a mid-gray disk which was followed after various temporal intervals by a white ring mask which surrounded but did not overlap the disk. The children were instructed to say "yes" when they saw the disk and "no" when they did not. The results indicated a linear decrease in masking as a function of increasing age suggesting that relative processing rate increases with age. However, a relationship between intelligence and processing rate was not found.

Liss and Haith (1970) also studied the speed of visual processing in children and adults. Working with subjects from the 4-5 and 9-10 year old age levels as well as adults, they found that backward masking (with a patterned mask) produced greater disruption than did forward masking. In addition, they found that the extent of disruption induced by both backward and forward masking decreased as age increased.

In another study on visual masking and developmental differences in information processing, Miller (1972) studied 8 and 12 year old children and 20 year old college students. In a backward masking experiment, age, sex, and temporal interval between the test stimuli (letters D, O, and S) and the mask (a crosshatched rectangular box) were varied. The results indicated greater accuracy with increasing age at all stimulus onset asynchronies except when the mask and target stimuli were simultaneously presented. Further, no differences in performance as a function of sex were found. The authors concluded that the developmental differences found in masking reflected differences in information processing speed.

A more extensive study on age effects in backward visual masking was reported by Welsandt, Zupnick and Meyer (1973). They conducted two separate experiments with different subjects although the stimuli (letters E, H, K, and X), mask (a square grid with criss-crossed diagonal lines), and procedure remained identical. The first study employed subjects aged 5, 10, 16, and 22-23 years old while the mean ages of subjects in the second experiment were 19, 35, and 55 years. The results of the first experiment indicated significantly increased accuracy with increasing age suggesting that the younger subjects exhibited a slower rate of visual information processing. In the second study, the 19 and 35 year old subjects performed most accurately and at approximately the same level. However, the 55 year old subjects showed a small but significant overall decrease in performance relative to the 19 and 35 year old subjects. The basis for this decrease in performance was not clear. However, that this latter result may not have been artifactual is suggested by the recent work of Walsh (1976). Using a backward masking paradigm, he found that the rate of visual information processing was approximately 24% slower in 60-68 year old subjects as compared to 18-23 year old subjects.

In an experiment intended to provide data on both iconic duration (sensory persistence) and processing rate in the same subjects as a function of age, Gummerman and Gray (1972) worked with second, fourth and sixth grade students and a group of college students. Their procedure involved presenting a test stimulus followed by either a homogeneous white field or a patterned masking stimulus. They maintained that the patterned mask would interrupt the processing of the icon (thus curtailing readout from iconic storage into short term memory) and thereby provide a measure of processing rate across ages. However, they believed that performance in the white mask condition would depend on both processing rate _and_ iconic duration. Therefore, less improvement with age would be expected in the white mask condition, compared with the patterned mask condition, as the slower processing of the younger subjects would be somewhat offset by their greater icon duration. The results indicated an increase in performance with age in the patterned masking condition suggesting that younger children do not transfer information from iconic storage to short term memory as rapidly as older children and adults. Further, no differences were found across ages in the white mask condition and the authors concluded that iconic duration was thus inversely related to age. Finally, no performance differences were found between male and female subjects at any of the age levels.

Pollack, Ptashne and Carter (1969) conducted a study which also sought to explore sensory persistence as a function of age. Their design employed children between the ages of 6-17 years whose task it was to detect the dark interval between two brief flashes of light. They reasoned that if the first flash persisted longer into the dark interval then the onset of the second flash could be delayed longer without a gap appearing. Thus longer duration interflash intervals would suggest longer sensory persistence while shorter interflash intervals would indicate the opposite. Flash durations were kept constant at 20 msec while interflash intervals ranged from 0 to 250 msec in 10 msec steps. The results indicated a linear decline in the Dark Interval Threshold as a function of increasing age thus suggesting that sensory persistence decreased with age. Further, no sex differences were found to exist at any age level on the task.

Taken together, the above evidence indicates that the relative visual information processing rate increases with increasing age up to approximately 20 years of age although it may actually decrease in later life. The only negative study in this regard was reported by Blake (1974). Working with four and eight year olds and college students in a backward masking paradigm, she found no age differences in processing speed on single item target arrays consisting of geometric shapes. However, four year olds were pregressively slower than eight year old and college students as target array size increased from one to two and from two to four items.

In summary, while the evidence supporting a direct relationship between age and processing rate in subjects up to 20 years old is based on consistency across a number of studies, the available data on sensory persistence and age appears to be considerably more tentative. The present research, outlined below, explored processing rate and sensory persistence as a function of age in both good and poor readers.

General Outline and Expected Findings

Sensory persistence was examined in each subject by employing a modification of the temporal integration task described by Hogben and Di Lollo (1974). In the present experiment, two horizontally adjacent 5 x 5 square dot matrix patterns were presented on a computer-driven oscilloscope by displaying a series of single dots evenly and successively over time (see Appendix A, Figure 2). The total temporal duration over which the dots were plotted on the oscilloscope on a single trial (plotting interval) was allowed to vary and on each trial a single dot from either the left or right matrix was not plotted. The experimental task was simply to specify the matrix from which the dot was missing.

When the plotting interval was brief, the dots forming the two matrices appeared clearly and simultaneously and the detection task was relatively easy. However, at comparatively long plotting intervals, the phenomenological impression was that several dots were missing from both matrices; the observer was thus confronted with several apparently empty matrix locations as well as the truly empty location.

It will be recalled that sensory persistence refers to the continued perceptual availability of information contained in a brief stimulus beyond the actual physical duration of the stimulus. Thus, considering the above stimulus conditions, when the dots forming the two matrices are presented within a brief plotting interval, they all remain perceptually available at the end of the interval and the missing dot is relatively easily detected. However, when the plotting interval exceeds a certain duration, some of the early dots become perceptually unavailable by the time the last dot has been plotted (Hogben and Di Lollo, 1974). Under these conditions, all the dots forming the matrices are not perceptually available at the same time and performance is impaired. Thus, the precise plotting interval at which simultaneous perceptual availability (or temporal integration) of all the dots just ceases provides an index of the duration of sensory persistence.

The plotting interval at which persistence ceases might be estimated by selecting a number of fixed testing levels (plotting intervals) of which some are believed to be clearly above and others clearly below the expected duration of persistence. Then, a fixed number of trials at each level is conducted and accuracy of performance measured. The specific level at which persistence appears to cease is then assessed by interpolation. One disadvantage of this classical approach is that it requires a relatively large number of trials at levels clearly thought to be above and below what might be considered the threshold level. Hence, the method is somewhat inefficient and perhaps, at the extremes, even somewhat frustrating and boring for the subject. In contrast, the present study estimated the duration of sensory persistence by employing one of the so-called "adaptive" psychophysical methods of parameter estimation. Unlike classical methods, adaptive tracking procedures do not require fixed numbers of trials at predetermined plotting intervals but rather focus on the threshold by adjusting the plotting interval on the basis of the subject's performance history at previous plotting intervals. The details of this approach pertinent to the present study are described in Chapter 2.

Estimates of sensory persistence as a function of age and reading competency appear to be somewhat tentative at present. However, on grounds outlined in the foregoing, it was expected that the duration of sensory persistence would be found to decrease with increasing chronological age. Conversely, a relationship between reading ability and sensory persistence was not anticipated.

The second aspect of visual information processing investigated involved assessing the relative rate of processing in relation to both reading capability and chronological age. In this part of the study a backward visual masking paradigm was employed on the assumption that this procedure limited the duration of processing to a constant temporal interval for all subjects. The stimuli were similar to those employed in the persistence task with the exception that the unplotted dot was missing from the centre of either the right or left matrix at random rather than from any location in one of the matrices (Appendix A, Figure 3). In addition, the dots forming the matrices were displayed on the oscilloscope effectively simultaneously. The masking stimulus (see Appendix A, Figure 4) followed at various interstimulus intervals (ISIs). The subject's task on each trial was again to indicate which matrix had a missing dot.

During testing it was observed that the stimulus displays appeared clearly and simultaneously and, at relatively long ISIs, the presentation of the mask did not interfere with performance in detecting the missing dot. However, when the ISI between the stimulus and mask was relatively brief, the phenomenological impression was that the time available between the presentation of the stimulus and the onset of the mask was too short to identify the correct matrix.

As outlined earlier, Di Lollo (1977) noted that perception of form is not instantaneous but rather emerges over time from a number of processing operations. Two successive phases of sensory coding were identified with the first phase involving feature encoding operations and the second phase consisting of interpretive operations. It was maintained that a stimulus display was subject to the disruptive effect of a masking stimulus while the display was only feature encoded and not after it had been meaning encoded at the interpretive level of processing. Thus, the more rapidly a display is processed the shorter the temporal duration during which it is susceptible to being disrupted by the presentation of a masking stimulus. Therefore, one index of the relative processing rate is provided by the amount of time that the presentation of a masking stimulus must be delayed in order for perception to emerge as measured by performance on a task. In this view, for example, achieving a given accuracy criterion on the above backward masking task at an ISI between stimulus and mask of 150 msec would indicate relatively faster processing than the same accuracy criterion achieved at an ISI of 250 msec. This general approach was used in the present study to assess relative processing rate.

As in the temporal integration part of the study, the same adaptive psychophysical approach was employed to estimate the ISI between the stimulus display and mask necessary to avoid the disruptive effect of the mask and to acheive a 75% correct accuracy criterion. In the masking study the exposure duration of the displays was held constant while the ISI between stimulus and mask was allowed to vary as a function of the subject's performance.

On the basis of findings outlined earlier, it was expected that differences in the relative rate of information processing would emerge as a function of reading capability with poor readers displaying a slower processing rate than the normal-reading controls. Further, it was anticipated that the relative processing rate in both groups would increase with increasing chronological age.

CHAPTER II

METHOD

Temporal Integration

Subjects

Twelve male students at each of four age levels -- 7, 9, 11, and 13 years -- from the Fort Garry School Division participated as subjects in the experiment. Half of the students at each age level were poor readers (experimental subjects) while the remaining six students served as normal-reading controls. All subjects were selected in consultation with their classroom teachers and with the school remedial reading clinician according to the following criteria: (a) at least average intelligence (checked by scores on the Peabody Picture Vocabulary Test) and regular school attendance; (b) normal or corrected to normal vision and normal hearing; (c) Canadian national origin with English as the native tongue; (d) absence of psychosis; (e) absence of gross social and/or cultural deprivation. The experimental subjects were all judged by school personnel to be performing below grade-level in reading; this was confirmed and defined more precisely by reading comprehension scores from Stanford Achievement Test (SAT) (see Appendix B). Conversely, the control subjects were all performing at or above grade-level in reading in the classroom and on the reading comprehension part of the SAT (see Appendix C).

Stimuli and Apparatus

The stimulus display (Appendix A, Figure 2) consisted of two horizontally adjacent 5 x 5 square dot matrices each measuring 1.0 cm square and separated by 0.5 cm. The 25 dots forming each of the two matrices were presented successively over time on a Tektronix 602 display oscilloscope (equipped with a fast P-15 phosphor) with one dot not plotted in one of the matrices on each trial. The matrix (left or right) and the precise location within the matrix missing a dot varied randomly from trial to trial. On every trial, each dot was plotted only once with the dots being evenly spaced within the plotting interval (the term "plotting interval" refers to the total time that elapses between plotting the first and the last dots). The temporal duration of each dot was 1.5 microseconds and the luminance of the stimulus display was adjusted so that a standard square patch plotted continuously in the centre of the screen yielded a reading of 0.35 lux as measured by a Tektronix J-16 digital photometer. A dim fixation dot, located 0.25 cm from the inner edges and 0.5 cm from the top and bottom boundaries of the matrices, was employed to aid and to standardize subject orientation to the screen. The fixation dot disappeared with the onset of the stimulus display and reappeared following a response. To aid focusing and convergence the oscilloscope display surface was dimly illuminated. All displays were generated by a Digital PDP-8/L computer which also performed all timing and scoring functions.

Procedure

Upon entering the laboratory the subject was told that the task in the experiment involved determining which one of the two dot matrices was missing a dot. To facilitate comprehension of the task, several flash cards analogous to the actual display stimuli were used. The cards demonstrated that a dot could be missing from any location within either the right or left matrix. When it was clear from the subject's performance with the flash cards that the task was understood, familiarization with the task when the display stimuli were presented briefly on the oscilloscope was conducted. Under the familiarization conditions, the stimulus display with a missing dot was presented effectively simultaneously. Only those subjects who after familiarization were able to identify which of the two matrices was missing a dot at an accuracy rate of 85% correct or higher were selected to participate in the temporal integration experiment proper. In the course of testing, it was not necessary to reject any subject for failure to meet this criterion.

During the temporal integration testing, the subject was seated in a quiet and dimly illuminated room and viewed the stimulus display binocularly through a Tektronix model 016-0154-00 viewing hood. In the viewing position the stimulus display was approximately 75 cm from the subject's pupils and subtended a visual angle of $1^{o}53'$ horizontally and $0^{o}46'$ vertically. The subject was instructed to focus on the fixation dot and to initiate a trial when ready by depressing a footswitch. Following the stimulus display, he was required to depress a switch which he held in his left hand if he thought that the dot was missing from the left matrix or to depress a switch which he held in his right hand if it appeared to him that the dot was missing from the right matrix. Immediately following the subject's response the fixation dot reappeared and the same sequence of events involving focusing on the fixation dot, initiating a display and responding proceeded for the next trial. The subject was instructed to work carefully and as quickly as possible without sacrificing accuracy and to make a best guess when unsure of the location of the missing dot.

The plotting interval was allowed to vary under the control of an adaptive psychophysical method developed by Taylor and Creelman (1967) known as PEST (Parameter Estimation by Sequential Testing). The PEST program was under direct computer control and operated according to rules specified in advance regarding when to change plotting intervals, what interval to try next, when to end a run and the means by which the parameter estimate was to be calculated.

A run began with the computer randomly selecting a starting plotting interval ranging from 3-127 msec. A series of trials was conducted at that plotting interval and the computer maintained a record of the subject's performance. In order to determine whether the subject's performance was above or below an accuracy criterion of 75% correct, a Wald (1947) sequential liklihood-ratio test (WALD), integrated with the PEST program, was performed on the data. Accuracy above 75% correct was considered to reflect a task which was too easy (too brief a plotting interval) while accuracy below 75% correct indicated that the task was too difficult (too long a plotting interval). If the task was too easy (or too difficult) the PEST program automatically increased (or decreased) the plotting interval initially by 16 msec and conducted a new series of trials at that plotting interval. One again, the results were stored (by PEST) and evaluated (by WALD) and a decision to increase or decrease the plotting interval on the basis of the subject's performance was made. Increases or decreases in plotting interval were doubled (until a maximum step of 32 msec was reached) on successive series of trials in which the change required in plotting interval was in the same direction as the immediately previous change. However, whenever a change in direction was required, the plotting interval changed by half the amount of the immediately previous change. (For example, assume that a plotting interval of 40 msec was too easy and that 16 msec was added resulting in a new plotting interval of 56 msec. Now, if the 56 msec plotting interval was too difficult, the next plotting interval tried would be 48 msec which would represent a reduction of half the immediately previous change (16 msec)). This process of increasing and decreasing plotting intervals continued until an adjustment in plotting interval duration was required which was smaller than 8 msec. At that point the run ended and the parameter estimate was given as that plotting interval in effect just prior to the required adjustment below 8 msec. (In the example referred to above, if the 48 msec plotting interval was now too easy an adjustment of +4 msec would be required. But since this adjustment would be less than 8 msec, the run would end and the parameter estimate would be 48 msec).

A series of eight runs was conducted per subject and the estimate of the duration of sensory persistence for each subject was calculated by determining the median plotting interval at which temporal integration appeared to cease based on the eight runs. A brief rest period followed each run which, on average, took approximately 2-3 minutes.

Backward Masking

Subjects

The same subjects who participated in the temporal integration part of the study also participated in the backward masking study.

Stimuli and Apparatus

The stimulus display (Appendix A, Figure 3) was fundamentally the same as the one employed in the temporal integration task with two exceptions. First, the unplotted dot was always randomly missing from the centre of either the left or right matrix rather than from any location. And, second, all the dots forming the two matrices were presented effectively simultaneously on the Tektronix 602 oscilloscope for a duration of 3 msec rather than over various plotting intervals. The luminance and dimensional characteristics of the stimulus display were identical to those used in the temporal integration part of the study. In addition, a random-dot visual noise masking stimulus (see Appendix A, Figure 4) of approximately equal luminance and temporal duration as the stimulus display was used in this part of the study to limit processing duration. The PDP-8/L computer was again employed to generate all displays and perform timing and scoring functions.

Procedure

The subject was told that the present task involved determining which one of the two dot matrices was missing a dot in the centre location. Again, flash cards depicting examples of the manner in which a given trial might appear on the oscilloscope were used to clearly explain the task. When the task was understood, the subject's ability to perform the task when the stimulus displays were presented on the oscilloscope was assessed in a no-mask condition. Again, only those subjects who performed at an accuracy rate of 85% correct or better were selected to participate in the backward masking experiment proper. And, once again, it was not necessary to reject any subject because of failure to meet this level of performance.

In the backward masking experiment, the testing environment and viewing conditions were identical to those in the temporal integration study. In addition, the same procedure associated with focusing on the fixation dot, initiating a trial, responding following the completion of the trial and setting up for the next trial was followed. However, the subject was advised in advance that a random dot masking pattern would follow and cover the stimulus display at various time intervals after the stimulus display was presented and that his task was to detect the missing dot in the first display.

In the experiment, the interstimulus interval between the display stimulus and the masking stimulus was allowed to vary under the control of the PEST and WALD programs noted earlier. Minor modifications in the PEST program were made in the backward masking experiment. A run began with the computer randomly selecting a starting ISI ranging from 0-127 msec. The initial increase or decrease in ISI, related to the task being either too difficult (too brief an ISI) or too easy (too long an ISI), was 16 msec. The accuracy criterion was again 75% correct and the maximum ISI adjustment permitted when changing from one series of trials to another was 32 msec. However, the minimal adjustment permissable in the backward masking PEST program was 12 msec. Operationally, the programs functioned as outlined in the temporal integration study.

A series of eight runs was conducted per subject and an index of the relative processing rate for each subject was calculated by determining the median ISI at which the subject performed at a 75% correct rate on the eight runs. A brief rest period followed each run which took an average of 3-4 minutes.

Experimental Design

Indices of both the duration of sensory persistence and relative processing rate were obtained from each subject in a counterbalanced design with performance of the two tasks being separated by approximately 24 hours. Thus, half the students at each age and reading level performed the temporal integration task on one day and the backward masking task on another day while the remaining students performed the tasks in the reverse order.

CHAPTER III

RESULTS

A complete summary of the age, I.Q., temporal integration, backward masking, reading level and task performance order data for all experimental and control subjects is presented in Appendixes B and C, respectively.

The data obtained from the experimental and control subjects under the backward masking experimental conditions is summarized in Table 1. It shows the mean ISI (msec) between the test stimulus and mask at which the 75% accuracy performance criterion was reached in the backward masking task in relation to reading level (experimental vs. control), task performance order and age level. This data was subjected to a 2 (reading level) x 2 (task performance order) x 4 (age) analysis of variance (ANOVA) which yielded a significant difference between the ages ($F(3, 32) = 22.3$, $p < .001$) and non-significant differences with respect to reading level and task performance order. In addition, none of the interactions were significant. A summary of this ANOVA is presented in Appendix D. Thus, the performance of both the experimental and control subjects improved with increasing chronological age under the backward masking conditions although the groups did not differ significantly from one another at any age level. Disregarding task performance order (which was not significant), the decrease in the mean ISI between the test stimulus and mask as a function of increasing chronological age and reading level is graphically displayed in Figure 1.

The data obtained from the same subjects in the temporal integra-

Table 1

Mean ISI (msec) between the test stimulus and mask at which criterion performance level was reached in the backward masking task

Age Level	EXPERIMENTAL		CONTROL	
	B.M. First[1]	B.M. Second[2]	B.M. First[1]	B.M. Second[2]
7	168.8	162.2	152.7	149.2
9	109.3	113.7	102.2	102.8
11	98.8	84.2	99.0	97.8
13	67.8	81.2	58.3	70.2

[1]Subjects performed the backward masking task before the temporal integration task

[2]Subjects performed the temporal integration task before the backward masking task

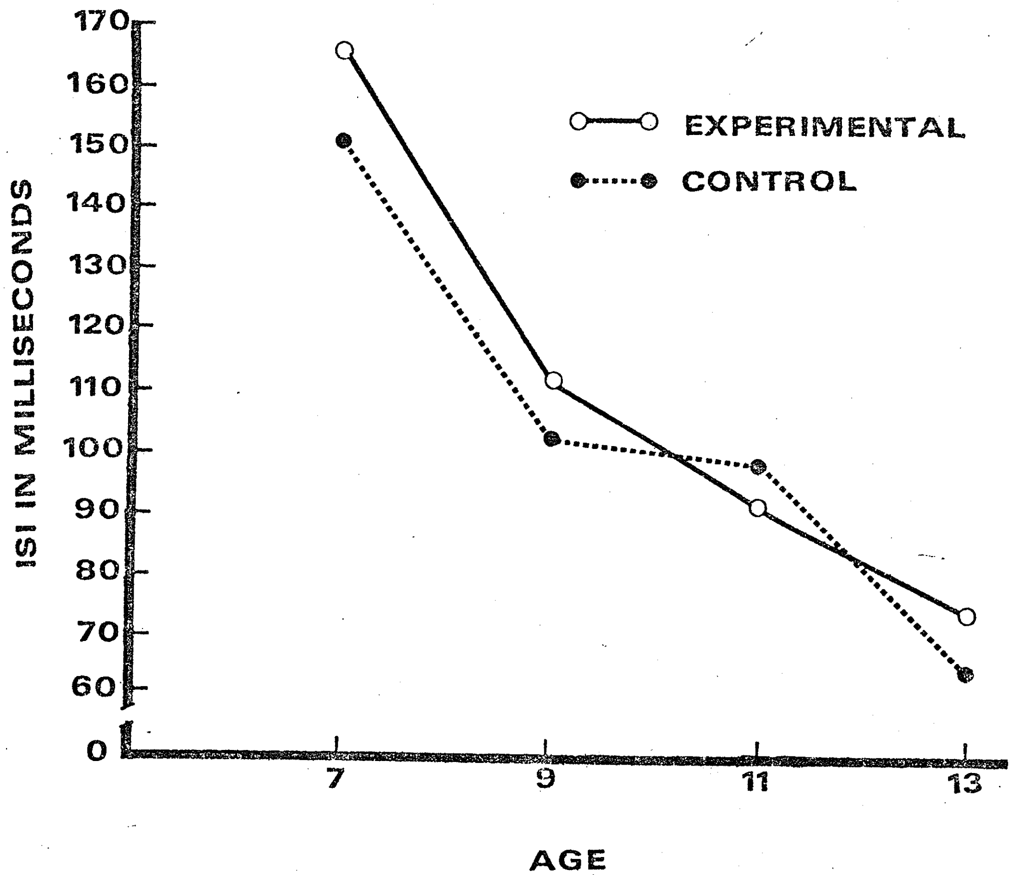

Figure 1. Mean ISI (msec) between test stimulus and mask as a function of age and reading level

tion part of the study is outlined in Table 2. It indicates the mean plotting interval (msec) at which the 75% accuracy performance criterion was reached in the temporal integration task in relation to reading level, task performance order and age level. A separate 2 x 2 x 4 ANOVA was performed on this data to evaluate the effects of reading level, age and task performance order on temporal integration. The analysis failed to reveal any significant main effects or interactions whatsoever. A summary table of the ANOVA is presented in Appendix E. Ignoring task performance order, the stability of the mean plotting interval in relation to both chronological age and reading level is shown graphically in Figure 2.

An inspection of the mean I.Q. data on the experimental and control subjects revealed a relatively small magnitude but systematic elevation in I.Q. in the controls across age levels. In order to statistically control for the I.Q. differences, separate 2 x 2 x 4 analyses of covariance (with the same factors as in the ANOVA's) were performed on the backward masking and temporal integration data with I.Q. as the covariate. The analysis of covariance on the backward masking data also revealed the significant effect of age ($F(3, 31) = 21.9$, $p < .001$) observed in the ANOVA although no other significant main effects or interactions were found. The summary table pertaining to this analysis is presented in Appendix F. Further, the analysis of covariance on the temporal integration data (see Appendix G) failed to reveal any significant main effects or interactions. Thus, when I.Q. is considered as a covariate, the results of the analyses are not altered appreciably relative to the analyses of variance reported earlier.

Table 2

Mean plotting interval (msec) at which criterion performance level was reached in the temporal integration task

Age Level	EXPERIMENTAL		CONTROL	
	T.I. First[1]	T.I. Second[2]	T.I. First[1]	T.I. Second[2]
7	42.7	44.3	44.2	55.5
9	46.5	50.3	48.0	47.2
11	47.8	44.3	50.3	51.3
13	49.3	48.5	50.3	43.8

[1]Subjects performed the temporal integration task before the backward masking task

[2]Subjects performed the backward masking task before the temporal integration task

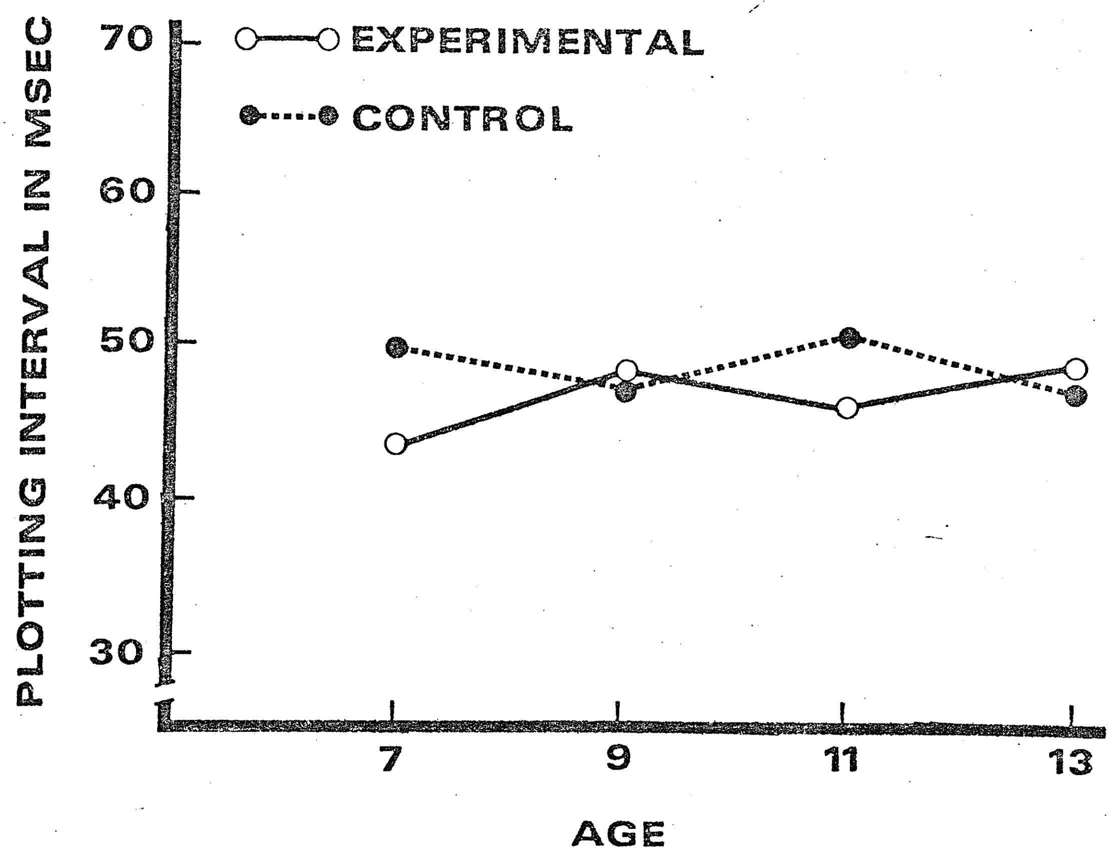

Figure 2. Mean plotting interval (msec) as a function of age and reading level

In order to assess the data for systematic relationships among the dependent and independent variables, intercorrelations on age, I.Q., temporal integration, backward masking and reading level were calculated. Inspection of the summary table of correlations presented in Appendix H once again shows the strong inverse relationship ($r= -.76$) between age and the ISI between the test stimulus and mask at which criterion performance level was reached in the backward masking study. In addition, a positive correlation between I.Q. and reading level ($r= .45$) was also found. While these were the only two significant relationships found in the correlation matrix, both were significantly different from zero beyond the .01 level of significance.

CHAPTER IV

DISCUSSION

The primary focus of the present research was directed at assessing whether certain information processing characteristics in poor readers differed from those in average or better than average readers. Specifically, the work of Stanley and Hall (1973) outlined earlier suggested that the rate of information processing was slower in poor readers than in normal readers while the duration of sensory persistence was longer in the deficient readers.

The results of the present investigation clearly demonstrate that the deficient and normal readers did not differ significantly from one another in performance on either the temporal integration or backward masking tasks at any of the four age levels studied. And, insofar as the temporal integration and backward masking tasks, respectively, provide indices of the duration of sensory persistence (Hogben and Di Lollo, 1974) and the rate of information processing (Blake, 1974; Gummerman and Gray, 1972; Liss and Haith, 1970); Spitz and Thor, 1968), it is evident that the poor and normal readers cannot be regarded as differing in either of these respects.

These results and conclusions regarding the rate of processing stand in disagreement with those of Stanley and Hall (1973) as well as with those anticipated by the present writer prior to conducting the research. In addition, the present results also fail to support the findings of Stanley and Hall with regard to the duration of sensory persistence although they are consistent with the data reported by Stanley and Molloy (1975) on the temporal extent of iconic storage.

There are a number of factors that might be considered in attempting to account for the discrepancies between the present findings and those reported by Stanley and Hall (1973) on processing rate and persistence duration and similar findings by Stanley (1975a) with respect to iconic storage duration. It may be suggested that the present tasks could have been generally insensitive to differences in sensory persistence and processing rate. If this were indeed the case, the failure to replicate the earlier results could well have been due to the inappropriateness of the tasks. However, this hypothesis does not appear tenable when it is realized that while no differences between the normal and deficient readers emerged at any of the age levels studied, the results clearly show that the rate of information processing increased with increasing chronological age. This is shown in the significant main effect due to age in the analysis of variance on the backward masking data. It is also evident in the highly significant negative correlation between age and backward masking which indicates that as age increased the ISI between the test stimulus and mask at which criterion performance was reached decreased, thus indicating more rapid test stimulus processing. Furthermore, an inspection of the backward masking scores revealed no overlap in performance between any of the seven and thirteen year old subjects. Thus, the backward masking task was highly sensitive to different developmental levels in both the experimental and control subjects and would be expected to be equally sensitive to differences in rate of processing ascribable to factors other than chronological age, notably reading deficiencies. It should also be noted here that the direct relationship between chronological age and processing rate is entirely consistent with several studies reported earlier relating these two variables (Gummerman and Gray, 1972; Liss and Haith, 1970; Miller, 1972; and Welsandt et al., 1973).

Another possible basis for not finding differences between the good and poor readers in the present study might have been related to the level of processing elicited by the stimulus conditions and task demands. In the Stanley and Hall work, alphabetic characters were used as stimuli and it may be that they elicited a greater depth of processing than the dot matrix stimuli presently employed. The argument might be made that at this deeper level of processing differences between the poor and control readers emerged. This line of reasoning follows from the Craik and Lockhart (1972) "levels of processing" conceptual framework which suggests that preliminary levels of processing are more concerned with the analysis of physical or sensory features of the stimuli while deeper levels of processing involve to a greater degree matching the input against stored abstractions from past learning. In this model, greater "depth" implies a greater degree of semantic or cognitive analysis. While this possibility cannot be discounted on the basis of the results of the present work, a recent study by Fisher and Frankfurter (1977) suggests that this may not necessarily be the case. In their assessment of performance of poor and normal readers using alphabetic letters under backward masking conditions, the poor readers were not found to be inferior to the age and reading-level matched controls on measures involving correct identification, correct localization, absolute number correct and number of intrusions. Hence, even though alphabetic stimuli may evoke a deeper level of processing than matrices, this does not appear to provide a satisfactory explanatory basis for the differences between the earlier work by Stanley and Hall (1973) and the present findings. Furthermore, with respect to the duration of sensory persistence, Fisher and Frankfurter (1977) failed to find any evidence indicating that duration of visual persistence was longer in the poor readers. In fact, they interpreted their results as possibly indicating longer iconic storage in normal readers, in contrast to the conclusions of Stanley and Hall.

An alternative hypothesis to account for the divergence between the present results and those of Stanley and Hall relates to the possibility that the poor readers in their study adopted a more conservative response criterion in both the temporal integration and backward masking tasks. As mentioned in the Introduction, this possibility appears viable when consideration is given to the poor readers' past history of failure in testing situations. Given this past history, it does not appear unreasonable to propose that they may have waited longer to be sure before indicating when the two-part composite stimuli appeared to separate in the temporal integration task as well as before reporting the target letter in the backward masking paradigm. Furthermore, the ascending method of limits procedure utilized by Stanley and Hall in both tasks is clearly subject to the effects of response bias. If indeed such response bias did occur, the mean ISI between the target letter and mask in the backward masking experiment as well as the mean separation threshold in the temporal integration task would have been artifactually inflated in the poor readers, thus leading to the conclusion that their duration of sensory persistence was longer while their relative processing rate was slower. The presently employed forced-choice methodology effectively eliminated response bias and forced all subjects to perform at their maximum level of discrimination. Under these forced-choice conditions, processing rate and the duration of sensory persistence were not found to be related to reading proficiency at any of the age levels studied. Interestingly, and in support of the present contention, Stanley (1976) subsequently employed a forced-choice approach in a digit identification task under backward masking conditions with poor and normal readers. Under these circumstances, his previous finding of more rapid processing by the normal-reading control subjects was not replicated.

Moreover, if group differences in reading ability at the age levels studied were associated with the speed of processing of the test stimulus, it might be expected that the nine, eleven, and thirteen year old experimental subjects would process information at a rate more like the seven, nine, and eleven year old control subjects, respectively, with whom they shared a similar reading level. However, this was not the case in that the results indicate that the nine, eleven, and thirteen year old experimental subjects were, on average, more similar in processing rate to their age-matched controls than to younger control subjects.

The present results concerning processing rate and persistence duration as a function of age and reading level do have practical and theoretical implications. The finding that subjects across the age levels studied did not differ with respect to the duration of sensory persistence suggests, on the basis of the Di Lollo (1977) processing model, that all subjects feature-encoded the information in the test stimuli at approximately the same rate. Furthermore, the fact that persistence duration was independent of reading proficiency indicates that poor and normal readers do not differ at this very early stage of visual information processing. This latter finding argues against the notion of a very basic perceptual deficit as a basis for reading disabilities. Further, the failure to find differences in backward masking between the poor and normal readers at any age level suggests that the rate at which the visual input is interpreted beyond the initial feature-encoding stage does not vary as a function of reading disability. However, the rate of interpretation or meaning abstraction does increase equally with chronological age in both groups presumably reflecting more rapid processing with increasing development.

The inference that the processing rate of poor and normal readers does not differ must, however, be qualified in at least two respects. First, the nature of the matrix stimuli and the response requirements in the present study permitted an assessment of visual information processing only at a relatively superficial level of analysis. That is, the experimental tasks employed did not necessarily involve any verbal or semantic encoding which clearly is involved in reading proper and is generally thought to occur at higher processing levels (Mackworth, 1972). Hence, it is possible under stimulus conditions and task demands more similar to those actually involved in reading that differences between good and poor readers would emerge in processing rate. And, second, the results of the Fisher and Frankfurter (1977) study indicate that processing load is a relevant dimension when processing rate is under investigation. They found that when the number of alphabetic characters in the test stimulus was greater than two, accuracy declined more rapidly in poor readers than in normal-reading subjects.

However, notwithstanding these qualifications, the results of the present investigation are not consistent with a general perceptual deficit hypothesis of reading disabilities. The implication of these results suggests that in studying reading deficiencies, it would appear to be potentially more productive to direct greater effort at studying higher levels of processing while placing less emphasis on the perceptual and more superficial levels of analysis. This clearly is not a novel suggestion although it is maintained that the improved methodology presently employed adds strength to the argument for this shift of attention.

References

Applebee, A. N. Research in reading retardation: Two critical problems. Journal of Child Psychology and Psychiatry, 1971, 12, 91-113.

Bachmann, T. & Allik, J. Integration and interruption in the masking of form by form. Perception, 1976, 5, 79-97.

Bakwin, H. Reading disability in twins. Developmental Medicine and Child Neurology, 1973, 15, 184-7.

Bannatyne, A. D. Language, Reading, and Learning Disabilities. Springfield, Illinois: Charles C. Thomas, 1971.

Bateman, B. Learning disorders. Review in Educational Research, 1966, 36, 93-119.

Bender, L. Problems in conceptualization in children with developmental alexia. In P. H. Hoch & S. J. Zubin (Eds.), Psychopathology of Communication. New York: Grune and Stratton, 1958.

Blake, J. Developmental change in visual information processing under backward masking. Journal of Experimental Child Psychology, 1974, 17(1), 133-146.

Blanchard, P. Psychoanalytic contributions to the problem of reading disabilities. In The Psychoanalytic Study of the Child, Vol. 2. New York: International Universities Press, 1946.

Bonner, A. F. The Psychology of Special Abilities and Disabilities. Boston: Little and Brown, 1917.

Clairborne, J. H. Types of amblyopia. Journal of the American Medical Association, 1906, 47, 1813-1816.

Craik, F. I. M. & Lockhart, R. S. Levels of processing: a framework for memory research. Journal of Verbal Learning and Verbal Behavior, 1972, 11, 671-684.

Critchley, M. The Dyslexic Child. Springfield: Charles V. Thomas, 1970.

Critchley, M. Is developmental dyslexia the expression of minor cerebral damage?. Slow Learning Child, 1966, 13(1), 9-19.

Di Lollo, V. On the spatio-temporal interactions of brief visual displays. In R. H. Day & G. V. Stanley (Eds.), Studies in Perception. Perth: University of Western Australia Press, 1977.

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

Eisenberg, L. The epidemiology of reading retardation and program for preventive intervention. In J. Money & G. Schiffman (Eds.), The Disabled Reader. Baltimore: Johns Hopkins University Press, 1966.

Fisher, J. H. Congenital word blindness (inability to learn to read). Transactions of the Opthalmalogical Society U. K., 1910, 30, 216.

Fisher, D. F. & Frankfurter, A. Normal and disabled readers can locate and identify letters: where's the perceptual deficit? Journal of Reading Behavior, 1977, 9(1), 31-43.

Geschwind, N. Neurological foundations of language. In H. R. Myklebust (Ed.) Progress in Learning Disabilities (Vol. 1), New York: Grune and Stratton, 1968.

Geyer, J. J. Comprehensive and partial models related to the reading process. Reading Research Quarterly, 1972, 1(4), 541-587.

Gibson, E. J. & Levin, H. The Psychology of Reading. Cambridge: MIT Press, 1975.

Gilbert, L. C. Speed of processing visual stimuli and its relation to reading. Journal of Educational Psychology, 1959, 55(1), 8-14.

Gray, W. S. Teaching of Reading and Writing: An International Survey. Cambridge: Harvard University Press, 1957.

Gray, W. S. Diagnostic and remedial steps in reading. Journal of Educational Research, 1921, 4, 1-15.

Gummerman, K. & Gray, C. Age, iconic storage and visual information processing. Journal of Experimental Child Psychology, 1972, 13(1), 165-170.

Haber, R. N. & Hershenson, M. The Psychology of Visual Perception. New York: Holt, Rihehart and Winston, 1973.

Hallgren, B. Specific Dyslexia. Acta Psychiatrica Neurologica, Suppl. 65, 1950.

Hermann, K. Reading Disability. Copenhagen: Munksgaard, 1959.

Hinshelwood, J. Word blindness and visual memory. Lancet, 1895, 2, 1564.

Hogben, J. H. & DiLollo, V. Perceptual integration and perceptual segregation of brief visual stimuli. Vision Research, 1974, 14, 1056-1069.

Kerr, J. School hygiene, in its mental, moral and physical aspects. Journal of the Royal Statistical Society, 1897, 60, 613.

Kinsbourne, M. & Warrington, E. K. Further studies on the masking of brief visual stimuli by a random pattern. Quarterly Journal of Experimental Psychology, 1962, 14, 235-245.

Lennenberg, E. H. Biological Foundations of Language. New York: Wiley, 1967.

Liss, P. H. Does backward masking by visual noise stop stimulus processing? Perception and Psychophysics, 1968, 4, 328-330.

Liss, P. H. & Haith, M. M. The speed of visual processing in children and adults: Effects of backward and forward masking. Perception and Psychophysics, 1970, 8(6), 396-398.

Lyle, J. G. & Goyen, J. Effects of speed of exposure and difficulty of discrimination on visual recognition of retarded readers. Journal of Abnormal Psychology, 1975, 84(6), 673-676.

Mackworth, J. F. Some models of the reading process: learners and skilled readers. Reading Research Quarterly, 1972, 7(4), 701-733.

Miller, L. K. Visual masking and developmental differences in information processing. Child Development, 1972, 43(2), 704-709.

Morgan, P. A case of congenital word blindness. British Medical Journal, 1896, 2, 1378.

Morris, J. M. Standards and Progress in Reading. National Foundation for Education Research, 1966.

Naidoo, S. Specific Dyslexia. Toronto: The Copp Clark Publishing Company, 1972.

Neisser, U. Cognitive Psychology. New York: Appleton-Century-Crofts, 1967.

Orton, J. L. The Orton Story. Bulletin of the Orton Society, 1957, 7, 5-8.

Orton, S. T. "Word Blindness" in school children. Archives of Neurological Sciences (Chicago), 1925, 14, 581-615.

Orton, S. T. An impediment to learning to read - a neurological explanation of the reading disability. School and Society, 1928, 28, 715.

Orton, S. T. Reading, Writing and Speech Problems in Children (The Salmon Memorial Lectures). New York: Norton, 1937.

Park, G. The etiology of reading disabilities: An historical perspective. Journal of Learning Disabilities, 1968, 1(5), 318-330.

Pearson, G. & English, S. Common Neuroses of Children and Adults. New York: Norton, 1937.

Piaget, J. & Inhelder, B. The Psychology of the Child. New York: Basic Books, 1969.

Pollock, R. H. Backward figural masking as a function of chronological age and intelligence. Bulletin of the Psychonomic Society, 1965, 3(2), 65-66.

Pollock, R. H. & Ptashne, R. I., & Carter, D. J. The effects of age and intelligence on the dark interval threshold. Perception and Psychophysics, 1969, 6(1), 50-52.

Pringle, Kellmer M. L. Deprivation and Education. London: Longmans, 1965.

Satz, P. Rardin, D. & Ross, J. An evaluation of a theory of specific developmental dyslexia. Child Development, 1971, 42, 2009-2021.

Satz, P. & Sparrow, S. Specific developmental dyslexia: A theoretical reformulation. In D. J. Bakker & Satz (Eds.), Specific Reading Disability: Advances in Theory and Method. Rotterdam: University of Rotterdam Press, 1970.

Scheerer, E. Integration, interruption and processing rate in visual backward masking. Psychologische Forschung, 1973, 36, 71-93.

Spencer, T. J. Some effects of different masking stimuli on iconic storage. Journal of Experimental Psychology, 1969, 81, 132-140.

Spencer, T. J. & Shuntich, R. Evidence for an interruption theory of backward masking. Journal of Experimental Psychology, 1970, 85, 198-203.

Sperling, G. A model for visual memory tasks. Human Factors, 1963, 5, 19-31.

Spitz, H. H. & Thor, D. H. Visual backward masking in retardates and normals. Perception and Psychophysics, 1968, 4(4), 245-246.

Stanley, G. The processing of digits by children with specific disability (Dyslexia). British Journal of Educational Psychology, 1976, 46, 81-84.

Stanley, G. Visual memory processes in dyslexia. In D. Deutsch & J. A. Deutsch (Eds.), Short Term Memory. New York: Academic Press, 1975.

Stanley, G. Two-part stimulus integration and specific reading disability. Perceptual and Motor Skills, 1975a, 41, 873-874.

Stanley, G. & Hall, R: Visual information processing in dyslexics. Child Development, 1973, 44, 841-844.

Stanley, G. Kaplan, I. & Poole, C. Cognitive and non-verbal perceptual processing in dyslexics. The Journal of General Psychology, 1975, 93, 67-72.

Stanley, G. & Molloy, M. Retinal painting and visual information storage. Acta Psychologica, 1975, 39, 283-288.

Stephenson, S. Six cases of congenital word-blindness affecting three generations of one family. The Opthalmascope, 1907, 5, 482-484.

Taylor, M. M. & Creelman, C. D. PEST: Efficiency estimates on probability functions. The Journal of the Accoustical Society of America, 1967, 41(4), 782-787.

Thompson, L.J. Reading Disability. Springfield: Charles C. Thomas, 1966.

Vellutino, F.R., Steger, J.A., & Kandel, G. Reading Disability: An investigation of the perceptual deficit hypothesis. Cortex, 1972, 8(1), 106-118.

Vernon, M.D. Reading and Its Difficulties: A Psychological Study. New York: Cambridge University Press, 1971.

Wald, A. Sequential Analysis. New York: John Wiley & Sons, 1947.

Walsh, D.A. Age differences in central perceptual processing: A dichoptic masking investigation. Journal of Gerontology, 1976, 31(2), 178-185.

Welsandt, R. F., Zupnick, J. J., Meyer, P. A. Age effects in backward visual masking (Crawford paradigm). Journal of Experimental Child Psychology, 1973, 15(3), 454-461.

Wender, P. H. Minimal Brain Dysfunction in Children. New York: Wiley-Interscience, 1971.

Reference Note

1. Di Lollo, V. Personal Communication. November, 1976.

APPENDIX A

Figures 1 to 4

Figures employed in the Stanley and Hall (1973) study and those utilized in the present temporal integration and backward masking tasks

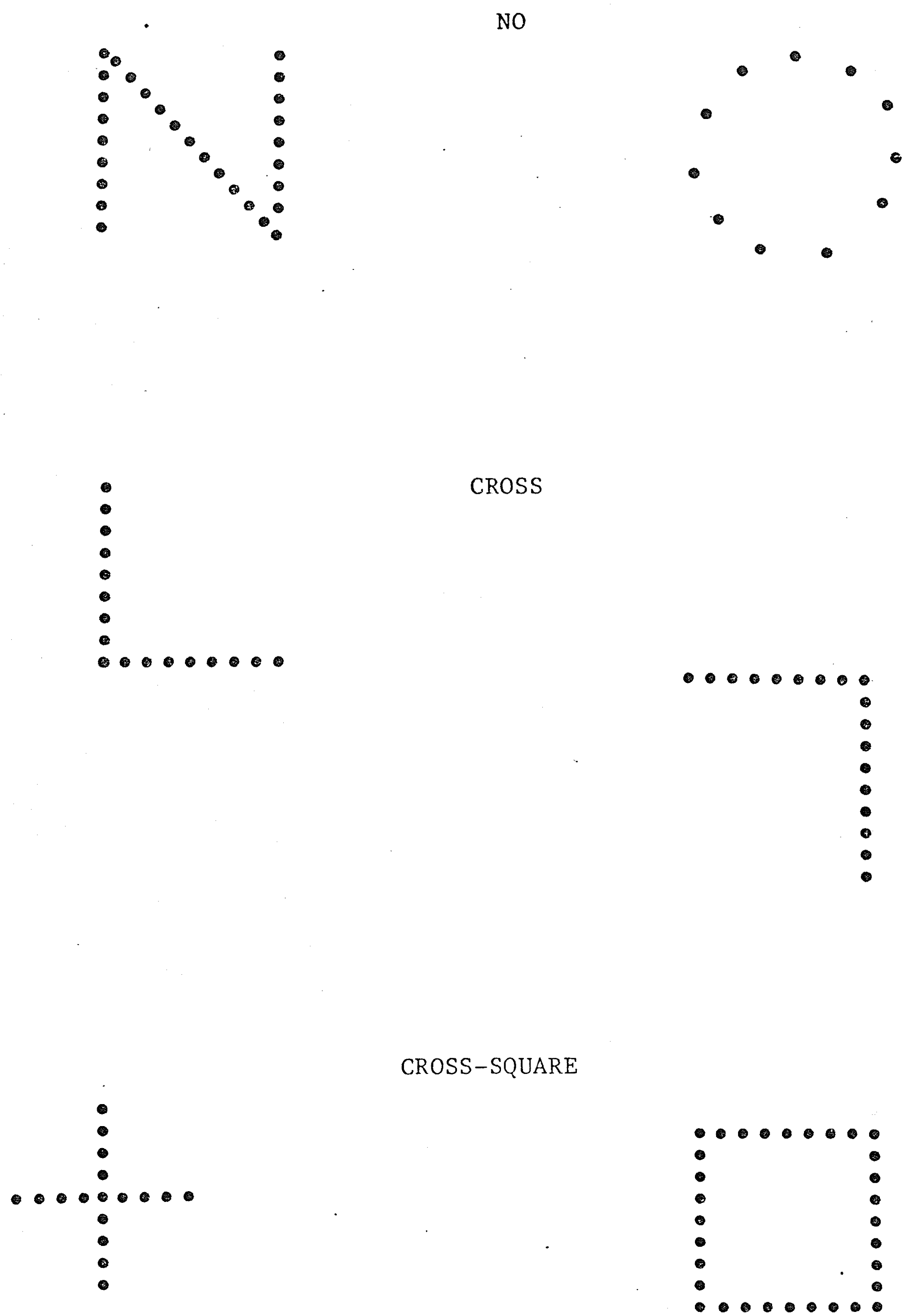

Figure 1 The two-part stimuli employed by Stanley and Hall (1973) in their temporal integration task

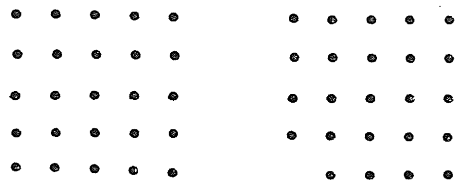

Figure 2 Example of the dot matrix employed in the temporal integration study

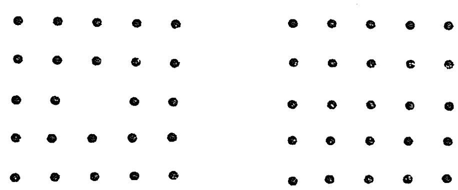

Figure 3 Example of the matrix employed in the backward masking study

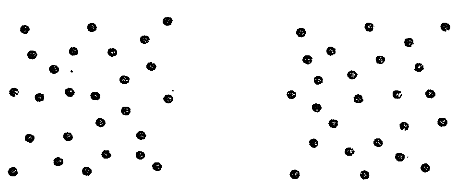

Figure 4 Example of the random dot patterned mask employed in the backward masking study

APPENDIX B

Summary of results on the Experimental subjects

BACKWARD MASKING TASK PERFORMED FIRST						TEMPORAL INTEGRATION TASK PERFORMED FIRST					
NAME	AGE (MONTHS)	IQ [1]	T.I. (msec) [2]	B.M. (msec) [3]	READING LEVEL [4]	NAME	AGE (MONTHS)	IQ [1]	T.I. (msec) [2]	B.M. (msec) [3]	READING LEVEL [4]
M.W.	89	104	39.0	204.5	- 1.3	T.D.	89	106	46.0	176.0	- 1.5
J.S.	84	122	47.0	129.5	- 1.1	B.R.	88	118	38.0	169.0	- 1.0
T.F.	91	106	47.0	172.5	- 1.6	L.C.	82	98	44.0	141.5	- 1.0
$\bar{X}$	88	110.7	44.3	168.8	- 1.3	$\bar{X}$	86.3	107.3	42.7	162.2	- 1.2
SD	3.6	9.9	4.6	37.6	.25	SD	3.8	10.1	4.2	18.2	.29
G.B.	104	106	63.0	135.0	- 1.7	R.G.	113	110	49.5	121.0	- 1.9
S.M.	111	115	41.0	100.0	- 2.1	K.H.	113	113	45.0	102.5	- 1.7
D.M.	113	94	47.0	93.0	- 2.1	G.T.	111	100	45.0	117.5	- 1.8
$\bar{X}$	109.3	105	50.3	109.3	- 2.0	$\bar{X}$	112.3	107.7	46.5	113.7	- 1.8
SD	4.7	10.5	11.4	22.5	.23	SD	1.2	6.8	2.6	9.8	.10
L.D.	134	112	44.0	128.0	- 2.0	S.W.	137	108	56.0	58.0	- 1.6
G.B.	126	103	47.0	102.5	- 1.6	T.M.	137	118	47.5	87.5	- 1.9
D.K.	137	109	42.0	66.0	- 1.8	K.M.	134	99	40.0	107.0	- 1.5
$\bar{X}$	132	108	44.3	98.8	- 1.8	$\bar{X}$	136	108	47.8	84.2	- 1.7
SD	5.7	4.6	2.5	31.2	.20	SD	1.7	4.6	8.0	24.7	.21
G.P.	161	117	40.0	83.0	- 2.1	B.A.	163	117	48.5	106.0	- 1.6
C.B.	161	104	58.5	69.0	- 2.5	W.G.	152	108	52.5	47.0	- 1.7
G.K.	152	101	47.0	51.5	- 1.8	R.C.	166	101	47.0	90.5	- 2.0
$\bar{X}$	158	107.3	48.5	67.8	- 2.1	$\bar{X}$	160	108.7	49.3	81.2	- 1.8
SD	5.2	8.5	9.3	15.8	.35	SD	7.4	8.0	2.8	30.6	.21

1. IQ based on the Peabody Picture Vocabulary Test (PPVT)
2. Median plotting interval at which criterion performance was reached in the Temporal Integration task.
3. Median ISI between the test stimulus and mask to criterion performance in Backward Masking task.
4. Number of years above (+) or below (-) school grade placement on the Stanford Achievement Test.

APPENDIX C

Summary of results on the Control subjects

BACKWARD MASKING TASK PERFORMED FIRST						TEMPORAL INTEGRATION TASK PERFORMED FIRST					
NAME	AGE (MONTHS)	IQ [1]	T.I. [2] (msec)	B.M. [3] (msec)	READING [4] LEVEL	NAME	AGE (MONTHS)	IQ [1]	T.I. [2] (msec)	B.M. [3] (msec)	READING [4] LEVEL
G.P.	80	106	46.5	140.5	+ 0.7	D.P.	90	110	45.5	142.0	+ 1.1
J.B.	82	112	48.5	189.5	+ 1.0	D.T.	85	128	44.0	144.0	+ 0.9
T.B.	94	113	71.5	128.0	+ 0.5	R.G.	86	118	43.0	161.5	+ 0.4
$\bar{X}$	85.3	110.3	55.5	152.7	+ .73	$\bar{X}$	87	118.7	44.2	149.2	+ .80
SD	7.6	3.8	13.9	32.5	.25	SD	2.7	9.0	1.3	10.7	.36
K.M.	111	111	49.5	138.0	+ 0.8	B.S.	108	104	52.0	96.0	+ 0.5
M.A.	110	125	40.0	98.5	+ 1.2	B.P.	109	121	41.0	61.5	+ 1.0
D.B.	109	107	52.0	70.0	+ 1.1	Z.P.	105	117	51.0	151.0	+ 0.8
$\bar{X}$	110	114.3	47.2	102.2	+ 1.0	$\bar{X}$	107.3	114	48.0	102.8	+ 0.8
SD	1.0	9.5	6.3	34.1	.21	SD	2.1	8.9	6.1	45.1	.25
G.B.	134	127	57.5	129.0	+ 0.6	M.J.	131	107	52.0	106.0	+ 1.4
D.C.	130	115	50.5	78.0	+ 1.2	A.M.	132	115	45.0	103.5	+ 0.6
J.L.	129	111	46.0	90.0	+ 0.9	A.L.	133	124	54.0	84.0	+ 0.4
$\bar{X}$	131	117.6	51.3	99.0	+ .90	$\bar{X}$	132	115.3	50.3	97.8	+ .80
SD	2.6	8.3	5.8	26.6	.30	SD	1.0	8.5	4.8	12.0	.53
C.B.	152	117	57.5	75.0	+ 1.4	D.S.	157	113	46.0	74.5	+ 1.0
G.W.	152	125	42.0	87.5	+ 0.5	J.P.	159	109	52.0	63.0	+ 0.7
T.B.	153	111	32.0	12.5	+ 1.3	A.S.	161	120	53.0	73.0	+ 1.7
$\bar{X}$	152.3	117.7	43.8	58.3	+ 1.1	$\bar{X}$	159	114.0	50.3	70.2	+ 1.1
SD	.58	7.0	12.8	40.2	.49	SD	2.0	5.6	3.8	6.3	.51

1. IQ based on the Peabody Picture Vocabulary Test (PPVT)
2. Median plotting interval at which criterion performance was reached in the Temporal Integration task
3. Median ISI between the test stimulus and mask to criterion performance in Backward Masking task
4. Number of years above (+) or below (-) school grade placement on the Stanford Achievement Test

APPENDIX D

Summary of the Analysis of Variance
on the backward masking data

Source	SS	df	MS	F	p
Age (A)	50187.90	3	16729.30	22.3	$<.001$
Task Order (T)	3.25	1	3.25	<1	n.s.
Reading Level (G)	543.37	1	543.37	<1	n.s.
A x T	756.04	3	252.01	<1	n.s.
A x G	796.33	3	265.44	<1	n.s.
T x G	24.79	1	24.79	<1	n.s.
A x T x G	131.17	3	43.72	<1	n.s.
Error	24002.40	32	750.07		

APPENDIX E

Summary of the Analysis of Variance
on the temporal integration data

Source	SS	df	MS	F	p
Age (A)	21.55	3	7.18	< 1	n.s.
Task Order (T)	7.12	1	7.12	< 1	n.s.
Reading Level (G)	53.12	1	53.12	1.0	n.s.
A x T	171.38	3	57.12	1.07	n.s.
A x G	147.05	3	49.01	< 1	n.s.
T x G	2.75	1	2.75	< 1	n.s.
A x T x G	122.93	3	40.97	< 1	n.s.
Error	1694.99	32	52.96		

APPENDIX F

Summary of the Analysis of Covariance
on the backward masking data

Source	SS	df	MS	F	p
Age (A)	50279.11	3	16759.70	21.85	$< .001$
Task Order (T)	1.91	1	1.91	< 1	n.s.
Reading Level (G)	765.62	1	765.62	1.0	n.s.
A x T	790.79	3	263.59	< 1	n.s.
A x G	746.95	3	248.98	≤ 1	n.s.
T x G	23.42	1	23.42	< 1	n.s.
A x T x G	136.54	3	45.51	< 1	n.s.
IQ Covariate	226.27	1	226.27	< 1	n.s.
Error	23776.13	31	766.97		

APPENDIX G

Summary of the Analysis of Covariance
on the temporal integration data

Source	SS	df	MS	F	p
Age (A)	21.63	3	7.21	< 1	n.s.
Task Order (T)	6.95	1	6.95	< 1	n.s.
Reading Level (G)	48.08	1	48.08	< 1	n.s.
A x T	166.17	3	55.39	1.01	n.s.
A X G	145.53	3	48.51	< 1	n.s.
T x G	2.72	1	2.72	< 1	n.s.
A x T x G	113.24	3	37.74	< 1	n.s.
IQ Covariate	1.26	1	1.26	< 1	n.s.
Error	1693.73	31	54.63		

APPENDIX H

Summary of intercorrelations on age, IQ, temporal integration, backward masking, and reading level across the experimental and control subjects

	Age (months)	IQ[1]	T.I.[2]	B.M.[3]	Reading Level[4]
Age		.03	.08	-.76*	-.09
IQ	.03		-.03	0	.45*
T.I.	.08	-.03		-.04	.09
B.M.	-.76*	0	-.04		-.05
Reading Level	-.09	.45*	.09	-.05	

* $p < .01$

[1]IQ - derived from the Peabody Picture Vocabulary Test (PPVT)

[2]T.I. - temporal integration (estimate of the duration of sensory persistence)

[3]B.M. - backward masking (estimate of the relative processing rate)

[4]Number of years above or below school grade placement on the Stanford Achievement Test(SAT)