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COMPUTERIZED INSTRUCTION OF CHILDREN WITH READING PROBLEMS:  
SKILL ACQUISITION AND TRANSFER OF TRAINING

by

Gary James Johnston

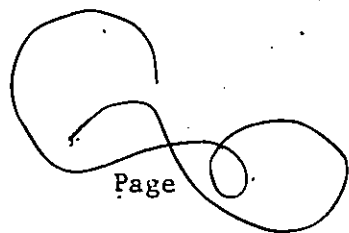
Thesis submitted to the School of Graduate Studies and Research  
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for the M.A. degree in Psychology

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ABSTRACT

The purpose of this study was to determine whether or not computer assisted instruction (CAI) mediated drill and practice training on a visual matching task would improve: 1) median response latencies (MRL's), 2) mean % errors, and 3) WRAT reading scores in a group of reading disabled children. The children were divided into two subgroups: Group N - the matching task involved nonsense syllables, and Group W - the matching task involved real words. The effects of anxiety on performance and "transfer" effects (from visual matching training to proficiency in other reading subskills tasks) were also investigated. After training, Group N showed significant improvement in MRL's. Group W showed no significant improvements after training. Two alternative explanations were given for the poor performance of Group W: 1) subjects in Group W may not only have completed the visual matching task, but may also have erroneously spent time on semantic decoding: 2) anxiety in Group W may have interfered with their skill acquisition; because of the task similarity to the real reading process (i.e., state anxiety), or because, by chance, trait anxiety levels in Group W were initially higher than those in Group N. Transfer effects were observed but no clear patterns emerged. Results of individual subjects were discussed and recommendations made for further research.

COMPUTERIZED INSTRUCTION OF CHILDREN  
WITH READING PROBLEMS:  
SKILL ACQUISITION AND TRANSFER OF TRAINING

INTRODUCTION

Introductory Statement

This thesis reviews existing theories of reading disabilities and their remediation and discusses them specifically in relation to the work of D.G. Doehring and his colleagues (Doehring, 1968, 1976, 1978; Doehring and Hoshko, 1977; Doehring, Hoshko and Bryans, 1979; Doehring, Trites, Patel and Fiedorowicz, 1981, in press). This work is of particular interest because it has the potential to bridge the gap that seems to have developed between theoretical and applied models of reading disability. Potentially valuable, and until now untested, are remedial theories based on achieving automaticity of key reading subskills by employing computer-based training methods.

Current views on the diagnosis and treatment of reading disabilities are numerous and, more often than not, contradictory. To say that a diversity of opinion exists would be an understatement. Fortunately, much of this conflict is illusory, and based on simple misunderstanding. Applebee (1971) attributes much of the confusion in the field to the uncritical borrowing of nomenclature from both the educational and medical areas. Diack (1971), referring to Morris (1949) to illustrate the longstanding problems concerning reading, language, and psychological

theory, found that "loose language" so greatly hindered clear discussion of psychological matters that a new vocabulary had to be developed.

Developing this new vocabulary, specific to reading disability theory, has not been an easy task. As might be expected, there is still a great deal of vagueness and obscurity. Many categories of research overlap. To define and differentiate them is often a very difficult task.

Only in the research of the last few years is there some suggestion that this new vocabulary is finally being realized.

#### Classification Schemes

Classification systems are used to systematically arrange items into classes or groups in order to, hopefully, add to our understanding of their interrelationships. In the case of reading disabilities, a variety of remedial approaches have been suggested. However, the interrelationships among these approaches has not always been well-defined. The need for a useful classification system has only recently been addressed with any success.

Cohen (1966) lists three main approaches to the study of reading disabilities: 1) psychoeducational, 2) psychosocial, and 3) perceptual. Applebee (1971) focuses on three slightly different areas: 1) the educational, 2) the medical, and 3) the research area. Spache (1976), in somewhat greater detail, and cutting across the traditional medical/non-medical lines of demarcation, outlines nine, reasonably independent approaches: 1) the counselling approach, 2) the operant approach, 3) organizational approaches, 4) perceptual deficit approaches, 5) the language deficit approach, 6) the cognitive approach, 7) the dyslexic approach, 8) the mechanical strategy approach, and 9) the sub-skill deficit approach. Of

necessity, many of these approaches overlap. And many of the best and most comprehensive theories on diagnosis and treatment of reading disabilities cut across several of Spache's categories. Brief examples of individual categories, followed by a more extensive discussion of the most significant modern theories, will underline this point.

#### Counselling Approach

The counselling approach postulates that the problem is essentially an emotional one, and can best be remedied by effective counselling techniques. Orlow (1974), Hoskisson (1974), and Hortman (1975) all represent recent examples of this approach.

#### Operant Approach

In the operant approach, as would be expected, no effort is made to find the underlying "cause" of the reading disability. Instead, attention is focused on correcting the reading problem through programmed learning (Hartley, 1972), performance contracting, and behaviour modification (Hartman and Hartman, 1973, Winefield, 1977). Egeland and Winer (1974) and Williams (1976) used a series of gradually "faded" tracing prompts to remediate letter reversals in young children.

#### Organizational Approach

Organizational approaches, as defined by Spache (1976), see the cause and cure of reading disabilities in ineffective teaching methods. Klann's (1972) work with teen tutors illustrates this line of research.

#### Perceptual Deficit Approach

The perceptual deficit approach theorizes that specific perceptual deficits in the visual, auditory, or visual-motor areas are responsible for reading disabilities (Spache, 1976).

Remediation through training on perceptual tasks has been demonstrated in a number of specific areas. For example, Nelson and Wein (1976) compared three training groups to a control group on a test of letter discrimination. The experimental groups were trained on; 1) high confusion alternatives, 2) low confusion alternatives, and 3) a sequence of low-, middle-, and high confusion alternatives. Although testing on post-test 1 (given after a criterion of two consecutive errorless training days) showed that those trained on low-confusion alternatives had not improved significantly, this was not the case on post-test 2. This second post-test was given after all three training groups had completed a standard number of twenty training days. At this time, all three training groups had improved significantly compared with the no-training control group.

Variations, such as the Frostig or Frostig-type visual perception training have had mixed results (Bieger, 1978) remedially. Much recent and interesting work has been done in the area of visual-motor, intermodal deficits (Bryden, 1972; Badian, 1977; Derevensky, 1977). Remediation techniques of intermodal deficits employ such devices as visual-auditory-kinesthetic-tactile presentation, the so-called VAKT technique, (Spache, 1976). Charuk (1974) using an intermodal training technique known as "visual-haptic" concluded that "the remediation of reading disabilities is enhanced when it is associated with a training program emphasizing the multi-sensory approach".

Support of perceptual deficit theories and remedial approaches is by no means universal. Especial criticism has been directed at visual perceptual deficit theories. Allington, Gormley, and Truax (1976) and Fisher and Frankfurter (1977) conclude that a visual perceptual deficit is unlikely

to be a major factor in reading disability. Vandever and Neville (1974) suggest that children "taught to strength" in reading skills did no better than those "taught to weakness". Their study covered visual, auditory, and kinesthetic modalities. Seaton (1977), although not arguing with the diagnosis of a visual perception deficit, takes exception to the idea that visual perceptual remediation will rid children of this deficit. He concluded that visual perceptual remediation has no significant positive effect on reading achievement, as measured on the Metropolitan Achievement Tests.

#### Language Deficit Approach

A fifth approach, the language deficit strategy, theorizes that reading disabilities are due to lack of linguistic development in the affected readers. Unfortunately, definitions of reading disability often fail to distinguish between linguistic and decoding components. Generally, although not always so-stated, the consensus seems to be that sufficient linguistic development is a necessary though not sufficient prerequisite for skilled reading (Wiener and Cromer, 1967). Models which fail to distinguish between the two components would appear to fail at a very basic level. Linguistic deficits are most notable in deprived, ethnic, or racial, minority pupils, and much of the remedial research has centred in these areas. If language growth can be stimulated, especially in pre-school years, then the reading disability will be alleviated. Examples of this type of remediation are found in the pre-reading programs of HEAD START, the U.S. federal education program for minorities; and in the work undertaken by the East Cleveland City School District (1974).

### Cognitive Approach

The cognitive, or learning style strategy, implies that different children employ different strategies in learning. These strategies depend partly on innate factors such as Piagets stages of cognitive development and partly on learning-differential responses acquired early in the childs' development (Mason, 1977). Sawyer (1974) contrasts styles such as constructed, flexible, field dependent and impulsive. Thus, remediation lies in identifying the childs' particular strategy, and adapting remediation techniques to suit the individual child.

### Dyslexic Approach

The dyslexic, or specific learning disability strategy, suggests that reading disability is due to neurological deficits. Although all reading disability theories which assume underlying neurological dysfunction are considered dyslexic, Spache (1976) designates a dyslexic category, as apart from the perceptual approaches, because of its primarily theoretical, not directly remedial, nature. (i.e., direct remediation of reading disability via neurosurgery and/or neurochemotherapy is not at present a common remedial approach).

These disabilities could be due to a variety of causes including brain damage, heredity, laterality disturbances, and mixed cerebral dominance (Benton, 1975; Spache, 1976; Tarnopol and Tarnopol, 1977). "Maturational lag" has also been a popular explanation of reading disability (Ingram, 1970). Satz and Sparrow (1970) quoting Money (1966): "The great majority of reading disability cases will be classifiable not on the basis of brain pathology, but simply as representative of a lag in the functional

development of the brain and nervous system that subserves the learning of reading". (p. 34) Diagnosis is based on behavioural signs, EEG testing, etc....

Blom and Jones (1970) suggest that the term "dyslexia", when used in the literature, refers to at least four different approaches; i.e., functional, aetiological, theoretical, and nosological; and that these variations are often confusing. Valtin (1978-79), in reviewing the literature, suggests that there are many deficits in research technique. The author cites; 1) sampling problems, and 2) inexplicit, vague models which emphasize psychophysical dysfunctions and fail to link them to the "reading" process. She suggests that a more realistic approach would involve either process-oriented or sub-skill approaches. Work by Ball and Owens (1968), Blank, Weider, and Bridges (1968), and Blank and Bridges (1972) suggests that children with reading disability do not suffer difficulty in perceptual tasks, as "classic" dyslexic theory would suggest, but are more impaired in temporal pattern recognition; a skill that is more conceptual in nature, and much more complex than perceptual functioning. Vellutino (1977) suggests that recent research doesn't support the "traditional" dyslexic models (i.e. - dysfunctions in visual perception or intersensory integration or temporal order perception), but rather a verbal deficit hypothesis related to linguistic dysfunction.

#### Mechanical Approach

Mechanical methods of improving reading are a particular source of disagreement among experts on reading disability (Leviton and Thompson, 1976). However, this conflict is often artificial, and a matter of

definition. Spaches' (1976) "reading machines" are generally of the tachistoscopic type (Tinker, 1965; Solan, 1973). These machines, which modify eye-movement patterns and reading speed, are sharply criticized for the fact that they can potentially do more harm than good. Since they have the ability to control things like eye regression, they may wind up harming processes important to reading, such as reading judgment and interpretation. However, Spaches' definition of mechanical strategies appears to be overly limiting. Even as certain investigators lament the use of technology in aiding in the remediation of reading disabilities (Rodriguez, 1976), they themselves limit their speculation to audio-visual systems that are already hopelessly antiquated, and of little or no advantage in comparison to a teacher (Leviton and Thompson, 1976).

More recent and widespread success has emerged with another variety of reading machine, the computer (Watson, 1972; Harley, 1972). Holtzman (1970), in discussing the value of computer-assisted instruction (CAI), lists the three key advantages of such a program; 1) the precise pre-analysis of the learning task (in this case, reading) structure, 2) the ability to control individual difference variables relative to task constraints, and 3) well-defined and controlled instructional paradigms.

Computers, and their accompanying software systems, such as PLATO (Venezky, 1975) have created new directions in the field. Venezky (1975) has demonstrated that a reading comprehension test can be transposed from a paper and pencil medium to PLATO with no effect on childrens' scores and with a greatly improved ability to score and analyze the test. This, in turn, has lead to the possibility of a fast, total on-line diagnostic system for reading disabilities.

Knights and Hardy (1976, 1977, 1978) have produced just such a CAI assessment and remedial program for children with reading disabilities. One unique aspect of the program was the modification of the testing package so that it required only the childrens' teachers for administration and evaluation, and not the services of specially trained administrators, e.g. - psychometrists. Their test package tapped a sampling of what they believed the basic reading sub-skills to be; visual segmentation, auditory blending, grapheme-phoneme production, word attack, and decoding of words. The program reliably differentiated good from poor readers, and adjacent grade levels on all five test areas. An important strength of it lies in its ability, based on the outcome of the assessment, to specify specific correctional reading exercises from commercially available reading packages.

Atkinson, Fletcher, Chetin, and Stauffers' (1971) work with CAI is also well-known. He developed his system to: 1) supplement classroom instruction in, 2) tasks that required individual instruction. Atkinson (1974) found several sex-related characteristics of reading. Among the "top" (highly proficient) readers he studied, girls outnumbered boys by 3:1 ratio, while among disabled readers, boys outnumbered girls by approximately 3:1. There also appeared to be a sex-differential effect of CAI with 42% of the male disabled readers improving, while only 17% of the female disabled readers improved. Thus, Doehring (1978) has suggested that CAI training may reverse the male-female differences normally found in disabled readers.

In any case, flexible, multi-branch programming promises the potential for individual learning tailored to the demands of the student. Repeated drill-and-practice no longer is dependent on dedicated remedial instructors. Although drill-and-practice is a proven method "in-the-field", its lack of

reward for the teacher often led to it being avoided as a remedial aid, much to the detriment of the reading-disabled student. Overall success with computer-trained, as compared with non-trained children, has been very good. However, research directly comparing CAI vs. other reading remediation techniques is extremely scarce.

Emotional Factors Affecting CAI. In a related topic area, the role of emotional factors in CAI has been studied at length (Alexander, 1972; Orlow, 1974). In particular, the significant effects of state-anxiety in experimentation with all types of CAI has been thoroughly researched (Gaudry and Spielberger, 1971; O'Neil and Richardson, 1977). In contrast, trait-anxiety appears to bear no direct relationship to training performance (Gaudry and Spielberger, 1977). The state anxiety/performance relationship is not linear. Studies (O'Neil, et al., 1969) suggest that:

...the Ss with high A-state made more errors on the more difficult materials than Ss with low A-state and they made fewer errors on the easier materials. This interactive relationship between anxiety and performance on a learning task which varied in difficulty would be predicted from Spences' Drive Theory. (p. 75)

Thus, in any study involving CAI, A-state would appear to be a relatively fundamental variable to monitor.

### Sub-Skill Deficit Approach

Sub-skill deficit approaches to reading disabilities, according to Spache (1976), date back to the 1930's. Their common focus lies in diagnosing reading sub-skills in which the child is assumed to be deficient. Rebers' (1977) list of sub-skills involved in reading includes: visual perception of letter strings (Rayner, 1976; Massaro and Kitzke, 1977), auditory phonetic analysis of spoken words (Rae, 1977; Shlomo and Calfee, 1977), learning of letter-sound correspondences, meaning, and comprehension skills. Farr (1969) isolates four sub-skills, but stresses that there are basic problems in accurately and validly measuring each of them:

1) vocabulary - "...there is confusion about how to measure reading vocabulary or whether there is a unitary trait which can be labelled reading vocabulary", 2) "there is uncertainty as to whether speed (rate) and comprehension are related", 3) comprehension - comprehension tests should be (generally) untimed and covered a variety of topics, but not necessarily divided into diagnostic subtests, 4) rate of comprehension - as material gets difficult, the relationship between rate and comprehension appears to become minimal.

Venezky (1976), in discussing reading sub-skills, highlights five molar areas: 1) an understanding of the reading process, 2) appropriate scanning behaviour, 3) letter and word recognition, 4) letter-sound generalizations, and 5) comprehension of written materials, at least to the degree that the reader can comprehend the same message when received aurally. Somewhat more molecularly, he subdivides (Venezky, 1976) word recognition into five sub-skill areas: 1) letter differentiation, 2) association of a sound with a symbol (letter), 3) blending, 4) identification of a sound within a word, and 5) sound matching within words.

Doehring (1978) has isolated four basic skill areas that he feels are crucial in reading-disabled children: 1) visual-matching skills, 2) auditory-visual matching skills, 3) oral-reading skills, and 4) comprehension skills. Maliphant, Supramanian, and Sarage (1974), in reviewing experimental research of acquisition of reading skill, subdivide the research into four basically similar areas: 1) visual perception, 2) auditory-visual integration, 3) decoding letters to sound, and 4) higher order processing.

Studies Relevant to Sub-Skill Approaches. DeHirsch, Jansky, and Langford (1966) and Jansky and DeHirsch (1972) isolated four factors highly predictive of reading failure. They were: 1) deficient visual-motor organization, 2) deficient pattern - matching skills, 3) deficient pattern memory, and 4) oral language deficiencies. Vernon (1977), although not intending to enumerate sub-skills, accomplishes an analogous task by discussing four areas in the reading process that are particularly prone to dysfunction. They are: 1) analysis of complex, sequential visual and/or auditory linguistic structures, 2) linking of visual and auditory-linguistic structures, 3) establishment of regularities in variable grapheme-phoneme correspondences, and 4) grouping into meaningful phrases.

Criticism of Sub-Skill Oriented Remedial Approaches. One of the most recent and detailed criticisms is the work by Arter and Jenkins (1979). They identify six basic assumptions of the sub-skill-oriented remedial model, and review research which strongly challenges these assumptions. They conclude that remediation in special education, and by implication in reading disability, is based on a largely unvalidated model.

Unitary vs. Non-Unitary Sub-Skill Models. Although all sub-skill models treat reading as a series of component processes, the majority of them still adhere to a unitary model of disability, and disagree over what this unitary model should be. In fact, it appears that sub-skill disability models need not be unitary. Applebee (1971) lists at least four different statistical models which all come under the rubric of sub-skills models. Although cautioning against the needless use of complex models, he does not hesitate in suggesting that the era of unitary models of reading disability has been eclipsed, with the development of more sophisticated research techniques. Doehring (1968), "...One definite conclusion...is that the term "specific" has been inappropriately applied if it is meant to indicate that all or even almost all of the (subskills)...are at a normal level in children with...reading disability". (p. 128)

Consolidation of Unitary and Non-Unitary Sub-Skill Models. A possible solution to this problem may be seen in the work of Applebee (1971). He posits neither a totally atomistic, nor a totally holistic approach to reading disability, but suggests a middle ground. In his MODEL ONE (holistic), reading ability/disability is a single continuum (y) made up of varying levels ( $b_1 \dots b_k$ ) of a single unitary skill (x). When the level,  $b_x$ , falls below an arbitrary level, the child is said to have a reading disability. MODEL TWO (atomistic), reading ability/disability is a single continuum (y) made up of varying levels ( $b_1 \dots b_k$ ) of different sub-skills ( $x_1 \dots x_k$ ). When the level,  $b_x$ , falls below an arbitrary level, a child is said to have a reading disability. There are an infinite number of levels of sub-skills which can lead to the disability, and no particular sub-skills are considered more important than others.

This is a relatively simplistic model. MODEL THREE is similar to MODEL TWO except more than one functional relationship ( $Y_1 \dots Y_k$ ) is involved.

That is, reading ability/disability involves different sub-skills for different groups. This implies the existence of more than one group of disabled readers, with each group having a different pattern of sub-skills.

### Reading Disability Subtypes

This conclusion is in line with much of the recent research in the area. Benton (1975) also came to the conclusions that the evidence is too contradictory and inconsistent to support the assumption that all "dyslexic" children suffer from the same basic deficiency. He suggested that attempts be made to classify reading disabilities into homogeneous groups on the basis of performance on a variety of reading measures. Along these lines is Boder's (1973) tripartite classification of: 1) dysphonetic-readers who are unable to syllabicate, 2) dyseidetic-readers who are gestalt blind, and 3) dysphonetic-dyseidetic-readers who are almost totally word blind (alexia). Lorton (1977) distinguished three levels of reading disability - mild, corrective, and remedial - and showed experimentally, that in terms of reading sub-skills, these three groups are different in kind (i.e. - different sub-skill patterns) rather than degree. Allington (1978) found two distinct types of disabled readers: 1) those in which word recognition was superior in-isolation, and 2) those in which word recognition was superior in-context. Stone (1976) using patterns of reading errors, isolated two subgroups, those with: 1) static reversal errors, and 2) kinetic reversal errors. Petrauskas (1978) employing neuropsychological, as well as sub-skill patterns, isolated three groups of disabled readers. Steinberg (1976) using a similar approach described: 1) a perceptually-

disabled group, 2) a linguistically-disabled group, and 3) a mixed group. Pirozzolo (1978) suggested two subgroups related to neurological dysfunction. He said that in normal readers, the cerebral hemispheres process "in parallel". In disabled readers, one of the two hemispheres predominates, producing categories very similar to Boders' (1973) dysphonetic and dyseidetic. Other researchers who have classified reading disabilities into subtypes include: Doehring and Hoshko (1977), Ingram (1960), Kinsbourne and Warrington (1963), Rabinovitch (1968), and Mattis, French and Rapin (1975). Table 1 provides a summary of research on reading disability subtypes.

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Insert Table 1 about here

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It seems clear that using homogenous patterns of sub-skill deficits to define qualitatively different types of reading disability represents one possible, and very elegant, solution to the controversy within the field; integrating many of the apparently diverse findings mentioned in the preceding pages.

#### A Two Subskill Model of Reading/Reading Disability

Of particular interest is the work of Cromer (1968) and Oaken, Wiener, and Cromer (1971). Cromer (1968) identified two subtypes of disabled readers: 1) those with a vocabulary deficit, and 2) those with an "organizational" deficit. He defines "organizational" deficit as a word-by-word inputting rather than organizing input into "meaningful" units prior to inputting. Oaken, et al (1971) furthered this work by suggesting, and then proving experimentally, that poor comprehension may result from any

one of three combinations of the two basic reading sub-skills: 1) poor identification and poor organization, 2) poor identification and good organization, and 3) good identification and poor organization. Two conclusions of their study are of particular interest: 1) poor readers appear to have only a single mode of input organization, while good readers seem to employ at least two modes of organizational input, and 2) good identification skills are not a sufficient pre-condition for good reading.

#### Equivalence of Various Subskill Models

It can be seen easily that the identification sub-skill can be broken up into sub-sub-skills such as: visual perception of letter strings, auditory-phonetic analysis of spoken words, and learning of letter-sound correspondences, for example; and that the organizational sub-skill could be broken into sub-sub-skills of meaning and comprehension, for example. In at least one manner, we can see how many of the sub-skill theories are equivalent, if not equal. That is, for the most part, the commonly accepted sub-skill theories can be easily moulded to fit into the two-sub-skill theory of Oaken, et al (1971). For example, Vernons' (1977) first three categories (previously listed) can be replaced in Oaken, et als' (1971) identification category, and her fourth category, "grouping into meaningful phrases", is synonymous with the organizational sub-skill. Atkinson, et al (1971) demarcate two aspects of reading, decoding and communication, which also appear to be highly similar to Oaken, et als' (1971) identification and organizational sub-skill. Atkinson, et al (1971) suggests that while communication/organization is best taught in the classroom, that decoding/identification is best accomplished through computerized drill instruction.

The DeHirsch, Jansky, Langford (1966) model can also be adapted to the two-sub-skill model. DeHirsch, et als' (1966) first three sub-skills fit easily into the identification category, while their fourth sub-skill can best be interpreted as a behavioural indication of poor organizational sub-skills. Jansky and DeHirsch do not suggest that "identification" is sufficient for skilled reading, but they do imply that it is more important, in disabled readers, than the organizational factor. That identification sub-skills are a necessary but not sufficient cause of good organization, and hence good reading, has been shown by other researchers as well, (Samuels, 1970). Perfetti and Hogaboam (1975) concluded that the difference between skilled and unskilled readers is "due to a low level (identification) skill difference, and is not dependent upon knowledge of meanings". Steinheiser and Guthrie (1977) did do some research suggesting that identification and organization are parallel rather than serial processes, and operate in tandem. However, they felt that this apparent contradiction to current theory could be better explained by the fact that the sentences and test words used in their study were simpler and more familiar than those used in previous studies; hence, there was little or no need for organization skills once identification had occurred.

#### Automaticity and Accuracy-Subskill Related Processes

Work that is related to, but different from that of Oaken, et al (1971) has been undertaken by LaBerge and his co-worker, Samuels (Samuels, 1970; LaBerge and Samuels, 1974). They suggest (LaBerge and Samuels, 1974) that three sub-skills are necessary for reading achievement: 1) visual decoding, 2) phonological encoding, and 3) semantic retrieval. Clearly, the first two

sub-skills are equivalent to the identification sub-skill of Oaken et al (1971). The third sub-skill, semantic retrieval, is similar to Oaken, et als' (1971) concept of organization. Additionally, LaBerge and Samuels (1974) theorize that each of their sub-skills must be accomplished with: 1) accuracy, and 2) automaticity. Automaticity, as defined by LaBerge and Samuels (1974), is the process whereby, "with further repetitions, the stimulus code should begin to short-circuit the episodic code and form a new direct link with the response code" (p. 316). This is particularly important because the sub-skills are assumed to follow each other in serial order (i.e., visual decoding followed by phonological encoding followed by semantic retrieval); and if accuracy and automaticity are not achieved at the first two levels then performance of a complex skill, like semantic retrieval, would be impossible because the capacity of attention would be exceeded. "So long as word meanings are automatically processed, the focus of attention remains at the semantic level and does not need to be switched to the visual system for decoding, nor to the phonological level for retrieving the semantic meanings". (p. 320).

This entire process that LaBerge and Samuels (1974) describe, made up of three sub-skills and two associated processes, can be mapped onto words, phrases, sentences, etc...depending on the skill of the individual. The larger the unit size it is capable of being applied to, the more "skilled" is the reader.

#### The Importance of Automaticity

One unique aspect of the LaBerge and Samuels (1974) theory lies in its renewed emphasis on speed, or automaticity. This is not a new concept (Huey, 1908), but one which until of late had fallen into some disfavour.

LaBerge and Samuels (1974) say, "the slower the rate of learning to read, the more the person becomes aware of these component steps;" the implication, being that awareness of the component steps hinders skilled reading. Although this is an innate-like process in normal readers, it must be trained in disabled readers. LaBerge and Samuels (1974) emphasize that latency feedback in training these disabled readers is important.

This concept of automaticity has found new support in recent years, in theories which may seem superficially dissimilar. Diack (1970) implies that a new word must be sub-, or fully-vocalized initially, but that once it is "known" (cognized), there is no necessity that it must be re-vocalized (hence, it must simply be perceived correctly) in order to be "re"-cognized. This appears to be very similar to LaBerge and Samuels (1974) description of automaticity.

Fries (1963) was an early proponent of automaticity theory. Atkinson, et al (1971) say that, "Fries stated that learning to make grapheme-phoneme associations was not only necessary...but also that these associations must become habits so automatic that the graphic shapes themselves sink below the threshold of attention".

Judd and Glaser (1969) studied response latencies relationship to learning, through three stages: 1) initial learning, 2) to a criterion of near-perfect performance, and 3) through over-learning. Latency showed no change throughout the first two stages:

...however, during the overlearning period, whereas response probability remained relatively constant, latency showed a significant and sustained decrease presumably related to the consolidation of learning during the overlearning period. The suggestion from

this work is that the latency measure, as a short-term learning history variable, seems to detect aspects of learning not detectable from response frequency and may be related to and predictive of future retention. (p. 81)

Smith and Holmes (1971) make a simple yet compelling argument for the value and necessity of speed in the reading task:

...unless the reader reads fast enough, that is, around 200 w.p.m. or more, he is not going to comprehend what he is reading simply because his memory system will not be able to retain, organize and store the fragmentary information in any efficient way. This is the situation of any reader who does not read fast enough, who relies too much on visual information: he will have very little comprehension of what he reads. (p. 412)

#### Disagreement with Automaticity

However, not all researchers show agreement with the ideas of LaBerge and Samuels (1974), and their supporters mentioned above. Finn (1977-78) describes how lexical marker-transfer feature theory differs from automaticity theory; "In other words, the lexical marker-transfer feature theory states that semantic processing facilitates automaticity of word recognition whereas the LaBerge-Samuels theory states that automaticity of word recognition facilitates semantic processing", (p. 535) and Venezky and Calfee (1970) suggest that meaning is never "created" without some form of semantic retrieval; "...extremely common words are retrieved from a

highly organized store which can be searched rapidly on the basis of such features as initial letters and length. Less common words are stored differently and are more accessible by sound than by any other form".

#### Problems Related to Subskill Training

Another area of as-yet-unresolved conflict involves two sub-skill-related topics: 1) the differential effect of training sub-skills with real words as opposed to nonsense words, i.e. words with no real meaning in English, and 2) what transfer, differential or otherwise, occurs with this training. That is, how much does training on one sub-skill transfer a positive effect to another untrained subskill, or more basically, to different test words within the same subskill.

#### Real Words Versus Nonsense Words

Cunningham (1976) found that training on a nonsense word pronunciation task produced no improvement on a real-word pronunciation task, while training on a real-word task did result in significant improvement. Silverman (1976) found that words, presented visually, are perceived integrally, whereas non-words are perceived as separable stimuli, thus, at least implicitly, supporting Cunningham (1976). In contrast, Baron (1974) found that pronounceable pseudowords are equivalent to real words, using both response times and accuracy measures.

#### Transfer of Training

Hundert and Bucher (1976) suggest that transfer of word discrimination skills only occurs among words of high similarity, and not among those of low similarity because of differential attendance to visual cues. Samuels

(1970) appears to disagree with this viewpoint. In discussing training of identification skills, he suggested that there is an important trade-off between speed of acquisition of word discriminability and amount of transfer to words not studied. He suggested, as did Knafle (1976), that children select the easiest cue for recognition. If words used in training are highly discriminable (i.e. - only single letter cues are used), then acquisition of skill in this mode (i.e. - single letter cue mode) will be speedy, but transfer to difficult word discrimination tasks, involving multiple letter cue modes, will be poor. Along the same lines, van Meel, Vlek, and Bruijfel (1970) suggest that the differential effects of stimulus complexity are much more significant for reading disabled than for normal reading children:

The present findings suggest that when the complexity of a visual discrimination task increases, the performance of children with learning difficulties is comparatively more hampered. When only a few dimensions of difference were involved their performance was equal to or even better than that of normal children of comparable age, but they began to lag when the number of relevant dimensions increased. (p. 112)

It thus becomes clear that reducing stimulus complexity in order to engineer a "cleaner" experiment, can potentially backfire and produce results that would not have appeared with more complex stimuli.

Similar erroneous conclusions could be reached after reading Ralls and Fry (1975). They found no transfer in children after training discrimination of similar letters using both simultaneous and successive training

techniques. However, Muller (1972-73) demonstrated that certain transfer phenomena (i.e. - transfer of letter training to word reading) observed in adults do not universally generalize to the pre-reader, and that training in certain intermediate tasks is often necessary before positive transfer is observed.

This sampling of the research suggests that the inconclusive findings may be due to attempts, on the part of researchers, to oversimplify experimental designs that study transfer. Especially important appear to be the trade-offs among transfer, speed of acquisition, and task difficulty on the one hand, and training task stimuli (i.e. real vs. pseudowords, pronounceable vs. non-pronounceable pseudowords; etc...) on the other.

#### The Work of Doehring and His Colleagues

This brings us to the work of Doehring and his colleagues (Doehring, 1968, 1976, 1978; Doehring and Hoshko, 1977; Doehring, Hoshko, and Bryans, 1979; Doehring, Trites, Patel and Fiedorowicz, 1981, in press) who in the past several years have integrated much of the reading research on reading sub-skills, subtypes of reading disabled readers, automaticity and computerized remediation programs.

Prior to this research there had been a discontinuity between theoretical and applied models of reading disabilities, because few, if any, researchers had taken theoretical models and methodically attempted to validate them in applied situations, i.e., the importance of this research is in the methodical, or logical, development of the investigations.

Doehring and Hoshko (1977) employed the Q-technique of factor analysis to analyze and differentiate reading disabled childrens' responses to a

variety of reading sub-skill tests. They isolated three subgroups of children; group 1 had deficits in oral word and syllable reading, group 2 had deficits in auditory-visual letter matching, and group 3 had problems in rapid perception of sequences of graphemes and phonemes. This work was replicated with a group of 31 children who had mixed difficulties (i.e. - learning disabled, special ed., language disabled, mentally retarded). Analysis of this group of children also revealed three main subgroups. Two of the subgroups were similar to subgroups 2 and 3 of the first study, and provided strong support for Doehring's theory of reading disability subtypes. The third subgroup in this replication had a problem described as "visuo-perceptual" disorder.

Doehring, Hoshko, and Bryans (1979) made another replication using four groups of normal beginning readers. Using Q-factor analysis, they identified subgroups of normal beginning readers, and compared them to their reading disabled subgroups. Based on this work, Doehring concluded that reading disabled subgroups were not merely exaggerations of normal reading subgroups, and did not resemble profiles of beginning normal readers.

Doehring, et al. carried out further unpublished studies to confirm his work. He combined 31 of his subjects from the original reading disabled group with 31 of the normal readers and matched them for age and sex. Again, using Q-factor analysis, the three reading disability subgroups were maintained and identified, while the normal readers showed evenly distributed loadings on each of the disabled subgroups component test scores. A second unpublished study duplicated and corroborated earlier work by employing cluster analysis, rather than factor-analysis.

Finally, a full replication of Doehring's first study was carried out

(Doehring, Trites, Patel and Fiedorowicz, 1981, in press) using 88 subjects selected from the clinical population of a hospital neuropsychology lab. Seven of these subjects were siblings of other individuals in the test, and had no reading disability. They were included as a further test of the discriminative power of Doehrings' three subgroups. Seventy-two of the subjects were placed into the three sub-group classification. Seventeen were unclassifiable, including the seven siblings with no reading problems. This study provided strong confirmation of Doehrings' earlier (Doehring and Hoshko, 1977) work.

The three subgroups he definitely classified were:

- O - oral reading deficit,
- A - auditory-visual matching deficit, and
- S - letter sequencing deficit.

They appear to represent authentic subgroups of the reading disabled population.

A fourth subgroup, identified as having "visuo-perceptual" problems, may represent a mixed aetiology of reading/learning disability, and has not been conclusively isolated as yet.

It is hopefully clear from this synopsis of the work of Doehring that he does indeed agree with and consolidate much of the research that has just been reviewed.

#### Doehrings' Work in Relation to Other Researchers

Doehring, et als' (1977) subtypes cut, perpendicularly, across Vernons' (1977) typology. This is probably because Vernons' approach was based, at least implicitly, on an R-factor (Doehring, et al, 1977) approach that takes

into account different sub-skills, while Doehring's Q-factor approach takes into account different reader subgroups. In fact, Vernons' (1971) typology is relatively congruent with the four main subdivisions in the reading sub-skills test package that Doehring has devised, as would be logically expected.

Doehring (1978), at least implicitly, agrees with the basic theory of Oaken, et al (1971). His research suggests that:

...different patterns of reading skill impairments can lead to the same practical limitation on the extraction of meaning from printed sentences. Although theoretically possible, there may be no subtype of developmental reading disability where comprehension skills exceed oral-word-readiness skills, as sometimes occurs in aphasic adults. (p. 351)

Thus, as Oaken, et al (1971) and others (Fleisher, Jenkins and Pany, 1977) point out, word identification skills are a necessary but not sufficient condition for effective reading skill.

Doehring (1976), also is consistent with LaBerge and Samuels (1974), "it may be assumed that to be effective, any training given to children with different kinds of reading problems must continue beyond mere accuracy to the point where speed of response is high enough for the skill in question to be integrated with other component reading skills". (Doehring, 1976)

It is clear then, from this brief review, that much of the research involving diagnosis and treatment is not as contradictory as it appears at first sight. There is a thread of communality underlying the research.

### The Present Study

In the present study the focus is less on the diagnostic theory, and more upon remediation, although the two are little more different than obverse sides of the same coin. As Doehring (1978) has said, "there is less apparent disagreement regarding methods for the remedial teaching of children with reading disability... However, no rigorous scientific evaluation of...remedial methods has been carried out".

### Purpose

The purpose of this study was to study acquisition of skill and transfer of training in a group of reading disabled children. Another very important purpose of this study, although not experimentally defined, was to "debug" the hardware and software, and provide suggested methodological guidelines for future study in this area.

### Assumptions

The following assumptions were made:

1. This research was assumed to be very preliminary. Most of the methodology, software, and hardware were new, and often required arbitrary decisions regarding their most effective dispositions.
2. The reading process was assumed to be made up of a number of subskills; namely,
  - i) visual matching skills
  - ii) auditory-visual matching skills
  - iii) oral reading skills, and
  - iv) comprehension skills.

The particular sub-skill being trained, in this case, was the visual-

matching sub-skill. This sub-skill was used for two reasons:

- i) none of Doehring's (1977) three identified subtypes had a unique deficit in visual-matching skills, but all identified subtypes shared commonly in this deficit, and
- ii) because of the lower frequency of the other subskill deficits, it proved impossible to form homogeneous experimental groups of any single one of these other subskill deficit areas.

The sub-sub-skills, within the visual-matching sub-skill, that were chosen were:

- i) 4-letter CVCC words, and
- ii) 4-letter CVCC nonsense syllables.

The decision to have two experimental groups, one trained with words and one with nonsense syllables, was based on past research (e.g. - Rubinstein, Richter, and Kay, 1975) which suggested differential training effects with these two groups. The choice of using 4-letter CVCC combinations, as opposed to a 3-letter, 5-letter, CCVC, CVCV, etc. combinations, was arbitrary.

3. Acquisition of skill was assumed to be best determined by automaticity of task completion, i.e. - response latency. Accuracy of response was assumed to be a lower-order index of skill acquisition. This was because automaticity, as here defined, implies accuracy; but accuracy of response does not imply automaticity.
4. Because disabled readers were not assumed to represent a homogeneous subgroup, but were assumed to be compiled of several subtypes, it was

assumed that there would be widely differential intra-group, as well as inter-group, responses to the treatment.

5. Because the sub-skill being treated belonged to the first of Oaken, et als' (1971) sub-skills, i.e. - decoding, it was assumed that acquisition of skill would not be transferred to the second sub-skill, i.e. - organization. However, transfer within the decoding sub-skill area was expected to occur.
6. Because of its flexibility of programming, and speed of presentation, a CAI mode was assumed to be superior to an instructor using a drill and practice method, as a remedial method.
7. Certain peripheral aspects of CAI, i.e. - training anxiety, were assumed to have played a major part in skill acquisition. They were to be investigated.

#### Primary Hypothesis

The primary hypothesis was that training on visual matching (of four-letter words and four-letter nonsense syllables), a sub-sub-skill of the decoding sub-skill, would result in significant improvement on the three main independent measures:

1. median response latency on Doehring's Test of Reading Subskills (TRS),
2. error rate on the TRS, and
3. Wide Range Achievement Test (WRAT) reading word recognition subtest scores.

Transfer effects were investigated to examine whether or not the visual-matching training had significant effects on:

1. competency on other visual-matching tasks,

2. competency on auditory-visual matching tasks, and
3. levels of oral and silent reading skills (i.e. - organizational skills), as measured by the TRS.

In addition, pre-post comparisons on the Five-Item State Anxiety Scale (FISAS) was made to see what, if any, effects the training had on state anxiety.

#### METHOD

##### Subjects

Subjects were 12 former patients (8 boys, 4 girls) at the Royal Ottawa Hospital's Neuropsychology Laboratory, who had been referred there for neuropsychological assessment.

All subjects had received a primary neuropsychological diagnosis of either: 1) reading disability, and/or 2) learning disability—language arts. All subjects met the criteria of severe reading disability as defined by Doehring, Trites, Patel and Fiedorowicz (1981, in press). Their criteria were: 1) WISC, WISC-R, or WAIS were in the dull-normal range (i.e. F.S.I.Q.), or higher, 2) reading levels on the WRAT or the Durrell were retarded by at least two (2) grade levels in comparison to chronological age expectation, 3) psychiatric and neurological disease ruled out, 4) educational opportunities were adequate for reading acquisition, and 5) hearing and vision were normal.

Subjects were rank-ordered according to age, grouped in threes and randomly assigned to one of the three treatment groups. Table 2 lists ages, WRAT reading scores, F.S.I.Q.'s and primary neuropsychological diagnosis for each of the twelve subjects.

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Insert Table 2 about here.

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### Apparatus

The computer trainer is made up of five main elements: 1) a so-called "main-frame" housing the logic circuits, 2) a disc reader that utilizes a floppy-disk memory system, 3) a printer on which individual subject results of each training session can be printed to create permanent records, 4) a television monitor and keyboard console from which the experimenter can control the quality and quantity of material presented to the subject, and 5) a touch-sensitive screen and loudspeaker on which the training material is presented.

Using this direct type of interface (the touch-sensitive screen), rather than having the subject respond by keyboard, allowed more "fluid" interaction, in which the test stimulus and the subject response were more closely linked. This resulted in increased efficiency and achievement in matching tasks. For example, as the response choices were presented on the screen, the subject merely "touched" his choice with his finger. Reinforcement was immediate. If the choice was wrong, all three stimuli remained on the screen, with the correct choice being outlined in a rectangular box. If a correct choice was made, the screen went blank, and a "+" sign appeared, followed automatically by presentation of the next test stimulus. In order to make sure that reaction times were equivalent, the subject was required, after each trial, to return his "responding" hand to a resting position, designated in front of the touch-sensitive screen.

The visual-matching training subprogram (VIS-M) of Doehring's

remediation package covers: 1) letter names, 2) 2-letter nonsense syllables, 3) 3-letter nonsense syllables, 4) 3-letter words, 5) 4-letter nonsense syllables - CVVC, CVCV, CCVC, CVCC, 6) 4-letter words - CVVC, CVCV, CCVC, CVCC, and 7) irregular words. Training for this experiment included only four-letter nonsense syllables and words.

The Doehring Test for the Training of Reading Skills (TRS) is a compressed version of the entire remediation program. It includes 26 subtests covering four different areas of reading subskills: visual matching, auditory-visual matching, oral reading, and comprehension skills (see Appendix A) and takes approximately 1 1/2 - 2 hours to administer.

In addition, an anxiety measure, the Five Item State Anxiety Scale (FISAS) was administered during testing each day. The FISAS was developed from the original 20-item State-Trait Anxiety Inventory (STAI) (Spielberger, Gorsuch, and Lushane, 1970). It was developed specifically for the study of computer-based learning tasks. The original STAI had a high degree of internal consistency (i.e., alpha reliability co-efficients ranged from .83 to .94). In addition, validity was demonstrated by showing that the mean of each test item increased when measured during a sequence of increasingly stressful situations (Spielberger, et al., 1970). To create the FISAS version, three major criteria were used: 1) the mean score for each item was to increase with increasing levels of stress, 2) each item was to discriminate significantly between a relaxation (resting) condition and a testing (examination) condition, 3) items were to be equally reliable for females and males. Ten items from the 20-item scale met these conditions. Five were chosen, at random, to constitute the scale. Reported alpha reliabilities for this shorter scale ranged from .83 to .93 in 17 different

comparisons (O'Neil and Richardson, 1977). Evidence of the construct validity of this scale has been provided by a number of studies (Leherissey, O'Neil, Herniach, and Hansen, 1973; O'Neil, Speilberger, and Hansen, 1969; Speilberger, O'Neil and Hansen, 1972). Administration time of the FISAS is approximately one (1) minute. A copy of the scale is reproduced in Appendix B.

The reading subtest of the WRAT was used as an index of acquisition of reading skill. The WRAT is an often used (Wilson, 1975; Spring, 1976) and well-validated (Wilson, 1975; Spring, 1976) instrument for measuring word recognition reading skills. It was chosen specifically because of its ease and speed of administration. Although one could hardly describe it as a comprehensive measure of reading "proficiency", it does measure skills related to the "decoding" subskill of reading, i.e., word recognition. A copy of the WRAT reading subtest is reproduced in Appendix C.

### Power

Under certain circumstances, an experimenter can use past experimental research in his field to calculate the smallest sample size necessary to produce a relatively "power"-ful experiment. Generally speaking, an estimate of treatment effects, as well as an estimate of the population error variance, are necessary for a calculation of this minimum necessary sample size (Keppel, 1973).

However, as was the case in this particular experiment, we are often faced with doing research in an area where not enough previous research has been done to allow us to make estimates of either treatment effects, or the population error variance. Under these circumstances there is not a great

deal we can do at the design stage except to consider what Keppel (1973)

says:

Another way of looking at the problem of sensitivity (power) is to realize that in most, if not all, of the experiments we conduct, the null hypothesis is false. That is, when we treat groups of subjects differently, they will behave differently. Sometimes the differences in behaviour will be small, but they are probably still present. With this conviction, one could reasonably advocate the strategy of choosing a sample size just as large as the researcher can "afford" in the sense of time, energy, and other resources." (p. 540)

In fact, this was exactly what was done in this case. Because there was no previous research on which to base estimates of treatment size and population error variance, the only strategy possible was to work with a sample size as large as could be "afforded".

### Design

Subjects were ranked according to age, grouped in threes and then randomly assigned to one of three experimental groups: 1) Group 1-"C" (n=4) was a control group which received no remedial treatment. It was used to control for the possibility that post-test improvement might have occurred without treatment. That is, the control group controlled for the effect of the training sessions, 2) Group 2-"N" (n=4) received 7 1/2 hours (1 1/2 hours x 5 days) training on four-letter nonsense syllables (CVCC, and 3) Group 3-"W" (n=4) received 7 1/2 hours (1 1/2 hours x 5 days) training on

four-letter words (CVCC).

Acquisition of skill results were analyzed with an ANCOVA using post-test MRL as the dependent variate and the pre-test MRL as the co-variate. In addition, acquisition of skill plus all other results were also analyzed using t-tests. This was because, with the relatively small number of subjects per cell, we didn't want any pre-post differences created by treatment effects to be obscured by chance inter-group variances. Dependent measures of acquisition of skill (i.e., median response latencies, mean percentage error and WRAT reading scores) were compared. In addition, pre-post scores (on the median response latencies and mean percentage errors) on non-trained subskills were compared to assess degree of transfer. Pre-post scores on the FISAS were also compared.

#### Procedure

Each experimental subject was given the TRS, the WRAT, and the FISAS in the first session. In the second through sixth sessions the subject was given a training program in visual matching skills (described below) employing either "real" words (Group "W") or "nonsense" words (Group "N"). Midway through each of these sessions the subject was given the FISAS. In the final session the subject was again given the TRS, WRAT, and FISAS. Control subjects were given the pre-test (TRS, WRAT, FISAS), waited five days, and then given the post-test (TRS, WRAT, FISAS). The training program, because of its preliminary nature, was an ad hoc design based on only two of the approximately 11 variables included in the software program, i.e., TARGET and CHOICE-DELAY.

At the first session the subject, typically in the company of one or both parents, was given a verbal description of the equipment, the general

experimental goals, and the envisaged training program as it related to the particular subject. After the initial part of the first session, the E. and S. were alone in the training room. The WRAT was administered to the subject, and it was typically at this point that the subject was introduced to first-hand working with the computer. The introduction, mediated by the E., was designed to be as "low-key" and non-threatening as possible. All S.'s in each group, "N" and "W", started at the same level -- i.e., the visual matching task began with SIMULANTEOUS presentation of the TARGET and the CHOICE-DELAY. At this level, as the name implies, TARGET and CHOICE-DELAY came on together, and remained on the screen until S. made a choice.

The subject had to match "target" to one of three "choices" by touching the correct choice on the screen. The reaction time per trial was measured from the time the "choices" appeared on the screen to the time the subject touched the screen to make his choice. After each trial the subject returned his hand to standardize the measurement of reaction time. If the subject's choice was correct, a small "+" appeared on the screen in place of the correct choice for approximately 300 milliseconds. If the subject's choice was incorrect, a rectangle encircled the correct choice for 1500 milliseconds.

Normally, 15 matching tasks were performed at each "unique" bivariable level. If, after each block of trials the S. reached a criterion level of 90% success, one of the variables was "stairstepped" up to a more difficult level -- i.e., the length of the display time for the TARGET was shortened, while CHOICE-DELAY was gradually increased. These variable intervals were arrived at in a somewhat arbitrary fashion. However, certain factors were considered: specifically, 1) overly small gradations would lead to waning

interest (i.e., due to lack of challenge) on the part of the subject, and 2) overly large gradations would lead to frustration and anxiety interfering with, and masking, performance capacity.

Typically, TARGET was shortened in 100 msec. chunks, while CHOICE-DELAY was increased in 500 msec. chunks. These variables were stairstepped up to "threshold levels" -- levels above which the individual could not achieve, in any reasonable series of trials to criterion. Although it was assumed that threshold level would be different in each case, it was noticed that (at least for the particular subjects in this experiment) all subjects tended to reach similar threshold levels. These occurred when TARGET presentation was at 100 msec. and CHOICE-DELAY was at 3000 msec. Once this threshold was achieved, a series of trial blocks was presented in which variables were "relaxed" -- i.e., variables were reduced to less difficult levels. This was done with at least two ideas in mind: 1) to reduce stress that had accumulated in the training session, and 2) to see if subjects "set" in working at "increasingly difficult levels" were hampered when the demand was reversed -- i.e., "decreasingly difficult levels" (D.D.L.).

After some preliminary work<sup>1</sup> with the first two subjects, the maximum number of trials per block was set at 15, and the number of blocks per training session was set at twenty. This optimal level seemed to discourage fatigue over the entire session and encourage maximum effort during each block. Three other rules governed the manipulation of variables in each session: 1) If the S. remained at one variable level (i.e., AxBy) for five blocks he was automatically moved to the next variable combination level. This helped a great deal in controlling discouragement, and in breaking "failure sets" that subjects would apparently pick up at indeter-

minate levels, when they were clearly functioning below capacity. 2) The second rule was that if the subject had not reached threshold and wasn't into the D.D.L. by the end of the 18th block, the final two blocks were nonetheless reserved to give the subject the D.D.L. experience -- 19th block being 500, 500, and the 20th being SIM, SIM. A third rule that was not thought necessary initially had to be added to the procedure somewhat into the program. Despite matching S. for level of reading ability as closely as possible, it nonetheless happened that certain individuals "caught on" and demonstrated an unpredictably high aptitude for the matching task. It was thought that to penalize these subjects by putting them through a standardized 20-block design per day would decrease their motivation. Thus in the case of two of the subjects, they achieved criterion and returned to base level in fewer than the 20 blocks.

Each day this entire process was repeated. The subject started at a low skill level, peaked at a threshold, and then returned to the low skill level in an attempt to distress<sup>2</sup> him.

### RESULTS

Acquisition of skill, as measured by the MRL index, was analyzed by means of a one-way ANCOVA with the post-test MRL's as the co-variate. Acquisition of skill, as well as all other group results, was also analyzed using matched pairs t-tests. 1-tailed t-tests were used, where noted. Although this increased the probability of Type II (i.e., false positive) error, the directionality of the hypotheses seemed to justify their use.

Individual results for the two experimental groups were also briefly described.

Group Results

Acquisition of Skill. Acquisition of skill was measured with three separate indices: median response latencies (MRL's), WRAT reading subtest scores, and mean percentage (%) errors. Table 3 lists pre-post MRL's for all subjects in each of the three groups - N, W, and C. Table 4 lists pre-post WRAT reading subtest scores for the three groups, and Table 5 lists pre-post mean % errors for each of the three groups.

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Insert Table 3 about here.

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Insert Table 4 about here.

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Insert Table 5 about here.

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Although results of the ANCOVA for acquisition of skill were non-significant ( $F = -.4862$ ), a matched pairs t-test done on each group did show a significant training effect for Group N,  $t(3) = 2.54$ ,  $p < .05$ , 1-tailed. This could suggest that there were significant treatment effects in one or both of the experimental groups but that the results were obscured in the ANCOVA by large inter-group variances.

Training did not produce significant changes in the WRAT scores or

error rates of any of the three experimental groups.

Transfer of Skill. Transfer of skill was assessed by comparing, pre-post 1) median response latency (MRL), 2) mean % errors with matched pair t-tests. 1) MRL--there were two subgroups: a) "CORE" Transfer was assumed to be transfer within the same sub-skill area, i.e., visual matching. The pre-post results for each of the three groups are listed in Table 6; b) "ADDITIONAL" Transfer was assumed to be transfer, either within the same subskill area, i.e., decoding; and qualitatively different, and/or transfer to the second subskill area, i.e., organization. The pre-post results for each of the three groups are listed in Table 7. Note: transfer to COMPREHENSION skills was not measured because of technical difficulties in presentation of stimulus items. 2) Mean % Error--there were two subgroups similar to MRL groups. The pre-post results for each of three groups are listed in Table 8 ("CORE" Transfer) and Table 9 ("ADDITIONAL" Transfer).

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Insert Table 6 about here.

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Insert Table 7 about here.

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Insert Table 8 about here.

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Insert Table 9 about here.

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In "CORE" Transfer as measured by MRL, there was only one significant decrease in MRL; from visual matching tasks involving 4-letter nonsense syllables to visual matching tasks involving 3-letter nonsense syllables,  $t(3) = 3.92$ ,  $p < .025$ .

In "ADDITIONAL" Transfer as measured by MRL there were six significant decreases in MRL; from visual matching tasks involving 4-letter nonsense syllables to auditory visual matching tasks involving nonsense syllables,  $t(3) = 3.63$ ,  $p < .025$ ; from visual matching tasks involving 4-letter nonsense syllables to oral reading tasks involving individual words,  $t(3) = 5.95$ ,  $p < .025$ ; from visual matching tasks involving 4-letter nonsense syllables to oral reading tasks involving sentences and phrases,  $t(3) = 4.58$ ,  $p < .025$ ; from visual matching tasks involving 4-letter words to visual matching tasks involving single letters,  $t(3) = 3.08$ ,  $p < .05$ ; from visual matching tasks involving 4-letter words to oral reading tasks involving individual words,  $t(3) = 3.14$ ,  $p < .05$ ; from visual matching tasks involving 4-letter words to oral reading tasks involving sentences and phrases,  $t(3) = 3.11$ ,  $p < .05$ . There was one significant MRL increase; from visual matching tasks involving 4-letter words to oral reading tasks involving letter names and sounds,  $t(3) = -4.36$ ,  $p < .025$ .

These findings, coupled with the lack of significance in pre-post comparisons of "C" suggest that transfer does occur with training. However,

the nature of any such transfer is unclear, especially because of the high number of significant findings in the "ADDITIONAL" Transfer section, and the lack of significant findings in "CORE" Transfer.

One possible consistency among the seemingly random results relating to transfer of skill (as measured by MRL) seems to occur in the transfer from training on visual matching tasks involving 4-letter words and nonsense words to oral reading tasks involving letter names and sounds, nonsense words, real words, and sentences and phrases (see Table 7). Transfer to all four areas reached statistically significant levels. However, possible interpretations of this pattern are difficult to make.

In "CORE" Transfer as measured by mean % error there were two significant decreases in % error; from visual matching tasks involving 4-letter words to visual matching tasks involving 3-letter nonsense syllables,  $t(3) = 2.40$ ,  $p < .05$ ; from visual matching tasks involving 4-letter words to visual matching tasks involving 3-letter words,  $t(3) = 2.52$ ,  $p < .05$ . There was one significant increase in % error; from the control group to visual matching tasks involving 3-letter nonsense syllables  $t(3) = -3.62$ ,  $p < .05$ .

In "ADDITIONAL" Transfer as measured by mean % error there were two significant decreases in % error; from visual matching tasks involving 4-letter nonsense syllables to visual matching tasks involving single letters,  $t(3) = 3.27$ ,  $p < .025$ ; from the control group to oral reading tasks involving sentences and phrases,  $t(3) = 3.67$ ,  $p < .05$ .

These findings do not support the hypothesis that training has differential transfer effects to the "CORE" and "ADDITIONAL" areas. In

fact, they could lead one to conclude that mean % error is a generally unreliable index of transfer, as compared to MRL.

### Individual Results

Due to the inconclusive group findings, I have given brief descriptions of subjects individual responses to training.

Group N. 1) S.B.—He showed steady improvement over the first three days, a sizeable regression on the 4th day, and then a "consolidating" type of improvement on the final day which brought his performance levels up to those achieved during the first three days. On the negative side, performance on the more difficult tasks, on the final day, did not achieve levels achieved on the first day of training.

2) S.G.—Performance was very unpredictable over the training period, although overall, performance did improve markedly. Wide fluctuations within this period suggest that for S.G. emotional stability may have been an important factor for success in training.

3) P.B.—He improved markedly over the course of the five-day training session. There was a steady decrease in the MRL, with the exception of a temporary plateau on day three. While ability on the less difficult tasks improved every day, the success rate on the more difficult tasks reached a peak on the third day, decreased markedly on the fourth day, and then improved slightly.

4) H.R.—A "typical" response pattern. Steady improvement for three days, a regression to earlier performance levels on the fourth day, and a final day improvement, almost back to the highest performance level achieved. Comparatively, there was much more improvement on the more complex tasks than on the easier tasks.

Group W. 1) R.S.--This subject also showed a "typical" response. Steady improvement in the first three days, followed by a minor regression on the fourth day, and ending with even more improvement on the final day.

Improvement was marked at all levels of task difficulty.

2) N.G.--This subject showed an almost steady decrease in performance throughout the training sessions, with performance on the fifth day far below that of the first day. Comparatively, however, over the training sessions, performance on more complex tasks showed a larger decrement. Results may reflect a low frustration tolerance for reading tasks of all levels of difficulty.

3) J.P.--This subject also showed unpredictability and fluctuation throughout the training sessions, with performance on the fourth day being extremely poor and well outside the range of performance for the other four days. Performance on the final day, in comparison to the first day, showed a major decrement on basic tasks, but a clear increase in skill on more complex tasks.

4) A.R.--Performance over the training period was very inconsistent. There was a marked improvement from the first day to the second day, but the third and fourth days saw a return to the skill levels of the first day. And, on the fifth day, there was a marked decrease in achievement level. This ambivalence and fluctuation was even more pronounced in the less difficult task areas. While results were not nearly so inconsistent at the most difficult task levels, they were negative, with an almost steady decrease in achievement level over the five-day period. The fact that there was no consistency between training and results suggests not simple fatigue but more probably a motivational problem. Whether or not it was due to the

fact that the training involved real words, as opposed to nonsense syllables, is impossible to decide with the experimental paradigm employed.

WRAT Scores as Predictors of TRS and FISAS performance. Table 10 presents single-subject scores (pre-post) of the WRAT, FISAS, and main TRS categories (i.e., 4LN and 4LW).

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Insert Table 10 about here.

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Pre-test WRAT scores proved to be excellent predictors of post-test performance rank within the "N" group. However, within the "W" group, only the subject with the first-ranked pre-test WRAT score achieved similar results in the TRS categories. This suggests that either the "W" group subjects were markedly different to the "N" group subjects prior to testing, or that the "W" group training was markedly different than the "N" group training.

The ranked FISAS scores did not appear to have any clear relationship to either WRAT or TRS scores.

#### Personality Variables - Anxiety

Anxiety as a contributing factor to acquisition and transfer of skill was measured by comparing pre-post scores on the FISAS with matched pair t-tests. Table 11 summarizes the means, pre-post, for the three study groups--N, W, and C.

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Insert Table 11 about here.

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Results were not significant.

#### DISCUSSION

This experiment achieved many of its major aims. Experimentally, results suggest that subskill training does have an ameliorative effect on children with reading disabilities. Training on visual matching skills using nonsense syllables resulted in significant improvement in those skills, as measured by median response latencies. The improvement on the median response latencies reinforces the theory that "automaticity", considered by LaBerge and Samuels (1974) as the most important prerequisite of skilled reading, can be significantly improved through a training program employing CAI-mediated drill and practice methods. Although this study did not directly compare the relative efficacies of different remedial approaches in dealing with disabled children, it did extend the development of one of the subskill approaches, the work of Doehring and his colleagues (Doehring, 1978, 1976, 1968; Doehring, Hoshko and Bryans, 1979, Doehring and Hoshko, 1977). The extension of an approach, from theory to practice, is often a sign of the "coming of age" of a particular model. In this case, the bulk of Doehring's work, up to this time, has been involved with replicating his theoretical classifications on actual groups of reading disabled children. The present experiment advanced the model one step further forward by taking remedial programmes, based on Doehring's research, and introducing them to reading-disabled children, to see if the programmes

had a remedial effect in their specified areas. This, in fact, did prove to be the case in the visual-matching subskill studied in this experiment. Not only did this study further Doehring's model but it more generally provided further support for all subskill models, and their close "relatives", reading disability subtype models. By showing that training of a particular subskill resulted in an improvement in an area considered vital to skilled reading (i.e. automaticity), the experiment helped to answer some of the charges of lack of validation directed at subskill models, particularly the criticisms of Arter and Jenkins (1979). A second way that this study provided validation for subskill models was by demonstrating how almost all models discussed could easily be equated with the "two-subskill" model of Oaken, Wiener, and Cromer (1971). Although certain theoretical differences still exist, the possibility of a commonly accepted subskill model in the near future does seem closer to realization. Methodologically, the experiment provided a groundwork for further research in the area. Basic problems involving software programs, hardware eccentricities, and training paradigms were broached, and solutions presented. Although the mini-computer system used was fully operational prior to the experiment, its use as a "hands-on" remedial tool had not been previously tested. Many problems which, at first glance, appeared to be insignificant proved to be persistent irritants. The meeting of these problems, and the solutions that were either implemented immediately, or suggested for future refinement, meant important progress in "shaping" the hardware to its intended (i.e. remedial) environment. Problems in this area included the potentially distracting effects of hardware operation (e.g. the presence of the experimenter as he supervised and controlled the program operation, noise

produced by the cooling fan on the mainframe, etc...), as well as technical problems associated with the touch-sensitive screen.

As anyone who works with software programs knows, the debugging of new programs is a necessary, but painstaking evil. As part of the preparations for this experiment, the programs were reviewed countless times, "bugs" were ferreted out, and corrections made. This was another important step in making the transition from a theoretical to a practical use of Doehring's model. Most important, from a practical perspective, was the development of a training paradigm. It was in the development of this paradigm that the experiment, fitting software to hardware to subject, achieved a synthesis which will hopefully prove of use in the further experimental development of Doehring's subskill model.

#### Questions of Interpretation

Findings in many other areas were equivocal, and raised important questions of interpretation that will doubtless prove of some significance for future research in this area.

Did Semantic Processing Increase MRL's in Group W? There is at least one plausible reason for the lack of training effect in group W. For the N group the task was straight forward--moving from print to visual decoding to visual memory to matching. However, the W group may have erroneously tried to include semantic processing (i.e., making the task more complex, and therefore more time-demanding, than it actually was). If, in fact, they accomplished a dual task (i.e., visual matching plus semantic processing) it is not difficult to see why their MRL's were slower. Despite the fact that this task more closely replicates the reading process, than does visual matching, it may detract from achieving automaticity, simply because it lays

more focus on higher stage processing (i.e., semantic processing), and less on the processing that is trying to be improved to an automatic level.

Interpretation of the WRAT Findings. Although WRAT reading subtest results were not significant, their interpretation should not be overlooked. Improvement in the WRAT scores in Group N approached significant levels,  $t(3) = 2.19$ ,  $p = .20$ . This tendency (which implies a transfer of skill from nonsense word visual matching tasks to real word pronunciation tasks) suggests that the observed improvement in MRL's on nonsense word tasks, may also have an effect on the real reading process; at least that first part of the process, identified by Oaken, Wiener, and Cromer (1971) as "identification" skills.

Responses to Task Instructions. Mean % Errors appeared to be a very poor indicator of acquisition of skill, and this appears to confirm Judd and Glaser (1969) findings that once initial learning is completed (which we would expect in those readers who were not beginners) that response latency becomes a better indicator of skill acquisition than does accuracy rate. However, it became obvious after the experiment started that individual subjects seemed to selectively attend to different aspects of the instructions. That is, it was emphasized that goals were dual in nature - "to reduce reaction time as much as possible while also trying to maintain minimal error rate". Individual results suggested that the majority of people followed the instructions effectively. However, some subjects seemed to channel their efforts to a near-zero error rate. This seems to point out the complexity of the reading process, i.e., it is often necessary to trade-off a certain accuracy for the sake of increased speed. This study showed indirectly, that unless given very specific instructional sets,

children do not necessarily choose optimal strategies.

Transfer of Skill. Indicators of "transfer of skill" were also masked. Although in all cases of "CORE Transfer", when using MRL as the indicator, MRL decreased (including the "C" group), only one (4LN-3LN) decrease was significant. This is in contrast to Cunningham (1976) who found transfer of skill from real word training tasks, but not from nonsense word training tasks. Although the nonsense-word task transfer in this experiment was significant, its practical value is questionable, since the transfer was to a nonsense task, and not to a real-word task. Since the other two Core transfer areas for 4LN were real word tasks, (i.e., 3LW and 4LW), it could be suggested that "task similarity" was the important factor in the transfer results. And, conversely, that since there was no acquisition of skill demonstrated in the other areas, that expecting transfer of skill from a decoding to an organizational subskill would be illogical thinking. However, when we examine "ADDITIONAL" Transfer, again using MRL as the indicator, possible interpretations become somewhat less certain. What is consistent, is that again there is no transfer for the control subjects. However, we do unexpectedly encounter transfer from 4LW to "so-called" "NON-CORE" areas. The transfer to VIS-M, LN and 4LN is understandable given that the 4LN group exhibited acquisition of skill. The transfer to VIS-M, LN and 4LW is also understandable if we accept the hypotheses set out in the above discussion. That is, the W group, when given a task with similarities to the normal reading process, set about completing it at a dual level, thus negating any training effect. However, given a task that is clearly and exclusively a matching task (i.e., single letter matching) then the practice effect does show up.

Transfer in Unexpected Areas. "ADDITIONAL" Transfer within the auditory visual matching (AVM) tasks was also unclear and unexpected. That is, transfer was seen in both N and W areas, not only in the W area. However, this pattern is not totally inconsistent with the first two hypotheses that were offered above. Transfer from W to AVM, N & W, can be justified if we assume that the AVM task is similar to the dual task that the W group may have theoretically employed in the VIS-M tasks. If this is indeed the case, then any skill increase would not be obscured (as it was in the VIS-M tasks) by the use of an unnecessary task, i.e., because phonological encoding was required.

Subject Patterns in Skill Training. Individual results in the N group (the only group to demonstrate significant acquisition of skill;  $t(3) = 2.54$ ,  $p .05$ , 1-tailed) suggest a moderately consistent pattern in the training. That is, an efficiency peak occurred sometime between the second and third days, followed by definite dropoff in performance on the fourth day, and finally a second efficiency peak, either equal to or better than the first peak, on the fifth day. The pattern was less consistent in the case of the W group, suggesting that the 4LN group were acquiring definite skills, consolidating them (hitting plateau), and then improving more.

Anxiety and Faulty Response Sets. Improvement in the Group W FISAS scores approached significant levels;  $1.73$ ,  $p .20$ . This suggests that for Group W, the training may have served to dissipate pre-task anxiety. The exact nature of this pre-task anxiety is questionable. One possibility is that reading disabled children, long-frustrated with reading problems, became anxious because of the task similarity (i.e., - state anxiety) to the normal reading process. Task involvement served to dissipate some of the

anticipatory anxiety that the subjects manifested, but not all of it. In contrast, Group N was not initially as anxious, because the task similarity to the normal reading process was less pronounced. And thus, although post-test anxiety was not reduced as much in Group N as in Group W, the initially lower anxiety level may have enabled them to benefit more from their training. Group C also generally fits this hypothesis because not only were pre-test levels lower than either of the other groups (the difference in pre-test FISAS means between Group C and Group N approached significant levels;  $t(3) = 2.04$ ,  $p .20$ ), but there was no change post-test. A second possible explanation is that subjects in Group W may have possessed, by chance, more trait anxiety than subjects in Group N. And it was higher levels of trait anxiety, and not state anxiety created by task similarity, that resulted in their poorer performance on the experimental tasks.

In addition, a specific problem seemed to arise regularly during the sessions (related to the more general problems of anxiety). That is, subjects seemed to develop incorrect response sets. They would make an incorrect choice, become more anxious, try to hurry on the following task, and again make an incorrect choice. This often happened for several trials in a row; sometimes it would only stop when the subject was asked to slow down and be more careful. This clearly underlines the role of anxiety in the training program, and perhaps more generally in the reading process.

Subject Variance. One possible reason for the lack of clearly significant results in this experiment could be attributed to the wide variance, of ages and IQ's, of subjects within cells. This wide variance among potentially significant variables could have been controlled if a larger sample population had been available. However, because of the

relatively rare frequency of the reading and language arts disabilities that the subjects suffered from, and despite the relatively large size of the available client population, it was not possible to restrict variance of age and IQ any more than was here accomplished. Some attempt to partially control the potential influence of this variance was made by ranking subjects according to age, grouping in three's, and then randomly assigning to one of the three treatment conditions. Nonetheless, there remains a distinct possibility that either age and/or IQ may have been intervening variables that obscured potentially significant training effects.

Post-hoc Determination of Power. A post-hoc determination of power (Keppel, 1973) yielded a value of approximately .30. If we still maintain that our main hypothesis was valid despite the lack of clearly significant results, we can suggest that one or more of the following three problems might have been to blame; 1) sample size too small, 2) inadequate length and/or strength of treatment, 3) uncontrolled sources of error variance.

Future experimentation in this area should use the estimates, of treatment effects and population error variance, obtained to pre-plan and employ sample sizes of sufficient power.

### Conclusions

Due to limitations of equipment, time, and sample size, most results are provisional and suggestive. Nonetheless, both experimental groups made gains relative to the control group (although group W gains were not statistically significant). And, by way of conclusion, it seems safe to say that acquisition of skill was demonstrated in group N via the MRL index. This provides support for the use of Doehring's (1978) reading disability

subtype model as a potentially important remedial tool, and reinforces the view of CAI as a valuable medium for the treatment of reading disability (e.g. Atkinson, 1971). The experiment also supports LaBerge and Samuels (1974) idea that "automaticity" (i.e. median response latency) is a useful index of acquisition of skill. It also seems safe to conclude that training results in some transfer of skill, although the pattern of this transfer was unclear; and doesn't seem to be consistent with any single theory currently offered to explain transfer in the reading process (e.g., Cunningham, 1976; Muller, 1973).

#### Recommendations

Several recommendations for the continuation of research in this area arise from this experiment:

1. More single-subject designs should be used. Although this experiment did comment on individual subject responses, its main focus was a traditional group design. However, it is clear that even by drawing subjects from as large a subject population as is available at a large hospital Neuropsychology Lab, it is difficult to match subjects closely enough to create homogeneous populations. Matching should eventually include subtype of reading disability, although it fell outside the scope of this paper to attempt this. Large inter-subject variations, as were seen here, could easily obscure results, intra-subject, that might have been more congruent with hypothesized patterns of results; (Williams (1976) is a good example of a single-subject design that is relevant to, although not strictly concerned with, reading disabilities; Hersen and Barlow (1976) discuss the value of single-subject design at length).

2. If single-subject designs cannot be employed, then: i) group sizes should be made substantially larger. Although this may involve considerable difficulties, the advantages gained (in statistical strength and generalizeability) more than offset the disadvantages; and ii) experimental groups should have specific, rather than common, deficits. That is, all subjects in this experiment were assumed, on the basis of theory, to have a common deficit in the visual-matching area (and then trained on a differential procedure, using either nonsense syllables or real words). It would have been much more useful to reverse this procedure and form each group (based on pre-screening) with a unique deficit (e.g., one group from each of Doehring's three identified subtypes of disabled readers), and trained on a common procedure. This would have eliminated the possibility that training procedures employing nonsense syllables produced different training effects than those employing real words.
3. The use of different independent measures of "acquisition of skill" should be carefully considered. Although MRL served as a good measure of actual increment in skill achievement, its lack of "independence" from the task causes problems when discussing the applicability of the results to the actual reading process. In this sense, the WRAT was a "better" measure, but it still tapped only one component of the task, that is "word recognition". It is important that we can employ a measure that more completely represents the normalized reading process. A measure like the QASOR, (Aulls, 1976), which was originally proposed, might prove to be a useful addition as an independent index of skill acquisition and transfer to the reading process. However, the

same factors which prevented its use in this experiment, including length of the test and complexity of scoring and interpretation, may not make it feasible in an experimental paradigm.

4. Perhaps there is a need to make the apparatus more attractive to children. Good Performance should be acknowledged and rewarded; e.g., the chance to play a computerized game with the operator. Perhaps the screen and operator terminal could be isolated from the mainframe, which tends to produce a lot of noise from the fan used to cool it.
5. Strategies for the training of different subskills (in addition to those involving visual matching tasks) should be developed, as well as techniques to compare how training in the various subskills transfers differentially to the reading process.
6. Other key factors requiring further consideration are: i) optimal length of training sessions, both daily optimum and total training optimum; training periods should be extended to determine their differential effect on acquisition of reading subskills; ii) the length of time that skills are retained after training is discontinued; iii) the most effective way of manipulating variables; that is, in this design there was an arbitrary decision to manipulate two variables and to "stairstep" them; e.g., it might prove more informative to manipulate only a single variable; iv) obtaining some comparative reaction times for normal readers on the TRS.
7. The development of normative data on "normal" readers would contribute to a much clearer understanding of whether the relationship between "normal" and "disabled" readers is continuous and quantitative, or discontinuous and qualitative.

8. The role of emotional factors in the training procedure should receive further study. Although no significant results were obtained, the trends observed suggest that certain factors, such as preconceptions about the task, task anxiety induced by the demand for a "correct" answer, congruence of task to earlier, frustrating tasks (e.g., reading), "wrong" response sets or cycles, and boredom with the training procedure, all played potentially important roles in producing good training results.

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## FOOTNOTES

<sup>1</sup> Throughout this paper, "model" will refer to any stylized or hypothetical representation. Whether a model is described as theoretical or applied will be defined by the degree of one-to-one correspondence between the model and reality, i.e., the greater the one-to-one correspondence, the more "applied" the model.

<sup>2</sup> In the preliminary work 30, 20, 15, and 10 trials per block configurations were tested. The 30 and 20 trials per block configurations were too stressful and tiring for the subjects because of the timed responses demanded by the training paradigm. The 10 trials per block configuration was usually adequate but suffered from inaccuracy when subjects would slip into "failure sets".

The average time per block was divided into the maximum time available per day for training. This generated the number of blocks per training session.

<sup>3</sup> Although this represents some de-conditioning effect, the ratio of conditioning to de-conditioning trials was high (i.e., on the average, 17:3). It was felt that any decrease in trained automaticity was more than offset by an improvement in motivation.

<sup>4</sup> It should be reiterated that subjects, upon reaching criterion at a given level, moved on to more difficult tasks levels. Thus the individual results graphs of both MRL X TRAINING SESSION and Mean % Errors X TRAINING

SESSIONS show increases that should not be misinterpreted as declining task skill on equivalent tasks, but rather, as momentary declines in task skill owing to increasingly difficult task demands.

Therefore, comparison to assess achievement due to training is most accurately accomplished by comparing absolute scores, pre-post, on MRL or Mean % Errors.

TABLE 1  
SUMMARY OF RESEARCH INVOLVING READING DISABILITY SUBTYPES

Researchers	No. of Subgroups	Description of Subgroups	Remarks
Applebee (1971)	> 1	several groups of disabled readers, with each group having a unique pattern of subskills and hence, a unique identity	statistical theory
Boder (1973)	3	<ol style="list-style-type: none"> <li>1. dysphonetic-inability to syllabicate (63% of reading disabled population)</li> <li>2. dyseidetic-gestalt blind (9% of population)</li> <li>3. dysphonetic-dyseidetic-alexia (22% of pop.)</li> </ol>	theory developed from clinical observations
Lorton (1977)	3	<ol style="list-style-type: none"> <li>1. mild differential classification</li> <li>2. corrective initially based on how much individual was below expected grade reading level</li> <li>3. remedial</li> </ol>	each group possessed a unique subskill pattern (unspecified)-"mild" group was further distinguished as having psychological as opposed to educational deficits
Allington (1978)	2	<ol style="list-style-type: none"> <li>1. word recognition superior in isolation</li> <li>2. word recognition superior in context</li> </ol>	although theorized, no evidence found to support differential group membership in first two groups on basis of hemispheric dominance
Stone (1976)	3	<ol style="list-style-type: none"> <li>1. kinetic reversal group-poor sequencing ability</li> <li>2. static reversal group-direction confusion, ambilaterality</li> <li>3. all other poor readers</li> </ol>	based on patterns of performance on various neuropsychological measures
Petrauskas (1978)	3	<ol style="list-style-type: none"> <li>1. auditory verbal and other language related deficits</li> <li>2. sequencing deficit</li> <li>3. verbal retention deficit, expressive language skill problems, eye-hand coordination difficulties</li> </ol>	

(continued)

TABLE 1 (continued)

Steinberg (1976)	3	<ol style="list-style-type: none"> <li>1. perceptually disabled</li> <li>2. linguistically disabled</li> <li>3. mixed</li> </ol>	very similar to Boders (1973) classification.
Pirozzolo (1978)	2	<ol style="list-style-type: none"> <li>1. visuo-spatial dyslexia</li> <li>2. linguistic dyslexia</li> </ol>	theoretical-compatible with Boders (1973) classification-based on cerebral asymmetry
Doehring and	3-4	<ol style="list-style-type: none"> <li>1. oral reading deficit</li> <li>2. auditory visual matching deficit</li> <li>3. letter sequencing deficit</li> <li>4. visuo-perceptual deficit</li> </ol>	first three groups extensively validated in different populations-fourth group theorized, but not isolated exp.
Ingram (1960)	2	<ol style="list-style-type: none"> <li>1. specific dyslexics (76% of the sample)</li> <li>2. general learning difficulties, including arithmetic, spelling and reading patterns (24% of the sample)</li> </ol>	group 1 appeared to have a genetic basis for their dysfunction-group 2 had more evidence of brain damage and/or dysfunction
Kinsbourne and Warrington (1963)	2	<ol style="list-style-type: none"> <li>1. language disorder</li> <li>2. sequential ordering deficit</li> </ol>	groups initially isolated on VIQ/PIQ split (20 pts.) on the WAIS-groups were related to developmental cerebral deficits
Rabinovitch (1968)	2	<ol style="list-style-type: none"> <li>1. primary-developmental dyslexia</li> <li>2. secondary-reading retardation</li> </ol>	similar to Ingrams (1960) classification
Mattis, French, and Rapin (1975)	3	<ol style="list-style-type: none"> <li>1. language impairment, phonologic problems, labelling and naming difficulties, inadequate knowledge of syntax</li> <li>2. dysfunction in motor systems in resulting in speech articulation problems and visuo-motor (handwriting) dysfunction</li> <li>3. visuospatial dysfunction-difficulty in visual discrimination and visual memory</li> </ol>	group 1 is the largest, while group 3 is the smallest
Oaken, Wiener, and Cromer (1971)	3	<ol style="list-style-type: none"> <li>1. poor identification and poor organization skills</li> <li>2. poor identification skills</li> <li>3. poor organization skills</li> </ol>	

TABLE 2  
INDIVIDUAL SUBJECT DATA

Subject	Age	Sex	Group	Pretest WRAT Score	F.S.I.Q.	Primary Neuropsych. Diagnosis
1. N.G.	12	F	W	4.2	82	reading disability
2. P.B.	13	M	N	5.4	90	reading disability
3. J.P.	16	M	W	4.4	100	reading disability
4. R.S.	15	M	W	7.1	109	reading disability, learning disability-language arts
5. S.G.	10	F	N	4.0	112	learning disability-language arts
6. H.R.	14	M	N	5.6	92	learning disability-language arts
7. S.B.	16	M	N	8.9	119	reading disability
8. K.C.	15	M	C	5.4	106	learning disability-language arts
9. M.F.	14	M	C	6.4	101	reading disability
10. R.G.	15	M	C	5.6	104	reading disability
11. A.R.	9	F	W	2.7	94	learning disability-language arts
12. M.J.	8	F	C	2.5	107	learning disability-language arts

TABLE 3Median Response Latencies  
(in milliseconds)

	Pre	Post
"N" *	1343.25	1170.63
"W"	1341.63	1238.38
"n"	1789.38	1769.30
"C"	-----	
"w"	1498.30	1406.50

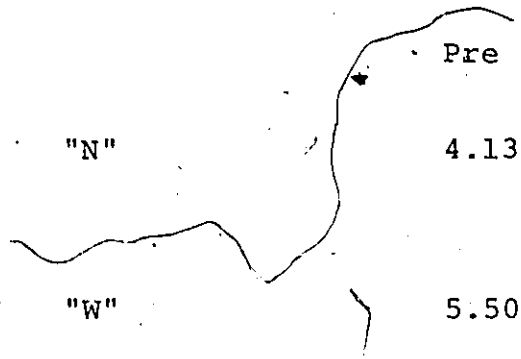
\* pre-post latencies significantly different at  $p < .05$

TABLE 4WRAT Reading Subtest Scores  
(in grade levels)

	Pre	Post
"N"	5.98	6.38
"W"	4.60	4.88
"C"	4.98	5.20

TABLE 5

Mean Percentage (%) Error



	Pre	Post
"N"	4.13	6.50
"W"	5.50	6.50
"n"	11.87	8.50
"C" -----		
"w"	6.37	5.16

TABLE 6

Median Response Latencies - "CORE" Transfer  
(in milliseconds)

VIS-M	Pre	Post
3LN*	1210.25	1070.50
-----		
"N" to 3LW	1192.63	1134.75
-----		
4LW	1183.25	1115.00
-----		
3LN	1408.50	1244.63
-----		
"W" to 3LW	1263.38	1206.25
-----		
4LN	1649.50	1379.38
-----		
"C" to 3LN	1537.63	1484.13
-----		
3LW	1477.63	1371.38

\* pre-post latencies significantly different at  $p < .025$

TABLE 7

Median Response Latencies - "ADDITIONAL" Transfer  
(in milliseconds)

	VIS-M		L-NS2		N3		W4		L-NS		N		W		OR-SP	
	pre	post	pre	post	pre	post	pre	post	pre	post	pre	post	pre	post	pre	post
"N" to	874.50	742.63	612.63	642.13	2011.25	1497.00*	1278.50	1156.13	1109.50	1228.33	2456.83	2215.33	1655.17	1517.83*	3036.50	2599.67*
"M" to	1021.13	697.25	711.13	771.50	2058.13	1723.50	1442.88	1133.13	1109.50	1241.88**	3023.75	2413.50	1649.25	1255.88*	3167.25	2867.00*
"C" to	925.50	880.13	750.72	841.20	750.72	841.20	1110.08	1227.53	1110.08	1227.53	1110.08	1227.53	1110.08	1227.53	2558.50	2328.50

\*pre-post latencies significantly different at  $p < .05$

\*\*pre-post latencies significantly different at  $p < .025$

- 1 letter naming
- 2 letter naming and sounding
- 3 mean MRL of 3 and 4 letter nonsense words
- 4 mean MRL of 3 and 4 letter real words

TABLE 8Mean Percentage (%) Error - "CORE" Transfer

	VIS-M	Pre	Post
"N" to	3LN	12.25	4.88
	3LW	4.00	9.88
	4LW	2.38	2.25
"W" to	3LN	7.13	3.13*
	3LW	7.13	3.00*
	4LN	8.63	9.75
"C" to	3LN	5.43	16.30**
	3LW	8.70	11.00

\*pre-post scores significantly different at  $p < .05$

\*\*pre-post scores significantly different at  $p < .025$

TABLE 9

Mean Percentage (%) Error - "ADDITIONAL" Transfer

	VIS-M		AVM		L-NS <sup>2</sup>		N <sup>3</sup>		W <sup>4</sup>		L-NS		N		ORW		W		OR-SP		
	pre	post	pre	post	pre	post	pre	post	pre	post	pre	post	pre	post	pre	post	pre	post	pre	post	
"N"	3.00	0.00**	1.50	17.00	10.50	8.75	6.38	3.30	0.00	25.33	18.50	12.00	9.83	8.67	8.67	20.75	29.75	11.25	3.00*		
"M"	0.00	0.00	4.89	22.00	20.63	9.75	11.33	1.50	3.25	34.25	28.00	16.38	14.75	20.75	29.75	20.75	29.75	11.25	3.00*		
"C"	1.00	2.00	4.89	22.00	20.63	9.75	11.33	1.50	3.25	34.25	28.00	16.38	14.75	20.75	29.75	20.75	29.75	11.25	3.00*		
			11.83	11.83	12.00	12.00	12.00	17.10	17.10	17.10	17.10	17.10	17.10	17.10	17.10	17.10	17.10	17.10	17.10	17.10	
			pre	pre	post	post	pre	pre	pre	pre	pre	pre	pre	pre	pre	pre	pre	pre	pre	pre	
			post	post	pre	pre	post	post	post	post	post	post	post	post	post	post	post	post	post	post	

\*pre-post scores significantly different at  $p < .05$   
 \*\*pre-post scores significantly different at  $p < .025$

- 1 letter naming
- 2 letter naming and sounding
- 3 mean MRL of 3 and 4 letter nonsense words
- 4 mean MRL of 3 and 4 letter real words

TABLE 10

Single Subject Scores (Pre-Post)

of the

WRAT, FISAS, and main TRS Categories

WRAT <sup>1</sup>		4LN		4LW		FISAS <sup>3</sup>	
Pre	Post	Pre	Post	Pre	Post	Pre	Post
5.4	3	1411.5	1416.	3	1184.5	1179.	7 .6
4.0	4	2024.	1827.	4	1801.	1982.	12 .10
8.9	1	969.5	643.5	1	758.5	561.	10 8
5.6	2	968.	796.	2	989.	738.	9 12
Group "N"							
WRAT <sup>1</sup>		4LN		4LW		FISAS <sup>3</sup>	
Pre	Post	Pre	Post	Pre	Post	Pre	Post
4.4	2	1657.	1326.5	2	1317.5	1447.5	8 5
2.7	4	1243.	1496.	3	1072.	1245.5	13 11
7.1	1	1593.	865.5	1	1357.	828.5	11 9
4.2	3	2105.	1829.5	4	1620.	1432.	10 9
Group "W"							
Pre	Post	Pre	Post	Pre	Post	Pre	Post
4.4	2	1657.	1326.5	2	1317.5	1447.5	8 5
2.7	4	1243.	1496.	3	1072.	1245.5	13 11
7.1	1	1593.	865.5	1	1357.	828.5	11 9
4.2	3	2105.	1829.5	4	1620.	1432.	10 9

1 in grade levels  
 2 MRL's in milliseconds  
 3 range: 0 → 20; low → high anxiety  
 \* within-group rank

TABLE 11

Mean FISAS Scores

	Pre	Post
"N"	9.50	9.00
"W"	10.50	9.00
"C"	7.50	7.50



Appendix B - FISAS

## The Five-Item State-Anxiety Scale

Items	Student Responds:			
	1 Not at all	2 Somewhat	3 Moderately so	4 Very much so
feel calm*				
feel tense				
feel at ease*				
feel jittery				
feel relaxed*				

\*Scoring is reversed.

Appendix C - WRAT Reading Subtest

Two letters in name (2)      A   B   O   S   E   R   T   H   P   I   U   Z   Q (13) 15

---

milk    city    in    tree    animal    himself    between    chin    split    form 25

grunt    stretch    theory    contagious    grieve    toughen    aboard    triumph 33

contemporary    escape    eliminate    tranquillity    conspiracy    image    ethics 40

deny    rancid    humiliate    bibliography    unanimous    predatory    alcove 47

scald    mosaic    municipal    decisive    contemptuous    deteriorate    stratagem 54

benign    desolate    protuberance    prevalence    regime    irascible    peculiarity 61

pugilist    enigmatic    predilection    covetousness    soliloquize    longevity    abysmal 68

ingratiating    oligarchy    coercion    vehemence    sepulcher    emaciated    evanescence 73

centrifugal    subtlety    beatify    succinct    regicidal    schism    ebullience 82

misogyny    beneficent    desuetude    egregious    heinous    internecine    synecdoche 89

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FOR INDIVIDUAL AND GROUP COMPARISONS USE ONLY STANDARD SCORES ON PAGES 16 TO 42 OF MANUAL.

LEVEL I - GRADE NORMS

LEVEL II - GRADE NORMS

Score	Grade	Score	Grade	Score	Grade	Score	Grade	Score	Grade	Score	Grade	Score	Grade	Score	Grade	Score	Grade	Score	Grade	Score	Grade	Score	Grade				
1	N.5	16-17	Kg.6	36-37	1.9	53	3.3	66	5.3	79	8.1	92	12.9	0	PK.5	16	1.3	29	4.4	42	6.8	55	9.3	68	13.0	81	16.8
2	N.8	18	Kg.7	38	2.0	54	3.5	67	5.5	80	8.4	93	13.3	1	PK.8	17	1.5	30	4.6	43	6.9	56	9.6	69	13.2	82	17.1
3	PK.1	19-20	Kg.8	39-40	2.1	55	3.6	68	5.7	81	8.7	94	13.7	2	Kg.1	18	1.7	31	4.8	44	7.1	57	9.9	70	13.5	83	17.4
4	PK.2	21	Kg.9	41	2.2	56	3.8	69	5.9	82	9.0	95	14.1	3-4	Kg.2	19	1.8	32	5.0	45	7.3	58	10.2	71	13.8	84	17.7
5	PK.4	22	Gr.1.0	42-43	2.3	57	3.9	70	6.1	83	9.3	96	14.5	5-6	Kg.3	20	2.0	33	5.2	46	7.5	59	10.5	72	14.1	85	18.0
6	PK.5	23	1.1	44	2.4	58	4.1	71	6.3	84	9.7	97	14.9	7	Kg.4	21	2.2	34	5.4	47	7.7	60	10.8	73	14.4	86	18.3
7	PK.7	24-25	1.2	45-46	2.5	59	4.2	72	6.5	85	10.1	98	15.4	8	Kg.5	22	2.4	35	5.6	48	7.9	61	11.3	74	14.7	87	18.6
8	PK.9	26-27	1.3	47	2.6	60	4.4	73	6.7	86	10.5	99	15.8	9	Kg.6	23	2.6	36	5.8	49	8.1	62	11.6	75	15.0	88	19.0
9	Kg.1	28-29	1.4	48	2.7	61	4.5	74	6.8	87	10.9	100	16.2	10-11	Kg.7	24	2.8	37	6.0	50	8.3	63	11.9	76	15.3	89	19.5
10-11	Kg.2	30-31	1.5	49	2.8	62	4.7	75	7.0	88	11.3			12	Kg.8	25	3.2	38	6.2	51	8.5	64	12.2	77	15.6		
12	Kg.3	32-33	1.6	50	2.9	63	4.8	76	7.2	89	11.7			13	Kg.9	26	3.5	39	6.3	52	8.7	65	12.4	78	15.9		
13-14	Kg.4	34	1.7	51	3.0	64	5.0	77	7.5	90	12.1			14	Gr.1.0	27	3.9	40	6.5	53	8.9	66	12.6	79	16.2		
15	Kg.5	35	1.8	52	3.1	65	5.1	78	7.8	91	12.5			15	1.1	28	4.2	41	6.6	54	9.1	67	12.8	80	16.5		

LEVEL I

cat    see    red    to    big    work    book    eat    was    him    how 36

then    open    letter    jar    deep    even    spell    awake    block    size 46

weather    should    lip    finger    tray    felt    stalk    cliff    lame    struck 56

approve    plot    huge    quality    sour    imply    humidity    urge 64

bulk    exhaust    abuse    collapse    glutton    clarify 70

recession    threshold    horizon    residence    participate    quarantine 76

luxurious    rescinded    emphasis    aeronautic    intrigue    repugnant 82

putative    endeavor    heresy    discretionary    persevere    anomaly 88

rudimentary    miscreant    usurp    novice    audacious    mitosis 94

seismograph    spurious    idiosyncrasy    itinerary    pseudonym    aborigines 100

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A   B   O   S   E   R   T   H   P   I   U   Z   Q 10

Two letters in name (2)

A   B   O   S   E   R   T   H   P   I   U   Z   Q 25