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Cognitive structuring of first and second grade children with learning disabilities

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Cognitive structuring of first and second grade children with learning disabilities

by

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CHAPTER I INTRODUCTION

Purpose of the Study

The purpose of this study was to compare the cognitive organization patterns used from auditory, visual, or haptic modalities of sensory input by children with learning disabilities and children demonstrating successful academic achievement.

Early school age children, usually associated with traditional first and second grade levels, were used because

> clearly, it is desirable to detect children with learning disabilities as early as possible. Not only can subsequent academic failure be avoided or lessened, but remediation (other things being equal) should be more readily and permanently accomplished (McCarthy and McCarthy, 1969, p. 25).

A new test was used to provide opportunity to evaluate similar cognitive organization patterns using isolated and different input modalities. According to Johnson and Myklebust (1967, p. 21), "Integrative learning functions are especially difficult to measure objectively because tests remain largely undeveloped". In an unpublished doctoral dissertation, Hurley (1965, p. 10) stated: "There are no direct tests of the integrative process itself; i.e., the organization and integration of incoming and outgoing sensory units".

Stated more specifically, then, the null hypotheses of this study were derived from the theories that between children with learning disabilities and children of average or above average academic achievement there were no differences in:

1. fluency of memory, use of short-term or long-term memory techniques, fluency of intrusion or redundancy effects, or associative clustering processes in an auditory recall task,

2. task performance in reconstruction or transposition of a progressive matrix with visual symbols,

3. task performance in reconstruction or transposition of a progressive matrix with haptic forms.

To measure these cognitive organizational patterns in children of first and second grade development levels a new test was introduced which could adequately and independently identify these structures in auditory, visual, and haptic modalities.

Importance of the Problem

The preliminary program of the 1972 International Conference of the Association for Children with Learning Disabilities (ACLD, 1972, p. 3-4) stated that:

> According to the most conservative estimates, as many as 3 percent of the total school age children are those with specific learning disabilities which interfere with the development

of their full potential. Recent studies show the incidence may be as high as 10 to 15 percent.

It is self-evident that any factor assumed to account for such a large percent of academic underachievement merits study, even if the lowest available estimates are considered.

Since its inception at Skokie, Illinois in January of 1964, the ACLD has grown in membership from a handful of parents to an international organization of over 20,000 members in 39 affiliated states, the District of Columbia, and the Virgin Islands. Since 1964 the ACLD has grown from 200 state and local affiliated groups to over 300 such groups in 1972. These data of membership are evidence of the growing concern of lay and professional representatives for the importance of learning disabilities.

During the past five years there has been a steadily increasing emphasis upon the study of learning disabilities reflected in the increased allocation of federal and state funds directed at the creation of various studies, demonstration programs, and graduate level stipends concentrating in learning disabilities. The magnitude of this emphasis is of such proportion that it would be both inappropriate and virtually impossible to list the projects related to learning disabilities presently available.

In the area of research on central processing dysfunctions of children, much remains to be done, and many difficulties are anticipated in developing adequate information for initial studies to use as guideposts. As stated by Chalfant and Scheffelin (1969, p. 139):

> The synthesis or integration of sensory information represents one of the most exciting and highly complex areas for future research. Much of the previous research has attempted clinical investigations of single functions while attempting to control for other functions. While this kind of research is urgently needed, further research efforts should not ignore the synthesis of sensory information.

Synthesizing or organizing sensory information assumes that stimuli have in fact been received. The perceptions of stimuli are, however, somewhat dependent upon the cognitive tactics used for assimilating new stimuli into existing cognitive structures. As pointed out by Rohwer and Levin (1971, p. 127):

> For the moment, however, it is appropriate to begin with two explicit assumptions: (a) the accomplishment most crucial for efficient performance on a learning task is that of selecting or concocting a tactic that renders the task easy; and (b) one of the major sources of difference in learning proficiency between persons is their facility in using, and, if necessary, producing effective learning tactics, as well as in their preferences for some kinds of tactics rather than others.

Not only is organization important for assigning sensory input to appropriate categories for meaningful assimilation, but also effective organization is essential for efficient storage or retention of knowledge. As asserted by Bruner (1963, p. 31-32), "Organizing facts in terms of principles and ideas from which they may be inferred is the only known way of reducing the quick rate of loss of human memory".

Definition of Learning Disabilities

The rate of incidence of learning disabilities and the study of children with learning disabilities is greatly dependent upon the definition established which provides the criteria for identifying children with learning disabilities. In their first annual report, the National Advisory Committee on Handicapped Children (1968, p. 34) determined that:

> A learning disability refers to one or more significant deficits in essential learning processes requiring special educational techniques for its remediation.
>
> Children with learning disabilities generally demonstrate a discrepancy between expected and actual achievement in one or more areas, such as spoken, read, or written language, mathematics and spatial orientation.
>
> The learning disability referred to is not primarily the result of sensory, motor, intellectual, or emotional handicap, or lack of opportunity to learn.
>
> Deficits are to be defined in terms of accepted diagnostic procedures in education and psychology.
>
> Essential learning processes are those currently referred to in behavioral science as perception, integration, and expression, either verbal or nonverbal.

> Special education techniques for remediation require educational planning based on the diagnostic procedures and findings.

From this definition it is clear that children with learning disabilities are children with normal or above normal intelligence (usually determined by IQ), diagnosed by educational and psychological procedures as experiencing an achievement deficit due to reasons other than peripheral nervous system disorders, emotionally based interferences, mental retardation, or lack of opportunity to learn.

Model for the Thinking Process

It is immediately recognized that there is merit in describing a model for thinking processes and clarifying the difference between learning and performance. As described by Hull (1952) performance and learning are not to be construed as synonymous concepts. This point is made most clear by a brief examination of Hull's model for performance:

$$f(H \times D \times K) - I = \text{performance}$$

where H is the "habit strength" or learning, D is the drive or motivational influences, K is the reinforcement factors, and I represents the inhibition factors, such as fatigue, etc. For the purposes of this study, motivation, reinforcement, and inhibition (dynamic psychological factors) are not considered. Without suggesting that such factors are less than vital in the total performance of learners, these variables are assumed to be equal in the testing situation presented, and are considered as separate factors from a study of preferred cognitive organizational patterns.

The framework from which most, if not all, psychological theory on learning is derived is reported in depth by Chalfant and Scheffelin (1969, p. 3) as follows:

> The computer model for information processing was adopted for this purpose (see Fig. 1). Auditory, visual and haptic stimuli (or sensory information) are transmitted to the central processing mechanism (brain) where they are analyzed, integrated, and stored. The behavioral response of the subject serves as an additional input source (feedback) for correcting or adjusting further behavioral responses.

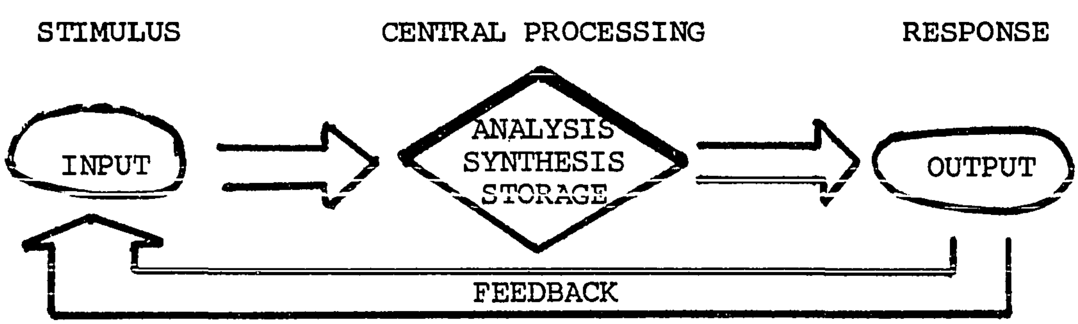

Figure 1. Computer model for thinking process

Specific mention of the auditory, visual, and haptic (kinesthetic plus tactile) stimuli is provided as it is generally accepted that through these three modalities the sensory input most useful to human learning, particularly cognitive operations, is derived.

Such a model can be deceivingly superficial if one assumes each step to be mutually exclusive. As pointed out by Hebb (1966), how one attends is dependent upon a temporary mental set the individual may adopt or be stimulated to adopt by means of verbal instructions. Gagne (1970) mentions that the first sequential step in all types of learning must be that of "apprehending", which includes attending perceiving, and coding. He points out that "strategies, after all, are rules that govern the individual's approach to listening, reading, storing information, and retrieving information, or solving problems....To be an effective problem-solver, the individual must somehow acquire masses of organized intellectual skills". The process of assimilation of attended stimuli is apparently varied by the selection of preferred strategies for assigning each stimulus to its designated apprehensive channel or mass (Herbart, 1913). This type of explanation reminds one of the familiar question of whether the egg or the chicken arrives first in creation, and points out that although etiology may be in question the interdependence of one upon the other seems self-evident.

Delimitations and Terminology

Cognitive organization patterns are generally interpreted to refer to any tactics, schemata, systems, or methods used to structure cognitive information. Cognitive information, as defined by Neisser (1966, p. 4), "refers to all the processes by which the sensory input is transformed, reduced, stored, recovered, and used....Given such a sweeping definition, it is apparent that cognition is involved in everything a human being might possibly do: that every physiological phenomenon is a cognitive phenomenon".

Obviously, such a sweeping definition of cognitive information requires delimitation if practical study is to be performed. For this reason specific representations of available cognitive strategies and conceptual types are selected.

Saltz (1971) describes the four basic types of concepts as simple, conjunctive, disjunctive, and probabilistic. For this study an emphasis is placed on the conjunctive concept, which implies that two or more previously unrelated attributes must be present simultaneously.

The cognitive strategy selected is that of transformation or transposition, used synonymously for this purpose. According to Merrifield (1966, p. 26),

> Transformation is a change, a redefinition, a realignment. One could almost consider transforming as an 'operation'; as a counter to this possibility is the feeling that a transformation can be operated on like other products-cognized, produced, remembered, and evaluated. A transformation seems to be the kind of product that is characterized by the 'closure' that leads from a class to a system; or the 'insight' that leads to a reinterpretation of a unit in terms of its newly considered relations to other units or

> classes or systems; or the substitutions of some relations for others that leads from a given system to a different system. Its essence is change--its occurrence is necessary in what is called creativity.

Therefore, what is being studied here specifically is the cognitive process of transformation of auditory, visual, or haptic input using materials which demonstrate the properties of a conjunctive concept.

Summary

Recognizing that a large percent of academic underachievement is attributed to learning disabilities, there is a growing concern for identification and remediation of specific dysfunctions of the syndrome.

One of the prevailing questions is whether or not children with learning disabilities generally differ from normally achieving children in their cognitive organization patterns or strategies for attaining and integrating knowledge, particularly through the auditory, visual, or haptic modalities.

An existing handicap in the investigation of this question is the limited availability of adequate techniques for measuring cognitive strategies.

This study offered an opportunity to evaluate differences and similarities of children with learning disabilities and children of average or above average academic achievement on auditory, visual, and haptic cognitive structuring.

CHAPTER II REVIEW OF THE LITERATURE

General Review on Brain-Injured Children

According to Money (1962, p. 222) the early interests in learning disabilities may have begun with Roussou's origination of the term "aphasia", which is still used in association with learning disabilities. However, the interest in scientific study of learning disabilities is more appropriately credited to early studies of brain-damaged subjects, specifically by Goldstein (1942) and his research with brain-injured adults in World War II.

Stimulated by the Goldstein studies of adults, Strauss and Werner (1942), Strauss and Lehtinen (1947), and Strauss and Kephart (1955) concentrated on the relationship between brain-damaged children and educational functions.

Strauss and Werner compared 20 mentally retarded (mean IQ 70) brain-injured children with 20 mentally retarded non-brain-injured children (mean IQ 73) on an object and picture sorting task to show that brain-injured children made more uncommon responses and more groupings influenced by insignificant and/or unusual details.

Strauss and Lehtinen offered several case studies and a diagnostic study of 139 endogenous and 39 exogenous mentally retarded, brain-injured children at Cove Schools for Brain-injured Children, Racine, Wisconsin. From the clinical observations and psychological investigations of these children were developed numerous "general principles in the education of the brain-injured child".

Strauss and Kephart reported several types of tests which had been developed by various clinicians for use with brain-injured children plus numerous case studies of individual brain-injured children; most of whom were also mentally retarded. Considerable attention was devoted to the pathological functions of the brain and their influence on behavior, cognitive and dynamic. Among the comments offered in this classical work is the quotation that:

> It is not a specific process which is disturbed but a mechanism which may be used in a variety of processes and which interferes with any integration in which one of the processes might normally use this particular mechanism (Strauss and Kephart, 1955, p. 127).

Stimulated by these classical works on brain-injury came several studies briefly mentioned here to indicate the general pattern of studies on learning disabilities during the pioneering stages of this still new field of study in education.

Weatherwax and Benoit (1957) found no significant differences between organic and nonorganic children on word and picture associative clustering tasks. All subjects were inmates of an institution for mental retardates. Gallagher (1957) found no difference between brain-injured and familial retardates' performance on visual perception, visual-motor performance on the Stanford-Binet Intelligence Scale.

Keller (1962) found no difference on a critical flicker frequency measure between brain-injured and familial mentally retarded boys residing in an institution for the mentally retarded.

Quay (1963) reviewed the available literature on mentally retarded children and cognition to that time and concluded that there was no reliable evidence that basic learning or achievement differences existed between mentally retarded children of equal mental age whether they were or were not brain-injured.

Several studies (i.e., Bensberg, 1958; Martin and Blum, 1961; Milgram and Furth, 1963) were reported which compared mentally retarded subjects to normal subjects on concept formation and found that for comparable mental ages there was no significant difference in concept formation provided language was not a major factor on the testing techniques used.

Ernhart, Graham, Eichman, Marshall and Thurston (1963) used 70 brain-injured children age 5 years with IQ ranging from 50 to 129 in a study comparing nonbrain-injured children on concept formation tasks to develop data indicating that brain-injured children were indeed inferior on conceptual ability tasks and all other nonpersonality tasks. It was noted that not only were several of the children in the experimental group mentally retarded, they also demonstrated very severe brain damage symptoms.

Recognizing that without exception these early studies of brain-injured children used subjects who were also mentally retarded, there is a need for some caution in drawing parallels with nonretarded children having brain-injury or learning disabilities.

There is also a concern that it may not be appropriate to consider brain-injury and learning disabilities as synonymous terms. As pointed out by McCarthy and McCarthy (1969, p. 2):

> Considerable confusion has resulted from the use of this term (brain-injured child), since, from its first application until present, two problems have persisted: (1) evidence that children exhibiting the behavioral pattern described do in fact have damage to the brain is poor, and (2) many children with known and independently verified brain damage (i.e., non-verbal neurologic or anatomic evidence) do not exhibit the patterns of behavior presumably characteristic of 'brain damage'.

Although these early studies may have limited inference to the present definition of learning disabilities, their historical foundations for learning disabilities and their continued implications for differential diagnosis of learning disabilities cannot be ignored. As will be seen later, a major shift in emphasis to the study of learning disabilities not dependent upon pathological implications has developed within the past ten years or so.

General Review of Cognitive Strategies

The review of literature pertaining to cognitive organization patterns, although relatively new, has been steadily accumulating, particularly as they related to the theories on origins of the intellect by Piaget (Phillips, 1969), Bloom's Taxonomy of Cognitive Domain (1956), Gagne's Conditions for Learning (1970), and Guilford's Structure of the Intellect (1959).

Explanation of each of these major theories and their supportive data is far beyond the scope of this review and generally known among students of cognitive learning, but it may be helpful to report a summary offered by Fowler (1971, p. 239):

> We may define three dimensions critical to the structure and development of competence which tend to cut across and be common to problem solving and learning regardless of area. The first of these is the acquisition of rule systems, the second is the development of problem solving strategies, and the third, the generation of self-propelled motivational systems in the form of affective-value hierarchies.

Clearly the concern of this study was with the second dimension, that of the development of problem solving strategies or cognitive organization patterns, particularly as they relate to children with learning disabilities.

Sigel, in his extensive review of concept attainment in children (1964, p. 233) stated that:

> Children with brain damage also have difficulty in attaining abstract concepts...in fact one of

> the important diagnostic tools for brain-injury is the degree to which a child has difficulty in coping with abstraction.

Although Sigel was citing studies using adults with brain-injuries, most of whom acquired their injuries after maturity, and which cannot be inferred directly to children with learning disabilities, the implications for future study in this field are stimulating.

An excellent reference to numerous studies on teaching concepts in the classroom was offered by Clark (1971). One of the important implications from Clark's monograph is that a preponderance of the many studies cited have been developed within the past ten years. Clark provided citation of several studies under each of 61 statements concerning the development of concepts which he considered to be candidates for "principles" of concept attainment. He suggested that the study of concept attainment requires concern for four major variables; concept, subject, stimulus, and task. It becomes rather evident that a great number of alternatives for each of these four variables is possible, and equally likely that until many of these alternatives are independently and empirically studied there is not going to be adequate information available for developing generalizations on concept formation strategies available to children with learning disabilities.

One such study concerned directly with concept formation ability of brain-injured children with normal intelligence was that by Elliott (1966). Because of the importance of that information to the present study, this research is reported in some detail.

Elliott referred to Cruickshank's (1966) preference of the term "brain-injured" on the grounds that any imbalance, disturbance or dysfunction of brain functioning is the result of some neurocellular tissue disturbance and therefore constitutes injury. It is interesting to note that although Elliott initially assumed that brain-injury and learning disabilities are synonymous terms, his conclusions include the comment that brain-injury may not be the same as learning disability (p. 104).

According to Elliott's definition, "Concept formation equals the way subjects organize and categorize objects and words presented to him" (p. 8). He used three tests of concept formation; an object sorting task, a verbal association clustering task, and an oddity task of visual discrimination. Due to the expressed concern for stimulus and task variables available to measure cognitive concept formation of children with learning disabilities these three tests are further detailed.

The object sorting test used by Elliott was an adaptation of the Gells-Goldstein-Weigl-Sheerer test consisting of 31 common concrete items. There were two tasks associated with the Elliott use of the OST; (a) active sorting, where subjects are given one object and asked to select from the remaining 30 items those that "belong with" the key item and to explain the basis for their grouping in each of nine trials using different key items each trial, and (b) passive sorting, where subjects are shown groups of objects and asked to explain why they are considered a group in each of eight trials using different items each trial. This was essentially the same test used by Strauss and Werner (1942) to study exogenous children, which showed that brain-injured mentally retarded subjects selected more objects, used more uncommon responses, were more concrete in their selection criteria, and were more influenced by insignificant details than retarded children who were not brain-injured.

The associative clustering verbal task used by Elliott was patterned after the experiment by Bousfield (1953) where 32 common words from four generalized categories were presented for three trials and scoring of recall by categorically adjacent words was observed. Although the materials and scoring used by Elliott and Bousfield are different than that used in the present study of verbal associative clustering, the general principle or theory involved was utilized.

The oddity test was developed by Elliott specifically for his study and involved the use of 20 cards with 4 or 5 geometric designs on each card where all but one design were identical. The one differing design varied in some detailed manner (i.e., 5 spokes on a wheel instead of 4 spokes as all other designs on that card).

The subjects used by Elliott were four groups of three girls and seven boys matched for IQ, sex, race, and socio-economic factors (based on paternal occupation and education level). All forty subjects were of normal or above IQ as determined by individually administered WISC total scores. The two experimental groups were identified as "brain-injured" by virtue of visual perceptual deficits diagnosed by the Frostig Visual-perceptual Test, Bender Visual-motor Gestalt test, the Bender Visual retention scale, plus abnormal electroencephlograph readings of mild range (Elliott referred to the latter as "soft neurological diagnosis"). The two control groups were identified as normally achieving children as determined by California Achievement Tests, California Tests of Mental Maturity, and by subjective classroom teacher evaluations of each subject. The ages of the subjects were 10-0 to 11-9 years, divided into two groups of ten and eleven year olds for both the experimental and control groups. The sample was again sub-divided by IQ for groups under or over a total performance score of 100.

Twenty-two separate scores were collected, however, only eleven scores were actually used in the report when the other half of the scores was judged to be inappropriate for a variety of reasons. These eleven scores were then tabulated under four report categories.

The results of the study were reported as follows: (1) the OST data yielded one significant factor; concrete reference was used more by brain-injured children than control children of low IQ and higher age, (2) the verbal associative clustering data revealed one significant factor for interactions of IQ and brain-injury on categorical intrusions, and (3) the oddity test yielded no significant differences in performance between any subgroups nor between the two basic (experimental and control) groups.

In the discussion and conclusions offered by Elliott the following paraphrased summarization was provided:

A. There was no significant difference between brain-injured and control children in the concept formation performances on these tasks. This was partially attributed to the theory that brain-injured children prefer highly structured environments such as the testing situation presented by Elliott, resulting in the possibility that the brain-injured children were more highly motivated than the control group children. Elliott also implied that because IQ was matched between experimental and control subjects, the WISC and Binet scales must be good predictors of concept formation ability as the data revealed no difference between average and high IQ experimental and control subjects on the experimental tasks.

Although it was certainly not the purpose of this study to critique the Elliott study, there were certain implications from the Elliott study useful for evaluation in the present study.

The use of the object sorting task to observe concept formation abilities of children this age may not be appropriate as this task was highly dependent upon subject skill in verbalizing attained concepts. If the brain-injured children were indeed having difficulty with concept formation they would also have difficulty expressing whatever systems they were using, but there is conversely no assurance that control group children may not have faced difficulty in verbalizing their strategy even when it may have been different than strategies used by experimental subjects.

The verbal associative clustering task appears to be a theoretically sound measure of cognitive organization through the auditory modality, assuming the material used has similar meaningfulness to all subjects. As will be briefly discussed later, meaningfulness is generally seen to be the single most influential variable of material in free recall experiments, and subjective organization procedures (which are dependent upon mater al meaningfulness to a large degree) are accepted as an important function in retention or memory. It may be that subjective organization or associative clustering is influenced by a difference in strategy for storing information long enough to be organized. More discussion on this possibility will be provided later.

The Elliott Oddity Test has already been discussed as very heavily influenced by visual discrimination skills and questionable opportunity for demonstrating any ability of concept formation skills. Using Elliott's own definition of concept formation, it is necessary to demonstrate skills or methods for organizing or categorizing information if such ability is to be measured. The Oddity test seemed to lack the essential ingredient for such demonstrations.

The Elliott study was seen as directly pertinent to the purpose of the present study in that it was directly concerned with observing the cognitive organization patterns used by children with brain-injury, which has often been confused as synonymous to learning disability. The use of materials possessing conjunctive concepts was further pertinent to the present study.

One question stimulated by the results of the Elliott study not previously mentioned is the possibility that there may exist different levels of one type of concept. Specifically is the simultaneous manipulation of two mutually inclusive attributes of a concept different from three or more such manipulations only in quantity or could there be a qualitative difference at work? Following a taxonomy of cognitive domain as proposed by Bloom et al. (1956), there could be a difference in quality between levels of concept formation such that demonstration of concepts through analysis or synthesis, for example, may not be the same quality of task. Elliott's tasks all required an analysis of existing concepts, and the present study attempts to examine at least in part, skills of synthesis of known concepts which exist in the materials and tasks.

The possibility of a qualitative and a different quantitative aspect of cognitive structure has been discussed at length by Flavell and Wohlwill (1969), summarized rather candidly in their statement that "Since the qualitative-differences position rather than the alternative appears to assert something positive about the nature of development, and seems to offer hope of interesting theory-building in the area, the burden of proof has generally been on those who wish to claim that it is true" (p. 76).

It has been suggested by numerous educational leaders working with learning disabilities that sensory perception is the major deficit demonstrated by children with learning disabilities and the only major question presently pressing is how to re-tool classroom teachers for skills in teaching to perceptual disabilities. One recent study by Sapir (1971) was specifically directed at first grade children with learning disabilities and deficit centered training in the classroom. The deficits identified were perceptual in nature, but implications from that study had bearing on the present concern for studies in concept formation abilities by children with learning disabilities.

In the Sapir study eighteen children were divided into matched pair design groups where one group received specifically designed curriculum, centered around perceptual training in a self-contained (experimental) classroom. The other half (control group) was mixed with normally achieving students under a traditional curriculum in a self-contained classroom. All eighteen children had been identified as children with normal intellectual potential, normal physiological potential, and generally comparable to nondisabled students of the control classroom in every way except achievement. Extensive pretesting and posttesting were provided. The conclusions of this study are sufficiently pertinent to report in some detail.

> The results of the present study indicate that significantly more growth took place intellectually, perceptually and in language skills in the experimental group than the control, but that this was not reflected in the academic performance. Since it has been suggested that IQ is a good indicator of academic success (Thorndike and Hagen, 1961), one should be able to predict that a group of children with increasing intellectual function should perform better in reading, arithmetic, and language arts. However, the present results do not bear this out.
>
> Two confounding factors may have contributed to the results: (1) it might be that children

> who develop unevenly have a distinctive learning pattern and process information differently, and (2) neurological impairment in the study population could have a negative effect on academic performance regardless of the WISC IQ. The WISC may not tap cognitive skills required to learn reading, writing, and arithmetic in children with neurological deficiencies.

From this study it can quickly be seen that although IQ may be highly correlated with academic success, it may be that some additional factors or variables seem to be at large. Where Elliott concluded that IQ may adequately identify concept formation ability, Sapir concluded that this must not be the dependent measure suspected by Elliott. Sapir further pointed out that something more than perceptual disability seemed to be inhibiting the academic success of children with learning disabilities, specifically their learning patterns.

Later in the same discussion, Sapir pointed out that "Differences in the developmental and academic growth patterns tend to be a result of what is taught directly". Such comments immediately bring to mind the well-known comment by Bruner (1963, p. 33) that "We begin with the hypothesis that any subject can be taught effectively in some intellectually honest form to any child at any age of development". Conversely, we are faced with the strong contention by Piaget and others that certain concepts cannot possibly be attained by children until appropriate developmental stages have been attained.

The present study did not attempt to teach any concepts to children of any age, but rather attempted to observe the cognitive patterns used by children with learning disabilities at particular ages. These patterns were obviously developed in some manner or other unless one subscribes to the theory that concept patterns are genetically inherited. Without dismissing the possibility of genetic influence on concept formation ability, this study was directed to observation of systems used by children with learning disabilities regardless of etiology. In this approach it is nonetheless valuable to consider, at least briefly, the implications of the developmental theory in concept formation.

Concept Formation and Developmental Theory

It should first be explained that original contributions by Piaget were not offered here due to the fact that Piaget has not produced any original works in English or other languages familiar to the writer.

It should further be explained that the purpose of this paper did not justify an extensive review of support or refutation of any developmental theory. It is recognized that there exists considerable support for Piaget's theory on structural development (i.e., Elkind, 1961; Lovell, 1961; Hunt, 1961; Flavell, 1963, etc.). These studies indicate that specific structural characteristics may not be available until an appropriate critical age (cognitive age) is attained. When using children of normal intelligence and of the age involved in the present study it is necessary to assume that they have reached the first concrete-operational subperiod if we can expect to observe any sign of the first operational "structures d'ensemble". This latter term from Piaget implies the ability to recognize both similarities and differences among objects, and the simultaneous and integrative involvement of several groupings within a single activity (e.g., class-inclusion and conservation behavior). Theoretically, for normal intelligence, this stage occurs between the chronological ages of 7 and 11 years among Swiss children. The basic defense for not providing a major effort to establish attainment of such abilities among the subjects of the present study was that experimental and control subjects were matched in chronological age and tested to be average or above in intelligence or achievement; and therefore, considered to be equivalent in development levels. Under these circumstances, whatever comparisons derived from tasks requiring "structures d'ensemble" should at least be comparable on the developmental scale as well as on the intellectual or achievement scales. This may not be an entirely justified priority assumption for, as pointed out by Bruner (1963) children are apparently often able to function in specific areas, such as mathematics, on a level of thinking above that which they are capable in general. If the size of the sample is assumed to be adequate for minimizing these individual differences, this concern for developmental differences is equally minimized. As mentioned previously, despite the need to study cognitive structures used by young school age children, particularly those with learning disabilities, the task is precarious and difficult. The only hope for eventual knowledge in this area is to begin with admittedly crude foundations from which more sophisticated techniques and theories can be evolved.

Bruner on Concept Formation

Bruner (1964) discussed three systems of processing information by which human beings construct models of their world: through action, through imagery, and through language. He also expresses a concern for integration, which he defines as "the means whereby acts are organized into higher-order ensembles, making possible the use of larger and larger units of information for the solution of particular problems" (p. 1). Bruner offered a summary of the results of an experiment by Bruner and Kenney concerned with the integrative abilities of children ages 5 to 7 years on a double classification matrix task using nine plastic glasses varying so they differed 3 degrees each in diameter and height. After acquainting the subjects with the matrix they scrambled the glasses and asked subjects to reconstruct the original pattern, which was sequential simultaneously by width and height. Thereafter the glasses were once again removed, but one glass was placed on the same grid such that a corner glass was moved to a new corner position and was not to be removed from this new position. Subjects were then directed to make something like what was there before, leaving the one glass just where it had been placed. The results were reported by Bruner (1964, p. 13):

> The results can be quickly told. To begin with, there is no difference between ages 5, 6, and 7 either in terms of ability to replace glasses taken from the matrix or in building a matrix once it has been scrambled (but without the transposed glass). Virtually all the children succeed. Interestingly enought, ALL the children rebuild the matrix to match the original, almost as if they were copying what was there before. The only difference is that the older children are quicker.
>
> Now compare the performance of the three ages in constructing the matrix with a single member transposed. Most of the 7 year-olds succeed in the transposed taks, but hardly any of the youngest children.

According to the data provided on the transposition task, Bruner reported that for age 5 years there were nearly three times more mean errors in replacement; for age six there were slightly over two times as many errors on transposition than on reconstruction of the matrix; and for the seven year-olds there was no difference in performance between reconstruction and transposition tasks. This information is consistent with the predictions of Piagetian development theory as applied to this visual task with concrete objects.

As will be discussed in Chapter III, this same task can be used to observe concept formation ability through the haptic modality, which will allow a comparison between a special experimental group and a control group similar to that used by Bruner.

Verbal Learning and Behavior

It was mentioned earlier that there has been some experimental study on the possibility that cognitive organization patterns are observable in verbal learning. It will be recalled that Elliott used verbal associative clustering procedures to examine auditory concept formation in his study of children with brain-injury.

The available literature of research on verbal learning and verbal behavior has accumulated at an amazing rate during the past twenty years and is far too extensive for the purposes of this study. It is important to provide some review of selected aspects of verbal learning utilized in this study, which are concerned with processes very similar to those used by Elliott.

Underwood and Schulz (1960) have produced evidence that there are two stages involved in paired-associate verbal learning: (1) availability, which can be related somewhat to sensory reception or accommodation, and (2) associative processes, which can be related to assimilation. The information that verbal learning is essentially a two-step process can be related to the computer model provided in Chapter I with the availability step represented by the input phase of learning and the association step represented by the integration phase of learning.

It has been mentioned that four major variables in the study of concept attainment must be considered: concept, subject, stimulus, and task. In verbal learning research it has been noted that the stimuli or materials used do indeed effect the results of any task performed by any subject. The one apparently stable variable in stimulus selection is that of meaningfulness. As stated forcefully by Kintsch (1970, p. 14), "There is little controversy about the effects of meaningfulness upon verbal learning: meaningfulness facilitates verbal learning". Meaningfulness, however, can contain an element of subjective interpretation derived from previous experience. Words which represent unique emotional or contextual meaning to an individual subject are not viewed in the same meaning expected otherwise. Furthermore, contextual clues can alter the meaning of many words even without emotional attachments. For example, the word "light" presented out of context in a word-association task may be paired with opposites of "heavy", "dark", "flush", etc.

Jenkins and Russell (1952) first investigated associative relationships in recall. They used a list of 48 words which consisted of 24 highly associated word pairs presented in random order except for elimination of immediately adjacent word pairs. An immediate recall test was given and a high degree of associative clustering was recorded. A study by Jenkins, Mink, and Russell (1958) used a similar pattern as the Jenkins and Russell study cited, except that the strength of relationship between groups of the word pairs was varied and the efficiency of recall varied in a direct relationship to the strength of relationship between the word pairs, showing the importance of the associative strength variable.

There is evidence that encoding of materials may follow selected schemes without subjects being aware (consciously) that they have made particular selections. According to Wickens (1970) subjects did not notice a change in materials of a paired-associate tasks but did behave differently toward the task when the materials changed.

Rothkopf and Coke (1961) reported that if two words were recalled in sequence, the second word tended to have many associations with the first word. In regard to this Bower (1970, p. 36) submitted that a type of dual-association skill requires a high-level cognitive strategy:

> Grouping or clustering is a low-level retrieval scheme, and in that case the retrieval cue for a word is recall of any other word in the group. Directly associating one cluster with another is a slightly higher-level retrieval scheme; it can be a slow heave, but its main advantage is that it is always applicable to any material.

This dual-association concept in verbal association will be discussed further in Chapter III as related to the material used in this study.

Bousfield (1953) developed the concept of category clustering from his study using a 60-word list which was composed of 15 items in four conceptual categories (e.g., animals, names, professions, and vegetables). The words were presented at three-second intervals followed by an unlimited recall period. Bousfield observed a significant measure of clustering of individual items by category in the recall.

Bousfield and Cohen (1953) studied clustering as a function of repeated presentation and recall trials by using the original Bousfield materials cited above with independent groups of subjects having one to five trials each. Total recall improved from 24 on one trial to 38 after five trials. At the same time, the number of items per cluster recalled in adjacent proximity (called "repetitions" by

Bousfield) doubled.

Cofer, Bruce, and Reicher (1966) reported that a categorized word list is better if all the items from the same category are presented in blocks than when presented randomly. In the same study recall improved and clustering increased when the subjects were given more time to study each item (presumably this was due to increased covert repetition by subjects).

Marshall (1967) showed that clustering scores and recall scores are positively correlated, so it would be expected that if subjects can identify more clusters they should have a higher total recall of items on a list.

In a study by Murakawa and Pierce-Jones (1969) using 5th, 6th, and 7th grade achievers and underachievers matched for sex, age, school year, IQ level, and socioeconomic status it was found that underachievers and achievers memorize things in different ways. It seems that achievers memorize necessary parts only by concentrating their attention effectively, while the underachievers focus on unnecessary parts as well. The verbal test used there was an association of first and last names in fifteen pairs which followed a similar form practice drill of five pairs of first and last names. This study also found underachievers to be low in deductive and inductive reasoning, but equal to or superior to normal achievers in perceptual and spatial ability. For immediate rote memory, underachievers were not inferior to achievers; however, underachievers were inferior both qualitatively and quantitatively in associative and meaningful memory.

A final concern of this study was the difference between experimental and control groups on the use of short-term and long-term memory. It is recognized that there is considerable controversy regarding the criteria for distinguishing between these two types of storage. There is also some debate about the proper techniques for identifying each.

On a repeated trials task, such as used in this study it is expected that normal subjects should improve total recall through trials of recall from a consistent list of materials, regardless of the order of items on the list, as found by Hellyer (1962) and Baddeley and Dale (1966). However, there is a reason to question if this would be the case with children having learning disabilities. It will be recalled from the study by Elliott that brain-injured children did not vary significantly from normal children in this function. Milner (1967) provided a case study of a subject with bilateral hippocarpal lesions (brain-damage) who suffered from an inability to form new long-term memory traces, suggesting that there may be some neurological basis for memory processes. Buschke (1968) used a missing-scan procedure where subjects read 12 randomly selected numbers for material with 27 brain-injured adults and a comparable number of control subjects. In the task presented by Buschke one type of list presented contained no repeated numbers while the other type of list contained some repeated numbers in the same list. The brain-injured subjects performed as well as the control subjects when there were no repeated numbers, but when lists with repeated numbers were recalled the control did significantly better than the brain-injured subjects. The assumption made by Buschke was that the control subjects could benefit from the repetitions due to a type of long-term retention not available to the experimental group.

Although these studies involved brain-injured subjects who were adults, there is sufficient impetus from these studies to investigate the possibility that children with learning disabilities also demonstrate a difference in memory processing.

To study the possible differences between control group and experimental group performance on long-term and short-term processing in this study, several assumptions are required which have limited support. Conversely, there is limited evidence that the needed assumptions cannot reasonably be submitted.

The first assumption required is that in a free recall task using repeated trials the items recalled first represent a preference for short-term memory if those items come from the end of the presentation list, provided the individual items of the lists are presented in a counter-balanced design. It should be added, however, that one interfering variable in this experiment is that the materials are not only meaningful but known to be highly associative for the purpose of studying associative clustering. As stated by Kintsch (1970, p. 153-4):

> If subjects are given a list to recall, the last items of the list, i.e., the ones most recently presented, will be recalled best. This is called the 'recency effect' in free recall. If one wants to attribute the recency effect to retrieval from primary memory, the question arises whether there are experimental variables which affect recall of the items or visa versa.

It may be possible, through extensive presentation of various studies, to build a case for the support of considering recency effect despite interference from the associative clustering variable. It could also be possible to produce opposition support, but neither is considered conclusive as related to the task and purpose of this study. A concern of this study was to observe if control and experimental groups tended to prefer reliance upon associative clustering processes or whether they preferred use of the recency effect technique, which will be called short-term memory. More important was the concern to see if there were differences between the groups in any manner related to methods of processing input through the auditory channel.

CHAPTER III DESIGN OF RESEARCH

Reliability Study Subjects

In an effort to establish some indication of the internal reliability of the testing materials designed specifically for this study by the writer, a small-sample test-retest experiment was conducted.

The reliability study subjects were all first and second grade students of the Ames, Iowa Community School District attending the same elementary school located in an upper-middle socio-economic university neighborhood.

Classroom teachers subjectively identified five average or above average academic achievers as a control group. The same teachers subjectively identified five students matched for age within six months and judged to be of average or above average intelligence with disproportionately low academic achievement. Of these ten subjects one second grade female was eliminated from the study due to an obvious error in following instructions during the initial testing experience.

The nine subjects were retested either 23 or 25 days after an initial testing with identical materials and procedures.

Two first grade and two second grade males, one first grade and four second grade females constituted the sex distribution of the reliability study. The achieving and underachieving groups each had two males, with three females in the achieving group and the remaining two females in the underachieving group.

There were three underachieving first graders, two underachieving second graders, four achieving second graders, and no achieving first graders in the sample.

The age range of the underachiever group was 80-93 months with a mean of 86.8 months. The achiever group age range was 88-97 months with a mean age of 92.0 months.

Although several difficulties were apparent in the size and selection procedures of subjects for this reliability study, the rationale of estimating the internal consistency of the new test when administered to subjects of approximate criteria with the study subjects was justified by the extensive individual testing required to identify subjects with learning disabilities.

Reliability Study

The small sample (N=9) reliability study was conducted to give a very general indication of the consistency of the subtest performance with a test-retest design. Not all scores were calculated as only an estimate on the battery was sought. The summary of the Pearson Product-Moment correlation for each calculated score is reported here.

Total uncorrected auditory recall r = .5886

Intrusions r = .5866

Redundancies r = -.0432

Total corrected auditory recall r = .6843

Associative clustering r = .4398

Short term memory r = .7573

Long term memory r = .8472

Visual reconstruction r = -.1504

Haptic reconstruction r = .6536

Even from this small sample and partial computational results it was evident that there was sufficient stability in the new test to justify its use in the study with carefully selected subjects and tighter design controls.

Study Subjects

In the spring and summer of 1971 a federally-sponsored demonstration project stimulated the referral of 225 kindergarten and first grade children of the Des Moines, Iowa school district for screening for learning disabilities. These referrals were made by classroom teachers based on the criteria provided by the project design. Each referred child was individually administered the Illinois Test of Psycholinguistic Abilities (ITPA) and the Wechsler Intelligence Scale for Children (WISC) by qualified school personnel.

A team consisting of the project director, one school psychologist, two learning disability consultants, and four demonstration teachers selected for the project prescribed additional evaluations (i.e., medical examinations, auditory and visual acuity evaluations, Wepman Test of Auditory Discrimination, Peabody Picture Vocabulary Test, etc.) as deemed appropriate for completing an adequate differential diagnosis for each child.

Based on the differential diagnosis, 122 of these children were judged to have distinct profiles qualifying them as children with serious learning disabilities. In an effort to establish three comparable groups within the total of 122, there were 42 assigned to a no-treatment project control group, and the remaining 80 were equally divided into two treatment groups. One treatment group was to receive intensive half-day instruction at a special demonstration center, the other treatment group would receive occasional consultive services to their regular classroom teacher.

The experimental group of this study was selected from the children of both the demonstration and consultive classes. Originally 35 demonstration students and 20 consultive students were selected as subjects for this study based on the criteria of having a total score IQ of 90 or higher on the WISC and ten or more points below score sum means in at least one subtest of the ITPA.

Nine public and two Catholic parochial elementary schools were represented in the study. All schools were located in middle to low-middle socio-economic neighborhoods containing considerable variety in race, religion, ethnic, and cultural populations.

The control group for this study consisted of children matched with experimental subjects for age (within six months), sex, and school. All but six pairs attended the same classrooms. Control subjects were judged by classroom teachers to be of average or above average academic achievement in all subject areas at their respective grade levels.

Due to attrition of pairs caused by relocations or selection of control subjects who did not meet the required criteria, the original 110 subjects were reduced to a total sample of 100. After completion of the differential diagnosis phase of the demonstration project there were four experimental subjects who were either retained or eventually returned to kindergarten classroom assignments for academic reasons. Each of these experimental group subjects were continued in the first grade data of this study on the basis that they were assigned to continuous progress programs of study where they completed a full day schedule combined with kindergarten.

The fifty pairs studied for reporting data were coincidentally divided evenly between first and second grade, providing twenty-five matched pairs for both grade levels. From the first grade, pairs of 15 males and 10 females were reported. There were 19 male and 6 female second grade pairs.

The age range for first grade experimental subjects was 77-94 months with a mean of 84.2 months. First grade control subjects age range was 74-92 months with a mean of 83.4 months. The age range for second grade experimental subjects was 91-111 months with a mean of 98.9 months. Second grade control group age range was 90-108 months with a mean of 97.8 months.

Description of the Test

The test used was designed by the writer for the purpose of conducting this study; however, the principles underlying each part of the test were patterned after selected tests mentioned in Chapter II and modified to meet the needs of this study.

There were three separate subtests to measure the auditory, visual, and haptic modalities in isolation. Each subtest is described individually.

Auditory subtest

Patterned after Bousfield (1953) and Tulving (1962) this subtest consisted of five high-association word pairs presented over five learning trials, each followed by a thirty-second recall period. Each item of the list was presented by tape recording at 1 second intervals. The list was preceded and followed by a bell to indicate the beginning and end of each presentation. The items were presented in a counter-balance design such that each item occurred only once in any serial position and no item preceded another item more than once throughout all five presentations. All items and association assignments were selected by the writer's own evaluation to be common speaking vocabulary of first grade or lower age level.

Subjects were instructed to recall (output) all items presented (input) in each list after hearing the bell at the end of the list input. Specific instructions are provided in Appendix A.

Scoring consisted of the following; total recall over all trials, total items repeated in recall of each list, total intrusions (words offered in recall which were not on the input list), total recall without repeated or intruded items, total associative cluster in recall (high-association word pairs recalled in adjacent output position regardless of input serial position), associative clustering ratio with total recall, short-term memory score, and long-term memory score.

The memory scores were computed as a result of the following five-step process:

Step 1. List all input items in order of input serial position for each trial separately.

Step 2. Assign input items subjective values of
- (a) long-term values of 10 to 1 respectively from the first item on the input list,
- (b) short-term values of 10 to 1 respectively from the last item on the input list.

Step 3. Assign output items subjective values of 5 to 1 in serial order beginning with the first word in output. All output words submitted by the subjects after the fifth word receive no value score for memory (were scored zero).

Step 4. Multiply subjective input values and subjective output values for each serial position of each recall list to obtain a process value (P).

Step 5. Add P values separately for long-term and short-term memory across all five trials.

A hypothetical example of scoring for auditory recall for one trial is described here for clarity. The input list is found in Appendix B, p. 88.

SCORE		SPV[a]		LTM	OUTPUT	STM		SPV[a]		SCORE
50	=	5	x	10	UP	1	x	5	=	5
24	=	4	x	6	TREE	5	x	4	=	20
24	=	3	x	8	GREEN	3	x	3	=	9
2	=	2	x	1	DOWN	10	x	2	=	20
5	=	1	x	5	LEAF	6	x	1	=	6
0	=	0	x	7	EIGHT	4	x	0	=	0
0	=	0	x	3	FIVE	8	x	0	=	0
105 = long term memory						short term memory =				60

[a]SPV = serial position value for all output.

The rationale behind scoring of short-term memory (STM) and long-term memory (LTM) is that items recalled from the ends of each input list are accoustic or STM, according to the recency effect theory as discussed in Kintsch (1970). The semantic primacy effect is assumed to represent LTM.

This scoring procedure obviously ignores the influences of learning over trials and intervening associative clustering influences upon serial order in recall, but it does provide a consistent framework for observing accoustic and semantic preferences between study groups.

One special calculation was obtained to study the theory of higher-order concept organization by simultaneous associations as suggested by Bower (1970). In the presentation list were the pairs of Red-Green and Tree-Leaf. It was submitted that the item Green could reasonably stimulate association with Red, Tree, or Leaf. Therefore, a simple t-test was calculated for the occurrence of adjacent output of green with red and either tree or leaf. Each occurrence of this adjacent combination in any order of those three items was scored as a value of one.

The complete presentation list used for this subtest is available in Appendix B.

Visual subtest

The visual subtest consisted of nine 2" x 2" tagboard cards sealed in plastic such that each card presented an identical tactile stimulus. These cards were placed on a grey 1/2" plyboard measuring 6 3/4" on each side marked with 2 1/8" squares painted on the board with black lines.

Each card contained a different symbol such that a progressive 3 x 3 matrix could be arranged, using squares which increased in number across columns and increased in size across rows. The squares across columns were placed inside each other with consistent dimensions, and the increased size was consistent across rows. The black lines of the squares were placed on a white background which was then placed on the red tagboard card.

The progressive matrix of cards was arranged on the grey board such that all cards of the row nearest the subject contained only the smallest size symbols, and the row farthest from the subject contained the largest symbols. Symbols on the cards in the column at the left of the subject contained only one square, the center column contained a square within a square, and the column to the right of the subject contained two squares with a square, as pictured in Appendix B.

Subjects were acquainted with the first (nearest) row of symbols by a task of reconstructing that row in proper order on the board after all three cards were removed. Subjects were acquainted with the left column of cards by a task of reconstructing that column in proper order after all cards were removed.

Subjects were then asked to study a presentation of the entire nine-card matrix until they were ready to attempt reconstruction of the positions of all cards as presented. All cards were removed, randomly mixed upside-down and given to subjects. Subjects were allowed to arrange cards until they were satisfied they had correctly reconstructed the original pattern of presentation.

Scoring of this task, called the visual reconstruction task, was obtained by assigning each card a value which represented the symbol size and configuration. For example, the card with the smallest size single square was identified as 1-1, which totaled to a value of 2. The card with the largest size and three square configuration was identified as 3-3, giving a card value of 6.

After calculating the values for each card of each position on the board as originally presented, the values of cards in each position reconstructed by the subject was subtracted and an absolute difference was calculated. The sum of absolute differences between presentation and reconstruction values for each position on the matrix yielded an error score for the reconstruction task.

An example of scoring procedures for both visual and haptic reconstruction tasks using a hypothetical performance situation is described here for clarity.

CORRECT PLACEMENTS			CORRECT VALUES		
1,3	2,3	3,3	4	5	6
1,2	2,2	3,2	3	4	5
1,1	2,1	3,1	2	3	4

HYPOTHETICAL PLACEMENTS			HYPOTHETICAL VALUES		
1,3	2,2	3,3	4	4	6
1,2	2,3	3,2	3	5	5
1,1	2,1	3,1	2	3	4

HYPOTHETICAL ERROR SCORES			TOTAL ERROR
4-4=0	4-5=1	6-6=0	1 + 1 = 2
3-3=0	5-4=1	5-5=0	
2-3=0	3-3=0	4-4=0	

The final task in the visual subtest was that of transposition of the total matrix to evaluate the use of conjunctive concepts in performance by the subject. In this task the examiner removed and randomly mixed all cards. The card which had originally been presented in the far right corner (3-3) was now placed in the position originally held by the 1-1 card in the near left corner. Subjects were told they could not move this card from its present position on the board and were to place all other cards in any position they thought the cards should be placed. Subjects were allowed to shift all cards except 3-3 until they were satisfied with their total placements.

Scoring of the transposition tasks required the following steps:

Step 1. Record the identification numbers for each card in each position subjects placed them on the board.

Step 2. Alter only the second digit of the identification number so that all numeral ones remained numeral one, all numeral twos converted to a value of four, and all numeral threes converted to a value of seven.

Step 3. Sum the original first digit and the new value for the second digit of each card identification number of the card in each position on the board.

Step 4. The resulting 9 numbers positioned on the board now constitute a 3 x 3 matrix suitable for calculation of analysis of variance. Correctly transposed matrices could assume either of two acceptable patterns, both of which would result in a square root residual of zero. Deviations from these correct patterns of transposition resulted in appropriate values of error residual in analysis of variance.

An example of scoring a properly transposed matrix for either the visual or the haptic transposition task is described here for clarity. The analyses of variance was performed on each weighted matrix to obtain the square root of residuals (errors) used for comparisons.

CORRECT PLACEMENT

31	21	11
32	22	12
33	23	13

ADJUSTED VALUES

31	21	11
34	24	14
37	27	17

WEIGHTED MATRIX

4	3	2
7	6	5
10	9	8

RESIDUAL SQUARE ROOT

0

Haptic subtest

The haptic subtest was developed from the nine-tumbler progressive matrix task used by Bruner (1964), modified to allow only haptic sensory reception (input).

Nine plastic tumblers manufactured such that the first row of the matrix consisted of three tumblers 1" in height, the second row consisted of three tumblers all 2" in height, and the third row of three tumblers were all 3" in height.

The tumblers simultaneously varied in width across columns such that the left column tumblers were all 1" in diameter, the second column tumblers were all 2" in diameter, and the third (right-side) column tumblers were all 3" in diameter.

A board was constructed for holding the tumblers in position during the haptic task. This board was 1/2" ply cut to 10 1/4" x 10 1/4". On the board were fixed strips of 1/4" x 1/4" board such that nine 3 1/4" x 3 1/4" square cubicles or "boxes" were constructed on the board.

To eliminate the use of visual stimuli on this task a 12" x 12" frame was constructed and a photographic changing bag was attached to this frame. A 3' X 3' board was cut to fit snuggly over the frame and changing bag, which resulted in complete visual wall to be placed in front of the board holding the plastic tumblers.

Subjects could sit in front of the visual wall and place their arms through the sleeves of the changing bag with freedom of movement by their arms without seeing beyond the visual wall. This entire apparatus was designed merely to omit visual stimuli without blindfolding subjects in the presence of a strange examiner during individual testing.

Each tumbler was assigned an identification number indicating the height and width in inches. For example, the tumbler which was two inches tall and three inches wide was identified as 2-3.

The task and scoring for the haptic subtest were exactly identical to those described for the visual subtest. The specific instructions for these subtests are provided in Appendix A.

Research Procedures

The order of task presentation was auditory, visual, and haptic subtests. The total test battery was administered by the writer individually to each subject such that each matched pair was tested in the same isolated room of their base school, usually within 60 minutes of each other. Five matched pairs were not tested on the same day due to absences from school on the scheduled testing dates, but in such cases the absent subjects were all tested within one week of their matched pair subject in the same isolation room.

Analysis and Statistical Procedures

Analysis of data was computer-assisted. The models on which the analysis of variance are based are conventional except that unequal numbers of pairs occur in sexes. The analyses reported are therefore based on weighted means.

CHAPTER IV FINDINGS AND CONCLUSIONS

The purpose of this study was to observe the cognitive structuring of early school age children with learning disabilities in auditory, visual, and haptic modalities when provided organized materials. To obtain this information it was necessary to develop a test which would adequately measure cognitive structuring through isolated modality input.

The null hypotheses of the problem posed in Chapter 1 were set forth to be tested. The hypotheses were: (1) there is no significant difference between group means of normally achieving children and children with learning disabilities on cognitive structuring processes of auditory stimuli as measured by a cognitive structuring test; (2) there is no difference between normally achieving children and children with learning disabilities on cognitive structuring processes of visual stimuli; and (3) there is no difference between normally achieving children and children with learning disabilities on cognitive structuring processes of haptic stimuli.

The calculations used to compute the analysis of variance were derived by performing separate analysis of variance on each sex and on the total pair data. This procedure provided a basis for calculation of main effects for differences in sex, pair performance on each task, and interaction effects.

Analysis of Covariance

The design for the selection of subjects required that all matched pairs of subjects be within six months in age. A complete analysis of covariance was performed on all data to test the effect of age as a factor on performance. The results of this analysis were consistently conclusive that age differences within the matched pairs did not significantly influence performance. Because this factor was not significant, the analysis of covariance using age as a covariate is not reported.

Analysis of Data

Auditory task

From the analysis in Table 1 it was apparent that no difference existed between sexes, pairs, or interactions of sex and pairs on performance in frequency of total recall when redundancies and intrusions are included in scoring.

It was evident from the summary of Table 2 that the control and experimental subjects were highly significant in their difference on use of redundancy (repetition of the same items in output). The group means of .9412 for the control group and 2.2647 for the experimental group shows that children with learning disabilities had more than twice as many redundant items on their output lists as did

Table 1. Summary of analysis of variance on auditory recall frequency without correction for intrusions or redundancies

Source of variation	Degrees of freedom	Mean square	F values
Sex (S)	1	.03	.00
Pairs (P) within sex	48	100.58	
Groups (G)	1	161.29	1.92
SG	1	32.61	.39
PG/S	48	84.01	

Table 2. Summary of analysis of variance on auditory recall redundancy of items on output

Source of variation	Degrees of freedom	Mean square	F value
Sex (S)	1	6.66	.71
Pairs (P) within sex	48	9.36	
Groups (G)	1	64.00	7.51**
SG	1	4.06	.48
PG/S	48	8.52	

**Significant beyond the .01 level.

Table 3. Summary of analysis of variance on auditory recall intrusions in output

Source of variation	Degrees of freedom	Mean square	F values
Sex (S)	1	1.91	.19
Pairs (P) within sex	48	10.20	
Groups (G)	1	4.84	.55
SG	1	19.06	2.17
PG/S	48	8.79	

normally achieving children.

There was no significant difference between sexes and no interaction effects on this task.

Table 3 shows that the reporting of intrusions did not influence performance.

Table 4 shows that there were no sex or interaction differences, but there was a highly significant difference between groups on adjusted score recall performance. The means were 27.0882 for the control group and 23.5294 for the experimental group, indicating that children with learning disabilities do not recall as many different words from a list as do normally achieving children of the same

Table 4. Summary of analysis of variance on auditory recall without redundancies or intrusions

Source of variation	Degrees of freedom	Mean square	F values
Sex (S)	1	27.36	.53
Paris (P) within sex	48	51.31	
Groups (G)	1	420.25	7.5446**
SG	1	15.55	.28
PG/S	48	55.70	

**Significant beyond the .01 level.

Table 5. Summary of analysis of variance on auditory associative clustering in output

Source of variation	Degrees of freedom	Mean square	F values
Sex (S)	1	9.48	.85
Paris (P) within sex	48	11.11	
Groups (G)	1	4.84	.47
SG	1	5.63	.55
PG/S	48	10.22	

age. This information is consistent with the results from Table 2 concerning redundancies.

From the summary of Table 5 it can be seen that there were no significant differences between sexes, groups, or interactions on performance in auditory associative clustering of high-association words pairs in output. As was stated in Chapter 2 this is generally viewed as one method available for cognitive structuring of auditory materials.

Because it has been theorized that cross-associations of high-association pairs having a common item relationship constitutes a high order of cognitive structuring (Bower, 1970), a student t-score was calculated on the frequency of all such combinations in output sequence with the following results: T = .1310. This comparison of the means between groups (control mean .82 and experimental mean .66) showed that there was no significant difference between these groups when within group variance (control group variance = .44 and experimental group variance = 1.05) is considered.

From the combination of simple associative clustering and high order clustering analyses, it was found that there were no significant differences between normally achieving children and children with learning disabilities.

From the Table 6 analysis of variance on percent of clustering in recall frequency (uncorrected) it was apparent that there were no significant differences

Table 6. Summary of analysis of variance on associative clustering ratio with total uncorrected recall frequency

Source of variation	Degrees of freedom	Mean square	F values
Sex (S)	1	170.11	2.47
Pairs (P) within sex	48	68.86	
Groups (G)	1	5.76	.10
SG	1	27.99	.47
PG/S	48	59.55	

Table 7. Summary of analysis of variance on short-term memory

Source of variation	Degrees of freedom	Mean square	F values
Sex (S)	1	5275.10	.73
Pairs (P) within sex	48	7219.60	
Groups (G)	1	16078.07	1.83
SG	1	9.40	.00
PG/S	48	8794.90	

between sexes, groups, or interactions.

The summary of Table 7 shows that as there were no significant differences between sexes, groups, or interactions on short-term memory processing of auditory materials in this task it is assumed that the use of accoustical recency effect is equally processed by normally achieving children and children with learning disabilities.

Table 8 summary shows that there was a significant difference between groups on the structuring of long-term memory process. The means were 358.220 for the control group and 323.100 for the experimental group, indicating that normally achieving children tend to use long-term processing techniques more than do children with learning disabilities.

Visual and haptic task

From the summary in Table 9 it can be seen that there was a highly significant difference between groups on the reconstruction task with visual and haptic skills combined. The means for reconstruction errors were 6.66 for the control group and 8.49 for the experimental group, indicating that children with learning disabilities made significantly more errors in reconstructing visual and haptic stimuli than did normally achieving children. This task is viewed as a memory processing function and is therefore consistent with the pattern demonstrated in auditory long-term memory

Table 8. Summary of analysis of variance on long-term memory

Source of variation	Degrees of freedom	Mean square	F values
Sex (S)	1	102.02	.02
Pairs (P) within sex	48	4540.75	
Groups (G)	1	30835.56	4.16*
SG	1	6.32	.00
PG/S	48	7405.52	

*Significant beyond the .05 level.

Table 9. Summary of analysis of variance on visual and haptic reconstruction errors

Source of variation	Degrees of freedom	Mean square	F values
Sex (S)	1	18.27	1.26
Pairs (P) within sex	48	14.51	
Groups (G)	1	167.45	8.71**
SG	1	12.75	.66
PG/S	48	19.22	
Modality (M)	1	541.20	31.69**
SM	1	5.68	.33
PM/S	48	17.18	
GM	1	.04	.00
SGM	1	0	0
PGM/S	48	12.22	

**Significant beyond the .01 level.

processing.

There was also a highly significant difference between the errors experienced between visual and haptic stimuli on the reconstruction task. The means here were 5.93 for the visual task and 9.22 for the haptic task, showing that memory for haptic modality materials is considerably more difficult to obtain than memory through visual modality.

Table 10 shows that there were no significant differences on either main effects or interactions in the visual and haptic transposition task. It is recognized that the main effect for differences between groups on this task ($.10 > P > .05$) was in the anticipated direction.

The task of transposition required cognitive structuring of conjunctive concepts through visual and haptic modalities, which constituted a primary function in the study of the problem.

Because it appeared from the results of the data that there was a general and significant difference between the control and experimental groups on auditory long term memory, visual reconstruction, and haptic reconstruction, there was an interest in determining if these three tasks were in fact related. All three tasks were assumed to require a long term memory process, each through a different modality.

To establish data on the possible correlation of the three tasks, the total sample was included for calculation

Table 10. Summary of analysis of variance on visual and haptic transposition

Source of variation	Degrees of freedom	Mean square	F values
Sex (S)	1	243.32	1.71
Pairs (P) within sex	48	141.90	
Groups (G)	1	348.38	3.17
SG	1	143.17	1.30
PG/S	48	110.02	
Modality (M)	1	124.07	1.77
SM	1	7.61	.11
PM/S	48	70.29	
GM	1	23.75	.27
SGM	1	7.85	.09
PGM/S	48	88.90	

of scores for each subject on each task. The results were reported as follows: auditory long term memory correlation with visual reconstruction was .01, and with haptic reconstruction the correlation was .07. The correlation between visual and haptic reconstruction scores was .13.

The summary of correlations between subtest scores on the cognitive structuring test reported in Table 11 showed correlations exceeding .70 existed between recall frequency

Table 11. Summary of correlations between subtest scores on the cognitive structuring test

f[a]	I[b]	R[c]	Cf[d]	AC[e]	AC/f[f]	STM[g]	LTM[h]	Vr[i]	Vt[j]	Hr[k]	Ht[l]
1.00											
.27	1.00										
.78	.21	1.00									
.71	.22	.42	1.00								
.71	.07	.55	.62	1.00							
.27	-.28	.17	3.1	.80	1.00						
.45	-.25	.31	.53	.39	.26	1.00					
.23	-.21	.04	.38	.17	.14	-.20	1.00				
-.21	-.06	-.24	-.13	-.05	.07	-.17	-.01	1.00			
.02	.11	-.01	.04	-.14	-.21	-.01	-.06	.08	1.00		
.04	.23	.04	-.16	-.05	-.05	-.13	-.07	.13	.05	1.00	
.02	-.02	-.02	.00	-.02	-.02	-.01	.14	.06	.17	-.05	1.00

[a]f = recall frequency.
[b]I = intrusions.
[c]R = redundancies.
[d]Cf = adjusted recall.
[e]AC = clustering.
[f]AC/f = clustering ratio.
[g]STM = short term memory.
[h]LTM = long term memory.
[i]Vr = visual reconstruction.
[j]Vt = visual transposition.
[k]Hr = haptic reconstruction.
[l]Ht = haptic transposition.

and redundancies (.78), recall frequency and clustering frequency (.71), and between clustering frequency and clustering ratio (.80).

Correlations ranging from .50 to .70 existed between redundancies and clustering frequencies (.55), adjusted recall frequency and short term memory (.53), and adjusted recall frequency and clustering frequency (.62).

From the summary of means on recall by trial found in Table 12, it was evident that both control and experimental groups progressively increased their mean recall with each new trial. The average increase over trials was .45 for the control group and .54 for the experimental group.

Table 12. Summary of group means on recall by trials

Trial	I	II	III	IV	V	Total
Control	4.70	5.34	6.14	7.34	7.94	31.46
Exper.	4.40	5.64	5.88	6.36	7.14	29.14

CHAPTER V DISCUSSION

The findings of this study indicated that the performance of early school age children with learning disabilities on cognitive structuring tasks using organized materials presented through isolated auditory, visual, and haptic modalities was not significantly different than the performance on these same tasks by children with average or above average academic achievement.

The specific tasks attributed to cognitive structuring were associative clustering and transposition of conjunctive concepts, none of which indicated a difference in performance between children with learning disabilities and the control group beyond the .05 level of probability. It was therefore concluded that the three null hypotheses of this study were supported. These results were also consistent with the findings of Elliott (1966) for children with brain damage.

The transposition tasks in visual and haptic modalities did indicate differences worthy of notation ($P > .10$), with the control group performance exceeding that of the experimental group. These results indicated that further study of cognitive structuring processes of children with learning disabilities would be justified. It may be that the tasks of this study were tapping a qualitative level of thinking which did not point out differences to be found at other levels of thinking described by Bloom _et al_. (1956) and Gagne (1970).

The proposition that different levels of thinking may be involved in cognitive structuring was tested in the auditory modality as suggested by Bower (1970), but no significant differences were discovered.

This study revealed several highly significant differences between control and experimental groups which were considered important to the understanding of children with learning disabilities.

It was found that children with learning disabilities demonstrated a greater use of redundancy in recall of organized verbal material. This performance was consistent with the traditional association of perseverance with learning disabilities (Strauss & Werner, 1942).

Buschke (1968) found that brain-injured children also demonstrated a significantly higher degree of redundancy in auditory recall than did normally achieving children. He theorized that brain-injured children could not benefit from repetition due to a long term retention deficiency. The present study also revealed a long term memory deficiency among children with learning disabilities, but the correlation of these two scores was only .04, indicating that Buschke's theory can not be applied to these results.

It may be that perseverance in auditory processing inhibits attention to verbal stimuli, or it may be that children with learning disabilities do not effectively edit their own output during auditory recall.

From the findings of this study it is consistent to suggest that long term memory strategies are an important factor in the identification of children with learning disabilities. Because the visual and haptic reconstruction tasks required long term memory skill in those modalities, this study demonstrated that children with learning disabilities are deficient in long term memory skills for each of the three modalities tested. These results are consistent with the findings of Murakawa and Pierce-Jones (1969) that underachievers and average or above average achievers memorize things in different ways.

It should be pointed out, however, that the correlation study of relationships between subtest scores indicated that memory skills in one modality are apparently not the same as memory skills in other modalities. Long term memory in the auditory task had a correlation of -.01 with visual reconstruction and -.07 with haptic reconstruction. Despite the nearly identical design of tasks for visual and haptic reconstruction, the correlation between those two scores was only .13.

These results indicate that although memory tasks constitute a common difficulty to children with learning disabilities, there is no common relationship demonstrated between memory skills of the separate modalities. This information supports the contention that learning disabilities constitutes a specific dysfunction unique to each child which must be individually diagnosed and remediated according to specific prescription. It is evident from these findings that the term of "specific learning disabilities" is appropriate.

Sapir (1971) contended that differences in academic achievement and developmental growth patterns tend to result in what is taught directly. It would follow from the results of this study that children with learning disabilities should benefit from direct instruction of strategies for improving long term memory. Such techniques are available from the field of psychology, particularly from the study of verbal learning and verbal behavior. Examples of these techniques include progressive part memorizing, mediation strategies, overt rehearsal, development of meaningfulness in materials, etc. Such techniques were found successful with mentally retarded subjects in a study by Belmont and Butterfield (1971), and may be equally successful with learning disabled children.

It was found in the present study that both the control and the experimental groups demonstrated consistent improvement in recall across trials in the auditory task. The two group means were nearly identical on the first trial, yet the control group mean was more than two words better than the experimental group mean for total recall. The steady improvement over trials demonstrated by both groups was consistent with the findings reported by Hellyer (1962) and by Baddeley and Dale (1966), and indicated that children with learning disabilities do learn from repetition. Perhaps direct instruction and activity in effective long term memory strategies would prove to be valuable, as suggested by Sapir.

Because there were no age differences found in the transposition or clustering tasks in this study, theories of developmental growth in cognitive structuring proposed by Bruner (1964) and by Piaget, as reported by Phillips (1969), were not supported. At the age where preoperation and concrete operation stages were alledged to meet, the subjects of this study did not demonstrate the differences in skills predicted by developmental theorists.

It should be noted, however, that this test measured cognitive structuring through isolated modalities and that typical learning situations are not restricted in such a manner. It would be logical to suggest that cross-modal structuring of organized materials may not produce the same results.

The lack of associative clustering differences between control and experimental groups in this study provided a rather firm rejection of this strategy as a significant factor in identifying children with learning disabilities. It was recognized that although the materials in this task were not complex, neither were they derived from empirical foundations for word association, such as provided by Entwisle (1966). Interlist associations could result in different relationship values between the words on a list, but it would have enhanced this study to determine the association values for this material.

The control group was selected by teachers to be average or above average in academic achievement for all school subjects, but no intelligence scores were obtained for the control subjects. Sapir (1971) proposed that intelligence may not have the high cause-effect influence on academic achievement often credited to it, particularly when learning disabled children are included in the sample. The potential importance of intelligence in performance on the tasks of this test is not ignored, however, and the addition of WISC total scores for the control subjects would have enhanced this study. Replication or followup on these subjects should include intelligence score data which could evaluate the influence of intelligence on the findings of this study.

In response to the stated need for an objective test of integrative learning functions (Johnson & Myklebust, 1967) the cognitive structuring test developed for this study provided additional avenues for future research on this function with children of an early school age.

In response to the need for additional screening materials at an early school age (McCarthy & McCarthy, 1969) the test used in this study did provide a potential addition to the diagnostic tools needed in the education of children with learning disabilities. Specific recommendations for improving this test for screening use were: modify the visual blind procedures, eliminate the transposition tasks, provide additional reliability data, and develop broader norms for a revised version of the test.

The advantages of the proposed revised edition of the cognitive structuring test would be its ease and brevity in administration, the need for only limited special training for administration, and the inexpensive materials required for its use.

CHAPTER VI SUMMARY AND RECOMMENDATIONS

The purpose of this study was to observe the cognitive structuring processes by first and second grade children with learning disabilities on organized materials through isolated auditory, visual, and haptic modalities.

To measure the cognitive structuring skills, a test was designed specifically for this study and a small (N=9) test-retest reliability analysis was conducted on selected sections of the test battery. The results of this analysis indicated that there was sufficient consistency to consider the test capable of reliable measurement with children at the age used in the study.

A sample of 50 Des Moines, Iowa boys and girls with learning disabilities were identified through differential diagnosis procedures. These 50 experimental subjects were then matched by classroom teachers with control subjects who were of the same sex, from the same school (usually from the same classroom), the same age within six months, and subjectively judged to be average or above average in academic achievement in all school subjects. All subjects were administered the cognitive structuring test individually by the writer.

The results of the analysis showed that children with learning disabilities do not significantly differ from normally achieving children on auditory associative clustering, recall intrusions, percent of associative clustering with total recall (adjusted for redundancies and intrusions), short-term memory processes, sex differences, or transposition performance on either visual or haptic materials which were organized on conjunctive concepts.

There were significant differences between normally achieving children and children with learning disabilities on the use of auditory recall redundancies (P>.10), total auditory recall corrected for redundancies and intrusions (P>.01), the use of long-term memory structuring (P>.05), and visual and haptic reconstruction performance (P>.01). In each case the children with normal achievement demonstrated better performance on these tasks than did children with learning disabilities.

There was a significant difference in visual and haptic reconstruction memory tasks (P>.01) with the haptic task being more difficult than the visual reconstruction task. Covariance of analysis on age showed no differences between ages on performance of any subtest.

Recommendations resulting from this study were:

1. Replication of the study or follow-up on these same subjects with the addition of intelligence scores for the control subjects.
2. Development of additional reliability, predictive

validity, and norm data for a modified version of the cognitive structuring test as a potential tool in early identification of children with learning disabilities.

3. Initiate further research on the relationships and effect of teaching long term memory strategies to children with learning disabilities.

4. Provide further study on cognitive structuring processes by children with learning disabilities, particularly with the use of cross-modal materials.

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and impossible. To these wonderful people I express my eternal love.

APPENDIX A

Task Instructions

Auditory:

"The goal of this task is to see how many words you can remember from a list of words you will hear on the tape recorder.

A lady will ring a bell and then she will say the list of words. When she has said all the words on the list she will ring a bell again and you tell me all the words you can remember on that list.

You will get five chances to hear the list of words, but each time you hear the list you are supposed to tell me all the words you can remember on that list."

Upon request, the subjects were given the same set of instructions a second time.

Visual:

(a) Reconstruction task -

"In this task I will place some cards on the board and let you look at them as long as you want. When you think you can remember where each card is placed on the board, you tell me that you are ready for me to mix them up. The goal of this task is to see if you can put all the cards back on the board exactly where they were.

You may take as long as you need and move the cards all you want until you are sure they are placed exactly where they were."

(b) Transposition task -

"I think I see how you remembered where all the cards were supposed to go, but I want to make sure. This time I'm going to put this card (3-3) right here (1-1) on the board and you are not to move it from that position. Now, you put all the other cards (now randomly mixed) where you think they are supposed to go when you can't move this one card."

Haptic:

(a) Reconstruction -

"For the next task we are going to use this board with all the boxes built on it. I have some plastic tubes for you to place into each box, but I can't show you the tubes because this is a 'no-peek' game.

To help you keep from peeking you are going to sit behind this big shield and put your arms through the sleeves of this backward coat so you can feel the tubes without peeking.

The bottom of this frame is here (place subject hands on frame bottom) and I call this the 'loading dock' because this is where I will put all the tubes after I mix them up for you. If you drop any tubes I will put them back on the loading dock for you. The tubes are plastic and cannot break.

I have put the tubes in their right boxes and you can feel them as long as you need until you think you can remember which tube is in each box. I will mix the tubes and put them on the loading dock when you are ready. The goal of this task is to see if you can put all the tubes back in the boxes where they were.

If you put more than one tube in any box I will put your hands on that box and tell you to leave only one tube in each box. If any tube falls down inside a box I will set it up in that box for you.

Tell me when you are ready for me to mix up the tubes and we'll see if you can put all the tubes back in the boxes exactly where they are now."

The examiner advised subjects when they had not felt all the tubes if subjects indicated they were ready before every tube had been felt in its original position.

The examiner advised subjects how many boxes remained empty if asked.

When more than one tube was placed in one box the examiner immediately placed both subject hands on that box and instructed the subject to leave only one tube in each box.

(b) Transposition -

"I think I see how you remembered where all the tubes were supposed to go, but I want to make sure. I'll put this tube (3-3) in this box (1-1) and you can't move it. Now, you put all the other tubes where you think they are supposed to go when you can't move that tube."

APPENDIX B

Materials

Auditory:

List 1	List 2	List 3	List 4	List 5
UP	EIGHT	FIVE	DOWN	MOON
STAR	LEAF	EIGHT	THREE	FIVE
GREEN	FIVE	DOWN	UP	STAR
EIGHT	UP	STAR	MOON	LEAF
TREE	GREEN	MOON	RED	UP
LEAF	MOON	GREEN	STAR	TREE
RED	STAR	UP	FIVE	EIGHT
FIVE	DOWN	LEAF	GREEN	RED
MOON	RED	TREE	LEAF	DOWN
DOWN	TREE	RED	EIGHT	GREEN

In this counter-balanced presentation of the same ten words of five high-association pairs, no word appears twice in the same serial position across lists and no word precedes another word more than once across lists. Each word was presented at one second intervals, each list was preceded and followed by a bell, and each recall period was thirty seconds. The high-association pairs were:

up-down, tree-leaf, five-eight, green-red, and star-moon.

Visual Subtest Materials Construction

The cards of the visual subtest were all made of red heavy weight tagboard cut 2" x 2" (see Figure 2).

The square symbols were all on white mimeograph paper dry mounted to the red tagboard cards. Three sizes of borders for each symbol were cut to 1 1/2", 1", or 1/2".

The symbols were black India ink rapidograph No. 2 line squares drawn inward from the border line in one of three sizes: 4/16" on the 1 1/2" squares, 3/16" on the 1" squares, and 2/16" on the 1/2" squares.

The entire card was heavily seal laminated to provide a uniform tactile stimuli. This also protected the cards from accidental visual identification by scratches or marks and provided a smooth surface for easy handling on the test board.

The test board was a 1/2" plyboard square measuring 6 3/4" painted glossy grey. Black thinline felt pen squares were painted on the board to form nine squares 2 1/8". The entire board was coated with a thin plastic seal.

Haptic Subtest Materials Construction

The nine haptic tubes were commercially constructed of clear plastic with 1/8" walls according to the following specifications (see Figure 3):

three tubes 3" length; diameters of 1", 2", or 3" each.

three tubes 2" length; diameters of 1", 2", or 3" each.

three tubes 1" length; diameters of 1", 2", or 3" each.

The placement board was a square 1/2" plyboard cut 10 1/4" x 10 1/4". Nine 3 1/4" square cubicles were built from 1/2" x 1/2" board strips nailed to the board. The board was sanded and painted flat black for safety purposes.

The entrance box was made of 1/2" plyboard 6" wide and 12" long, sanded and painted flat black.

The blind board was made of 1" plyboard 3' in width and 2' in height with a 1' 3/4" x 1' 3/4" square hole cut 1' from each side and 1' from the top.

The flexible arm shield was a commercial photographic changing bag attached to the entrance box. The blind board fitted snuggly over the changing bag and entrance box to provide a complete visual shield between subjects and tubes.

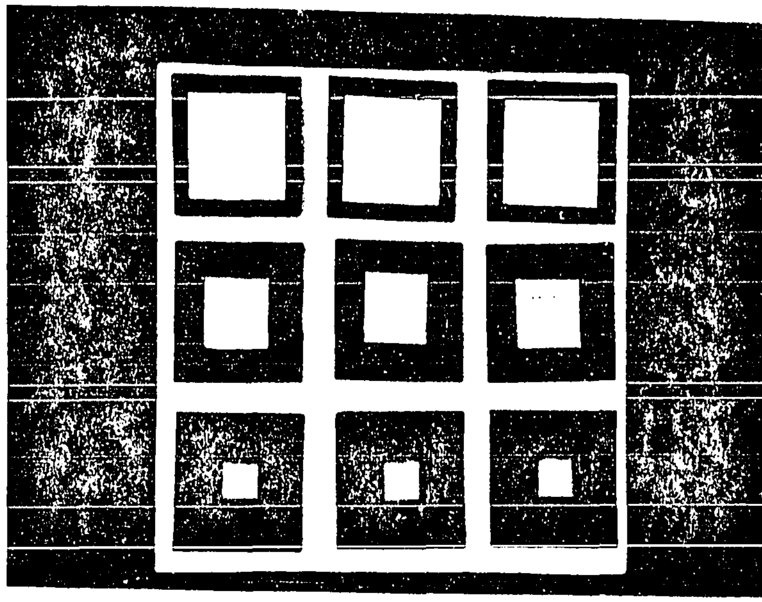

Figure 2. Visual subtest materials construction

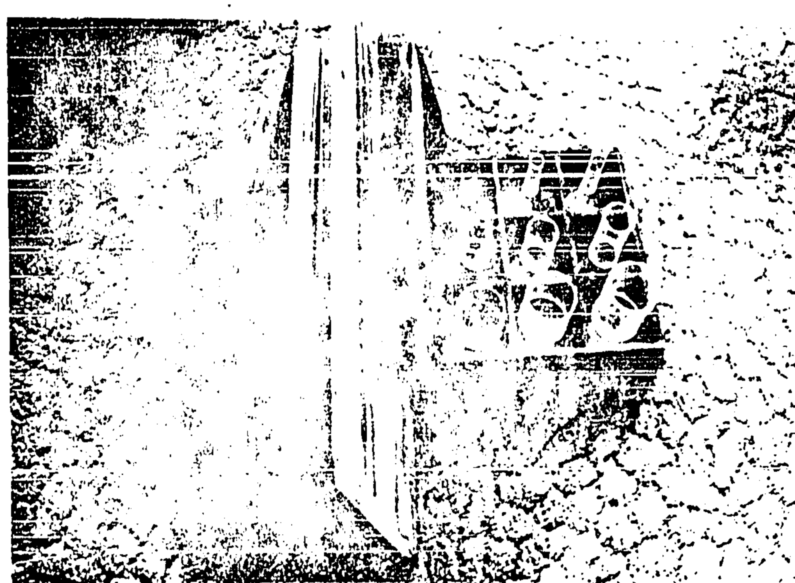

Figure 3. Haptic subtest materials construction