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CHAPTER 9

ENCODING WRITTEN LANGUAGE

Two children are sitting at their desks. They have been asked to write a short statement about their vacation. The first child is sitting properly, holding his pencil gently, but firmly, head turned at the correct angle, feet flat on the floor, and apparently ready to write. After several minutes pass, he writes his name and the date in the prescribed corner. When the papers are collected 10 minutes later, this child's paper is blank. In response to the teacher's question he replies, "I couldn't think of anything to say." If the teacher had asked this child to tell about his vacation at Yellowstone National Park, it is probable that the child would exhibit the same poverty of self-expression.

The second child has also visited Yellowstone National Park and is eager to relate the many experiences he had there. He is concentrating on the writing task, but is having difficulty producing the graphic symbols. His slow laborious printing is interrupted by many erasures. At the end of 10 minutes the second child had managed to write his name and the date on the paper. Both children exhibit failure in encoding written language, but the reasons for these failures seem to be quite different.

If a child has difficulty in the comprehension and use of spoken or read language, he will probably have difficulty learning to use written language. Similarly, problems in visual stimulus processing or in the performance of voluntarily controlled motor movements of the hand will interfere with the formation and structuring of letters. In either case, the end result is an impairment in the writing process as a means of self-expression. Because writing is dependent upon the reception and comprehension of auditory and visual language forms, Myklebust (1965) believes that writing is "* * * Man's highest achievement verbally and is achieved only when all of the preceding levels have been established." (p. 6)

The Writing Act

In acquiring competence in the task of using writing as a means of self-expression, the child must perform the following subtasks: Possess the need to communicate, formulate the message, retrieve the appropriate auditory-language signals, and produce the appropriate motor movements for producing the graphic symbols. See table 14.

Table 14.—Encoding Graphic-Language Symbols: A Task Analysis

I. Intention:
  (*a*) Possess the need to communicate.
  (*b*) Decide to send the message in graphic form.
II. Formulate the message:
  (*a*) Sequence the general content of the message.
  (*b*) Retrieve the appropriate auditory-language symbols which best express the intent of the communication.
III. Retrieve the graphic-language symbols which correspond to the selected auditory-language signals.
IV. Organize the graphic-motor sequence:
  (*a*) Retrieve the appropriate graphic-motor sequence.
  (*b*) Execute the graphic-motor sequence for producing the graphic-language symbols.

One of the most basic steps that needs to be taken is to identify the specific developmental hierarchy of writing tasks. A hierarchical sequence can be used to help identify the point of breakdown in the writing process. Also, specific standardized tests and subtests can be related to their respective levels within the hierarchy. An example of such a hierarchy of writing tasks is presented in table 15.

Correlates to Writing Disorders

It is difficult to consider the writing process without considering it within the larger contexts of both language and perceptual-motor areas. While very little research has been done with respect to identification of psychological and neurophysiological correlates to writing, there are several theoretical models which provide some insight as to the nature of these correlates.

Myklebust (1965) has developed a schematic representation of the psycho-neurosensory processes which he believes are basic to the hierarchical relationships

Table 15.—Developmental Hierarchy of Writing Tasks

I: Scribbling.
II: Tracing:
  (*a*) Connected letters or figures.
  (*b*) Disconnected letters or figures.
III: Copying:
  (*a*) From a model.
  (*b*) From memory.
  (*c*) Symbolic and nonsymbolic.
IV: Completion Tasks:
  (*a*) Figure.
  (*b*) Word completion—supply missing letters:
    1: Multiple choice.
    2: Recall.
  (*c*) Sentence completion—supply missing word.
V: Writing from dictation:
  (*a*) Writing letters as they are spoken.
  (*b*) Writing words and sentences.
  (*c*) Supply missing word.
  (*d*) Supply missing sentence.
VI: Propositional Writing.

of comprehension, spoken, read, and written language. See figure 5. According to Myklebust, written language is the last language skill acquired and is achieved only when all of the preceding levels have been established. Osgood's (1957) model of psycholinguistic abilities provides another approach to the psychological correlates to writing. The concepts of: (*a*) the auditory, visual, and haptic channels, (*b*) the processes of encoding, association, and decoding, at the (*c*) representational or nonrepresentational levels offer an organized approach to pertinent psycholinguistic factors.

The process by which thought is converted to the written form has been described by Hermann (1959):

1. Sentences are formed within the inner language system by calling up words into consciousness and placing them in their proper grammatical relationships.
2. Spelling is accomplished by mobilizing letter symbols which represent different sounds of the language.
3. Recall of letter shapes and knowledge of how letter shapes are constructed precedes the motor act of writing.
4. The manual construction of written symbols represents the last stage of the writing process.

Relatively little is known about the neurophysiological correlates to the writing process. There have been some attempts to localize disorders in writing to certain areas of the brain which have suffered damage. After reviewing pathological findings obtained by autopsy and biopsy, for example, Nielsen (1962) concluded that the highly specialized function of printed and written language is located in the frontal writing center at the foot of the second frontal convolution, and in the angular gyrus. Most studies of this kind have been done with adults. Whether or not findings obtained on adults can be extended to children remains open to question.

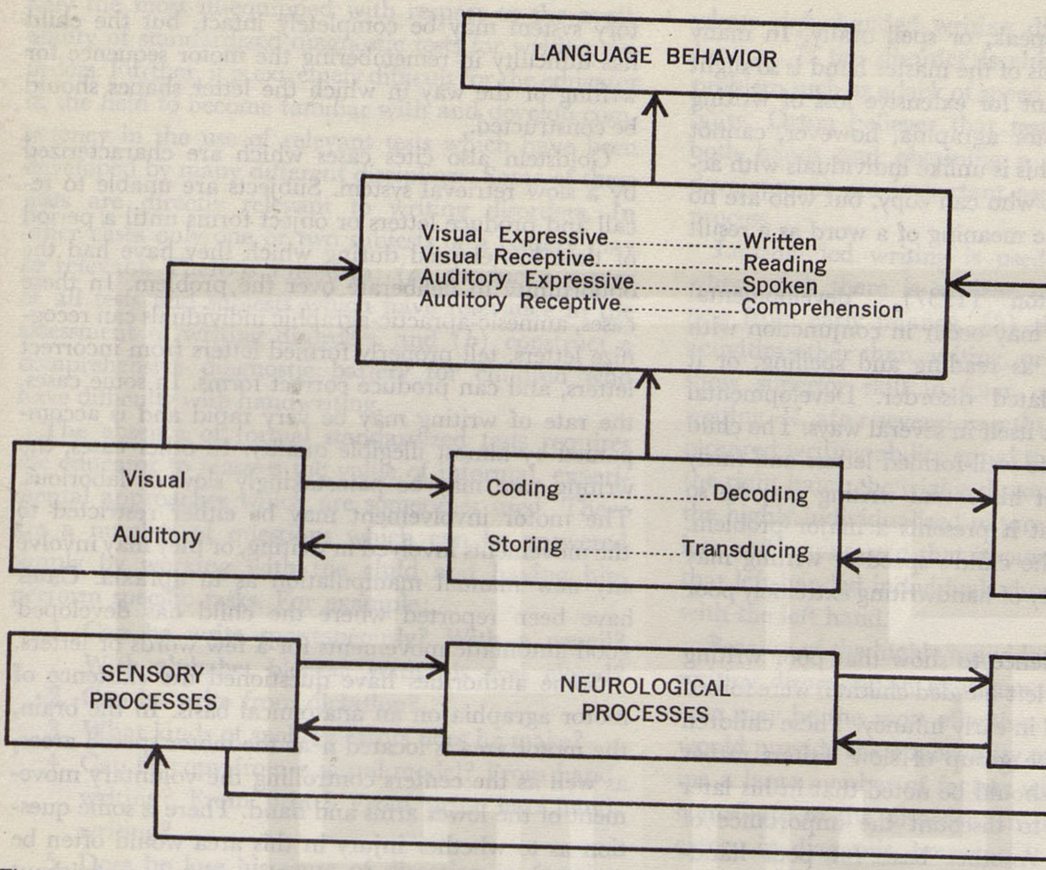
There is some evidence to support the view that the physiological mechanism for writing seems to involve the complex interaction of different areas of the brain. According to Penfield and Roberts (1959), writing is carried out by the dominant hand which is controlled through the motor-hand mechanism in the opposite hemisphere, and involves the kinesthetic image of the movement required to reproduce each word. Penfield and Roberts believe each movement in writing is initially under voluntary control, but that the execution of these motor movements eventually becomes automatic. They state that the critical ideational aspect of speech, whether written, spoken, heard, or read depends upon the employment of one hemisphere. In right-handed individuals, it is normally the left cerebral hemisphere.

Until more evidence is acquired through research, any statements or hypotheses about the transmission of neurological impulses in relation to the ideational and motor aspects of writing remain highly speculative. There is need to obtain more accurate information about the complex processes by which thought is converted to the written form. More specifically, it is necessary to obtain a detailed analysis of the psychological and neurophysiological correlates to writing.

Disorders in Encoding Graphic Symbols

The literature is somewhat contradictory as to what a writing disorder is. There seem to be three major problem areas which have been treated as writing disorders. In some cases a writing disorder is described as a dysfunction of the language system. In other cases, it is presented as a dysfunction of the auditory or visual-perceptual systems. A writing disorder has also been described as a dysfunction of the motor components of writing. It is not uncommon for elements of all three points of view to appear in a discussion of disorders of writing.

It is helpful to distinguish between "writing" and "handwriting." Writing refers to the act of committing one's thoughts to the written form and encompasses the ideational use of language as well as visual, auditory, and visual perceptual-motor abilities. In contrast, handwriting as treated in this chapter will focus on the motor aspects of writing.



The psychoneurosensory processes involved in facility with the written word.

Development and Disorders of Written Language. Myklebust, Helmer R., Vol. 1, New York: Grune and Stratton, 1965. (Reprinted by permission)

Figure 5.—The Psychoneurosensory Processes Involved in Facility With the Written Word.

Writing disorders can be caused by breakdowns in the comprehension and use of spoken or read language, visual stimulus processing, or the motor movements necessary to structure and form letters. While dysfunctions of the language system as the auditory or visual perceptual systems may interfere with the writing or spelling process, they will not be considered handwriting disorders. They will be treated as specific language, visual, or auditory disorders which require remedial efforts directed toward language, visual or auditory areas. These disorders were discussed in chapters 2 and 3. This chapter will be primarily concerned with the motor disorders which affect handwriting although language and sensory disorders may be mentioned from time to time for purposes of clarity.

Myklebust (1965) uses the term "dysgraphia" in describing handwriting disorders. This term refers to a partial inability to write because of a dysfunction in the brain, which interferes with the ability to associate mental images with the motor system for writing. Myklebust has stated that since he considers dysgraphia to be a type of apraxia, it is possible that:

> * * * it is a deficiency in remembering the motor sequences for writing, not the words to be written. The individual knows the words he wishes to write; he can recall what they sound like as well as what they look like, but he cannot produce the necessary motor movements. Because those having this problem have no difficulty with either the auditory or visual aspects of the word, they are not helped by having someone dictate or sound out the word, nor are they helped by seeing it, hence, they cannot copy. In other words, providing them with the auditory and visual aspects of the word does not benefit them; they have these. (pp. 18–19)

Orton (1937) cites case studies in which the loss of the ability to write in adults is sometimes restricted to the motor function. In these cases, there is no disturbance in the ability to recognize words by sight, read with comprehension, speak, or spell orally. In many cases the actual paralysis of the master hand is so slight that it does not account for extensive loss of writing skill. Persons with motor agraphia, however, cannot trace or copy letters. This is unlike individuals with acquired word blindness, who can copy, but who are no longer able to grasp the meaning of a word as a result of brain damage.

According to Orton (1937), "developmental agraphia" in children may occur in conjunction with other disabilities such as reading and spelling, or it may exist as an isolated disorder. Developmental agraphia may manifest itself in several ways. The child may be able to produce well-formed letters and fairly good handwriting, but his actual writing may be so painstakingly slow that it presents a major problem. On the other hand, the child's speed of writing may be rapid, but the quality of handwriting extremely poor or illegible.

Orton presents evidence to show that poor writing quality occurred when left-handed children were forced to use their right hand in early infancy. These children seemed to fall into the group of slow writers rather than poor writers. It should be noted that in his later work, Orton tended to discount the importance of changed dominance. Another basis for poor handwriting may result from a lack of skill in finer movements of the hands and fingers. This disability may be extended to include an inability to learn any new manual manipulation, as in apraxia. Orton reports cases in which children were able to produce a better quality of writing with their eyes closed than when their eyes were open.

Impairment of the complex motor act of writing has also been discussed by Goldstein (1948). He refers to the motor dysfunction as "primary agraphia" and describes several different kinds of involvement. If the problem is "lack of impulse," for example, the child may have difficulty in beginning to write or in completing a word. In these cases, copying or writing from dictation is usually better than spontaneous writing, because spontaneity is not required. Goldstein also cites cases in which letter form is disturbed. The child will make wrong hooks, arcs, etc. This disorder seems to manifest itself equally in both hands. Copying is disturbed, dictation is not better than spontaneous writing, there is some difficulty in recognizing letters, and in identifying the failures in wrongly written letters; however, the child can write words for which he has developed good automatic motor movements. The forms of apraxia which are described by Goldstein concern the preparatory state of writing. The innervatory system may be completely intact, but the child has difficulty in remembering the motor sequence for writing or the way in which the letter shapes should be constructed.

Goldstein also cites cases which are characterized by a slow retrieval system. Subjects are unable to recall and produce letters or object forms until a period of time has elapsed during which they have had the opportunity to deliberate over the problem. In these cases, amnesic-apractic-agraphic individuals can recognize letters, tell properly formed letters from incorrect letters, and can produce correct forms. In some cases, the rate of writing may be very rapid and is accompanied by almost illegible quality. In other cases, the writing rate may be painstakingly slow or laborious. The motor involvement may be either restricted to the movements involved in writing, or they may involve any new manual manipulation as in apraxia. Cases have been reported where the child has developed good automatic movements for a few words or letters.

Some authorities have questioned the existence of motor agraphia on an anatomical basis. In the brain, the motor area is located near the motor speech areas, as well as the centers controlling the voluntary movement of the lower arms and hand. There is some question as to whether injury in this area would often be so circumscribed as to involve the writing area without causing some paralysis of the right hand, a speech disturbance, or both. In any event, there is a need to obtain comprehensive descriptions of the behavioral concomitants which accompany cerebral damage.

Assessment and Treatment of Writing Disorders

Because there are so many factors which can interfere with the use of the written word, the child who cannot write presents a major assessment problem. In order to intervene with the most appropriate remedial procedures, the assessment process should provide for the systematic examination of all factors which may contribute to the problem. These include: (*a*) development deviations; (*b*) psychomotor aspects such as paralytic disorders, ataxia, and apraxia; (*c*) visual processes; (*d*) auditory processes including dysnomia, syntactical aphasia, receptive aphasia, reauditorization of letters, auditory sequencing, syllabication and auditory blending; (*e*) a discrepancy between spoken and written language; (*f*) reading disability; (*g*) speech handicaps; (*h*) social or emotional disturbance; (*i*) deafness; (*j*) cultural deprivation; and (*k*) instructional factors (Myklebust, 1965).

Of all professionals who may become involved in the diagnosis of writing disorders, the educator is probably the most ill-equipped with respect to the availability of standardized diagnostic tests for writing disorders. Further, it is extremely difficult for the educator in the field to become familiar with and develop competency in the use of relevant tests which have been developed by many different disciplines. Some of these tests are directly relevant to writing disorders. In other cases only one or two subtests of a battery may be relevant. There is a need to: (*a*) conduct a survey of all tests and subtests which have relevance to the assessment of writing disorders, and (*b*) construct a comprehensive diagnostic battery for children who have difficulty with handwriting.

The absence of formal standardized tests requires the educator to reassess the value of informal, experimental approaches which are sometimes used. There are a number of questions which can be answered simply by working with the child and having him perform specific tasks. For example:

1. Can he write spontaneously? With a pencil? With alphabet blocks? With his eyes closed?
2. Can he write from dictation?
3. What kinds of spelling errors does he make?
4. Can he copy from a visual model? From handwriting? From print? From print into handwriting?
5. Does he lose his sense of direction in forming letters?
6. Can he copy geometric figures which are not symbols?
7. Can he write in one language and not in another?
8. Does he do mirror writing?
9. Does the child profit from auditory or visual assistance?
10. Does he exhibit gross and/or motor incoordination?
11. Has he had opportunity to practice?
12. Does he have a basic language deficiency?
13. Does he understand what he sees and hears?

Orton (1937) advocated an experimental approach to the diagnosis of writing disorders. This procedure involves the testing of writing facility in both hands by observing the child in situations which make demands upon the abilities necessary for writing. For example, Orton cites case studies which indicate that there are natural left-handed individuals: (*a*) who are able to write rapidly and legibly with the right hand; (*b*) whose speed and legibility have suffered by an enforced shift; (*c*) who write well with the right hand, but whose threshold of fatigue is low; or (*d*) whose right-handed writing distracts them from the content. If the disorder is characterized by a motor problem such as a lack of speed in writing or poor legibility, Orton believes that testing writing facility in both hands and obtaining a history of handedness development are important aspects of the diagnostic process.

Left-handed writing is used as a trial procedure when: (*a*) there is a clear history of left handedness from early infancy, (*b*) the left is preferred in activities other than writing, or (*c*) when motor tests show superior skill in finer movements other than writing. If, after several months, the left hand has not required writing ability equal to or better than that of the right hand, the trial is discontinued. Orton stressed the highly individualized nature of each writing problem and emphasized that it cannot always be assumed that left-handed individuals should be taught to write with the left hand.

Because of the highly individualized nature of handwriting disorders, an experimental approach to each case may be the most effective way to proceed. This would provide the opportunity to systematically examine a large number of factors which could potentially contribute to the disorder. In order to increase efficiency in diagnosis, however, it is imperative that a manageable battery of diagnostic tests and procedures be developed.

A review of the handwriting series used in regular elementary classrooms shows that publishers such as Economy (Eppler, et al., 1953), Harr Wagner (Billington and Staffelbach, 1958), Seale (Veal and Davidson, 1963), Palmer (McLean and King, 1963), and Allyn and Bacon (1965) are remarkably similar in their approaches. All employ a basic "look-trace-copy" method or some modification of this method. A common instructional sequence, for example, introduces the strokes for forming letters and words before actually copying the alphabet. Lessons include training in the correct posture and placement of the paper in relation to the hand. Letter size is gradually reduced through the elementary grades. At the upper grade levels, writing is purposely related to other content areas such as grammar and composition. All methods provide time for practice and review.

Gardner's (1966) text for remedial handwriting is representative of remedial approaches for ameliorating disorders of writing. The manual-workbook is a more detailed version of developmental methods and techniques. The writing process has been broken down into small steps and exercises have been provided for each level. One section of the book outlines motor-kinesthetic exercises and practice in hand-eye coordination and left-right movement.

Of particular significance is the observation of Ilg and Ames (1950) that several of the current practices do not proceed in accordance with principles of child development. According to Ilg and Ames a remedial program must take into account the chronological and mental age of the child as well as the status of his visual-motor abilities. It is important, therefore, that remedial techniques remain consistent with the child's maturational level. There is a glaring lack of data to support the approaches recommended in the popular handwriting series.

Because the writing mechanism may be affected by a variety of sensory, neurological, and psychological processes, as well as cultural and instructional factors, it may be necessary to recommend a remedial program which is directed toward several different problem areas at the same time. While there are a number of different remedial approaches, most of them are directed toward a single kind of disability. There is a need therefore, to conduct a thorough inventory of remedial procedures and integrate them into a single remedial battery, which is immediately accessible to teachers. This battery should probably be organized so that the various remedial procedures parallel the developmental abilities of children as closely as possible.

If the writing disorder stems from a language dysfunction, training is directed toward language, not toward the capacity for forming letters. When the problem is one of relating spoken language to written language, training is given in reading. Remedial methods in language and reading are discussed in chapters 7 and 8.

One such example of a remedial program is training of the left hand for writing. How does one determine when the left hand should be trained? Because the tests for handedness are not reliable, Orton (1937) studied the history of left handedness, gave motor tests for five movements with the left hand, and sometimes advised left-handed writing for a few months. Orton emphasized that the individual character of each writing problem requires an experimental remedial approach. In their book on remediation techniques for aphasic victims, Agronowitz and McKeown (1959) have outlined several procedures which may be used if agraphia is present. They suggest that handedness should be changed only if the patient is certain that he wishes to make the change.

There are a number of questions which might be asked about the need for retraining the left hand for writing. How effective are the tests for handedness? What kinds of motor tests for fine movements are needed to assess finger involvement? What are the factors which should be taken into consideration before a retraining program is initiated?

Agronowitz and McKeown (1959) have also described various writing exercises which they believe will improve memory, spelling, etc. These exercises include procedures such as having the patient: (1) trace and copy lines and curves, (2) trace and copy alphabet letters and numbers, (3) perform cursive writing, and (4) copy the name of an object which is displayed on a picture card. Later exercises require the patient to write entire paragraphs.

Another remedial approach to writing disorders is to teach the child to produce the letter by feel (Orton, 1937). The kinesthetic pattern is utilized rather than the visual guidance system. This approach is intended to train automatic kinesthetic patterns without reliance upon visual control. Orton continues:

> For this purpose the child learns to draw the letter form from a pattern set at a distance and with the paper on which he is writing hidden by a cardboard shield. Once the patterns have been established, practice in this may be carried out with the eyes closed or even blindfolded. The obvious purpose of this method is to train the kinaesthetic patterns so that the hand will more or less automatically produce the letter form without visual control * * *. (p. 183)

The decision to intervene using the kinesthetic approach seems to be based on the assumptions that: (*a*) the visual guidance system is defective and probably will be unresponsive to remediation, and (*b*) training kinesthetic patterns may supplement other remedial approaches. More information is needed concerning the factors which indicate that intervention with the kinesthetic approach is the most appropriate action.

Cases have been reported in which the child is able to produce a single letter accurately but encounters difficulty in attempting to write words. Thus, in cases where sequencing is important, the child should first practice copying from a printed text until the mechanics of writing entire words have been improved, write from dictation, and eventually do propositional writing (Orton, 1937). Until some progress has been made, the children are often excused from written work in school. If writing letter sequences is a major problem, it may be necessary to determine whether left-right disorientation, directionality or laterality are involved. If so, simple copying from a printed text may not be an appropriate remedial intervention.

Goldstein (1948) presents a number of methods for teaching children who have disturbances of writing.

These methods are selected for use with respect to the kind of writing impairment and the ability of the child. If the child has a problem in beginning or completing written work, for example, training consists of copying letters and forms and taking dictation. This is intended to train "intentional impulses" for initiating and completing written work. If the problem is motor agraphia, the objectives of the remedial program are to teach the actions for forming letters. This may be done through copying movements, and by sounding or naming the letter as it is being copied or written. If visualization is good or can be improved, it is sometimes possible to let the subject copy from his imagery. Similarities between object forms and the forms of letters may be pointed out to strengthen visual memory. In cases where visual imagery is poor, Goldstein attempts to train motor automatisms, by: (*a*) guiding the pupil's hand according to letter form and gradually reducing guidance and increasing pupil independence, (*b*) tracing on a pane of glass under which patterns are placed, (*c*) writing the letter while the learner watches so he is able to imitate the sequence of movement, and (*d*) associating the movements for better formation with other movements.

Hermann (1959) has found that in the children he referred to as "congenital word blind," writing difficulties are usually pronounced and particularly resistant to treatment. He points out that the performance of word-blind individuals is frequently inconsistent. They will write a letter correctly and neatly one moment and a few moments later make the letter improperly or disfigure it. This inconsistency in performance may be misinterpreted by teachers as carelessness which sometimes results in unwarranted pressure being placed on the child to be more attentive.

The application of the typewriter as an instructional remedial tool has not been fully explored. An early study by Conrad (1935) demonstrated that the use of the typewriter did not adversely affect handwriting, and that speed and legibility of handwriting among third graders was improved. This improvement was not found among fourth-grade pupils. Factors of sample selection, growth, and development may have been responsible for the difference between third- and fourth-grade pupils.

Skinner (1968) has developed a set of instructional materials, with teacher's manuals to teach manuscript printing and cursive writing. These materials are printed on specially constructed paper, which turns a different color when marked on any place but the place where the writer is expected to write.

In summary, remedial methods might include work in revisualization, auditory memory, letter symbol-sound associations as in spelling, language or grammar, handedness, the formation and structuring of letters, and motor movement. While remedial methods may be found for each of these areas, the major problem is to determine which area or areas are deficient. This requires a thorough differential assessment of the problem. Because few remedial programs have been developed specifically for handwriting, teachers have had to outline remedial procedures which correspond with each child's individual needs. Intervention, however, should be consistent with the principles and levels of child development and the mental age and chronological age of the child. With respect to emotional problems which may be associated with handwriting disorders, it is not particularly helpful to discuss anxiety, introversion, and inhibition in a general way. It will be necessary to examine observable behavioral symptoms of each child and relate these behaviors to specific learning situations.

Directions for Future Research

A basic step in studying dysfunctions in encoding written language symbols is to identify the developmental hierachy of writing tasks. These tasks can then be studied with respect to the psychological and neurological correlates which may contribute to breakdowns in the writing process. This kind of specificity should help clarify the different kinds of disorders which may occur.

There is need, also, to develop systematic procedures for assessing and treating disorders of written language. Both formal and informal tests should be constructed for use in conducting thorough analyses of writing problems which will guide teachers towards the most appropriate instructional alternative.

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CHAPTER 10

QUANTITATIVE LANGUAGE

An analysis of the different kinds of tasks which are used in arithmetical and mathematical operations suggests that the conceptual approaches to disorder in these areas may have been oversimplified. A number of different cognitive abilities are probably involved in comprehending the structure of numbers, performing arithmetical operations, and developing quantitative concepts.

In considering these disorders it is helpful to make a distinction between arithmetic and mathematics as is being done in recent "modern math" programs in schools. Mathematics is the abstract science of space and number which deals with space configuration and the interrelations and abstractions of number. Arithmetic is a branch of mathematics that deals with real numbers and their computation. The distinctive peculiarity of numbers is that they represent concrete entities. In contrast, Barakat (1951) points out that a mathematical expression is an abstract scheme which does not represent anything concrete and requires a Gestalt quality for the appreciation of form and configuration.

The concrete nature of arithmetic and the abstractness of mathematics not only suggests that different cognitive abilities may be involved but that they might be disordered in several different ways. In mathematics, for example, children might experience difficulty in handling the operations, interrelations, and abstractions of number, or the structure, measurement, and transformation of space configurations. Difficulty in arithmetic might include such things as reading or writing isolated numerals or a series of numerals, reading and writing numbers whose names are not written the way they are spoken (twenty one=21, not 201), recognizing the categorical structure of numbers (units, tens, hundreds, thousands), and doing computational operations.

The reading and writing of numerals and the calculation of numbers with or without numerals are often disturbed at the same time. The reading-writing and the calculation are frequently grouped under a single designation, causing confusion. Hermann (1959) points out that there is a difference between: (*a*) the reading and writing of numbers (numerals); and (*b*) the calculation of numbers. He believes that the defective ability to read numbers (numerals) should be classified under "dyslexia," and that the term "dyscalculia" or "acalculia" should be reserved for defective ability to perform calculation. The distinction between the inability to read and the inability to perform arithmetical and mathematical operations is helpful, because it identifies two different aspects of a general problem area.

Correlates to Quantitative Thinking

There are a number of studies in the area of education, psychology, neurology, and child development which provide information about the basic cognitive processes that may underlay the attainment of quantitative concepts. These studies suggest that in addition to the general intelligence factor there are at least four other factors which seem to be related to the attainment of quantitative concepts; spatial ability, verbal ability, problem-solving ability, and neurophysiological correlates.

1. *General Intelligence:* The importance of general intelligence to arithmetical ability has been demonstrated in many studies. Barakat (1951) studied the mathematical ability of 160 boys and 160 girls and found that intelligence was an important factor in mathematical attainments of every kind. A study by Sutherland (1942) also found intelligence to be a major factor in arithmetic and mathematics. Schonell and Schonell (1958) point out that general intelligence contributes a greater share towards ability in problem arithmetic than in mechanical arithmetic. This supports the experience of teachers who find it more difficult to produce improvement in problem solving than in doing simple calculations.

2. *Spatial Ability and Its Sub-Factors:* Research indicates that spatial ability seems to be an important factor for aptitude in mathematics (Rogers, 1918; Holzinger and Swineford, 1946; Barakat, 1951;

Werdelin, 1958; Wrigley, 1958). Smith (1964) reviewed studies by Gastrin, by Seigvald, and Smith which indicated that spatial tests have higher correlations with marks in geometry than in arithmetic and algebra. Among college students, arithmetic and algebra correlated more highly with the verbal factor while advanced mathematics and physics correlated with the Matrices Test (Vernon, 1950). Hills (1957) found that spatial visualization and spatial orientation are important in college courses in mathematics. Verbal reasoning and vocabulary comprehension were found to be relatively unimportant for success in higher mathematics. A study by Wrigley (1958) also concluded that mathematical ability, as distinct from arithmetical skills, appeared to be more closely related to spatial ability.

Despite studies such as these, spatial ability is not fully understood or clearly defined. There is still some question whether spatial ability is a single ability or is composed of several types of abilities. Consequently, it is not an easy task to identify and distinguish different spatial factors. There are a number of studies, however, which have attempted to identify different types of spatial abilities.

Factorial studies conducted by Guilford and Lacey (1947) identified a visualization factor, a perceptual speed factor, and a length estimation factor. Thurstone (1950) identified three factors having to do with visual orientation in space: the ability to recognize the identity of an object when it is seen from different angles; the ability to imagine the movement of internal displacement among the parts of a configuration; and the ability to think about spatial relations in which the body orientation of the observer is an essential part of the problem (kinesthetic imagery may be involved here). These factors are probably closely related to the concepts of object constancy, directional constancy, and form constancy mentioned by Alexander and Money (1967). French (1951) reviewed the factorial investigations prior to 1951. In discussing the nature of the three spatial factors which had been reported, French wrote that: The space factor represented the ability to perceive and compare spatial patterns accurately; the space orientations factor seemed to involve a person's ability to remain unconfused by the varying orientations in which spatial patterns may be presented; and the spatial visualization factor seemed to represent the ability to comprehend imaginary movement in three-dimensional space or the ability to manipulate objects in imagination.

A study by Zimmerman (1954) tested the hypothesis that space and visualization factors were differentiated only by their complexity or difficulty. It was hypothesized that a single test could emphasize each of the four factors simply by varying item difficulty and complexity on perceptual speed, space, visualization, and reasoning. Zimmerman administered three different and increasingly difficult forms of the Visualization of Maneuvers Test to aviation students. The simplest form of the test had the highest loading on perceptual speed, the second more difficult form measured the space factor, and the most difficult form was the best measure of the visualization factor. None of the tests was loaded on the reasoning factor. Apparently, either the reasoning factor did not belong to the spatial syndrome or none of the three forms of the Maneuvers Test was sufficiently difficult to measure it. Zimmerman's study suggests that distinction between the spatial factors may represent a continuum of the difficulty and complexity involved.

A study by Michael, Guilford, Fruchter, and Zimmerman (1957) summarizes research in this field prior to 1957. They generated three groups of factors: (1) spatial relations and orientations which include the ability to comprehend the nature of elements within a visual stimulus pattern in reference to the subject's body; (2) visualization which was thought to involve movement sequences requiring the mental manipulation of visual objects, and recognition of new position, location, or changed appearance of objects that had been moved within a complex configuration; and (3) kinesthetic imagery which was believed to represent left-right discrimination in reference to the subject's body. While there is probably some correlation between the three factors (Roff, 1952), Michael, Guilford, Fruchter, and Zimmerman believe it would be helpful to consider the three "factors" as being conceptually independent.

Form perception is probably closely related to the development of spatial abilities. The ability to identify objects and to distinguish one object from another is essential if the child is to manipulate objects for purposes of meaningful classification and grouping, and to differentiate written and number symbols. Forms can be distinguished by sight and by touch.

Another important spatial concept is that of object permanence (Piaget, 1964). Until this concept is acquired, children presumably believe that an object which is out of sight no longer exists. By 2 years of age, most children learn that objects have substance, occupy space, exist even though hidden from view, and have an independent permanence of their own (Werner, 1948; Wallach, 1963). The child who has not acquired the concept of object permanence will probaby have difficulty thinking in terms of objects not physically present and may have difficulty in addition, subtraction, multiplication, and division of objects, and the manipulation of symbols which may be the ideational representations of absent objects.

3. *Verbal Ability:* The significance of verbal ability for the acquisition of quantitative concepts may have been underestimated by educators. There are a number of studies which have identified the presence of a verbal or language factor which seems to be associated with algebra, problem arithmetic, attainment in arithmetic operations, reading comprehension, and vocabulary meaning (Kelley, 1928; Mitchell, 1938; Barakat, 1951; Smith, 1954; Wrigley, 1958; Werdelin, 1958; McTaggart, 1959; Kaliski, 1962).

Children who lack the language system of their community may have difficulty organizing and categorizing information and focusing on more than one aspect of a problem at a time. Generalization is more difficult because the child is less capable of verbalizing the underlying principles. The ability to label and use words will facilitate the handling of concepts of magnitude, conservation, time, and number. When we examine the mental age at which receptive or expressive use of words appears in children's vocabulary, the relationship between mental age and the acquisition of quantitative concepts becomes apparent (Gesell, 1940; Gesell and Ilg, 1946; Ilg and Ames, 1951).

Concepts of magnitude seem to emerge quite early in the cognitive development of children. While these concepts are nonverbal, they tend to be highly functional. The concepts of "littlest," "middle," "biggest," "many," and "more" are formed between the ages of 1 and 2½ years. "Bigger" and "smaller" are usually mastered by age 3 or 4. Thrum (1935) studied the concepts of littlest," middle," and biggest" among children of 2 to 5 years of age, and found that "littlest" was the easiest to select correctly; "biggest" was the next in difficulty and "middle-sized" was the most difficult concept. In training children to discriminate between large and small stimuli, Ling (1941) showed that children who had learned to discriminate gross differences could then generalize to narrower differences.

Concepts of size, unlike color and form discrimination, are not straightforward perceptual tasks. Appreciation of size is relative and requires abstract thinking and conservation (Sigel, 1954, 1961, 1964; Kagan and Lemkin, 1961).

Concepts of quantity require greater cognitive sophistication, because they require: (*a*) an appreciation of likeness, (*b*) knowledge that only like elements are additive, and (*c*) that spatial dispersion, spreading out, or grouping does not affect the quantity. Children must understand for example, the invariance of continuous quantity when the shape of the container for liquids varies or the shape of an item is altered.

Quantity seems to be understood in conservational terms by the age of 7 or 8; weight by the age of 9 or 10. The concept of volume seems to be more difficult to grasp and does not appear until the age of 11 or 12 (Piaget and Inhelder, 1941; Lovell and Ogilvie, 1960, 1961a, 1961b; Elkind, 1961a, 1961b, 1961c). The importance of intelligence in the performance of a conservation task was found by Kooistra (1963) in a study with children 4 through 7 years of age (average Stanford Binet IQ of 135). The results using mental age as a criterion were comparable to results obtained using chronological age as a criterion. Conservation seems to develop in a sequence of mass, weight, and volume, and the mental age of a child seems to be an important factor in determining the onset of each stage (Sigel, 1964).

The first indication of time appreciation occurs when the child coordinates his own movements sequentially. At this stage of development, there is no concept of duration; only sequence. Next the child conceptualizes the before-and-after relationships, but durational intervals are conceived only in concrete terms. Finally, the child is able to deal with concrete images of future and past events, and eventually he is able to represent them through verbal and written symbols.

Children normally respond to time vocabulary before they utilize those words as part of their language system. The child is able to relate time to his daily activities before he learns to use the clock or is able to answer questions about time relations. The word "today" appears at about 24 months, "tomorrow" at 2½ years, and "yesterday" at 3 years. He is able to distinguish between "morning" and "afternoon" between 3½ and 4 years. At age 5 he realizes that birthdays are repeated and knows how old he will be on his next birthday. A 6-year-old will be able to tell what time it is when the hands show the hour, but the finer divisions of time are very difficult for him to grasp. At 7, he knows the time of day, the month, the season, and how many minutes are in a half hour. The 8- or 9-year-old usually knows the day of the month, and can name the months of the year.

Comprehending and using the conventional time system continues to be a problem for many children until at least 11 years of age. The acquisition of time concepts seems to be a cumulative product of incidental experience. According to Ausubel (1958) the acquisition of time concepts includes several kinds of conceptualizations such as concrete to abstract, specific to general, current to remote, precategorical to categorical, and subjective to objective thinking.

4. *Approach-to-Problem Solving Factor:* An approach-to-problem solving factor involving an ability to compare and organize data prior to the solution of a problem presented in verbal, arithmetical or spatial form was identified by McTaggart (1959). Werdelin (1958) studied the nature of mathematical ability and found that a deductive factor, and a general mathematical reasoning factor were related to mathematical ability as measured by school marks.

An approach-to-problem solving factor probably represents the sum total of all the factors which are related to arithmetical and mathematical operations. Problems which involve complex kinds of reasoning often require the ability to handle abstractions at higher levels. Chronological age or, more appropriately, mental age, seems to be an important factor in problem solving (Ausubel, 1958). Older children usually have the advantage of a more highly developed language system with which to facilitate the process of generalization, whereas younger children are more dependent on concrete imagery and derive less benefit from abstract symbols. With increasing age, children become more aware of the existence of problems, problem solving becomes more systematic, solutions tend to be less stereotyped and perseverative, the frequency of trial and error approaches toward problem solving declines, and hypothetical approaches and insightful solutions become more common.

5. *Neurophysiological Correlates:* When one or more of the higher mental processes is disrupted, difficulty in participating in calculation systems, and in the development of quantitative concepts may be expected. If we are correct in assuming that the development of quantitative concepts is to a certain extent dependent upon general intelligence, spatial ability, verbal ability, and problem-solving ability, we may turn our attention to the ways in which these higher mental processes may be disrupted.

Attention was first directed to disorders of calculation in adults. Case studies were made of persons who had no previous disturbance of their arithmetical faculties, but who later suffered some insult to the brain. Whether or not brain pathology in adults is relevant to brain pathology in children is open to question, as practically all of the research in brain pathology has been done with adults. Henschen (1919) observed that difficulties in identifying and naming printed or written figures and numbers could occur without disorders of calculation, and that number blindness could occur without any accompanying blindness for words. He described this condition and named it "acalculia."

In a postmortem study, Henschen found that acalculia was present with accompanying lesions in the occipital, frontal, parietal, and temporal areas. These findings led Henschen to conclude that the integrity of several areas of the cortex is necessary for calculation, and that a separate system probably exists for the use of language.

In 1924, Gerstmann described a syndrome consisting of bilateral finger agnosia, right-left disorientation, agraphia, and acalculia. A child who has finger agnosia, for example, cannot differentiate, correctly name, indicate specific fingers on command, nor imitate given finger postures. (For further discussion, see diagnosis section, "Finger Agnosia," in this chapter.) Mistakes are usually more pronounced with the three middle fingers. Gerstmann showed that finger agnosia tended to occur in association with right-left disorientation, agraphia, and acalculia. Historically, the Gerstmann Syndrome has created considerable interest in relating specific behavioral symptoms to localized areas of the brain.

From biopsies and autopsies, primarily performed on adults, Gerstmann (1924, 1927, 1930a, 1930b) associated the syndrome with organic damage to the parieto-occipital region in the dominant hemisphere, corresponding to the transitional region of the angular gyrus and the second occipital convolution.

Guttmann (1936) reports several operative case studies which relate acalculia to the parieto-occipital region. In one instance, a male, age 50, had a meningioma removed from the falx on the mesial side of the occipital lobe. Before the operation, the patient could count visually, calculate quickly, tell time, and set a watch. He had trouble, however, with spatial orientation, and alexia for words, letters, and figures. After the operation, symptoms appeared which suggested involvement of the parieto-occipital region, including the inability to distinguish right from left, constructional apraxia, and acalculia.

Nielsen (1938) reviewed the research on Gerstmann's Syndrome and found that in all verified cases reported there was a lesion in the major parieto-occipital area. Nielsen also cited eight case studies in which verification was made of the lesion at the time of the operation or during autopsy. In comparing disturbances of body schema resulting from lesions of the two sides, lesions on the major side seemed to cause disturbance of knowledge of the two hands, especially the fingers. This suggests that the major parieto-occipital area is a lateral-coordinating area, and damage to this area may result in right-left confusion, and in some cases, a loss of the sense of direction. Nielsen points out that the more closely the lesion approaches the occipital lobe, the more of the visual element one finds in the disturbance. As the lesion approaches the parietal lobe, the more the sensory element becomes involved; as the lesion approaches Wernicke's zone, the more the language or symbolic element is affected.

Nielsen (1962) cites a number of case studies which localize finger agnosia on the border between the major angular gyrus and the second occipital convolution; visualization of inanimate objects in the right occipital lobe; and visualization of animate objects in the left occipital lobe.

Siegel's (1957) study of visual-verbal concept formation demonstrates the difficulty that brain-injured children have in forming concepts. A brain-injured child is often able to employ one concept, but difficulty may be encountered in shifting from one concept to another. For example, having learned that $1+2=3$ the child might insist that $2+1$ are not equal to three.

According to Luria (1966) lesions of the left inferoparietal or parieto-occipital area result in disintegration of visual-spatial synthesis. When this occurs the categorical structure of number loses its significance and difficulty performing calculations may result. Lesions of the left temporal region, which result in acoustic aphasia, also cause difficulties in arithmetic. Because there is no obvious disturbance of spatially oriented operations, people can still perform arithmetical operations on paper, and understand the meaning of individual figures and the categorical structure of numbers. Difficulty is experienced, however, when the individual is forced to calculate aloud or rely on speech processes for resolving arithmetical problems.

When lesions of the frontal lobes are involved, discriminatory disturbances occur as well as breakdowns in the regulatory role of the verbal association system. In these cases, both the categorical concept of number and elementary arithmetical operations may remain intact unless there is an extensive lesion in the frontal lobe. Luria points out, also, that arithmetical problems are related to motor aphasia. Impairment of internal speech may lead to difficulty in the performance of complex arithmetical operations. General cerebral disturbance resulting in the weakening of cortical processes may disturb complex arithmetical operations.

There is some evidence that lesions in the occipital area seem to cause difficulty in handling number symbols and in reducing visual retention and visualization. Impaired ability to deal with abstract numbers, however, has been attributed to the frontal lobes. Grewel (1952) takes issue with the presumed effects of frontal lobe damage. According to Grewel, deterioration in computational abilities will affect concrete as well as abstract computation. Further, Grewel raises the question as to whether any number is ever really abstract. In general, however, Grewel concurs that frontal lesions may tend to lower the level of productive thinking.

Subsequent clinical study has not fully supported the localization of the lesion responsible for Gerstmann's Syndrome. Critchley (1953), for example, reviews a number of studies which relate finger agnosia to angular gyrus disease, right-left disorientation to the supramarginal gyrus, and finger aphasia to temporal lobe lesions. A study by Heimberger, De Meyer, and Reitan (1957) also suggests that brain damage responsible for the Gerstmann Syndrome is not limited to a small prescribed area. Case studies of 23 patients who manifested this syndrome had cerebral lesions which were large, multiple, and in some cases bilaterally involved. Generally, involvement was greater in the dominant hemisphere in the Sylvian Region. Eighty-three additional patients were studied and the severity of brain damage increased in proportion to the number of components of the Gerstmann Syndrome. These studies continue to raise the question as to whether the complete Gerstmann Syndrome is the result of an isolated lesion in the angular and supramarginal gyri or of more extensive damage.

Discussion

There are several possible explanations why little is known about the nature and severity of learning disorders in arithmetic and mathematics among children with minimal brain dysfunction. First, the significant dimensions of arithmetic and mathematics may have been narrowly conceived. Much of the literature, for example, has focused on content, student attitudes toward content, and instructional procedures. Second, failure to distinguish between: (*a*) arithmetical operations, (*b*) mathematical operations, and (*c*) their underlying psychological correlates has probably contributed to the confusion in this area. Third, research has identified a number of factors which seem to be related to success in arithmetic and mathematical operations, but the extent to which these factors, either singly or in combination, contribute to the attainment of different kinds of quantitative concepts is still open to question.

Children usually acquire these basic concepts and abilities almost incidentally, with only minimal informal guidance and in many instances, none at all. When children fail to acquire these concepts, the parent or teacher is confronted with the problem of trying to determine what should be taught and how it should be presented.

Assessment

The present status of research provides some direction for the assessment of children who are failing in arithmetic and mathematics. A general diagnostic procedure might be outlined in several steps. The first step in diagnosis is the screening and identification of children who are failing. The identification process should also provide information about the kinds of operational errors which are made. The second part of the diagnostic process should be an examination of the sensory and intellectual abilities to determine if the problem results from sensory disorders, mental retardation, or instructional or environmental factors. This kind of information will also help establish an estimate of the child's capacity for learning. The third step of the diagnostic process is to test the integrity of the psychological and neurophysiological correlates. The final step is the development of an hypothesis about the factors contributing to the problem which will lead to recommendations for remediation.

1. *Screening and Identification:* Children who fail in arithmetic are readily identified by the classroom teacher. The initial evaluation of arithmetical operations, however, should include a series of tests of varying complexity which will reflect the processes taking place at different levels of difficulty, such as: the addition and subtraction of single digits; addition and subtraction outside the range of 10, which requires numbers to be added into groups; operations with round numbers and subsequent addition of the remainder; repeated carrying over into the next column; compound multiplication and division; and fractions in which the visual component is relegated to the background and the core of operation is composed of abstract verbal-logical operations. Achievement tests such as the California Achievement Test, Tiegs, E., and Clark, W. (1957); the Metropolitan Achievement Test, Durost, W., Bixler, H., Hildreth, G., Lund, K., and Wrightstone, J. (1960); or the Stanford Achievement Test; Kelley, T., Madden, R., Gardner, E., Terman, L., and Ruch, G. (1953) provide additional information about specific arithmetic concepts such as number ideas, the idea of place values, fraction ideas, operations ideas, geometric ideas, and measurement ideas.

Additional information about the problem can be obtained by asking the child to recite all aspects of the process aloud, or having him write down the operations. At first the child should be requested to do simple calculations, and then addition and subtraction involving carrying and borrowing. Written calculation is requested for both horizontal and vertical problems. Horizontal problems require retention of all elements, whereas, vertical calculation is a more automatic operation. The examiner should carefully observe the kinds of mistakes that are made and analyze the various processes used by the subject. Only the more severe forms of brain dysfunction are reflected in tests of arithmetic. For this reason, complex arithmetical operations, though limited, assume a more prominent place in the diagnostic process for disorders in arithmetic and mathematics.

2. *Estimate Capacity for Learning:* A child who is failing should also be examined for sensory disorders, mental retardation, and the influence of cultural, environmental, or instructional variables. Children who have these kinds of problems should be handled accordingly. If the problem seems to arise within the child from a possible brain dysfunction, additional testing is needed to establish the nature of the impairment.

3. *Examine the Psychological and Neurophysiological Correlates:* Having ruled out sensory impairment, mental retardation, cultural, environmental, and instructional factors, the examiner should look for deficiencies in the psychological and neurophysiological correlates to learning. It is important to ascertain the presence, nature, and extent of these correlates for purposes of prognosis and possible medical treatment. There are several behavioral symptoms in arithmetic and mathematics which have been correlated with brain damage. These symptoms, therefore, might be used by some as gross indicators of psychological and/or neurophysiological impairments.

A. Comprehension of number structure and arithmetic operations: Luria (1966) describes several procedures for investigating the comprehension of number structure and arithmetical operations in children with brain lesions. There are several critical areas which Luria (1966) believes should be investigated:

1. Does the child have difficulty in understanding the verbal names given to numbers? Can he read or write numbers that are not spoken? Children who have difficulty understanding a number name when it is spoken may be able to recognize it when it is written as well as perform arith-

metical operations with it. A disorder of this kind, notes Luria, may be indicative of a receptive aphasia.

2. Can the child indicate how many fingers correspond to a given number, or can he call out the number of fingers shown to him? When the child can neither read nor write a number, but can indicate how many fingers correspond to a given number or can call out the number of fingers shown to him, the disorder may arise from a lesion in the occipital area (Luria, 1966).
3. Can the child visually recognize figures shown to him? Research shows that visual-spatial disorders have been found to occur in patients with lesions of the infero-parietal, parietal, and parieto-occipital areas. Luria points out that failure to recognize complementary Roman or Arabic numerals (XI, IX and 17, 71) may be an indicator of left-right confusion resulting from a visual-spatial disorder.
4. Can he write single figures? multidigit figures? Difficulty in writing single or multidigit figures, confusion in recognizing and writing numbers and assigning categorical values to individual digits may stem from left-right confusion due to lesions in the parieto-occipital area (Luria, 1966).
5. Does he try to apply categorical structure of numbers which are arranged in different ways? Can he identify which of two written numbers is larger when the smaller number of a pair (178 and 210) contains smaller digits in all categories below the highest? Can he do simple automatized calculation? carry numbers? horizontal as well as vertical calculation? The disintegration of the categorical structure of numbers (units, tens, hundreds, thousands) has been linked with visual-spatial ability (Luria, 1966). Asking children to: (*a*) tell which of a pair of multidigit numbers is larger; (*b*) read or write multidigit numbers that are not written the way they are spoken; or (*c*) apply categorical structure to numbers arranged in different ways (925 or $\begin{matrix}9\\2\\5\end{matrix}$) is of use in determining the extent to which the categorical structure of number is understood. Categorical impairment is obvious if the child is unable to handle or attend to the position of columns, sums, or remainders. Luria points out that the reading and writing of numbers whose names do not coincide with their categorical structure may also be due to a form of echopraxia arising from damage to the frontal lobe.
6. Can he do serial arithmetic operations (7+3=10)? Consecutive arithmetic operations such as counting backward from 100 in 3's or 7's not only require understanding of the categorical structure of numbers, but make major demands on the nervous system. After subtracting 3 from 100, for example, the subject must use the difference as a starting point, subtract, and continue to repeat the process. Perseveration of one operation (100–97–87–77) is characteristic of inactive or inert higher nervous processes (Luria, 1966).

B. Spatial orientation: A study by Hills (1957) found that spatial tests were more valuable in predicting success in advanced courses of mathematics than in grammar school arithmetic. Nevertheless, research seems to show that spatial ability leads to left-right awareness which is important for developing the basic conceptual framework for achievement in mathematics and arithmetic. Bender (1946), Kephart (1960), Beery and Buktenica (1967), and Frostig (1964) have developed tests of spatial ability which may prove helpful in identifying the presence of spatial disorders. Hermann (1959) and others have mentioned the importance of left-right orientation to academic work in arithmetic. Uncertainty as to the direction in which to work through a calculation may be an indication of dyscalculia. While reading is conducted from left to right in the Western culture, addition, subtraction, and multiplication are calculated in the opposite direction, that is, from right to left. The fact that division is done from left to right only adds to the confusion.

When numbers are printed on the same line, individuals with right-left confusion do not know which number should be the subtrahend. If an individual has difficulty in writing and reading numbers, he may be considered to have dyscalculia since the development of number concepts is closely linked to the number symbols themselves. One should remember that children can perform a large number of easy calculations without knowing what the higher numbers are called. In this case, language is not an absolute prerequisite. Even when one calculates on paper, an important part of the addition is done in one's head. This is difficult for the word-blind person because he finds it difficult to visualize numbers insofar as he cannot visualize words or does so only with uncertainty.

C. Finger agnosia: The direct relationship between the accuracy of finger localization and arithmetic is open to question. Studies by Strauss and Werner (1938) and Werner and Carrison (1942) reported that achievement in arithmetic was higher for those with good finger localization ability than for those with poor finger localization ability. A third study conducted by Benton, Hutcheon, and Seymour (1951) found no relationship between finger localization capacity and arithmetic ability. After reviewing the research, Benton (1959) concluded that defects in finger localization and arithmetic ability are not more closely associated with each other than they are to other behavioral deficits shown by individuals with brain injury. It should be noted, however, that problems with finger localization may be helpful in identifying children with possible brain dysfunction in the parieto-occipital area.

Schilder (1931) describes five conditions of finger function that had some localizing value: Optic finger agnosia was located near the occipital area; finger agnosia between the angular gyrus and the second occipital convolution; constructive finger apraxia between the supramarginal gyrus and the transitional zone between the angular gyrus and the second occipital convolution; apraxic disturbance in finger selection at the supramarginal gyrus; and finger aphasia in the extension of Wernicke's Zone.

Benton (1959) classified finger agnosia into three basic types. These include the inability to: (1) name or designate the fingers of either hand in response to oral command, even when he is permitted to see his hands; (2) name or designate the fingers of either hand in response to oral command or to localize tactual stimulation of the hands when his eyes are closed; (3) localize tactual stimuli applied to the fingers of one hand when the eyes are closed, while this ability is preserved in the other hand. Bilateral parieto-occipital disease leading to tactual-visual deficits may result in bilateral finger agnosia. Benton also draws attention to the verbal function involved in naming fingers or responding to finger names. Benton mentions the fact that the names of the inner fingers are acquired later than the others, and many adults fail to learn their proper designation.

D. Verbal Ability: Investigation into the nature of arithmetic disorders should include an assessment of the extent to which language involvement contributes to the problem. This area is discussed in chapter 2.

4. *Development of Hypothesis and Recommendations:* Having described the kinds of operational errors, eliminated the involvement of sensory disorders, mental retardation, and environmental variables as casual factors, and having examined the psychological and neurophysiological correlates, it is necessary to develop hypotheses about the cause of the problem and the most effective procedure for amelioration.

Discussion

At present, there is no systematic procedure for evaluating and diagnosing disorders in arithmetic and mathematics. In addition to achievement tests, there are a variety of different tests which are currently used to measure correlates of arithmetic and mathematics. These include tests such as the Metropolitan Readiness Tests, Hildreth, G., and Griffiths, N. (1949); New York Test of Arithmetical Meanings, Wrightstone, J., Justman, J., Pincus, M., and Lowe, R. (1956); Pintner General Ability Tests, Nonlanguage Series (1945); Wechsler Intelligence Scale for Children (1949); Frostig Developmental Test of Visual Perception (1964); Developmental Form Sequence (1967); the Graham-Kendall Memory-for-Designs (1960); and the Illinois Test of Psycholinguistic Abilities (1968).

The diversity of these tests reflects the many different variables which are involved in learning arithmetical and mathematical operations. Among these are general intelligence, spatial ability and its subfactors (object constancy, visualization, perception, perceptual speed, right-left discrimination, and object permanence); verbal ability, approach to problem solving, as well as accompanying psychological and neurophysiological correlates.

It is important to note the presence of behavioral correlates and their interrelationships. For example, finger agnosia, right-left disorientation, aphasia, and acalculia, individually or in combination, are thought to be indications of organic pathology. There is a need, however, to determine which correlates are relevant to different kinds of learning tasks, and what implications these hold for the effectiveness of different remedial methods. It is necessary, therefore, to develop techniques for measuring the significant correlates.

Further, there is need to develop comprehensive testing procedures for children with arithmetic and/or mathematic problems. Such a battery should probably include: (*a*) background information; (*b*) task analysis of the pupil's achievement in each aspect of the subject; (*c*) a test of general intelligence; and (*d*) tests of the various cognitive abilities and any other correlates to success in arithmetic and mathematics. Careful examination of this kind of information and the interrelationships of the significant variables should lead to a working hypothesis as to the cause of the problem and the selection of a remedial method for its amelioration. There is need, therefore, to apply a theoretical model of some kind within which concepts of quantity, weight, time, volume, grouping, classification, sequencing, the use of abstract thought or symbols, approach-to-problem solving, and their interrelationships can be systematically examined.

It may be possible to develop diagnostic procedures which roughly parallel Piaget's four stages of development (Muller-Willis, 1965). During the sensori-motor stage of development, abilities such as perception, discrimination, object permanency, object constancy, directional constancy, form constancy, and spatial visualization are usually acquired. Testing procedures could also be developed to measure quantitative concepts at the preoperative, concrete, and formal operations stages. A theoretical model would provide a framework within which to conduct a detailed task analysis of arithmetical-mathematical operations, identify the significant variables, study their mode in children with minimal brain dysfunction, and provide a basis for remediation.

Training

A child who has not been taught arithmetic skills properly, or who has simply failed to learn because of environmental factors, will usually benefit from individualized or correctional instruction. If the child has not learned because of a verbal, spatial, perceptual, or memory deficiency, it may be necessary to provide specific remedial procedures to ameliorate the basic disorder.

Strauss and Lehtinen (1947) were among the first to develop techniques for teaching brain-injured children. They considered number concepts to be based on the perception of objects in space related to the ability to develop inherent organization, and to make abstractions. According to Strauss and Lehtinen, difficulties in arithmetic are caused by general disturbances of perception and behavior or by specific perceptual disturbances. This produces a deficit in the ability to organize meanings and develop perceptual schemas. They cite four principles of learning quantitative concepts for brain-injured children:

1. Number concepts are based upon organized perceptual experiences which depend upon the relationships of objects in space and the resulting development of a number scheme.
2. Development of number schemes is the outgrowth of the ability to organize. It is contingent upon the ability to understand the relationships of parts, and parts to the whole.
3. The visuo-spatial scheme will be abstracted from its perceptual concrete origins when relationships are grasped and meanings are understood. This implies the need for perceptual experiences (concrete or semiconcrete) until such organization occurs.
4. For a child with organic disturbances, it may be necessary to develop special materials and techniques of instruction based on our knowledge of such disturbances.

The teaching techniques which Strauss and Lehtinen discuss are somewhat general in nature. Specific techniques must be devised for each child. Perceptual readiness activities (e.g., sorting cards into piles of one, two, or three) are important to avoid meaningless rote naming of numbers. Intersensory integration of visual, motor, and verbal channels is developed by simultaneously counting and touching objects. Frequent changes in activities are recommended for children who perseverate. If children are highly distractible it is suggested that only one arithmetic problem be placed on a page.

Kaliski (1962) has described techniques for teaching brain-injured children which are similar to those of Strauss and Lehtinen. She indicates that difficulty with spatial relationships (conceptualizing common words, e.g., up, down, far, near) interferes with visualization of the number scheme and hyperactivity interferes with counting and other activities.

In order to train all avenues of mental functioning, Kaliski advocates a multichannel approach. Kinesthetic training, tapping, and counting on the fingers are all used to help develop counting and verbalization of numbers. Color cues are used to help focus attention on numbers. In some instances, hyperactivity is reduced by interspersing auditory cues between numbers when counting.

A very important aspect of this program is the emphasis on language and reasoning. Like Strauss and Lehtinen, Kaliski found that brain-injured children have difficulty in learning higher order abstract concepts. Kaliski suggests that the language used in teaching the child must be as concrete as possible. Problem solving, for example, can be made more manageable by breaking questions down into subsets and having the child graphically produce the problem. In this way, Kaliski attempts to utilize the development of perceptual organization and of language and reasoning.

Kephart (1960) also believes that problems in arithmetic may stem from a visual-spatial disorder. He has developed a series of activities to enhance perceptual-motor integration. Kephart indicates that arithmetic concepts can be included in sensory-motor training.

For example, when a child is practicing walking and turning on a balance beam, the instructor may have the child count the number of steps to the center of the board and back.

Frostig and Horne (1965) have described an approach for ameliorating visual-perceptual disorders. This program is based on the premise that the child's major developmental task between the ages of 3 and 7½ is in the area of perception. This is an important concept when viewed from Strauss and Lehtinen's position that problems in arithmetic may be perceptual in nature. The Frostig exercises attempt to train discrimination in the area of eye-hand coordination, figure-ground perception, form constancy, position in space, and spatial relationships. Frostig and Horne (1965) state that in addition to perception, their program trains gross and fine motor coordination, and eye movements. The authors also report that the program enhances body image and concepts.

Gallagher (1960) conducted an experimental study in which 42 brain-injured mentally retarded children were tutored. The subjects resided at the Dixon State School for the Mentally Retarded at Dixon, Ill., and ranged in CA from 7 years 4 months to 13 years 9 months. Their Stanford-Binet IQ scores ranged from 33 to 63. The 16 girls and 26 boys in the study had been in residence for an average of 42 months, with the time of institutionalization extending from 1 month to 113 months.

The subjects were assigned to experimental and control groups and were matched on mental development. Subjects in the experimental group were tutored for 21 months. The control group received no tutoring during this period. During the next 12 months, the experimental group received no tutoring, while the control group was tutored. This phase was designed to study the permanence of any improvements that might have taken place during the 2 years of tutoring.

During the tutoring periods the children received instruction in perceptual skills, language skills, memory skills, conceptualization and reasoning, and quantitative conceptualization. Tutoring in quantitative conceptualization emphasized the ability to recognize differences in size, weight, shape, and other distinguishing characteristics. Counting and ordering numbers were the next higher skills taught. Motor activities were used to develop attentional control.

Gallagher found that these kinds of activities improved number aptitude in brain-injured children. Results showed that both groups evidenced significant improvement in quantitative skills following tutoring, especially in the ability to write and recognize numbers, and to apply grouping principles up to five. Gallagher believed that improvement in the application of grouping principles was most important because this activity requires more abstract thinking than counting or writing of numbers.

Discussion

There are a number of remedial methods in arithmetic which children who present different clinical patterns of assets and deficiencies in the same problem area often require different remedial programs. It should not be surprising, therefore, that textbook descriptions of teaching methods have been somewhat limited to general presentations.

Remedial programs in arithmetic seem to stress one or more aspects of visual-perceptual training, language and vocabulary, concrete operations, auditory memory, rote memory, the ability to generalize, recognize relationships, and concept development. Teaching methods are of little value, however, unless the teacher knows when it is appropriate to apply one method instead of another. This requires the teacher to: (*a*) know what the significant correlates are; (*b*) be able to identify the underlying deficits; and (*c*) select the appropriate teaching methods and techniques for the particular level of functioning.

There are several remedial methods in arithmetic which have been developed for children with sensory or environmental handicaps. While they are not designed for children with minimal brain dysfunction, they deal with many of the same psychological correlates and behavioral symptoms. Despite the difference in etiology, certain aspects of these methods may be helpful for teaching children with brain dysfunction.

In teaching deaf children who have severe language problems, for example, O'Neill (1961) organized a teaching sequence consisting of: (*a*) counting, rote counting, enumeration, identification, reproduction and grouping; (*b*) measures and operations, grouping, value, time, length, weight, temperature, contents, surface, capactiy, and metric measure. This sequence may be of value because it too provides a concrete approach to children who have language problems.

Kaliski (1962) and Frostig and Horne (1965) have suggested a concrete approach utilizing Stern's (1949) structural arithmetic program. Initial number concepts are developed by the use of blocks. Number names are not introduced until later in the program, then symbols are taught. Block games, counting boards, and other concrete materials are used to develop skills. These games are used to give the child a concrete and structured introduction to arithmetic skills. The program is based on the idea that arithmetic lies in understanding the structure of arithmetic through manipulation of concrete objects rather than abstract symbols.

A remedial program has been developed at the Lt. Joseph P. Kennedy, Jr. School for Exceptional Children at Palos Park, Ill. This program is based on 10 principles of learning: readiness; minimal change; repetition and overlearning; distributed versus massed practice; accuracy versus speed; active versus passive learning; immediate knowledge of results; reinforcement; motivation; and transfer of training. Because this program was developed for use with mentally retarded children it makes few assumptions about the skills or knowledge a child entering the program should have, and is carefully programmed beginning with mental ages as low as 3 and progressing step by step to more advanced levels. The four ultimate objectives of the program are visualization of numbers in sequence; recognition of the numerals 1–10; arrangement of numbers in sequence; and counting.

The language of instruction seems to be an important aspect of all teaching programs. Kaliski (1962) points out that directions must be clear and unambiguous for children who have brain injury. Language must be concrete and general, questions must be broken down into smaller more specified questions, and children should be encouraged to use arithmetical terms. Bereiter and Engelmann (1966) have developed a linguistic approach to training arithmetic skills in disadvantaged children which may have implications for the child with minimal brain dysfunction. They stress the importance of consistent, precise instructional language and recommend certain words be employed with the carefully sequenced program. The basic operations of this program include: counting out loud, counting objects, recognizing number symbols, learning what number comes next, using identity statements, and translating arithmetic operations into counting. The program utilizes auditory skills, the chalkboard, and extensive small group work. Note that the brain-injured child often has high verbal ability, but little real understanding of arithmetic skills. Development of receptive and expressive language might include activities which force the child to focus attention on the speaker; increase attention span; and determine the child's understanding of the problem by verbalizing solutions in structured situations. Caution should be exercised to avoid the acceptance of meaningless rote verbalizations.

Directions for Future Research

Research in the area of arithmetic and mathematics is sparse. There is need to identify the tasks and skills which are necessary to be successful in dealing with quantitative concepts.

Future research should attempt to study the effectiveness of existing assessment and remedial methods, as well as develop new remedial methods. D'Augustine (1968) presents many researchable questions and useful techniques for training. Further, there is need to see if the significant psychological correlates can be ameliorated, and whether or not this improvement increases skill in arithmetical and mathematical operations. Another related research question that should be answered is whether or not a remedial procedure is more effective with younger children than with children in older age groups.

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SUMMARY OF RESEARCH NEEDS

CHAPTER 11

DIRECTIONS FOR FUTURE RESEARCH

The first 10 chapters of this report attempted to: (*a*) summarize the present status of research with respect to central processing dysfunctions in children and (*b*) identify the major research needs in these complex problem areas. More specifically, this report has attempted to investigate the present status of knowledge with respect to dysfunctions in the analysis, synthesis, and storage of sensory information, and their impact on symbolic operations in school related tasks.

Focus and Direction

There are at least five general stages in advancing the status of knowledge in any discipline: (1) recognition that a problem exists; (2) active investigation and identification of possible factors, which may be contributing to the problem; (3) synthesis of relevant information; (4) translation into practical application; and (5) dissemination of knowledge.

The review of research which is presented in this report represents an attempt to synthesize relevant research findings. This chapter is intended to highlight the major problem areas in which research is needed.

(1) Precise descriptions of specific observable behaviors related to dysfunctions in learning.
(2) Procedures for recording these behaviors.
(3) Procedures for educational assessment and diagnosis.
(4) Prevalence and incidence.
(5) Effective remedial or compensatory methods of intervention.
(6) The efficient delivery of services to children.
(7) Prevention.
(8) The nature of learning.

In order to seek the answers to these problem areas it will be necessary to mobilize resources at the Federal, State, and local levels of government. A decision to commit money, personnel, and facilities must be made at each of these levels. The magnitude of the problem is such that it will probably require a "total push" effort by Federal, State, and local agencies to mount an attack which carries with it any probability of success. A heirarchy of these commitments is outlined as follows:

1. Passing legislation which provides financial support.
2. Coordination of Federal, State, and local agencies.
3. Training qualified personnel.
4. Providing facilities and equipment.
5. Gaining access to preschool and school-age populations.
6. Researching the problem areas.
7. Field testing.
8. Demonstration and dissemination.

Without a definite commitment to support long-range research efforts, it will not be possible, nor is it realistic, to expect resolution of the research needs presented in this chapter.

For purposes of organization, these research needs will be discussed under the following headings: (*a*) "Screening, Identification, and Referral"; (*b*) "Assessment and Diagnosis"; (*c*) "Intervention"; (*d*) "Mobilizing Community Resources"; and (*e*) "The Need for Basic Research." It should be noted that if the reader desires a more detailed discussion of research needs, he should refer to the appropriate chapter and section. This chapter is intended only to provide a brief overview of the more salient research needs.

Screening, Identification, and Referral

Figure 6 is a flow chart which represents the administrative procedure by which most school districts identify, assess, and refer children who have difficulty in school. Staff members who participate in the formal screening program for the pupil population usually include classroom teachers, school physicians and nurses, school social workers, guidance and counseling personnel, speech correctionists, and school psychologists. Formal screening programs are designed so that all the children in the school system are tested every 2 or 3 years. Teacher referrals supplement

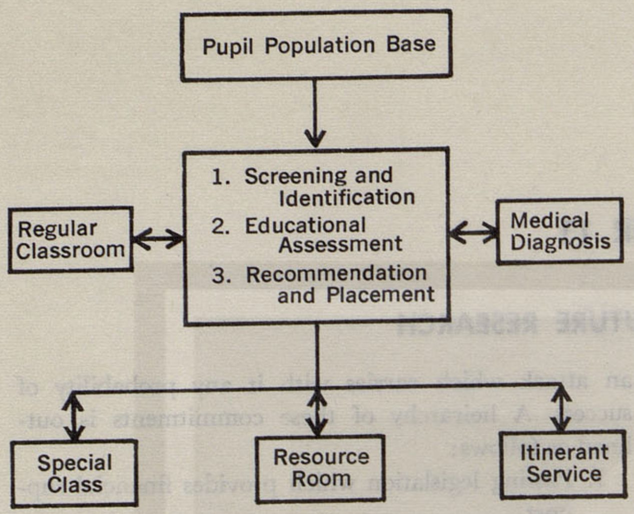

Figure 6.—Flow Chart for the Identification, Assessment, and Referral of Children Who Have Difficulty in School

the more formalized screening program. Children who do not have obvious problems are returned to their regular classes. If a child with a problem is not identified by the screening program, his teacher will make the referral when the child experiences difficulty in the classroom.

Children who are identified by the screening program as having learning problems are referred for individual testing or examination to provide more detailed information upon which an educational recommendation can be based. In some cases it may be necessary to refer a child to the family physician, audiologist, otolaryngologist, pediatrician, or other medical specialists. A child might be placed in a regular classroom and receive an itinerant service such as individual counseling, speech correction, or remedial reading. He might also be placed in a special education class.

These procedures for screening, individual evaluation, recommendation, and placement meet the needs of the majority of children with educational problems, but they are neither sufficient nor adequate for diagnosing specific learning disabilities or for making recommendations for specific remedial instruction.

At present, there seems to be some confusion with respect to the specific population in question. This confusion is reflected by the terminology and definititions in use and the diversity of problems upon which emphasis is placed in the literature. These differences should not be surprising because professionals in special education, speech correction, psychology, child development, and neurology and other branches of medicine are frequently called upon to deal with these problems. Differences in background, theoretical orientation, and professional responsibility probably account for many of the differences in terminology and definition.

Because the characteristics exhibited by children with learning disabilities are diverse, there is no consistent behavioral pattern which identifies the group in question. This complicates the development of a definition which is descriptive of the group in question. Identification and definition are further complicated in that many of the behavioral symptoms found among children with learning disabilities are also found among normal or bright children who experience no difficulty in learning. Early identification is difficult because a learning disability may not become obvious or manifest itself until the child is of school age and attempts to read, write, or compute arithmetic problems.

In order to identify more clearly the children who have central processing dysfunctions, it will be necessary to identify the specific observable behaviors or clusters of behaviors which are symptomatic of these dysfunctions. These observable behaviors should eventually include the anatomical, neurological, and physiological symptoms as well as the psychological and educational symptoms related to difficulty in learning.

When specific behaviors or behavioral syndromes have been identified, it will be possible to develop checklists and other recording systems for use by classroom teachers. The systematic application of checklists should increase the number of referrals by classroom teachers. There is need to develop these behavioral checklists for different age levels, preschool through high school, to help account for sequential development of specific skills by different age groups. Such checklists would include observable behaviors which are indicative of central processing dysfunctions in: (*a*) auditory, visual, and haptic processing; (*b*) synthesis of sensory information; (*c*) storage or memory; and (*d*) the processing of symbolic information in auditory language, reading, writing, and arithmetic and mathematics.

When the kinds of disorders in question are clearly identified, it will be possible to launch controlled prevalence studies at local, state and national levels. This information will enable school administrators to estimate the number of teachers needed to serve the population and permit institutions of higher education to project staff and facility needs for teacher preparation programs.

Assessment and Diagnosis

The assessment and diagnosis of central processing dysfunctions is difficult to accomplish because the analysis, synthesis, storage, and manipulation of symbolic information take place in the brain, or what is commonly referred to as "the little black box." Central processing is not accessible for direct observation and must necessarily be inferred from behaviors which are accessible to observation. The functions of the brain are very complex and the present status of knowledge with respect to what goes on in the brain is limited.

Because the brain of a living individual is not readily accessible, autopsy and animal research have been used to study the psychological effects of brain damage. Generalizations from animal research have obvious limitations with respect to comparing the functioning of the brain of the animal with the brain of the human. Animals do not suffer with the type of learning disability observed in humans—i.e., specifically those having to do with language. Any information on this problem must be derived from the human. Although animal studies cannot help with problems such as language, they can elucidate certain learning mechanisms. There is only now beginning to be a strong effort to study the differences of the effects of brain injury in immature versus adult animals.

While pathological examination of the brain is an important research area, there are several methodological problems in studying the psychological correlates of the brain lesions. Since learning disabilities are studied most prominently in children, the likelihood that such an individual will die and be available for anatomical examination of the brain at post mortem is unlikely. In other instances where there is an accidental death, those interested in the autopsy are probably unaware of the fact that the child suffered from a learning disability, and the brain has not been studied from this point of view. If enough people are sensitive to this rather crucial need, it will be possible to obtain anatomical specimens.

Another problem is the relative inadequacy of the methods for examination of the brain. We are not dealing with gross brain damage. If physical damage exists it must be of the most subtle type. It may ultimately require the ability to make quantitative studies of neuronal populations in the brain to determine the anatomical substrate of the learning disability. There is also a lack of correlation between the individual who has studied the child and the individual who has the opportunity to examine the brain. Another complication is that other injury to the brain may have occurred during the time intervals between the initial trauma, testing of the subject, and the autopsy. Finally, the degree to which it is possible to make inferences about children based on research evidence obtained from adults is open to question.

In the past, research effort focused upon localization of brain function, while comparatively little research was directed toward the difficult task of studying interaction within the brain. There is need to study the behavioral implications of brain injury as related to the type and extent of lesion, duration of the lesion, the age at which the lesion was sustained, and how lesions in one area of the brain affect the functioning of intact areas of the brain.

At present, most educators take the position that knowledge of brain damage does not tell them what to do. The rationale is: (*a*) the educator cannot fix the brain, (*b*) he does not know what he would do differently if he knew that the brain was damaged, and (*c*) inferences about brain damage or problems which lie within the brain tend to stop attempts at remedial work on the assumption that the damage and its behavioral consequences are permanent. The educator, therefore, finds it more helpful to observe the situation under which learning failure occurs, then attempt to arrange procedures and materials differently than the child has experienced. This educational approach bases new ideas and new techniques on empirically demonstrated theories of learning. If the child fails on one program, then try something else!

The fact remains, however, that there may be conditions arising from within the child that will interfere with particular remedial approaches. Some of these conditions may be remediable through certain kinds of training. Other conditions may not be remediable. In these cases it may be necessary to devise compensatory methods for learning. Also, certain conditions may be alleviated through surgery or drug therapy. In any case, there is need to pinpoint the behaviors which are related to dysfunctions in the brain and study their prognosis and responsiveness to different kinds of treatment programs. This kind of information hopefully will provide a more systematic approach to teaching, lead away from a trial-and-error philosophy, and provide a more efficient and effective approach to dealing with learning disorders. Until educators and the medical profession can find the links between organic pathology and treatment, educators should continue to focus their service efforts on observable behaviors, but their research efforts should include interdisciplinary exploration with the medical profession and active participation in increasing the status of knowledge in this complex problem area.

The remainder of this section will highlight the research needs with respect to the: (*a*) analysis of sensory information; (*b*) synthesis and storage of sensory information; and (*c*) the processing of symbolic information.

The Analysis of Sensory Information

Both basic and applied research is needed if effective procedures are to be developed for the assessment and differential diagnosis of dysfunctions in the analysis of sensory information. Basic research is needed to identify the mechanisms for processing auditory, visual, and haptic stimuli. This will require study of the psychological, neurological, biochemical, and physiological correlates to these central processes.

There is need, also, to examine the traditional distinction made between central and peripheral disorders. For example, there is need to study: (*a*) the functioning of the eye as an adjustor; (*b*) the eye as a transducer; (*c*) the cerebral cortex as a central processor; and (*d*) to clarify the interrelationships between these mechanisms. Hopefully, this kind of basic research will lead to more efficient and effective medical and surgical procedures for prevention and contribute to the improvement of procedures for educational assessment and treatment.

Because the educational assessment and diagnosis of central processing functions are largely dependent upon observable behavior, there is need to provide more detailed descriptions of the behavioral symptoms which are characteristic of: (*a*) normal functioning at different age levels and (*b*) dysfunctions in processing auditory, visual, and haptic information. For purposes of both differential diagnosis and treatment, research is needed to link behavioral symptoms with neurological, biochemical, and physiological correlates. This kind of information will make it possible to develop more discrete procedures for diagnosing auditory, visual, and haptic dysfunctions.

Auditory Processing.—It is often difficult to identify the causes of auditory processing disorders, because different etiological factors are often characterized by many of the same behavioral symptoms. Failure to respond to auditory stimuli may be due to peripheral deafness, central deafness, mental retardation, severe emotional disturbance, aphasia, or auditory imperception (Myklebust, 1954).

A thorough differential diagnosis often requires diagnostic skill and training beyond that of the individual practitioner. The otolaryngologist, pediatrician, neurologist, psychiatrist, psychologist, audiologist, speech pathologist, and educator all have specific contributions to make to the diagnostic team. These is an urgent need to improve the diagnostic procedures for disorders of auditory processing. The use of precise descriptive terms will help facilitate communication between disciplines. One of the basic steps that should be taken to provide detailed and comprehensive descriptions of the behavioral responses to auditory stimuli, which are characteristic of peripheral and central deafness, mental retardation, emotional disturbance, aphasia, and disorders in the central processing of auditory stimuli.

For example, a child whose mental ability is severely limited may not respond normally to auditory stimuli. It is necessary, therefore, to examine the child's total pattern of behavior to ascertain whether or not mental retardation is a contributing factor. There is some evidence that auditory behavior tends to be consistent with mental age and that the mentally retarded seem to respond better to meaningful test stimuli, than to the more abstract pure tone test (Myklebust, 1954). There is need, however, to develop diagnostic procedures to further differentiate mental retardation from other etiological factors.

For example, children with peripheral hearing losses have been found to use their residual hearing in a consistent and meaningful manner (Myklebust, 1954). In contrast to the consistent responses of children with peripheral hearing losses, the behavioral responses to auditory stimuli made by auditory aphasic children tend to be inconsistent and disintegrated (Monsees, 1961).

According to Myklebust (1954) the inconsistent and disintegrated behavior of aphasic children is due to their apparent difficulty in attending and integrating auditory input. Myklebust points out that inconsistent responses to auditory stimuli are not caused by shifts in sensitivity, but by shifts in the ability to attend and integrate. Response consistency and the ability to integrate auditory stimuli seem to be two important variables in differentiating the child with a peripheral hearing loss from the child with an auditory aphasia. There is need to develop specific procedures for measuring these variables and obtaining clinical information.

There is need, also, to evaluate the effectiveness of various classes of auditory stimuli as well as the response modes of the subjects. Research should examine the processing of auditory stimuli which varies along different acoustic and presentational dimensions. This kind of applied research should lead to greater efficiency in selecting stimuli, mode of input, and method of indicating response, which in turn should lead to improved diagnosis.

In summary, research is needed to explore procedures for evaluating auditory processing disorders such as: Differentiating sound from no sound; sound localization; discriminating sounds varying on one acoustic dimension; discriminating sound sequences varying on several dimensions; auditory figure-ground selection; and associating sounds with their sources. The use of precise terms will help facilitate communication of these behaviors, and the recent advances in electronics should be of assistance in studying many of these problems.

Visual Processing.—There are a number of ocular-motor tasks which are critical for the central processing of visual information. These include such tasks as distinguishing light from no light, seeing fine detail, scanning, and tracking. Central processing tasks include activities such as developing visual-spatial relationships, discriminating object qualities, differentiating figure-ground, completing visual wholes, and recognizing objects. Research is needed to provide more accurate descriptions of both ocular-motor and cognitive tasks and to study the relationships between these tasks.

The question of whether or not there is a common visual perceptual factor or several separate factors remains unresolved. Attempts to study this question are complicated by the fact that the perception of printed words, individual numbers, groups of digits, or geometric forms represent different visual perceptual tasks which make slightly different demands upon the visual processing mechanism.

There is need to develop more effective procedures for the screening and identification of visual processing dysfunctions. Unless the child is referred to an ophthalmologist, it may be very difficult, if not impossible, to identify subtle visual problems such as structural anomalies, refractive errors, and muscle imbalances, or problems in color vision, depth perception, binocularity, dominance, or other central dysfunctions. If gross indicators of possible central visual disorders can be identified by simple behavioral tests, it may be possible to develop screening techniques for use by school personnel. These techniques should provide additional specific information for use in referrals to ophthalmologists for diagnosis.

Haptic Processing.—There is comparatively little information with respect to the assessment of haptic processing. There is need to acquire a more thorough understanding of the system or subsystems which process cutaneous and kinesthetic stimuli, and the kinds of information which are obtained through integrating cutaneous and kinesthetic sensory input. Future research efforts should attempt to develop systematic procedures for the diagnosis of haptic processing disorders.

One apparent problem in the assessment of haptic processing is the use of auditory language in the test procedures. If the subject has difficulty in following directions or is unable to express himself, the language deficit may confound the test results.

The Synthesis of Sensory Information

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. For example, a child may be able to process auditory information on task A, process visual information on task B, but when task C is presented, the child may be unable to process auditory and visual information simultaneously. This example represents a breakdown in intersensory integration. The simultaneous or successive processing of multiple sensory stimuli and the storage and retrieval of sensory information are two important problem areas which should be investigated.

Multiple Stimulus Integration.—There is comparatively little research concerning the integration of multiple stimuli. The complexity in studying the processing of multiple stimulus integration has undoubtedly been a factor which has limited research efforts to date. There is need to learn more about the intersensory and intrasensory processing systems for multiple stimuli. What constitutes these systems? How do they develop? How do they function? What are the educational, psychological, physiological, neurological, and biochemical correlates which are related to these systems?

At present, there are only a few procedures which have been used to assess dysfunctions in this very complex area. This is unfortunate since so many school tasks make demands on the processing of multiple stimuli. Research is needed to develop more precise methods for assessing the intersensory and intrasensory integration of multiple stimuli.

Memory.—In the absence of definitive information about the psychological, neurological, and biochemical factors which contribute to the storage and retrieval of information, several theories have emerged to attempt to provide an explanation of the memory phenomenon.

There are several issues which need to be explored. Are memory disorders usually specific or general? Are the memory dysfunctions described in adults characteristic of memory dysfunctions found among children? Is memory global or molecular? How does sensory memory differ from intellectual memory? How does memory process relate to memory product? What is the difference between storage, screening, and retrieval of information? Research is needed to identify the psychological and physiological processes which involve the storage and retrieval of symbolic information.

At the present time, comparatively little is known about the process by which memory is stored in nervous tissue. There is need to conduct research on neurophysiological changes which occur in the brain when something is learned. There are several questions which need to be explored. What is the nature of anatomical or biochemical changes at the synapses along the neural pathways? What kinds of chemicals found in the brain are most important for learning? To what extent does the amount of various chemicals affect the rate of learning? Is the ratio of one chemical to another an important factor? Do chemical imbalances in the distribution of chemicals in different areas of the brain create problems in storage and retrieval?

Procedures for assessing the memory function typically rely upon recall and reproduction tasks, afterimage and memory span, delayed response, the effect of aspiration level, and the application of learning strategies to facilitate remembering. Assessment procedures should take into account the nature and quantity of the material to be learned, whether or not the material is meaningful, the specific steps necessary to learn the material, the amount of time necessary to learn the material, activities which are introduced during the retention period and the duration of retention. Instead of relying upon digit or word span, perhaps educators should begin thinking of assessing memory in terms of specific school tasks where recall and recognition are required for achievement in specific content areas.

Symbolic Operations

The processing of symbolic information is the basic task the school demands of all children. To succeed in school a child must be able to acquire, retain, and use auditory language; read, or decode graphic symbols; write or encode graphic symbols; and solve problems in arthmetic and mathematics. In addition to obtaining information about the kinds of behavioral errors in performing symbolic operations, future research should attempt to learn more about the brain mechanisms and the psychological correlates which underlie failure to acquire, retain, and use symbolic information. This section will present a brief summary of the research needs with respect to auditory language, reading, writing, and quantitative concepts.

Auditory Language.—During the past few years, there has been increased interest in determining the developmental sequence in which the universals of the English language are acquired. While linguists are providing a steadily growing body of information with respect to the children's utterances, disagreement exists concerning the manner in which children acquire the language code, and the impact of various dysfunctions on language acquisition. There is need, therefore, to clarify the developmental sequence or sequences for acquiring a first language and to study the effects of central dysfunctions on this developmental sequence. Research should attempt to identify the brain mechanisms which underlie language functions, and those central processing operations which play a role in the attainment of auditory language. Methods for assessing performance on various subtasks need to be developed for both the normal and atypical populations.

Reading.—Future research in the assessment and diagnosis of reading disorders should result in a thorough analysis of the reading act including: (*a*) a description of terminal reading behaviors; (*b*) the conditions under which they occur; (*c*) the identification of specific subtasks which are necessary to achieve these terminal behaviors; and (*d*) a hierarchical sequence for the subtasks. Also, attention should be directed toward the elements of the graphic language code, particularly the graphic shapes, the space direction sequence, and spelling.

Failure in reading has been linked with a number of physical and psychological correlates including sensory deficiencies; low intelligence; low verbal ability; dysfunctions in auditory, visual, and kinesthetic perception; memory disorders; integrative dysfunctions; poor laterality; emotional disturbance; and genetic factors. The extent each of these variables is related to success or failure in reading is not clear. There is need to determine the extent to which a deficiency in any of these correlates affects the acquisition of reading skills as well as determining the results of various combinations of dysfunctions.

Research into diagnosis of reading difficulties should include medical considerations as well as educational and psychological assessment. There is need to develop administrative structures to maximize cooperation in interdisciplinary assessment and diagnosis.

The diagnostic program should distinguish between children who have failed, the child who is in the process of failing, and the child who might be expected to fail prior to instruction in reading.

For the child who has failed, research is needed to develop more effective procedures for estimating reading potential, determining reading level, describing the behavioral symptoms of faulty reading, and examining the physical and psychological correlates to reading failure.

There are no systematic procedures for identifying the child who is beginning to fail. There is need for more systematic procedures for measuring progress in beginning reading and describing the reading behaviors of the children. Checklists, for example, may help teachers make early judgments about the behavioral symptoms of these children who are beginning to fail so that early referral and intervention can take place.

For the child who might be expected to fail, the need for assessment procedures leading to the prediction and prevention of reading failure is especially crucial. The identification of correlates to reading at an early age and the development of procedures for measuring these correlates appears to be a promising area for future interdisciplinary investigation. The concept of reading readiness has led to the development of tests for reading readiness. Yet, one's concept of reading readiness depends upon one's definition of beginning reading. Ready to do what? There is need to devise specific tests for the various subtasks which make up the reading act or are necessary for beginning reading activities.

Writing.—Encoding written language symbols requires the intent to communicate, formulation of the message, retrieval of graphic-language symbols which correspond to selected auditory-language signals (spelling), and organization and execution of the graphic-motor sequence. A problem at any one of these levels will interfere with communication through writing. The assessment and diagnosis of writing disorders must be considered within the larger contexts of both the language and the perceptual-motor areas. It is important for the diagnostic procedure to differentiate between dysfunctions in the ideational use of language and the visual-motor execution of thoughts onto paper.

Future research should investigate those factors which may contribute to the problem. These include: (*a*) developmental deviations; (*b*) psycho-motor aspects such as paralytic disorders, ataxia and apraxia, (*c*) visual processing; (*d*) auditory processing such as dysnomia, syntactical aphasia, receptive aphasia, reauditorization of letters, auditory sequencing, syllabication, and sound blending; (*e*) discrepancies between spoken and written language; (*f*) reading and written language; (*g*) speech handicaps; (*h*) social or emotional disturbance; (*i*) poor auditory acuity; (*j*) cultural deprivation; and/or (*k*) instructional factors. The correlates to the writing process need to be identified more clearly. There is need, also, for descriptions of dysfunctions in the language system, visual-perceptual system, and motor symptoms which interfere with the encoding of graphic language symbols.

Quantitative Concepts.—The present status of research suggests that a number of different cognitive abilities are probably involved in comprehending the structure of numbers, performing concrete arithmetical operations, and developing abstract quantitative concepts. In addition to general intelligence, at least four other factors seem to be related to the attainment of quantitative concepts: spatial ability; verbal ability; problem-solving ability; and neurophysiological correlates. There is need to identify other factors or subfactors which are related to the acquisition, retention, and use of quantitative concepts.

There is need, also to devise comprehensive tests and procedures for the screening, identification, and diagnosis of children who have difficulty in arithmetical and mathematical operations. These diagnostic instruments should measure those correlates which are relevant to specific kinds of learning tasks and lead to appropriate intervention techniques.

Intervention

At present there is a comparatively small number of school districts which are effectively meeting the needs of children with learning disabilities. Several reasons may account for this. First, a factor which has impeded special programs has been the necessity within the school system for mass production. Overwhelmed by increasing numbers of students, the schools have had to provide the best they can for the average individual. There is still serious question whether our best effort at this time is toward upgrading the general level of instruction by providing the regular classroom with flexibility to meet the varied needs and abilities of varied children, or whether we should focus on special education for those with special disabilities. At the moment we are heavily committed to mass production.

Second, the group in question has not been clearly defined. Third, there is a shortage of professional personnel trained in diagnosis and remediation. Fourth, there are only a few techniques for screening, and the tests for differential diagnosis which pinpoint disabilities are crude. Fifth, remedial methods based on the educational diagnosis are in the process of being developed. Sixth, in the past, these children have not been identified accurately and have been placed in special education classes which do not provide educational programs designed for their needs. Many children with learning disabilities have been placed in classes for the retarded, despite the fact that they have normal abilities in many areas. Appropriate educational intervention might remove some of them from the classification of mental retardation. In some instances, children who cannot recognize objects or printed letters or words are placed in classes for the visually handicapped. It is even more common, however, for the child to remain in the regular classroom where the teacher does whatever she has time to do.

It is difficult to secure local, State, or Federal support for an educational program in which the group of children in question has not been well defined, where the educators have differences of opinion on some of the key issues, and the status of knowledge is diffuse and controversial. There are several steps which need to be taken to resolve these problems:

1. Establish a definition that is meaningful to those who work with the group in question.
2. Construct effective tests for the early identification of children with learning disabilities, and for pinpointing areas of deficits which lead to remediation.
3. Develop remedial techniques for specific kinds of learning disorders.
4. Train psychological examiners who are interested in educational problems and who have had some exposure to remedial teaching methods.
5. Train diagnostic teachers and supervisors who have knowledge of test practices and developmental, corrective, and remedial techniques.
6. Field test teaching methods, and new ways of utilizing personnel.

Selecting Remedial Objectives

In reviewing the research on remediation, it is rather surprising to note that the objectives of educational intervention are not clear. Is the objective normalcy? Near normalcy? Academic success? Changes in test scores? Modification of specific behaviors? Unless the teacher designates specific objectives or a series of subobjectives, and specifies criterion standards for having learned, it is difficult to determine the effectiveness of remedial programs.

There are several viewpoints with respect to educational intervention. One point of view is that the purpose of remediation is intended to ameliorate a psychological deficit, usualy defined in vague terms, which will enable the child to generalize the ability to other behaviors. A second point of view is that remediation should be directed toward training a specific skill. It may be more to the point to ask if it is possible to train one and not the other. In other words, as we train behaviors, are we in fact training the substrata of basic skills?

There is some question whether time should be invested in attempting to ameliorate the deficit area or to teach through the asset areas and strengthen compensatory behaviors. Is such a dichotomy possible in actual practice? In most cases the teacher is confronted with both the assets and deficits and must deal with both during instruction.

The Rationale for Educational Planning

A principle of educational planning which has gained wide acceptance, at least on a verbal and written level, is that remedial approaches should be based on an educational diagnosis. The assumption, here, is that by pinpointing the nature and/or the correlates of the learning disability, the teacher will have a rational basis for selecting a particular remedial method. How is this differential diagnosis accomplished?—

1. Standardized Tests: The traditional approach to remedial planning is to administer a series of standardized tests which are intended to give some indication of achievement levels, intellectual capacity, and psychological functioning.

2. Structured Observation: More recently attention has been directed toward structured observation as the basic methodological entity.

3. Diagnostic Teaching: A third and related approach to educational planning is the concept of diagnostic teaching. When formalized tests fail to provide sufficient information about the area of difficulty, remediation then becomes part of the diagnostic process. The concept of diagnostic teaching is based on the assumption that effective teaching procedures contain many of the same procedural sequences which are found in effective diagnostic procedures. Children are placed in one or more carefully controlled learning situations and taught over a period of time.

4. Neurophysiological Correlates: A fourth approach to remedial planning is examination of the neurophysiological correlates to behavioral disorders.

At present, educators seem to be somewhat impatient with the medical profession, because knowledge of these correlates "* * * does not tell us what to do with the child."

It is true that educators possess only a few remedial alternatives, and it is true, also, that the medical profession is trying to improve the status of knowledge. Research has demonstrated that changes in ability and personality accompany brain lesions. Although knowledge of brain injury will not tell the teacher what to do, it might help the teacher anticipate future problems, particularly if the condition is progressive and cannot be arrested. Knowing the age at which a lesion was sustained is an important consideration. One would expect a lesion sustained by an infant to have different effects than a lesion occurring in the brain of a young child, or an adult. In some cases, knowledge of the nature, location, extensiveness, and duration of the damage may be relevant to the behavioral sequences. At present, the relevancy of brain lesions to behaviors is not clear. Another important consideration is how much spontaneous recovery is it reasonable to expect over a given period of time? These areas should be targets for future research.

The educator cannot afford to overlook the potentialities for treatment that future research in biochemistry or neurophysiology might bring. Medical or surgical intervention procedures or drug treatment may eventually prove to be some of the most effective ways of meeting the needs of many children.

Future research needs are clear. We need to improve the technology for standardized testing, structured observation, diagnostic teaching, and medical diagnosis. Unless we improve the status of our technology we will not be able to fulfill the ultimate goal of diagnosis—to obtain the maximum amount of useful information with respect to etiology, prognosis, and treatment.

5. Temporal Considerations: Other aspects of educational planning include temporal instructional considerations. The decision of how much time to allocate for remedial instruction is often based on the availability of the teacher, and not on the needs of the child. Most research studies in remediation have been conducted on a short-term basis. Is 20 minutes to an hour a day for 2, 3, or even 5 days a week sufficient time in which to bring about marked change? How many months or years will be required? Are we talking about 6 weeks, 6 months, or 6 years? There are little data which help the teacher determine either the length of each session, the number of sessions per day per week, or the total duration of remedial intervention. Time is critical to remedial programming, and there is need to acquire more definitive data for specific kinds of disorders.

It is important to note that any social institution, such as our educational system, has an obligation to provide a built-in evaluation for any new program or method which it proposes to introduce. With billions of dollars being spent for education, the taxpayer is entitled to a cost benefit analysis in terms of the manpower and expenses required to mobilize a new program against the money saved through the lack of school repeats, and the social and economic consequences of learning failure.

6. Instructional Setting: Remedial programs are being implemented in special classes, resource rooms, and through itinerant teachers. There is need to determine when one approach is more appropriate than another for a particular child.

7. Multiple Disabilities: The child with learning disabilities seldom presents a picture of a single clear-cut disorder. It is more common to find children with several disabilities. The presence of multiple disabilities not only complicates the task of assessment, evaluation, and diagnosis, but makes remedial planning even more difficult. Much of the research literature is concerned with a specific kind of learning disability. In many cases the remedial program is focused on only one aspect of the child's problem, while other aspects remain neglected.

There is need to develop teaching approaches for use with children who have multiple problems. It is doubtful that the child has time for us to deal with one problem at a time. In addition to developing a rationale for selecting remedial priorities, we need to develop remedial approaches which will permit multiple attack on multiple disabilities. This will not only require flexibility and versatility in the individual teacher, but will require collaborative programs between different disciplines as well.

In the past, many remedial approaches were developed by clinicians or master teachers. Clinicians are very knowledgeable and have had a long history of working with children, but they tend to be service oriented. The clinician says, "I'm a clinician, not a researcher. I like to spend time working with children and dealing with their problems." The clinician is not particularly interested in measurement. He is too busy working with people. As the clinician gains experience, he refines and records his procedures, and a book is eventually written. Thus we have a remedial approach with very little evidence or data to back it up. In the absence of objective data, the teacher or administrator may use the procedure in an inappropriate situation and charges are leveled that the procedure is ineffective. When controversy arises, the researcher, who is concerned with measurement, comes on the scene and starts to explore the efficacy of the procedure under different situations. Educational research has typically been conducted with groups on a short-term basis.

Attempts to study learning disabilities have not been very successful because the groups in question do not represent single clinical syndromes. Also, much of the research has often focused on a small number of discrete variables, while other potentially significant variables have been omitted from investigation.

In order to better understand the nature of different kinds of learning disabilities, and their amenability to different remedial procedures, there is need to break with traditional group studies and study the learning problems of individual children in depth. A longitudinal N=1 case study approach offers promise for finding specific answers for specific problems. When a number of case studies have been compiled on a specific problem, it may be possible to formulate hypotheses which lead to future research efforts. Placing case study data on IBM cards will further facilitate data retrieval as well as the study of interrelationships between different variables. The interdisciplinary graphic description of individual subjects may provide one of the most fruitful approaches to this complex problem area.

There is need, also, to develop more precise descriptions of teaching procedures. One of the major problems in remediation is that it is very difficult to describe what goes on during the teaching process. We have to have accurate descriptions of teaching procedures so that teachers can replicate teaching procedures. Thorough reporting should include a description of the tasks which are presented in terms of stimulus input, information about the subject, and a quantitative and qualitative description of the responses.

Mobilizing Community Resources

The mobilization of local, State, and Federal resources is necessary to provide needed services for children. There is comparatively little research, however, with respect to the organization, administration, and supervision of programs for children with central processing dysfunctions. Research priority has not been placed on administrative problems in mobilizing resources. Instead, research priority has been directed toward: (*a*) describing the emotional, physical, social, and cognitive characteristics of children with dysfunctions; (*b*) developing procedures for assessment; and (*c*) refining teaching techniques and methods.

Descriptive Studies

There is need to conduct descriptive studies which describe how administrative units have attempted to resolve problems in providing services. What are the basic philosophies upon which these programs are founded? What policies have been found to be successful? What procedures for screening, identification, and placement of pupils have been developed? What are the criteria for teacher selection? What kinds of supervisory services are needed? How can in-service training programs be implemented successfully? What kinds of legal and financial arrangements are effective?

For example, the concept of the regional center is one approach which has been used to resolve many of the demographic and economic problems inherent in establishing services for children with learning disabilities. It would be helpful to have descriptions of the programs between school districts or counties. By joining together, two or more school districts or counties increase their pupil population base and provide sufficient numbers of children to justify needed services. Being a contract of policy, a cooperative program is better assured of being both continuous and stable, reducing the per capita cost for the program, permitting the sharing of space and facilities, and creating a situation which will attract competent staff and supervisory personnel. There is need, however, to conduct descriptive and evaluative studies of different kinds of administrative arrangements.

Normative Data

Normative data studies are needed at the local, State, and national level. Research would include such things as the characteristics and prevalence of central processing dysfunctions; the kinds of services and facilities which are available as well as the number which is needed; information about the recruitment, training, placement, and retention of personnel; expenditures for program support; and staffing patterns and staff utilization. Correlational studies will provide knowledge of the interrelationships of the many variables with which administrators must be concerned.

For example, one of the first steps in mobilizing local or State resources for program support is to study the nature and extent of the problem and determine what kinds of educational services are needed to meet the needs of the children. A study of the nature and extent of the problem requires the adoption of a criteria which can be used to identify children with specific learning disabilities and an extensive screening effort for establishing prevalence. A thorough statewide prevalence study should utilize all local and State personnel who can contribute to the screening and identification process. Normative data will provide a basis for planning and program evaluation.

Program Evaluation

Program evaluation studies are needed to provide information about the effectiveness, efficiency, and appropriateness of different administrative approaches to solving administrative problems. Few administrators have attempted to apply evaluative methods to programs which have been implemented. The evaluations which have been done are in retrospect. The probability of an objective appraisal is increased by selecting goals, procedures, and evaluative techniques before the program or the study begins. Evaluative studies have potential impact on policy, procedures, and legislation. This kind of research approach may be termed "action research."

For example, research is needed to evaluate the different kinds of educational services which are being offered. At present, there seem to be three administrative approaches to providing services for children with learning disabilities. Special classrooms have been established which require the teacher to provide instruction in all academic areas as well as attempt to do remedial work with the basic disability. Being all things to these children is a difficult responsibility to fulfill. The homogeneous grouping of children in classes and integrating them back into the regular school program also poses major problems.

The resource room offers a second alternative for the teacher. School buildings with large enrollments can support resource rooms for remedial work. Children remain in the regular school program and report to the resource room for remedial training. The teacher may meet with individual children or small groups. A third alternative is the itinerant teacher who travels from one school to the next. The question that needs to be answered is, "Under what conditions should these alternative educational techniques be used?"

Another problem area that needs to be investigated is that of teacher preparation. It would be helpful if professionals from different disciplines would sit down together and conduct an objective, impersonal task analysis of the specific subtasks which are necessary to provide needed services. Knowing the specific tasks which need to be accomplished will make it possible to estimate the minimal amount of training necessary to accomplish each task. This information will give universities and school systems an objective basis for establishing training programs which can train larger numbers of personnel in as brief a time period as possible.

The eventual outcome of this approach may be a gradual restructuring of professional roles which will hopefully provide great efficiency in the effective use of personnel in our schools. It is important, therefore, that our schools maintain sufficient flexibility to field test the effectiveness of personnel who have been trained in innovative programs. This may require school districts to create new and innovative job positions in order to evaluate the effectiveness of a particular service.

There is need to study the effectiveness of different approaches to teacher preparation. Preservice training in learning disabilities is being conducted at different levels. Several universities are beginning to explore the feasibility of training remedial teachers at the undergraduate level. There is some question, however, whether the 120 hours of a bachelor's degree curriculum provides sufficient time for the undergraduate student to attain basic competencies with normal children as well as children with learning disabilities. The 4-year remedial teacher would probably work under close supervision and execute or carry out educational programs which are prescribed by their supervisors and those who have attained greater competency in assessment, evaluation, diagnosis, and educational planning.

It should be noted that most university programs are presently training remedial teachers at the master's degree level to work as tutors, itinerant teachers, resource room teachers, or special class teachers. These programs emphasize the interpretation of test results, ongoing assessment, and extensive remedial training. A sixth year of advanced clinical training prepares personnel to work as diagnostic teachers. Training programs at several universities provide advanced practicum in assessment, evaluation, and diagnosis and remedial procedures; supervisory experience; and the opportunity to work as a consultant with school districts which are developing programs.

Students at the doctoral level are being prepared for teacher training, research, and leadership roles in service agencies. Doctoral programs also include advanced clinical practicum courses in assessment, educational intervention, learning theory, and statistical procedures.

The problem of providing effective in-service training programs provides another potential area of study. In-service training for teachers of children with specific learning disabilities often have limited value in changing teacher behavior. Workshops and extension courses on week nights usually consist of lectures and an exchange of information and experiences between teachers. There is need to investigate the use of videotape, films, various content, and time of workshops to determine the most productive approach to in-service training.

Prevention of Learning Failure

At this point in time, we probably know more about learning failure than we do about the learning process itself. It is very difficult to talk about the prevention of central processing dysfunctions when our present state of knowledge is limited. Before effective procedures for prevention can be developed and put into action, it is necessary that we: (*a*) obtain precise descriptions of specific observable behavior related to the central processing dysfunctions; (*b*) develop procedures for educational assessment and diagnosis; (*c*) determine the prevalence and incidence of these problems; (*d*) develop effective remedial or compensatory methods of intervention; and (*e*) find ways to deliver services to children at an early age.

The Need for Basic Research

If we are to make major inroads on this problem of prevention, it is essential that we learn more about the learning process. This means that a major thrust should be made in areas that are sometimes classified under the term "basic research." Basic research has been shown to have the effect of accumulating the "critical mass" of information necessary for a quantum leap in several scientific disciplines. It is important that the knowledge obtained from basic research in learning and the knowledge obtained from studying children with learning disorders be integrated, in order to establish educational programs for preschool children which would hopefully contribute to preventing and/or ameliorating central processing dysfunctions.

Despite the fact that present knowledge is limited, it is important to begin studying and working with the preschool population. It is encouraging to note the recent attention and financial support given to the education of preschool children and to prenatal care. This kind of effort should contribute toward the development of educational programs for early intervention and prevention.

A Final Recommendation

This report has attempted to: Summarize the present status of knowledge with respect to central processing dysfunctions in children; identify gaps in the present status of knowledge; and indicate directions for future research. The major focus of this report was directed toward the analysis, synthesis, and storage of sensory information and symbolic operations. An attempt was made to investigate the major questions and issues which had both theoretical and practical implications.

In undertaking a review of the vast amount of literature related to this problem area, the authors imposed an organizational structure to which the relevant research could be related. There are many studies which have not been cited in this report. Important problems and issues may have been neglected as a result of our limitations in knowledge and judgment. Despite our efforts to provide an objective report, our prejudices may be apparent in what we have written.

Looking to the future, it would be regrettable if in the year 2069 two unsuspecting individuals were asked to review the research which had been conducted during the past 100 years. We recommend, therefore, that a more systematic procedure be devised which would provide for the quadrennial and interdisciplinary review of research in this problem area. This will create a more manageable task for those involved, keep the field up to date with new developments and ideas, insure the dissemination of current research, and stimulate the professionals of tomorrow to investigate and resolve many of the problems and issues which are confronting us today.

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APPENDIX A

DEFINITIONS OF A LEARNING DISABILITY

Kirk, S. A. Educating exceptional children. Boston: Houghton Mifflin Co., 1962. (p. 261)

"A learning disability refers to a retardation, disorder, or delayed development in one or more of the processes of speech, language, reading, spelling, writing, or arithmetic resulting from a possible cerebral dysfunction and/or emotional or behavioral disturbance and not from mental retardation, sensory depreviation, or cultural or instructional factors."

Myklebust, H. R. Psychoneurological learning disorders in children. In S. A. Kirk and W. Becker (eds.), *Conference on children with minimal brain impairment.* Urbana, Ill.: University of Illinois, 1963 (p. 27).

"* * * we use the term 'psychoneurological learning disorders' to include deficits in learning, at any age, which are caused by deviations in the central nervous system and which are not due to mental deficiency, sensory impairment, or psychogenecity. The etiology might be disease and accidents, or it might be developmental."

Bateman, B. An educator's view of a diagnostic approach to learning disorders. *Learning disorders, Volume I.* Seattle, Washington: Seattle Seguin School, 1965 (p. 220).

"Children who have learning disorders are those who manifest an educationally significant discrepancy between their estimated intellectual potential and the actual level of performance related to basic disorders in the learning processes, which may or may not be accompanied by demonstrable central nervous system dysfunction, and which are not secondary to generalized disturbance or sensory loss."

Clements, S. D. Project Director. *Task Force I: Minimal brain dysfunction in children,* National Institute of Neurological Diseases and Blindness, Monograph No. 3, U.S. Department of Health, Education, and Welfare, 1966 (p. 9–10).

"The term 'minimal brain dysfunction syndrome' refers in this paper to children of near average, average, or above average general intelligence with certain learning or behavioral disabilities ranging from mild to severe, which are associated with deviations of function of the central nervous system. These deviations may manifest themselves by various combinations of impairment in perception, conceptualization, language, memory, and control of attention, impulse, or motor function.

"Similar symptoms may or may not complicate the problems of children with cerebral palsy, epilepsy, mental retardation, blindness, or deafness.

"These aberrations may arise from genetic variations, biochemical irregularities, perinatal brain insults or other illness or injuries sustained during the years which are critical for the development and maturation of the central nervous system, or from unknown causes."

Kass, Corrine. *Conference on Learning Disabilities.* Lawrence, Kans., November 1966.

"A child with learning disabilities is one with significant intradevelopmental discrepancies in central-motor, central-perceptual, or central-cognitive processes which lead to failure in behavioral reactions in language, reading, writing, spelling, arithmetic, and/or content subjects."

Kirk, S. A. *The diagnosis and remediation of psycholinguistic abilities.* Institute for Research on Exceptional Children, University of Illinois, 1966 (pp. 1–2).

"A learning disability refers to a specific retardation or disorder in one or more of the processes of speech, language, perception, behavior, reading, spelling, or arithmetic."

Learning Disabilities Division Formulational Meeting, National Council on Exceptional Children (C.E.C.), St. Louis, Mo., April 1967.

"A child with learning disabilities is one with adequate mental abilities, sensory processes and emotional stability who has a limited number of specific deficits in perceptive, integrative, or expressive processes which severely impair learning efficiency. This includes children who have central nervous system dysfunction which is expressed primarily in impaired learning efficiency."

First Annual Report, National Advisory Committee on Handicapped Children, January 31, 1968, "Special Education for Handicapped Children, Toward Fulfillment of the Nation's Commitment * * *"

"Children with special learning disabilities exhibit a disorder in one or more of the basic psychological processes involved in understanding or in using spoken or written languages. These may be manifested in disorders of listening, thinking, talking, reading, writing, spelling, or arithmetic. They include conditions which have been referred to as perceptual handicaps, brain injury, minimal brain dysfunction, dyslexia, developmental aphasia, etc. They do not include learning problems which are due primarily to visual hearing or motor handicaps, to mental retardation, emotional disturbance or to environmental disadvantage."

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