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ABSTRACT

Research on central processing dysfunctions in children is reviewed in three major areas. The first, dysfunctions in the analysis of sensory information, includes auditory, visual, and haptic processing. The second, dysfunction in the synthesis of sensory information, covers multiple stimulus integration and short-term memory. The third area of research, dysfunctions in symbolic operations, concerns auditory language, decoding and encoding written language, and quantitative language. In addition, research needs are summarized. (JD)

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U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
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CENTRAL PROCESSING DYSFUNCTIONS IN CHILDREN:

A Review of Research

Phase Three of a Three-Phase Project

by

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and
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PREFACE

The increasing complexity of our modern society has created increased pressures on each individual for a greater degree of conformity to expected norms of ability and performance. These expectations have their heaviest influence during the school years, for it is at this time that certain arbitrary standards of achievement are most rigidly applied, and that the individual is subjected to the most rigid and intensive comparative evaluation. Within this system, it has long been recognized that many children do not measure up to expectations. The intelligence test was developed as a measure or predictor of academic ability, and the concept of mental retardation reflects a widespread acceptance of the fact that there are quantitative differences in the overall intellectual abilities of children.

The fact that there may be significant qualitative differences in the abilities of children has been far slower in receiving adequate recognition. The last few years, however, have seen an increasing awareness that many children, whose overall intelligence appears normal, still exhibit peculiarities or deficiencies of their mental processes which interfere with their ability to cope with certain of the standard educational requirements. With special instruction, appropriate to the specific characteristics of the individual child, many are able to surmount those difficulties and move ahead to normal or superior academic and social achievement. As the existence and the needs of this group of children have become more apparent, increasing concern has developed for the more precise definition of the problem; the delineation of the programs and services required to meet it, and the evaluation of our present state of knowledge and research.

In 1963, under the auspices of the several interested agencies of the U.S. Department of Health, Education, and Welfare, and the National Easter Seal Society for Crippled Children and Adults, a committee was assembled to consider this problem. It recommended the establishment of three task forces. The first on Definitions has completed its report.* It recommended the use of the term "minimal brain dysfunction" for a group of children of normal overall intelligence, who exhibit certain characteristics of learning or behavior attributable to a dysfunction of the nervous system. This term, which assumes all learning and behavior to be a reflection of brain function, emphasizes that at a given time it is the child rather than the environment that is different. It avoids the issue of causation, recognizing that disorder or peculiarity of brain function may stem from many causes. It avoids the more limited term "learning disability" because the disturbances of behavior, in many instances, extend further than the learning situation or the classroom.

The second task force has carried out an analysis of the medical and educational services required for children with minimal brain dysfunction. Its report is in the process of publication.

The report of Task Force III, prepared by Drs. Chalfant and Scheffelin is a review of scientific knowledge regarding the learning disabilities of these children.

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*"Minimal Brain Dysfunction in Children," NINDB Monograph No. 3, Public Health Service Publication No. 1415. U.S. Department of Health, Education, and Welfare, 1966. (For sale by the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402. Price 20 cents.)

Its purpose is not only to summarize the current facts, but especially to point out crucial gaps in our understanding. It is a remarkable and comprehensive piece of work, highlighting above all the diversity of problems which are involved and the variety of scientific disciplines whose contributions will be required for their solution. A major problem has been the breadth of the topic and the massive literature which has been reviewed (the book includes 848 citations, but over 3,000 references are in the file). Wide gaps of knowledge exist in every area, and one is almost overwhelmed by the questions in need of elucidation.

The final summary of research needs highlights the chaotic state of our current efforts in this field. We are dealing with a poorly defined population. The methods for early recognition of the child with learning difficulties are still to be worked out and tested. There is no standard or generally accepted systematic screening program through which every child could be tested for a learning disability. The characterization of the individual deficit is on a very superficial basis, with the emphasis dependent largely upon the biases of one or another special school of thought. Remedial methods are found to rest on varied and shaky hypotheses, and have rarely been subjected to scientific evaluation even on an empirical basis.

The last few years have seen encouraging developments in these areas of research; however, one reaches the sobering conclusion that an all-out systematic research attack on the problem of the learning disabilities is long overdue.

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CONTENTS

LIST OF TABLES

LIST OF FIGURES

To our teachers

Samuei A. Kirk
Professor Emeritus
University of Illinois

and

Severina Nelson
Professor Emeritus
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CHAPTER 1

INTRODUCTION

Public schools are confronted with the problem of providing educational programs for all children. In order to accomplish this task, school curricula are usually organized in a developmental sequence. Most children are introduced to a curriculum in nursery school, kindergarten, or first grade, and progress from one level to the next until their formal education is terminated.

Unfortunately, many children do not progress through the normal curricular sequences. When a child experiences difficulty in learning, the teacher, the building principal and the superintendent of schools are responsible for initiating action to: (*a*) Specify the behavioral symptoms which are related to failure in school-related tasks; (*b*) investigate possible causal factors; and (*c*) make recommendations for correcting, ameliorating, or compensating for poor performance.

In some cases, the cause of the learning problem may be obvious, as in blindness, severe mental retardation, emotional disturbance, deafness, or crippling and other health impairments. In other cases, the cause of the problem may not be so obvious. There are children with major learning problems who are not mentally retarded, deaf, blind, or emotionaly disturbed, nor do they have demonstrable brain damage. It has been hypothesized that these children have learning problems related to minimal brain dysfunction. Unfortunately, the traditional categories of special education programs do not provide services for these children. Without competent screening programs and diagnostic services, it is difficult to distinguish between children who have a minimal brain dysfunction, disorders or delayed development resulting from mental retardation, sensory deprivation, cultural deprivation, or instructional factors. Unless these differentiations are made, a child may be placed in an educational program which may not be appropriate for his educational needs.

A review of the literature reveals that a number of different terms are being used to refer to the population in question. Among these are terms such as "brain-injured," "learning disabilities," "learning disorders," "psychoneurological learning disorders," "developmental imbalances," and "minimal brain dysfunction syndrome." Definitions for these terms have been advanced by a number of individuals, professional organizations, and special committees. (See app. A.) It should be noted that these definitions focus on one or any combination of several biological and psychological events. These are outlined as follows:

1. Biological events
   a. Genetic events
   b. Neurophysiological events
   c. Structure and function of the nervous system
2. Psychological events
   a. Cognitive development
   b. Social-motivational development
   c. Present behavioral symptoms
   d. Educational consequences

A variety of descriptive characteristics may be found among these definitions. Characteristics which are often mentioned include disorders in one or more of the processes of thinking, conceptualization, learning, memory, speech, language, attention, perception, emotional behavior, neuromuscular or motor coordination, reading, writing, arithmetic, discrepancies between intellectual achievement potential and achievement level, and developmental disparity in the psychological processes related to education.

Some definitions, but not all, include references to etiological correlates such as: Injury or infection of the brain before, during, or after birth; genetic variations; biochemical irregularities; illness during the development of the central nervous system; and unknown causes. Definitions sometimes include statements about what the disorders are not. For example, children who are mentally retarded, sensorily impaired, culturally deprived, poorly instructed, or emotionally disturbed are often excluded by definition.

Table 1.—Emphases of Medicine, Psychology, and Education

Discipline	Levels of assessment	Relevant factors	Definitional emphasis
Medicine	Physiological	Etiology Prevention: Medical treatment: Changes in function and structure:	Biological events: Genetic events: Neurophysiological events: Structure and function.
Psychology	Psycho-educational correlates to learning:	Measurement Cognitive development: Remedial treatment:	Cognitive development: Pyschological events:
Education	Behavior	Prevalence Classification: Management: Behavior modification: Developmental methods: Corrective treatment:	Educational consequences: Social-emotional behavior: Motivation: Observable behavior:

Differences in terminology and definition should not be surprising since the problem area spans different disciplines including special education, psychology, speech correction, child development, neurology, and medicine. In some instances, definitions have relevance for administrative classification, while other definitions have relevance for developmental change in function and structure, adaptive behavior, diagnosis, remediation, or preventive measures. When professionals with different backgrounds, theoretical orientations, and varied professional responsibilities focus on the same problem area, differences in terminology and definition are inevitable. (See table 1.)

To clarify the problems of terminology and identification of children who have deviations in nervous system function, the National Institute of Neurological Diseases and Stroke, the National Society for Crippled Children and Adults Inc., and the Easter Seal Research Foundation provided the initiative for a special task force to study the problems of terminology and identification. The result of this task force was an extensive list of symptoms attributed to children with minimal brain dysfunction which further emphasized the behavioral diversity of the population in question (Clements, 1966). In order to provide a common term and definition which would have relevance for as many professional and lay groups as possible, the term "minimal brain dysfunction syndrome" was selected by this task force (see app. A).

The term "dysfunction" is not intended to imply etiology and was selected to avoid the implication that all individuals with this group of symptoms necessarily have demonstrable brain damage. Among the children classified as having minimal brain dysfunction are those with clear-cut organic injury of the brain. A large number of children, however, do not have a lesion in the strictest sense of the word. The learning problem may stem from a constitutional deviation in the development of the central processing system and remain undiagnosed because the neuropathological techniques for diagnosis sometimes fail to identify those deviations. Perhaps the greatest value of the term "minimal brain dysfunction" is the implication that the problem arises from within the child and not from environmental factors.

As Gallagher (1966) suggests, the criteria for selecting a definition should be one of relevance. It may be unrealistic to expect a single definition to hold relevance for many different disciplines. That which is relevant for the neurologist and pediatrician, for example, may not be relevant for the educator. It may be necessary, therefore, to formulate several kinds of definitions, each of which would have a relevance and a function for the respective user.

Since the educator must deal with behavior, it may be helpful for the educator to use terms which are descriptive of these behavioral deviations. This report focuses attention on the deviant behaviors which arise from dysfunctions of the central processing mechanisms. More specifically, this report attempts to summarize the present status of knowledge and identify future research needs with respect to the analysis, storage, synthesis, and the symbolic use of information.

Purpose of the Report

The purpose of this report is to summarize both the present status of knowledge in and the future research needs for identifying, assessing and treating children with central processing disorders arising from minimal brain dysfunctions. A number of related events led to this report. First, parents and professional groups have indicated a growing concern for children with minimal brain dysfunctions. Second, this concern has not only fostered increased interdisciplinary collaboration, but has intensified conflicts between professional groups. Third, the public schools have been developing a variety of diverse educational programs for meeting the educational needs of these children. Fourth, the efforts of the public schools are frustrated by the lack of effective procedures for identification, assessment, and treatment. Fifth, institutions of higher education are beginning to mobilize their resources for training needed personnel, but there seem to be differences of opinion among school districts and State offices of education about the requirements necessary for preparing qualified teachers.

Recognizing these problems, the National Institute of Neurological Diseases and Stroke awarded a 2-year contract to the University of Illinois for the purpose of gathering information on the status of research on minimal brain dysfunction in children. The scope of work included:

(a) Exploration of the field of research pertinent to the assessment and treatment of minimal brain dysfunction in children.
(b) Delineation of the special areas which are significant for the purpose of this study.
(c) Consultation with specialists in the various fields of research pertaining to brain dysfunction.
(d) Review of the literature to identify significant studies undertaken and the researchers involved.
(e) Site visits to the various centers where pertinent research is being conducted.
(f) Compilation of information and research data and/or case histories on the status of research among the various research teams, their accomplishments and approaches taken in the assessment and treatment of minimal brain dysfunction.
(g) Preparation of narrative reports on the findings of site visits supported by bibliographic, case history, and research data materials, as applicable.

Procedure for Conducting the Study

The first 9 months of the project were spent in determining the scope of the problem, reviewing the literature and gathering pertinent information. During the data-gathering phase, a number of site visits were made to various centers to consult with specialists in the various fields of research. Journals, periodicals, and books were reviewed to identify the different problem areas which were pertinent to the purpose of the study. Research studies from education, psychology, child development, biology, biochemistry, neurology, and many other disciplines all seemed to have some relevance to the problem.

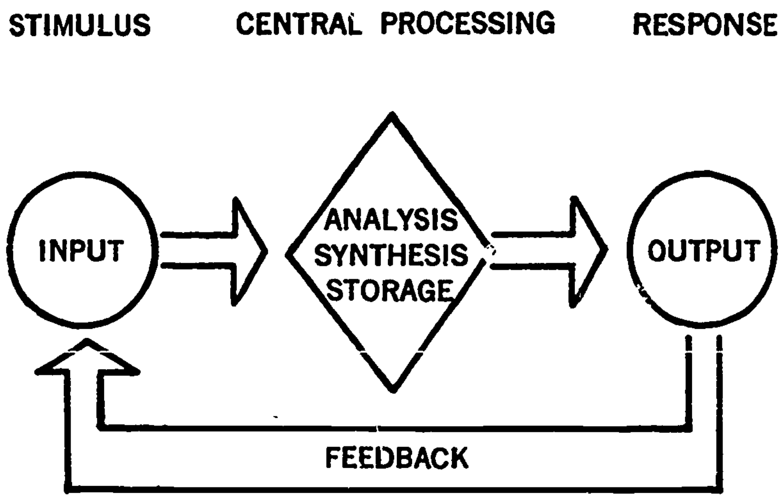

Figure 1.—Computer Model for Information Processing

Approximately 5,000 references were identified screened, and categorized. Abstracts were made of the more significant studies. It is obvious that the large number of studies and the time limitation make it impossible to cite all the significant studies. An effort has been made, however, to include representative studies as the basis of the report.

In order to communicate with the reader it was necessary to develop a conceptual framework into which the research could be placed. The computer model for information processing was adapted for this purpose (see Fig. 1). Auditory, visual, and haptic stimuli (or sensory information) are transmitted to the central processing mechanism (brain) where they are analyzed, integrated and stored. The behavioral response of the subject serves as an additional input source (feedback) for correcting or adjusting further behavioral responses. This model was used as the framework for categorizing and relating research studies from different disciplines. The remaining 15 months were spent outlining chapters, organizing the key references, integrating information, and writing the report.

Limitations of This Report

In view of the large mass of literature which has been written about the problem area, it was necessary to develop guidelines for delimiting the scope of the project so it could be completed during the 2-year duration of the study.

The first guideline was to focus on behavioral problems which have particular relevance for educators.

The second guideline was to report research on children, as much as possible. It should be noted, however, that in the absence of research on children, studies on adult subjects and animals have been included.

The third guideline was to report research and generally exclude literature which reflected opinion. In the event that research data were not available, unsupported theoretical hypotheses occasionally have been included.

The fourth guideline was to exclude the large mass of research with respect to emotional disturbance and social maladjustment. While these behavioral deviations are most certainly relevant to education, they represent a large and distinct problem area which merits special study in its own right. Some mention of these problems is included in this report, however, to indicate how they relate to the particular content area under discussion.

Major Issues of Concern

In reviewing the research, three major bodies of literature were identified. First, research studies from experimental child psychology typically report findings on the responses of normal children to discrete auditory, visual, or haptic qualities of stimuli. Second, research studies from clinical psychology and clinical education report findings on the responses of atypical children with perceptual disorders to the objects themselves. Third, research studies from the medical profession report findings on neurophysiological correlates. The experimental child psychologist has focused his attention on children's responses to discrete stimulus qualities such as shape, color, form, size, area, etc., while the clinical educator and the clinical psychologist have been attempting to teach children to respond to and manipulate objects which represent multiple stimulus qualities. Unfortunately, the findings from experimental research have not been translated into useful procedures for the clinical assessment and training of children, nor have the clinical procedures been described in the specific details necessary for replication and experimentation. Most of the research by the medical profession on organic brain damage has been conducted with adult subjects. Comparatively little information is available about children who have suffered known brain damage.

As a result of these different approaches and independent research efforts, there are gaps in the present status of knowledge for those who attempt to relate the research findings of experimental child psychology, clinical education, and clinical psychology, and the medical profession. One of the major objectives of this report is to attempt to relate the research findings from these three disciplines.

A number of major issues with respect to the identification, assessment, and treatment of central processing dysfunctions were highlighted by the review of the literature. Some of the more important issues are presented here in question form and are discussed throughout the report.

1. What are central processing tasks?
2. What is the significance of processing tasks for learning?
3. What are the anatomical, neurological, and physiological components which constitute the central processing mechanisms?
4. What observable behaviors are symptomatic of central processing dysfunctions?
5. How are these behavioral symptoms linked with organic brain dysfunction?
6. How effective are the procedures for identifying and assessing the severity and extent of central processing dysfunctions?
7. What aspects of diagnosis are most relevant for educational intervention?
8. How effective are the procedures for preventing, ameliorating, or compensating for specific central processing dysfunctions?
9. How can research design be sharpened to determine the effectiveness of specific treatment procedures for specific kinds of dysfunctions?
10. What future research is needed to resolve these issues?
11. Where does the responsibility lie for conducting needed research?
12. How can research findings be disseminated to the practitioner in the field?

To make an authoritative analysis of this problem, the authors should be highly specialized in anatomy, neurology, biochemistry, physiology, audiology, vision, experimental child psychology, educational psychology, learning theory, psycholinguistics, and behavior modification, all of which are related to central processing dysfunctions in children. It is obvious that no author is a specialist in all these areas. In our particular case we were fortunate enough to have consultants from these areas to assist us and to criticize the manuscript. The authors may be more accurately described as consumers of research. The difficulty we encountered in attempting to pull together and integrate the mass of conflicting and sometimes confusing information may be typical of the difficulty experienced by other professionals. At best, this report represents an ordinary effort. A beginning. A search for the right questions.

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DYSFUNCTIONS IN THE ANALYSIS OF SENSORY INFORMATION

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CHAPTER 2

AUDITORY PROCESSING

The auditory channel is one of the most important avenues through which children and adults receive information about their environment. The importance of hearing acuity for obtaining such information has been established, but there is little known about the central processing of auditory stimuli. There are children, for example, whose hearing acuity is within the normal range of hearing, but who have difficulty processing and obtaining meaning from auditory stimuli. A child who has difficulty processing auditory stimuli may be observed to perform poorly in some of the following tasks: (*a*) Identify the source of sounds; (*b*) discriminate among sounds or words; (*c*) reproduce pitch, rhythm, and melody; (*d*) select significant from insignificant stimuli; (*e*) combine speech sounds into words; or (*f*) understand the meaning of environmental sounds in general.

Clinical case studies typically have reported such observable behaviors as being characteristic of children who have difficulty in processing and responding to auditory stimuli. In many instances, the clinical report simply mentions the existence of these behaviors and does not provide a comprehensive description of the conditions under which the subject was unable to process and respond to the auditory stimuli in an appropriate manner. There is need to describe disorders in processing and utilizing auditory stimuli in more detail. The use of more precise terms will help facilitate communication between different disciplines.

Many of the observable behaviors which seem to be characterized by difficulty in perceiving auditory stimuli have been referred to as "auditory perceptual disorders." Myklebust (1954) defines auditory perception as the ability to "* * * structure the auditory world and select those sounds which are immediately pertinent to adjustment (p. 158)." According to Berry and Eisenson (1956), children with auditory perceptual disorders can hear sounds, but are unable to recognize the sounds that they hear. The term "auditory perception," as it is used here, refers to the central processing of auditory stimuli.

In 1954, Myklebust made a number of important distinctions concerning auditory disorders in children. Unfortunately, the present status of knowledge has not advanced very far beyond the early contributions of Myklebust (1954), Goldstein (1948), Nielsen (1948), and others.

Several factors may have contributed to the lack of empirical data on auditory stimulus processing, especially in children. First, is the lack of data on the nature of auditory stimuli, especially speech sounds. Second, it is difficult to measure and study responses to auditory stimuli. Third, the organization, structure and use of sound in the environment is achieved at different ages by different individuals. Fourth, confusion is generated by overlapping terms. Some terms such as "psychic deafness" refer to diagnosis. Terms such as "sound localization" refer to a specific task, while terms such as "hi-frequency loss" refer to aspects of the stimuli.

The purpose of this chapter is to provide an overview of the disorders which can occur in processing auditory stimuli. More specifically this chapter will discuss: (*a*) The processing mechanism; (*b*) different kinds of auditory processing tasks; and (*c*) the needs for future research in assessment and training.

The Auditory Processing Mechanism

A deficit in hearing acuity which blocks incoming acoustic stimuli will interfere with the perceptual process (Myklebust, 1957). For this reason, any discussion of the mechanism for processing auditory stimuli should include a description of the human ear as a transducer of acoustic stimuli, as well as a brief discussion of the cortex as an auditory processor.

The Ear as a Transducer

O'Neill (1964) has described the sequence of physical pressure changes by which acoustic stimuli are transmitted to the cerebral cortex via acoustic, mechanical hydraulic, and electrical signals. O'Neill's description of what happens to the pressure changes

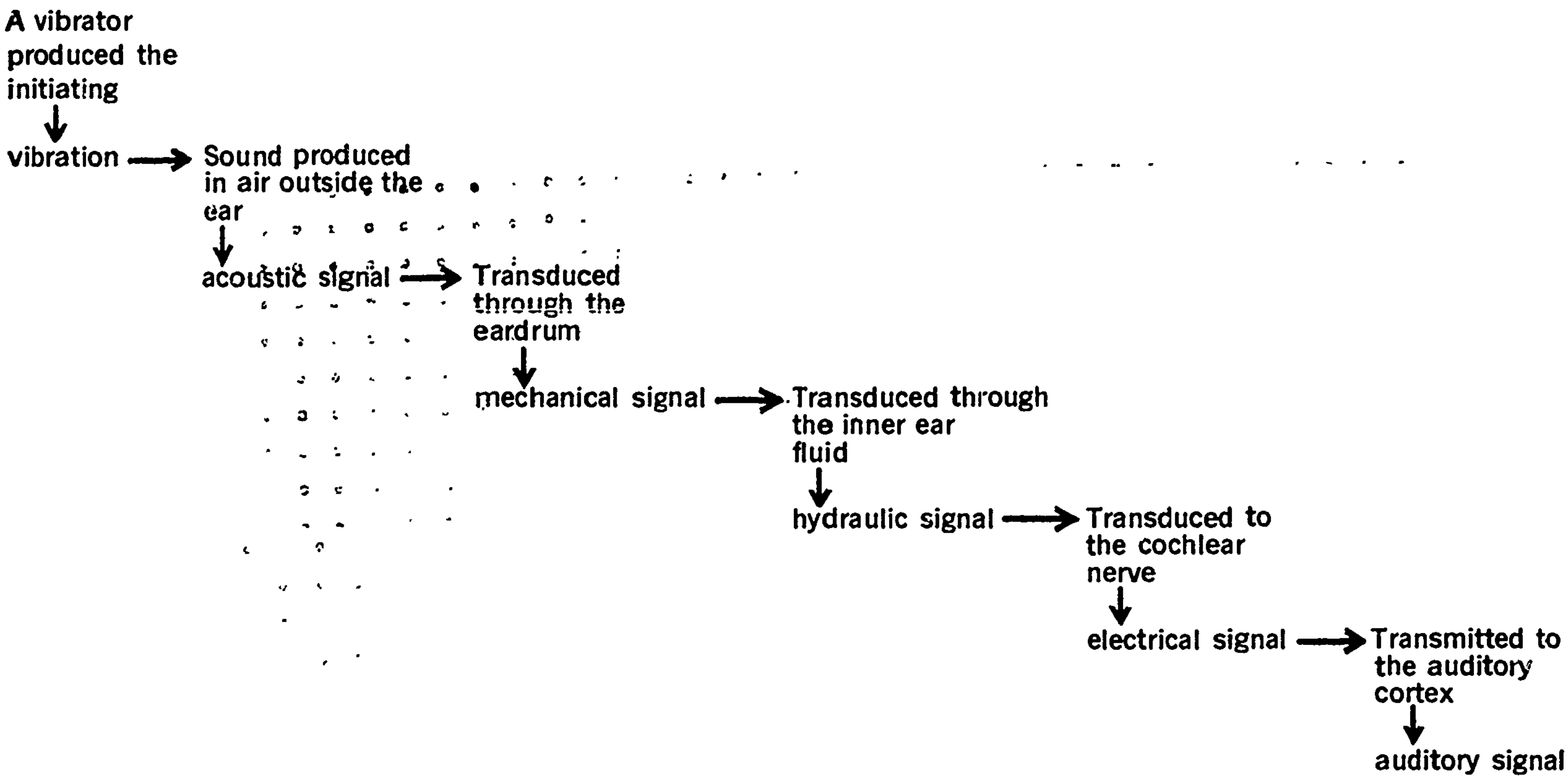

Figure 2.—The Transduction of Auditory Stimuli

created by the original sound source has been adapted and expanded in figure 2. A vibrator (larynx, bell, reed) produces an initiating stimulus. The sound produced in the medium outside the ear (usually air) is transduced through the inner ear fluid, to the cochlear nerve, and then to the auditory cortex of the brain. The amount of energy that appears to be necessary for detection of a sound stimulus is extremely minute. O'Neill says a sound pressure of 0.0002 dynes per centimeter "* * * is considered the lowest intensity of sound that the human ear can detect" (p. 10). This amount is one ten-trillionth times as weak as the most intense sound that can be tolerated by the ear. "The human ear is able to detect some 340,000 * * * differences in frequency and intensity (O'Neill, 1964, p. 20)."

The Cortex as an Auditory Processor

The auditory cortex has been viewed as a passive receptor of auditory stimuli which are transmitted along the auditory nerve. More recently, it has been conceptualized as a selective analyzer. According to the theory of selective-analysis, "* * * sensation incorporates the process of analysis and synthesis of signals while they are still in the first stages of arrival (Luria, 1966, p. 97)." This may result in increased excitability and sensitivity with respect to some components of the stimulus such as color or in decreased excitability with respect to others such as form (Granit, 1955; Sokolov, 1958).

According to this theory, the sensory divisions of the cortex seem to be responsible for the analysis and integration of complex signals and are not responsible for the first stage, reception of sensation. Therefore, lesions in this area will not necessarily alter the threshold of sensation, but will instead result in a disturbance of the higher, analytic-synthetic function. Research workers in both the Soviet Union and in the United States have found that extirpation of the sensory cortex in animals disturbs the ability to differentiate between pairs of both simple and complex signals, and results in an incapacity to form new conditioned reflexes in response to complex sound stimuli (Kryzhanovskii, 1909; Babkin, 1910; Butler, Diamond and Neff, 1957; Goldberg, Diamond, and Neff, 1957). Findings such as these suggest that pathology of the auditory divisions of the cortex is reflected in the more complex forms of differential auditory analysis and not in hearing acuity (Luria, 1966).

The reflex theory of higher mental functions including auditory analysis rejects the localization of sensory perception in an isolated area of the brain. The reflex theory, which views mental functions as complex reflex processes having their origin in the child's response to adult verbal commands, regards the brain as a system of acquired complex intercentral connections (Luria, 1966). While this theory of auditory analysis may give us a more substantial basis for understanding the behavioral symptoms which arise from lesions in the auditory divisions of the cortex, it is very difficult to study, in detail, the role played by the cerebral cortex in auditory functions.

There is some evidence which suggests: (*a*) That the primary receiving strip for auditory stimuli is located in the Sylvian margin of the temporal lobe, area 41 (Penfield and Rasmussen, 1950); and (*b*) that the secondary division of the first temporal convolution is responsible for the analysis and integration of sound signals (Luria, 1966). It should be noted that most of the research conducted with human subjects has been with adults who have suffered tumors, abscesses, or traumas to the temporal lobe.

As early as 1873, Ferrier (1876) demonstrated in animals the localization of the auditory center in the temporal lobe. Electrical stimulation of the temporal lobe of either side close to the fissure of Sylvius will produce auditory sensations. Campbell (1905) recorded the location of points which, when stimulated, appeared to produce auditory sensations in humans. A variety of auditory sensations in the contralateral ear or in both ears were recorded. When the cortex was stimulated in the same place in different patients, different sensations were reported. Thus, the lack of interpatient reliability makes it difficult to analyze in detail the precise function of the cortex in auditory functioning.

The research concerning the function of the secondary divisions of the auditory cortex is less clear. It may be here that the complex forms of auditory analysis and integration occur (Penfield and Rasmussen, 1950; Luria, 1966). This region may be largely responsible for the systematic deciphering of sound signals necessary for the perception of speech. According to Luria (1966):

> * * * the disturbance of discriminative hearing, which can now be interpreted as a disturbance in the analytic-synthetic activity of the auditory cortex * * * may be regarded as the fundamental symptom of a lesion of the superior temporal region of the left hemisphere, and the resulting acoustic agnosia may be regarded as the fundamental source of speech disturbance (pp. 106–107).

It is suggested that future research should attempt to identify the fundamental defects resulting from lesions of the secondary divisions of the auditory cortex. There is need, also, to conduct research on the disturbances which [illegible] from lesions of the middle segments of the convex portion of the left temporal region. This area has a high incidence of lesions (tumors and abscesses) and the disturbances associated with these lesions have not been clearly defined. The clinical behaviors are varied and complex, and include auditory and visual hallucinations, dreamy states, emotional changes, and changes in the state of consciousness (Penfield and Roberts, 1959).

Auditory Processing Tasks

The term "auditory perception" has been used to describe many behavioral responses to auditory stimuli. In order to present an organized view of auditory perception or auditory stimulus processing, seven different auditory tasks have been identified and are presented in table 2. It will be noted that the seven tasks are described according to the stimuli presented, the response required, and terms commonly applied either to the task or to failure in performing the task. Each of the seven tasks will be described in separate sections, which will include whenever possible a discussion of the: (*a*) Nature of the task; (*b*) neurophysiological correlates; (*c*) consequences of failure in performing the task; (*d*) remedial procedures; and (*e*) future research needs.

1. *Attention to Auditory Stimuli.* The first concern in testing or teaching responses to auditory stimuli is to determine whether or not the child is attending to the stimuli which are being presented. Inattentiveness to auditory stimuli might be related to: (*a*) Low level or absence of hearing acuity; (*b*) distractibility involving competitive visual or auditory stimuli; (*c*) hyperactive behavior; (*d*) severe emotional disturbance; (*e*) severe mental retardation; or (*f*) inability to obtain meaning from auditory stimuli.

A thorough differential assessment of children who seem to have difficulty processing auditory stimuli should include an examination of all the correlates to the attentional factor. It is important to remember that attention to auditory stimuli is inferred from the subject's responses such as inclining one's head toward the source of sound, facial expressions, or verbal or motor responses. There is need to develop systematic procedures for assessing the reasons for what appears to be inattentiveness to auditory stimuli.

There is little research available about the most efficient ways to teach the child to attend to auditory stimuli. The literature typically describes clinical suggestions or approaches to this problem. For example, the use of amplification can help intensify auditory stimuli and create an awareness of the differences between sound and no sound. Toys, musical instruments, and household appliances which can be manipulated by the child can be used for training purposes. Suggestions include repeatedly turning the child's head toward the source of sound, or making the sound source visible to the child when he turns his head.

Table 2.—Auditory Processing Tasks

Stimulus presented	Response required	Common terminology
1: Auditory stimulus	Indicate awareness through verbal or motor response:	Attentional problem, distractible, hyperactive:
2: Sound versus no sound	Yes/no	Acuity, detection:
3: Sound from several different origins	Indicate direction from which originated	Sound localization:
4: Sounds varying on one acoustic dimension:	Same/different	Discrimination of pitch, loudness, speech sounds, noises:
5: Sequences and patterns of speech or nonspeech sounds varying on more than one acoustic dimension:	Reproduce sequence: (a) Imitation, e.g:, tapping; (b) speaking; (c) singing:	Pitch, rhythm, melody, "arhythmical, can't carry a tune, tone-deaf, poor auditory memory:"
6: Sound preselected as "figure" versus sound preselected as "ground."	Select "figure" sound	Differentiate, discriminate.
7: Sounds from one or more sources	Identify by: (*a*) Pointing to a visual representation of the sound source; or (*b*) naming the sound source:	Associating sounds with their actual sources:

Selective reinforcement, contingent upon response, and other principles of behavior modification can be used to help increase attentiveness to auditory stimuli (Sloane and MacAulay, 1968). There is need to conduct research on the ways in which attentiveness to auditory stimuli can be increased in those individuals who tend to ignore the significance or meaning of sound.

2. *Sound Versus No Sound*. The first level of assessment of sound discrimination is to indicate whether or not the sound has been heard. A basic procedure in assessing sensitivity to sound, for example, is to present pure tone or warbled tone stimuli to determine if the child can differentiate sound from no sound. Lowered acuity in hearing alone does not represent an auditory perceptual disorder. For auditory processing to occur, however, the hearing mechanism must be capable of transmitting the mechanical, hydraulic, and electrical signals to the auditory cortex. A hearing deficit will reduce the accuracy of discrimination.

3. *Sound Localization*. Some children have difficulty in localizing or indicating the source or the direction of a sound. When the source of sound is equidistant from both ears, the sound is said to be difficult to locate even by practiced adults. If the sound source is moved, either to the right or to the left of the midline of the body, it is closer to one ear than the other, and the closer ear is stimulated somewhat earlier. Since the acoustical complexity of a sound is partially a function of distance from the ear, the ear closest to the sound will receive a stimulus of greater complexity than the ear farther away. The sound should then appear different to the two ears. The time difference between the detection of the signal presented to each ear should also be a clue which can be used to detect the source of sound. Children who have difficulty in identifying the source of sound may not learn that different people have different voices or that the sound made by one person is specific to that person and not produced by a random source.

In reviewing the literature, no data were found on the assessment or training of sound localization. There is need to develop activities which will improve the ability to localize sounds in terms of distance as well as direction. Being able to localize sounds will help the person visually link sounds with their sources and help establish associations between sounds and objects or events.

4. *Discriminating Sounds Varying on One Acoustic Dimension*. For our purposes, auditory discrimination is defined as indicating whether two acoustic stimuli are the same or different. Given a pair of auditory stimuli, the subject must indicate whether the two members of the pair are alike or different. The response required varies from vocal ("same-different," "same-not the same," "now I hear it") to various forms of nonverbal communication (turning toward the source of sound, performing an agreed upon action representing "same" or "different," pointing to a pair of similar objects, rather than to a pair of unlike objects).

Auditory stimuli may vary along several acoustic dimensions and several presentational dimensions. Individual acoustic stimuli can be measured on several physical scales such as frequency and intensity. These physical scales are related to auditory-psychological dimensions such as pitch and loudness. Presentational dimensions which include number, rate, and duration of stimuli have auditory-psychological counterparts in rhythm and melody. The kind of sound (speech versus nonspeech sounds) and the location of the sound are also presentational dimensions. Auditory stimuli may be presented either simultaneously or successively to one ear or both ears. The relationship of the hearer to the acoustic stimulus will affect his judgment of the auditory stimulus. For example, the farther away a person is from the source of the acoustic stimulus, the lower the pitch and the softer the intensity will appear to be.

The assessment of differential responses to pairs of auditory stimuli involves discriminations along one or more acoustic or presentational dimensions. There are two major classes of sound sources. There are human sources (vocal sounds and words, etc.) and nonhuman sources (bells, watches, machines, etc.). Most standardized discrimination tasks include only a few different sound sources and may include stimuli from either one or both classes of sound sources.

In view of the fact that a large proportion of human communication consists of speech, a series of vocal acts, it is not surprising that several tests of speech-sound discrimination have been developed. Among the most widely used tests are the Wepman Auditory Discrimination Test (Wepman, 1958), the PERC test (Drake, 1965), and the Boston University Speech Sound Discrimination Picture Test (1955). Norms are available for the Wepman and are being secured for the PERC. The chief difference between the two tests is that the child is required to say "same" or "different" to each pair of words on the Wepman, whereas he is required to say "same" or "not the same" on the PERC. Extensive descriptions of several widely used speech sound discrimination tests, and lists of the words or sounds presented to the subject, are supplied by Berry and Eisenson (1956, pp. 449–501). Caution should be exercised in interpreting scores from these tests, because of the problems in presenting vocally produced stimuli in a consistent manner. It is possible that the repeated readings of the list of words do not necessarily give equivalent forms of a test because of day-to-day differences in the speaker's presentation.

Disorders in sound discrimination have been found to be caused by lesions in the temporal lobe. Some individuals experience difficulty in identifying similar sounds, which they perceive as being different (Korst and Fantalova, 1959). Difficulty in discrimination also occurs when sound complexes are presented which have the same components but are presented in a different order (Traugott, 1947; Babenkova, 1954). A disturbance of discriminative hearing may result from a lesion of the superior temporal region of the left hemisphere. Luria (1966) views a disturbance in the analytic-synthetic activity of the auditory cortex, and the resulting acoustic agnosia, as the fundamental source of speech disturbance.

There are individuals who have adequate hearing acuity, but who do not discriminate one sound from another. Failure to discriminate between auditory stimuli has a number of possible consequences. If children are unable to hear the differences or similarities in initial or final sounds of words, consonant blends, or vowels, they will have difficulty in acquiring, understanding, and using spoken language. Some individuals have difficulty in distinguishing between single speech sounds. It is more difficult to discriminate between similar sounds (/d/, /t/, /p/) than if the sounds are widely different (/h/, /k/, /s/). Some individuals are aware that a difference exists between two sounds, but may not be able to specify the nature of the difference.

The analysis and synthesis of series of speech sounds is basic to learning the phonemic structure of language. A child who is unable to analyze series of sounds into their separate parts or to synthesize separate sounds into wholes, may suffer impaired auditory memory, speech, and reading ability. Monroe (1932), for example, found that among first grade children, a group of nonreaders made significantly more errors on auditory discrimination tasks than did a group of adequate readers. Yedinack (1949) and Monroe (1932) found a high proportion of poor readers had speech defects. Monroe concluded that either the speech defect was a factor in reading disability or both the reading and speech problems were the result of a common cause, probably the inability to discriminate successfully the sounds of words. Chronological age of the child is an important consideration, because many children continue to improve in discriminating sounds as late as the eighth year (Wepman, 1960).

If we are to understand the processing of auditory stimuli, there is need to study the ways in which an individual processes auditory stimuli varying along different acoustic and presentational dimensions. In reviewing measurement techniques, Reichstein and Rosenstein (1964) recommended that four important variables should be studied. These include the selection of the stimuli, the mode of input, the method of response, and motivational factors. They have summarized both the various modes of presenting auditory stimuli and the kinds of responses that are required. The pure tone audiometer is used to present auditory stimuli. Similar to the pure tone is the warbled pure tone which differs only in that the tone is not steady. When the auditory stimulus is speech, word lists or word games are often used. Complex nonspeech stimuli such as music, noise makers, and animal sounds are frequently employed as another mode of presenting auditory stimuli.

The child may be required to respond in a variety of ways. His perception of the auditory stimulus may be measured by a reflex response which the stimulus evokes or by an indication of locating the stimulus. The child may be required to voluntarily indicate his perception by saying something or raising his hand. In the conditioned response method the child is conditioned to reach for or do something pleasant each time he perceives an auditory stimulus. In the simple "play" conditioned response, the child performs a simple motor act when he hears the auditory stimulus. In the complex "play" conditioned response upon hearing tone the child is to respond by performing some action with a complex toy.

Lists of representative studies related to the selection of auditory stimuli and mode of response are presented in tables 3 and 4. These lists, while not exhaustive of the kinds of variables that should be accounted for, demonstrate the wide variation in the procedures employed. In addition, pretest training to teach children response alternatives is an aspect of testing that has not received sufficient attention.

There is need to develop and program sequential training activities which will help individuals discriminate the differences between sounds. The concept of auditory discrimination is rather broad. Research efforts in this area, therefore, probably should be directed toward the discrimination of different kinds of auditory stimuli. Variables such as duration, pitch, frequency, volume, symbolic or nonsymbolic stimuli, speech sounds, and noises should be considered.

Training should follow the principle of beginning with maximum contrast between the members of the pair to be discriminated. Discrimination should begin with gross sounds commonly heard as those found on training phonograph records (Utley, 1950) and proceed to finer sound differences. Mecham (1966) suggests extensive training in recognizing and discriminating the sound or sounds which are later to be reproduced. According to Berry and Eisenson (1956), some children require more time to absorb material and will respond more readily if the stimuli are intensified and repeated. Miller (1951) suggests that children can be trained in the automatic repetition of sequences such as the number series 1–10. After the child has

Table 3.—Selection of Stimuli

Type of stimulus	Reference
1. Pure tone	Myklebust, 1954.
2. Warbled pure tone	Douglass, Fowler, and Ryan, 1961.
3. Speech	Keaster, 1947.
	Siegenthaler, Pearson, Lezak, 1954.
	Dale, 1962.
	Solomon, 1962.
	Wolfe and MacPherson, 1959.
	Sortini, 1960.
4. Music, noisemakers, animal sounds	O'Neill, Oyer, Hillis, 1961.
	Streng, Fitch, Hedgecock, Phillips, and Carrell, 1958.
	Solomon, 1962.
	Whitehurst, 1961.

Table adapted from Reichstein and Rosenstein (1964).

Table 4.—Mode of Response

Type of response	Reference
1. Reflex-localization	DiCarlo and Bradley, 1961.
	Ewing and Ewing, 1958.
	Downs, 1960.
2. Direct-voluntary indication	Myklebust, 1954.
3. Conditioned response methods	Thorndike, Hilgard, and Skinner (in Hilgard, 1956).
	Miller and Dollard, 1941.
4. Complex-play conditioned response	Dix and Hallpike, 1947.
	Guilford and Haug, 1952.
	Wolfe and MacPherson, 1959.
	Sills, 1962.
	Meyerson and Michael, 1960.
5. Simple-play conditioned response	Ewing and Ewing, 1944.
	Lowell, Rushford, Hoversten and Stoner, 1956.
	Meyerson and Michael, 1960.
	Costa, Mandel, and Rapin, 1962.

Table adapted from Reichstein and Rosenstein (1964).

mastered the auditory-vocal sequence, he can be trained to pick out the visual representation of the auditory number name. After the initial gross discrimination task has been performed successfully, the task can be made progressively more difficult by decreasing the range of differences.

Implications for training methods may be discovered in Mecham, Berko, Berko, and Palmer's (1966) rationale for dividing learning behavior into three aspects: (1) Conditioning discriminative stimuli; (2) differential reinforcement of successive approximations of the desired behavior; and (3) chaining or sequencing behavioral patterns.

5. *Discriminating Sound Sequences Varying on Several Acoustic Dimensions.* A child may be able to discriminate one sound from another, yet experience great difficulty in discriminating or reproducing groups or patterns of auditory stimuli. Rhythm is the sequential pattern of several auditory stimuli in time. Processing auditory stimuli varying on several acoustic dimensions is an important factor in the acquisition of spoken language. At present, there is little information about the wider implications of disorders of rhythm, pitch, and their combination, melody. The purpose of this section is to explore some of the implications which have been mentioned in the literature.

Luria (1966) cites case studies of individuals who have suffered brain damage to the fronto-temporal region having a history of musical disorders in which the rhythm and melody functions are impaired but the pitch relationships remain unimpaired. The involvement of the short-term memory function in fronto-temporal disorders may help account for the difficulty in reproducing rhythm patterns, while pitch relationships remain unaffected. Pitch discrimination activities do not usually make severe demands upon the memory function, because one pitch is usually presented immediately after another. The investigation of the perception and reproduction of pitch relationships in musical melodies is an important aspect in studying pathology of the temporal and premotor divisions. Simple tests consist of comparing whether one pitch is higher or lower than or equal to a second pitch.

Semeritskaya (1945) found that patients with lesions in the temporal region can reproduce a rhythmic pattern if it is presented slowly and can be counted. These same patients, however, have great difficulty in reproducing rhythmic patterns which are presented rapidly. When the auditory analysis and integration functions are disturbed, patients can reproduce single rhythmic groups, but are frequently unable to repeat the rhythmic pattern over and over as in a series. These symptoms have been related to lesions of the superior left and right temporal regions. Auditory disturbances may not be so conspicuous in patients with lesions of the inferior division of the left-temporal region as are auditory disturbances resulting from lesions of the superior divisions.

There is at present little information as to how the perception of rhythm is disturbed by lesions in the motor system. There is some evidence that the evaluative role played by the motor analysis of rhythms suggests that lesions in the anterior divisions of the brain may interfere with the proper evaluation of rhythmic structures. With frontal lobe lesions there is difficulty in analyzing rhythmic structure. The tendency is to overestimate rhythmic patterns and to successively change rhythmic structures from groups of two to groups of three.

One of the important aspects in examining children is to determine the conditions under which they find it difficult to perform tests based on rhythm. Is it actually a problem in analyzing acoustical images? Is it a defect in the regulatory role of verbal instructions? Is it defective motor functioning? Is it the shift from reproducing one rhythmic structure and then another which is an indication of the mobility of nervous processes?

When the reproduction of rhythms is disturbed by lesions of the premotor region, the disturbance of the system of higher automatisms makes smooth reproduction of melodies impossible. In these cases each tap forms part of a rhythmic pattern and requires an isolated impulse. The child does not appear to develop an automatic presentation of the rhythmic pattern. He forms each tap individually. The difficulty is increased with an attempt to increase the tempo, and inhibition of the tapping becomes more difficult and superfluous taps appear. Although the child is aware that these taps are out of place, he is not always able to suppress them. Damage to the motor analyzer leads to difficulty in reproducing the accentuated rhythms. It is difficult for the subject to change from tapping one rhythmic group to tapping another. He is more apt to tap out the same sequence rather than the new ryhthm.

There is usually no difference between the reproduction of rhythms in the imitation of acoustic images and the production of rhythms from verbal instruction in patients with lesions of the premotor region. There is, however, a tendency toward preservation on the initial stimulus item under both imitation and verbal instruction conditions. Inability to correct mistakes may often persist when rhythms are reproduced from an acoustic image. This repeated failure suggests that the fundamental effect of the rhythms reproduced by patients with a frontal syndrome is associated with the disturbance of the selective aspects of the motor act, and of the regulatory influence in originating the motor act.

Generally, patients with lesions of the temporal divisions of the brain often have difficulty reproducing rhythms from an acoustic pattern, particularly when the rhythms are presented quickly and the patient is unable to count them. The counting response is an element which can be controlled by the experimenter. If the child has the ability to count, patterns can be presented in such a way that counting is ruled out as a mediator. On the other hand, if the child is having extreme difficulty, perhaps counting could be introduced as a mediator to improve his ability in dealing with rhythm.

Quantitative aspects of the stimuli, such as the number of units in groups of acoustic signals, is an important consideration. The task can be made more complicated by manipulating the number of taps, complexity of pattern, and number of groups. The rapidity with which groups are presented in succession is an important temporal variable. Auditory tap patterns require the acoustic analysis and reproduction of the rhythmic structure. Apparently, the perceived acoustic structure must be coded as sounds corresponding to a series of consecutive motor movements, before they can be reproduced. This is a difficult task for some persons to perform.

On occasions when a rhythmic structure is presented at a slightly faster rate, or rhythmic counting aloud is forbidden, some patients are unable to evaluate the pattern. The complaint is that the taps are presented too quickly, the patient cannot keep up, and there may be a tendency to overestimate the number of taps in such series. For example, when slow taps are followed by two fast taps, the second group is often judged to contain three taps. Some patients do not benefit when a particular rhythmic group is repeated many times in succession. This kind of presentation normally enables the subject to conduct a longer comparison of one group with another. But other patients often believe that there are too many taps when they cannot identify the rhythm in which they are presented.

6. *Auditory Figure-Ground Selection.* Some children experience difficulty in selecting the relevant from the irrelevant auditory stimuli in their environment. Because most verbal communication takes place by auditory speech signals, a child who is unable to attend to speech sounds or to differentiate speech sounds from the remainder of the auditory stimuli in the environment will probably experience difficulty in learning to comprehend and in acquiring language as a communication system. Other behaviors sometimes include distractibility, short attention span, and ignoring some auditory stimuli in listening activites.

Assessment of the interference effects created by competing auditory stimuli may be accomplished by presenting a significant stimulus, and at the same time, presenting stimuli which have been declared by the examiner to be insignificant. The response required of the subject is to indicate either that he has heard the significant stimulus, or that he can reproduce the significant stimulus. Little is known about children's performances on a task of this type. There are many clinical reports of children who respond to insignificant auditory stimuli during testing or teaching situations. The so-called distractible child is an example of a person who appears to attend to the irrelevant auditory stimuli of a situation. In a classic study, Miller, Heise, and Lichten (1951) presented a series of words, together with random noise, to adult subjects. The subject's task was to repeat each word. The results showed that incorrect responses were influenced by the number of words in a set, the number of previous presentations, familiarity, and the acoustic power of the irrelevant auditory stimuli.

There is little information concerning the interference effects of presenting two or more auditory stimuli at the same time or at different points in time. The sequencing and timing of auditory stimuli may be an important variable. Interference effects may occur, when two auditory stimuli are presented at the same time, or one auditory stimulus is presented either before or after another. Delayed auditory feedback has been used to investigate interference effects. The air-conducted sound of a subject's voice is delayed electrically and presented at a specified delay interval to the subject by means of earphones. When two or more stimuli are presented at the same time, "masking" is said to be taking place. When two or more stimuli are presented at different points in time, "fatigue" is said to be taking place (Hirsh, 1952).

Little research has been done on methods or materials for teaching a child to select significant from insignificant auditory stimuli. There is need to conduct a systematic program of research in which various aspects of attention, organic conditions in the brain, effect of drugs, and nature and presentation of auditory stimuli are thoroughly explored.

7. *Associating Sounds With Sound Sources.* Some individuals seem to have difficulty establishing a correspondence between sounds and their producers. The inability to link sounds with their sources may involve correlates such as intelligence, auditory memory, the ability to localize sounds, and acoustic discrimination. The end result is difficulty in obtaining meaning from sound and acquiring the use of language as a means of receptive and expressive communication.

The term auditory agnosia refers to an impairment in an individual's recognition of sounds or combinations of sounds and his attachment of meaning to those sounds. The problem is not one of acuity. The person is aware of sounds and hears sounds but does not relate these sounds to other experiences.

When the auditory agnosia is confined to speech sounds, it is described as word deafness or auditory aphasia. In some cases auditory agnosia is confined to nonspeech sounds such as mechanical or animal noises. Also, an agnosia for musical sounds, melody patterns, and rhythm has been reported. Myklebust (1957) distinguishes between auditory agnosia and aphasia as follows:

> * * * the aphasic finds all sounds in his environment useful and meaningful with the exception of the spoken word. In contrast, the auditory agnosic not only cannot use these spoken sounds in this environment but he cannot attribute meaning to any sounds in his auditory world (p. 511).

Myklebust points out:

> Severe auditory perceptual disturbances and auditory agnosia are highly similar in symptomatology but comparatively the condition of agnosia seems to be considerably more severe. It seems that an auditory agnosia does not occur unless an aphasia also is present (p. 511).

The person with an agnosia for acoustic stimuli is unable to recognize sound patterns and requires training to establish associations between sounds and situations, sounds and their sources, and sounds and actions.

In 1869 Bastian (1898) described "word deafness" in which the adult subject was able to hear, but was unable to recognize words. Wernicke (1874) hypothesized the location of the general auditory speech area of the brain in the first temporal convolution. A loss in this area was found to produce a loss in understanding speech. Nielsen (1948) reported cases in adults which show that word deafness is due to a lesion in the middle third of the first temporal convolution on the major side. Damage to this area seemed to result in failure to recognize spoken words. The adult subject does not understand anything that is said to him, nor can he repeat words, nor write from dictation, but spontaneous speech may not be affected.

In acoustic agnosia the subject is unable to recognize the sounds he hears. Auditory verbal agnosia results from a lesion of Wernicke's area and occasionally from lesions in its vicinity within the temporal lobe.

Directions for Future Research

In contrast to the body of knowledge which has been gathered on hearing acuity, comparatively little research has been done on the processing of auditory stimuli. There is need to more clearly identify auditory processing tasks, and describe and categorize the observable behaviors which are associated with these tasks. There is a need to describe the behavioral symptoms which characterize efficient auditory processing, as well as dysfunctions in auditory processing.

Research is needed to explore the behaviors of auditory processing disorders related to: (*a*) attention to auditory stimuli; (*b*) differentiating sound from no sound; (*c*) sound localization; (*d*) discriminating sounds varying on one acoustic dimension; (*e*) discriminating sound sequences varying on several dimensions; (*f*) auditory figure-ground selection; and (*g*) associating sounds with sound sources. The use of precise terms will help facilitate communication about these behaviors.

Basic research is needed in neurology and biochemistry if we are to link specific behavioral symptoms or clusters of behaviors to neurological and physiological correlates. The present status of technology and the relative inaccessibility to the human brain makes it difficult to study the role of the cortex in auditory functions. While some research has been done, there is need to improve our technology and attempt to increase our knowledge of neurophysiological behavior. Unless this happens, assessment and classification will continue to be substituted for differential diagnosis.

The lack of reliable and valid diagnostic procedures and the lack of standardized terminology make fine diagnostic differentiation a difficult task. DiCarlo (1960), for example, reevaluated 67 children who had been diagnosed as aphasic by other diagnosticians. He found that 28 children were mentally retarded, 15 peripherally deafened, and 20 were emotionally disturbed. He found only four to be aphasic. It is 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 attributed to peripheral deafness, central deafness, mental retardation, severe emotional disturbance, aphasia, or to auditory imperception (Myklebust, 1954). One of the most basic research steps which should be taken is to attempt to provide more detailed and comprehensive descriptions of the behavioral responses to auditory stimuli which differentiate these conditions.

There is some evidence, for example, 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; Wolfe and MacPherson, 1959). There is need, however, to develop diagnostic procedures to further differentiate mental retardation from other etiological factors. Also, children with peripheral hearing losses have been found to use their residual hearing in a consistent and meaningful manner (Myklebust, 1954; Whitehurst, 1961).

Children who give consistent, although frequently incorrect, responses to an auditory stimulus are typically classified as "peripherally deaf." On the other hand, children who respond inconsistently are typically classified as "centrally deaf," "auditory agnostic," or "auditory aphasic" (Hardy and Pauls, 1959; Wepman, 1960; Monsees, 1961).

Myklebust (1954) hypothesizes that the inconsistent responses of so-called asphasic children may be due to fluctuations in attention, not to differences in sensitivity in auditory stimuli of different frequency. If this is true, then 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 operationally defined procedures for measuring these variables and obtaining clinical information.

There is need to conduct studies on neurological abnormalities which may help differentiate children suffering from peripheral deafness, central deafness, and aphasia. A study of 183 aphasic and deaf children was conducted by Goldstein, Landau, and Kleffner (1960). They found that 32 percent of the aphasic population had no neurological abnormalities. Approximately 40 percent of both the aphasic and deaf children had abnormal encephalograms. Only gross neurological abnormalities and a few etiological categories were found to differentiate deaf from aphasic children. Goldstein et al. (1960), also reported that an autopsy of a 10-year-old child with aphasia and near-normal hearing revealed extensive bilateral degeneration of the auditory areas of the temporal lobes and of the medial geniculate nuclei. The authors state, however, that a large portion of their aphasic population failed to show clinical or laboratory evidence of extensive lesions. Further research is needed to develop diagnostic techniques for establishing the presence of neurological correlates.

Both central and peripheral disorders can have a disrupting effect on language acquisition. For this reason, it is necessary to more clearly define those behaviors which are associated with central and peripheral auditory disorders, and develop procedures to differentiate between the two conditions.

One approach to differential diagnosis is to place the child in a teaching situation, observe his performance and maintain records of significant behaviors (Monsees, 1961; Bangs, 1961; Reed, 1961). Longitudinal studies of children for whom the etiology of a certain condition is known will add easily verifiable data to the present mass of speculation. There is need to record the behavioral responses which are obtained through diagnostic teaching. Information of this kind may help identify the behaviors and learning characteristics of children with different etiological conditions.

The literature concerning the evaluation of auditory capacity and behavior is quite extensive (Ewing and Ewing, 1944; Hardy and Bordley, 1951; Barr, 1955; Lowell, Rushford, Hoversten, and Stoner, 1956; Reichstein and Rosenstein, 1964). At present, however, clinical observation of behavioral symptoms seems to provide the main basis for assessment, evaluation and diagnosis. There is very little experimental evidence to support these clinical observations, and there is need to conduct systematic investigation in these areas.

To better evaluate children with auditory processing disorders, there is need to develop more effective procedures for presenting auditory stimuli, eliciting responses, and increasing the number of response modes. Greater efficiency in selecting the stimulus mode of input, the method of indicating response, and motivating the child to respond may help reduce the amount of response inconsistency. Recent advances in electronics should help accelerate study of the reception and processing of auditory stimuli.

A thorough assessment and diagnosis often requires skill and training beyond that of the individual practitioner. The otolaryngologist, pediatrician, neurologist, psychiatrist, psychologist, audiologist, speech pathologist, and educator all have specific contributions. Research is needed, however, to develop and recommend administrative alternatives for mobilizing these individuals and creating administrative structures which will permit them to work as a team.

The purpose of auditory training is to help the child make active use of his hearing. This concept has been implemented in working with the residual hearing of hard-of-hearing children but comparatively few studies have been reported concerning the training of auditory perceptual disorders. As in many other areas of perception the literature is heavily weighted in favor of diagnosis and the development of diagnostic procedures. There are a few studies which indicated that some degree of amelioration is possible. Unfortunately, these studies often fail to provide a detailed description of the remedial procedures which are used or the nature of the disorders to which remediation was applied. The methods section of reported studies often consists of abbreviated lists including such topics as hearing and distinguishing sounds; listening games; listening to contrasting sounds, loud and soft, fast and slow, high and low; following directions; hearing through poetry; listening through stories; music to develop sound discrimination; reproduction of auditory stimuli; and auditory memory training. Despite the lack of detail in reporting remedial approaches, there seems to be clinical agreement that training should be attempted in the deficit areas.

There is need to identify and distinguish the different auditory activities and develop specific remedial approaches for these activities. Table 2, for example, attempting to make distinctions between seven different kinds of auditory activities, provides some direction for developing specific remedial procedures.

A basic research question which needs to be answered is to what extent can remedial effort establish or restore behavioral processes which have been disturbed by organic damage? Luria (1966) has observed that the elementary physiological functions such as sight, hearing, touch, or simple movements are disturbed after lesions of the corresponding areas of the human cerebral cortex and are practically incapable of regeneration. In contrast, however, the more complex forms of mental activity which are affected by local brain lesions are more responsive to retraining. Studies have been conducted to show the success of active attempts of individuals to overcome a defect, and while destruction of certain areas is irreversible, in many cases the complex behavioral processes which have been disturbed by damage may be restored. The way in which this takes place, however, is not clear (Goldstein, 1942; Luria, 1948).

Other practical research questions which need to be answered are: How can the principles of learning be applied to help expedite the remediation of auditory processing disorders? How can we help children attend to auditory stimuli; associate sound with experience; reinforce learning through concrete objects, pictures, gestures, and pantomime; retain sound sequences; reorganize and recall word names; analyze sound sequences; synthesize isolated sounds; retain melody and rhythm patterns; differentiate significant from insignificant stimuli; localize sound; and discriminate between sounds?

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CHAPTER 3

VISUAL PROCESSING

This chapter is concerned with central dysfunctions in which the subject can see, but experiences difficulty in: (*a*) visually examining the individual details of an object; (*b*) identifying the dominant visual cues; (*c*) integrating or combining individual visual stimuli into simultaneous groups and obtaining meaning from the object; (*d*) classifying the object in a particular visual category; and (*e*) comparing the resulting visual hypothesis with the actual object as it is perceived. This process for receiving, integrating, and decoding or interpreting visual stimuli has been commonly referred to as visual perception.

For many years, traditional psychology and education viewed visual perception as a passive process, which was mainly dependent upon the stimuli reaching the sense organs. Thus, the visual perception of an object simply resulted in the direct and passive visual reflection of that object. There are a number of research studies, however, which indicate that the processing of visual stimuli is not only a more complex act than previously supposed, but a highly active and investigatory process as well. Table 5 presents an outline for the processing of visual stimuli. These eight stages help point out the complexity and the active nature of visual processing operations. The subject actively scans the object, identifies the significant visual cues, and attempts to integrate them into a simultaneous spatial construct. The visual image is tentatively put into a category and compared with the actual object as it is perceived. If the visual image is consistent with the object, the person terminates the perceptual activity. If the visual image and the actual facts are in disagreement, corrections are introduced into the previous visual hypothesis.

Objects which are unfamiliar to the viewer may require all eight stages. In contrast, the process for perceiving familiar objects is more brief. Complex visual objects which are familiar to the viewer can be identified from one dominant sign, and verification that the image is correct takes place almost instantaneously (Gibson, 1966).

It is important to note that the central processing of visual stimuli actually begins with the identification of visual cues. While operations such as receiving visual stimuli, orienting the head and eyes to the light source, and scanning the object do not represent central processing operations in the strictest sense of the word, they are intimately concerned in the process of perception.

The Mechanism for Processing Visual Stimuli

In reviewing the research, it seems that the visual processing mechanism consists of three major parts: (*a*) The ocular-musculature as an adjustor; (*b*) the eye as a transducer; and (*c*) the cortex as a visual processor. This section will present a brief discussion of these mechanisms and their relationships to the central processing of visual stimuli.

The Ocular-Musculature as an Adjustor

The significance of eye movement in "visual perception" has not been made clear. Both autonomic and voluntary movements are intertwined in the complex act of seeing. Morgan and King (1966) point out that the ocular-musculature is never at rest. According to Yarbus (1956), lasting visual impressions require minute muscular movements of the eyes which continually alter the position of the image on the retina. These frequent eye jumps cause the object to be viewed by new receptors. Thus, the electromagnetic

Table 5.—Steps in the Processing of Visual Stimuli

1. Receive visual stimuli.
2. Orient head and eyes to the light source.
3. Scan the object.
4. Identify the dominant visual cues.
5. Integrate the dominant visual cues.
6. Tentatively classify the object in a visual category.
7. Compare the resulting visual hypothesis with the actual object as it is perceived.
8. Confirm comparison or introduce corrections into the previous visual hypothesis.

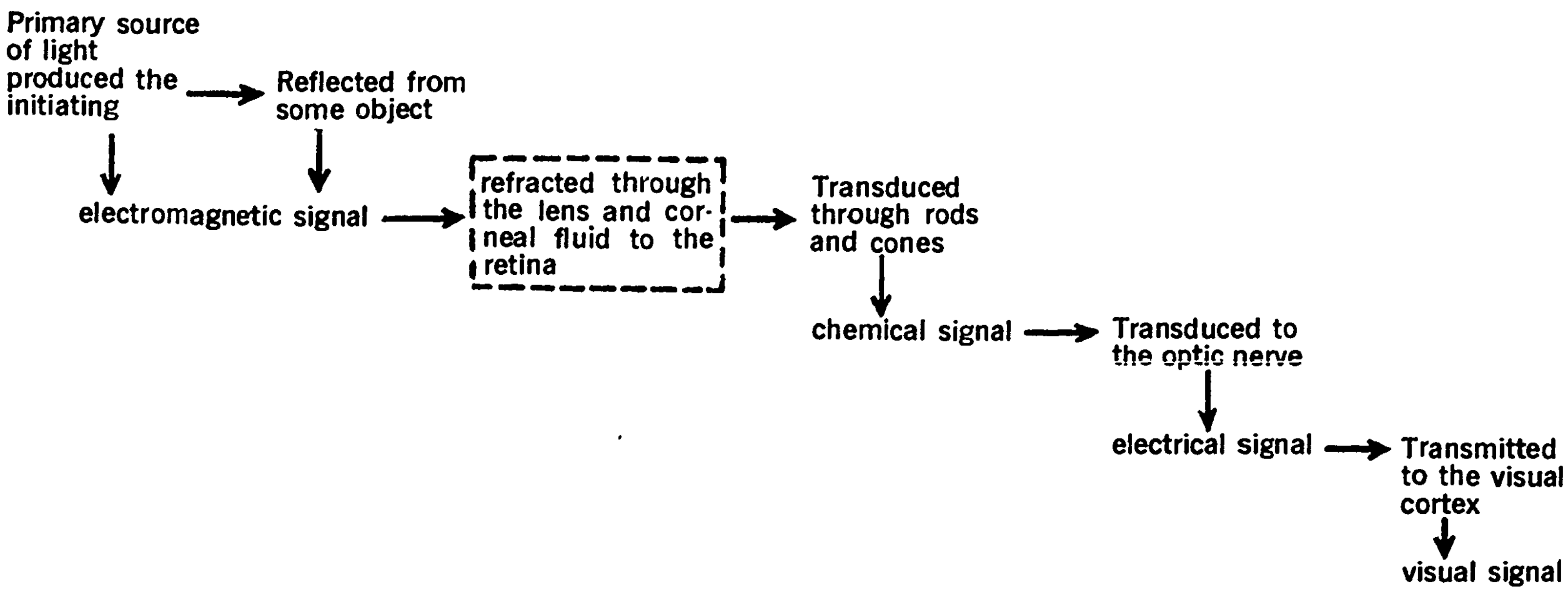

Figure 3.—The Transduction of Visible Stimuli

excitation is spread over a fairly wide area of the retina which probably prevents fatigue of the receptor elements. These extremely small tremors of the three pairs of eye muscles (saccadic movements) are essential to vision (Riggs, Ratliff, Cornsweet, and Cornsweet, 1953). When an image falls on a single immobile point of the retina for a period of 2 to 3 seconds, it will no longer be perceived (Yarbus, 1956).

In addition to the constant automatic or reflex movements of the eye muscles, the eye actively searches for information in the visual world by scanning the optic array (approximately 140° horizontally and 120° vertically). Scanning is accomplished by using the three pairs of opposing eye muscles to move the eyeball. An exact and subtle nervous system maintains the center of fixation upon both foveas at the same time. Gibson (1966), in comparing the eyes to the front wheels of an automobile, says that the eyes would move as if connected by an invisible tie rod. Failure to develop control may result in poor information transmission. "Each eye can no longer explore the array on its own, for the saccadic movements have what is called compulsory conjugation. Rotations are equal in angle and synchronized. This is necessary, of course, if the fixations are to coincide at the end of a movement. The same is true of pursuant movements." (Gibson, 1966, p. 177)

The Eye as a Transducer

For visual perception to occur, light waves must be transmitted to the central cortex, which presupposes a certain degree of sensitivity of the retina to visible light. The human eye is responsive to two classes of visible light. The first represents the original or primary source of light, which is transmitted through the atmosphere, and impinges directly upon the eye. The second class of visible light is referred to as luminance or reflected light, which is the light that is reflected by leaves, houses, automobiles, pictures, lines, printed words, and other tangible objects which are not primary sources of light.

Figure 3 is a schematic description of the changes which occur to the original light waves emanating from the light source until they reach the visual cortex as electrical signals. The primary or secondary light source produces electromagnetic signals which are transmitted through the lens and corneal fluid to the retina. The ciliary muscles attached to the ligaments holding the lens in place contract so that the lens becomes flat and thin to bring far objects into focus on the retina. When the ciliary muscles are relaxed, the lens becomes curved and thick and near objects are brought into focus on the retina. The rods and cones in the retina transduce the electromagnetic signals into chemical signals which are in turn transduced into electrical signals at the optic nerve. The electrical signals are then transmitted to the occipital cortex.

The Cortex as a Visual Processor

Information on the structure and function of the central nervous system mechanism for visual stimulus processing comes from two main sources: Direct stimulation of the exposed brain, and the study of patients with brain lesions. Extensive investigations of the results of electrical stimulation of the exposed brain are reported by Penfield (1958), Penfield and Jasper (1954), and Penfield and Roberts (1959). Extensive reviews of the literature on cerebral dominance were compiled by Kirk (1935) and Downer (1962). Most of the data are gathered from adults, and consequently few conclusions can be drawn about the development of the visual system.

It is generally accepted that the retina is an outward extension of the cerebral cortex. The retina of each eye is divided along a vertical line into two halves. Optic nerve fibers transmit sensations from the retina in each eye to the visual cortex of the brain. The optic nerves which lead from the outside halves of each eye transmit sensations to the homolateral hemisphere of the brain. Nerve fibers from the interior or nasal halves of the retina cross at the optic chiasma and transmit sensations to the contralateral hemisphere. The net result is that visual information is relayed through each eye to both hemispheres, and the electrical impulses arising from the retina are transmitted along the optic fibers to the lateral geniculate body and nuclei of the thalamus to the visual areas (areas 17, 18, and 19) of the occipital region of the cerebral cortex.

Studies of animals have shown that extirpation of the occipital portion of the cortex markedly impairs visual discrimination (Lashley, 1930, 1942; Klüver, 1927, 1937, 1941; Chow, 1952; Mishkin and Pribram, 1954). Complex discrimination tasks which required selective discrimination in size, shape, and color were most seriously disturbed by damage to the occipital lobes, whereas the ability to recognize light was not destroyed. These findings suggest that one of the more important functions of the occipital cortex is the analysis and synthesis of visual stimuli. It should be noted, however, that postoperative disturbances may be dependent not only upon destroyed striate area, but upon other regions of the cortex as well. In studying the discrimination of complex visual patterns in rats, Kirk (1936) found that the habit of reaction to a complex visual pattern in terms of relearning is closely proportional to the extent of the lesion, and is not mainly dependent upon the destruction in the area striata or the posterior cortex.

The frontal lobes have been identified as an anterior ocular-motor center for voluntary eye movement. A lesion in the frontal lobes, which disrupts the voluntary control of the eyes, will interfere with active visual investigatory activity (Holmes, 1919, 1938). There is need, however, to study the interrelationships between the occipital and frontal lobes with respect to the processing of visual stimuli.

Many individuals consider motor development to be an important part of the development of vision. Getman (1965) notes that development of vision is dependent upon the motor development of the child. Flavell (1963) described Piaget's theory of sensory-motor development in relation to the development of vision. Dunsing and Kephart (1965) also emphasize the importance of what they term the perceptual motor match.

These is need to conduct additional research on the mechanism for processing visual stimuli. The functioning of the ocular-musculature as an adjustor and the cerebral cortex as a central processor need further investigation. Also, it is important to clarify the interrelationships between the two.

Visual Processing Tasks

Because of the vague and ambiguous terminology and the sketchy procedural descriptions in many research reports, it is difficult to identify specific visual processing tasks. Furthermore, a false distinction seems to have been made between peripheral acuity and central processing perceptual tasks. In reviewing the literature it becomes obvious that there is no clear-cut boundary between visual acuity and the processing of visual stimuli. Instead, there is a continuum of tasks. Nevertheless, for purposes of reporting the research literature, this continuum has been divided into two main classes.

The first class of visual processing tasks consists of the ocular-motor tasks, which are responsible for the reception of visual stimuli. The second class of visual processing tasks are cognitive tasks, which require the analysis and synthesis of visual information.

The discussion of each task will include descriptions of the: (*a*) procedures used to assess performance on these tasks; (*b*) different kinds of visual processing dysfunctions; and (*c*) training procedures which have been developed to ameliorate or compensate for these dysfunctions.

Ocular-Motor Tasks

Ocular-motor tasks include distinguishing light from no light, seeing fine detail, binocular fusion, convergence, and scanning. The relationships between these ocular-motor tasks and visual processing have not been fully explored. According to Gibson (1966), the eye receives visible light and transmits visual information. There is evidence that performance in ocular-motor tasks affects visual processing. As previously noted, the retina is an extension of the cerebral cortex. The importance of the autonomic saccadic eye movements to the continual registration of retinal images has also been discussed. This section will describe the major monocular and binocular motor tasks which have been identified and which are related to the processing of visual stimuli.

361-752 O—70——3

1. *Distinguishing Light From No-Light.* Sensitivity to light is a prerequisite to "visual perception." Without this sensitivity electromagnetic signals cannot be transduced to chemical and electrical signals which are directed to the occipital cortex. The usual procedure for determining sensitivity to light is to present a visible stimulus to discover if the subject can detect light from no-light.

2. *Seeing Fine Detail.* The amount of visual stimuli which is processed is determined, in part, by the detail which can be discriminated. Tests of visual acuity attempt to assess the extent to which the eye or eyes can discriminate details of a series of objects gradually decreasing in size.

Most tests of visual acuity are presented first to one eye and then to the other. Acuity is typically measured by performance on a standard set of printed designs. The Snellen chart, designed to test vision for objects 20 feet from the person, measures responses to the printed letter E. Children are asked to tell which way the "fingers" of the E are pointing, or to point with their own finger or hand in the same direction. The apparent size of an object varies with its distance from the eye. By varying the actual size of the object, symbol, or picture, the distance at which the person can effectively see and report details can be estimated. The Landolt ring, a form shaped like a capital C, and the parallel bars, two rectangles, are also used to assess visual acuity. The person being tested indicates the direction in which the white space points in the Landolt ring, or whether he sees two bars or one. Unless the child has shown such behavior as squinting, holding things close to his eyes, and not recognizing objects and people across a room, examinations for visual acuity are typically not performed until a child enters school.

Organic conditions such as cataracts, tumors, glaucoma, lack of color vision, or damage to the retina will reduce sensitivity to visual stimuli. Failure to respond to light can also be due to damage to the occipital cortex. Total destruction of the occipital cortex of both hemispheres has been found to result in central blindness.

Partial lesions may lead to a blind spot or visual loss in part of the visual field. Teuber (1960a) has shown that the visual area which remains intact continues to function and helps compensate for the deficit caused by the constricted visual field. Luria (1966a) cites case studies by Potzl where lesions of the projection divisions of the occipital cortex are accompanied by hemianopsia, in which the visual field became blurred for a short time or was partially lost, and compensatory eye movements tended to occur.

When damage occurs to the occipital cortex in only one hemisphere, partial blindness, hemianopsia, will occur in both eyes. Half the visual field in both eyes will be affected (Morgan and King, 1966). If the right occipital cortex is damaged, for example, blindness will occur in the outside half of the left visual field and in the nasal half of the right visual field. A lesion which extends outside the primary visual cortical fields, however, may produce different effects. A unilateral lesion involving the parieto-occipital area may result in a hemianopsia which is not compensated for by eye movements. To test the visual fields, the subject is asked to gaze at a fixed point and report the appearance of a second object at the periphery (Luria and Skorodumova, 1950). These conditions are medical problems and should be diagnosed and treated by an ophthalmologist and neurologist.

3. *Binocular Fusion.* Since the visual fields overlap, visual information coming to the brain from the overlapping portions of the visual fields must be integrated into a single set of visual information. The process of integrating the visual fields is binocular fusion.

If one eye is different in refractory power, the quality of the images reflected upon the retinas will differ, and so will the information transmitted to the cortices. This can result in interference between the two sets of information. Some children apparently suppress the image coming from the less effective eye. After several years, information coming from that eye may not be interpreted, and the end result is that the eye is not functioning. If a structural muscle defect prevents an eye from rotating sufficiently, surgery by an ophthalmologist may be needed.

Screening tests for binocular fusion include the Keystone Telebinocular, the Ortho-Rater, and the Massachusetts Vision Test. Care must be taken to ensure that the child knows what is expected of him during the test. Poor binocular fusion is a medical problem and should be diagnosed and treated by the medical profession.

4. *Convergence.* Muscular imbalance can contribute to poor convergence. Coordinated movements of the eyes are necessary for focusing an image on the fovea. In some cases vision training has been instituted by optometrists, more than any other professional group, in an attempt to provide eye muscle training for the separate and coordinated action of the ocular-motor musculature. Vision training usually consists of eye exercises designed to develop: (*a*) More efficient patterns of ocular behavior for reading and other

ocular tasks, (*b*) divergence-convergence relationships, and (*c*) accommodative facility. Many ophthalmologists do not believe these exercises to be beneficial for most patients.

Taylor and Solon (1957) found that no more than 35 hours of training were needed to develop adequate convergence and about 15 hours to establish comfortable vision, provided that the problem has not been complicated by squinting. Strabismus (crossed-eyes) may require from 75 to 200 hours of training before eyes can be coordinated well enough to respond to a visual examination. Waldstreicher (1962) and Getman and Hendrickson (1966) have also reported remedial programs stressing vision training.

Several methods of vision training have been summarized by Lambeth (1966). For the most part, methods used in vision training are not described in detail and there is little research evidence as to the effectiveness of these training procedures either in ameliorating eye-muscle disorders or improving the processing of visual stimuli.

5. *Scanning*. Gibson (1966) identifies three kinds of scanning tasks in which the eye scans the surface and briefly fixates the image upon the fovea. The first is the natural zig-zag scanning that occurs when a child looks around the room. The second is the pursuit or tracking of a moving object which can be done by one eye at a time. Third is the learned systematic scanning, which is required for reading.

An assessment of scanning performance may include an investigation of both the reflexive and psychomotor systems (Luria, 1966a). The elementary reflex system refers to "* * * the reflex fixation of the point to be perceived by a movement of the eye so that the projection of this point lies in the central visual field (fovea)." (p. 358)

Damage to the brain stem or to the posterior ocular-motor centers of the cortex disturbs the elementary reflex fixation of the point in the central visual field. Moving a light source in an arc at a fixed distance is a way to check if the subject can follow the light by moving his eyes and/or by turning and orienting his head toward the object.

Complex or psychomotor movements refer to the direction of the gaze in response to a verbal instruction or in accordance with the patient's own intention. This is a more complex act than the reflex and requires the use of the second signal system. The second signal system refers to the control of motor behavior through verbal mediators. Luria and Homskaya (1962) state that lesions of the anterior ocular-motor centers or of the frontal lobe lying anterior to these centers may disrupt the eye movements used in the active investigation of an object.

Psychomotor functioning can be measured by asking the patient to look right or left or to the side opposite the object. If the eye movements are the same with respect to speed, range, and steadiness, both the reflexive and psychomotor systems are intact. If the reflex movements are intact, but the psychomotor movements are impaired, the cortical apparatus may be defective. In these cases, special laboratory methods may be used to obtain graphic recordings of eye movements through motion pictures. Instruments may be used to record the movements of the pupil, or to trace the movements of a spot of light reflected from a mirror attached to the cornea.

In testing scanning, the tasks which are presented to one eye at a time may be presented to both eyes at the same time. In an ordinary scanning task, the subject is allowed to visually explore an object or a picture, while his eyes and head movements are observed. Disturbances of the visual field may result in altered search patterns.

A number of studies suggest that frontal lobe damage interferes with the ability to actively search, scan, or examine objects. Lesions in the frontal lobes may result in a "pathological inertia" of the sensory process which apparently interferes with the motor scanning aspects of perception.

Another syndrome, involving frontal lobe lesions, consists of difficulty in examining the picture or object due to passive looking, or slight shifts of the gaze from one point to the next. Little effort is made to actively seek out the identifying signs. When conclusions are reached about the picture, statements are made with confidence, and with no attempts at correction, even if the examiner asks the subject to study the picture more carefully. In some cases detail which is reported from one picture is incorrectly reported in subsequent pictures in which that detail is either absent, or no longer significant.

Apparently, frontal lobe lesions may also result in difficulty in perceiving fast moving objects (Cohen, 1959; Teuber, 1960b). There are four main variables in tasks involving the tracking of a moving object: (1) The amount of head and/or body movement permitted or required; (2) the speed of movement of the target; (3) the angle through which the target is moved; and (4) the response required. When performance on pursuit tasks is being tested, the subject may be requested to hold his head still, or he may be allowed or requested to move his head. The target, usually a point of light or a small object, is moved through a wide arc in several planes: up-down, side-to-side, closer and farther away. The speed and the angle of the motion may be varied. The subject may be required to name certain details on the object, or merely to follow the target.

It should be noted that most ocular-motor visual processing tasks are closely related to school oriented tasks such as reading, writing, and arithmetic. Referral for examination, therefore, is typically made after failure on some school-related task. The initial observation of a deviant behavior, however, is often made by the parent, a pediatrician, or a teacher or school nurse. Parents notice such aspects as clumsiness, crossed eyes, or poor performance in ball-playing activities. Pediatricians notice physical abnormalities such as crossed eyes and inflammations. Teachers notice behaviors which are typically found on checklists such as excessive blinking, rubbing the eyes, unusual head positions while reading, and physical symptoms, such as tearing, inflammation, and redness of the eyes (Betts, 1954; Bond and Tinker, 1967). There is need to develop checklists for parents and teachers which will help in the early identification of visual problems.

If problems can be identified, then the child can be referred for further assessment and treatment to medical and surgical specialists such as an ophthalmologist and pediatrician or to an optometrist who is trained to correct refractive errors and to detect certain structural and functional abnormalities.

The course of development in atypical individuals has been studied, as has the functioning of individuals who have developed normally and then through injury do not perform adequately.

In order to study the possible effects of brain damage on visual acuity, eye muscle control, and other aspects of visual stimulus processing, a number of investigations have been conducted on cerebral palsied children. Cruickshank, Bice, and Wallen (1957) found that sensory (acuity) defects among cerebral palsied subjects differed little from sensory defects found among the normal population. Performances in visual perception and figure-ground differentiation were slightly poorer among the cerebral palsied, particularly the spastic cerebral palsied. These findings are consistent with the literature reported prior to 1957.

A study of cerebral palsied children by Abercrombie (1960) found that visual processing difficulty with certain tasks may be due to uncoordinated eye movements, or eye-hand incoordination. Faulty eye movements may result in disordered pattern discrimination, which might influence perceptual and visual-motor ability. Abercrombie raised the possibility that developmental lags or arrested development might contribute to problems in these areas.

An investigation of visual processing disorders in normal, spastic, and athetoid children by Wedell (1960) found that impairment is generally limited to the spastic group, where one would expect to find greater impairment in the control of the eye muscles. It is difficult to interpret data from investigations of persons who do not have adequate voluntary control over the skeletal muscular system. Frequently, the type of response required is not explicitly reported in the literature, and consequently statements are made concerning the effect of poor eye-hand coordination on visual perception.

Cognitive Tasks

According to Webster (1965) cognition includes both awareness and judgment. The processing of visual stimuli at the higher cortical levels involves: (a) visual analysis, the separation of the whole into its component parts; (b) visual integration, the coordination of mental processes; and (c) visual synthesis, the incorporation or combination of elements into a recognizable whole. A review of the literature reveals a variety of cognitive tasks requiring the analysis, integration, and synthesis of visual information. While it is recognized that these cognitive tasks are all interrelated, for purposes of presentation, these tasks will be discussed under three major groupings, spatial relationships, visual discrimination, and object recognition.

1. *Spatial Relationships.* Body orientation and spatial relationships are among the first visual processing tasks which the infant and young child begin to acquire, and they are among the last to be fully developed (Piaget, 1935). Spatial awareness includes awareness of space which is located left and right, before and behind, above and below the child's own body. Initially, spatial orientation is ego-centered. Physically, the universe centers around the child. The child gradually develops an awareness of space through input and feedback of the visual, muscular, and vestibular mechanisms.

Dysfunctions in spatial orientation are said to be characterized by: (*a*) Difficulty in left-right discrimination; (*b*) avoidance of crossing the midline of the body with the hand; (*c*) poor depth perception; (*d*) reversals such as, b/d; (*e*) rotations such as, p/d; and (*f*) difficulty in perceiving one's own body in space (Nielsen, 1962; Kephart, 1960).

Children with these dysfunctions typically have trouble placing their hands in a particular position;

matching shapes of geometric figures; maintaining their sense of direction; differentiating vertical from horizontal; copying geometric figures, letters, or numbers; dressing themselves; reading; telling time; or using maps. Situations or tasks which require the differentiation of symmetrically opposite points (b/d) are particularly difficult (Holmes, 1919; Gerstmann, 1924; Head, 1926; Bender and Teuber, 1947, 1948; Critchley, 1953; Hécaen and Ajuriaguerra, 1956).

Spatial disorientation has been attributed to damage to the occipital cortex and to cortical lesions in the infero-parietal and parietal-occipital areas (Nielsen, 1962; Luria, 1966a).

Diagnostic procedures for disorders of this kind include investigation of the motor functions of the hand, the perception of pictures which are disoriented to the reader (upside down, etc.), graphic tests for the spatial arrangement of lines, and correct orientation to the parts of figures forming mirror images. Luria (1966a) reports the development of tests for spatial orientation, utilizing maps, floor plans, or routes by Kolodnaya (1949, 1954) and Shemyakin (1940, 1954). Money (1962) has developed a Road Map Test.

Tests for visual orientation with respect to spatial relationships include tasks such as the construction of patterns or figures from wooden blocks which require visual-spatial preservation and the breaking up of homogeneous parts of a pattern into their component spatial elements (or vice versa).

Tests which measure the complex performance of intellectual operations in space are often focused on the solution of mechanical problems, the ability to trace spatially presented movements, and construction of squares of a certain color using small cubes which have sides painted different colors. (For example, the Block Design Test of the WISC.) Luria suggests that such tests are valuable because they reveal specific types of difficulty and provide qualitative insights into the nature o.. the child's performance.

The status of development of assessing spatial orientation tasks is primitive. This may be due to the lack of: (*a*) specific descriptions of the significant behaviors which characterize correct and incorrect performance on these tasks; (*b*) information as to the specific stimuli which are effective in eliciting these behaviors; and (*c*) systematic instructions which ensure that the subject understands what is expected of him. There is need for future research to develop behavioral tests, and, if possible, link performance with etiological factors.

Luria (1963) describes a type of "afferent apraxia" in which the subject is able to execute purposive behavior and preserve basic spatial coordinates and kinesthetic sensitivity, but is unable to perform a gesture or action of a symbolic or descriptive nature. Kirk (1961, 1968) has termed this type of communication "motor encoding" or "manual expression." While he can functionally dial a telephone, he may be unable to imitate the dialing of a telephone.

Approaches to compensating for these disorders consist of analyzing the motor act and providing the subject with various aids such as logical explanations of motor sequences which are involved in the movement, utilizing kinesthetic feedback and concrete guides. This approach usually consists of providing general principles in a problem area which can be transferred to other tasks which are somewhat related. Unfortunately, subjects with low verbal ability or who have difficulty generalizing or applying principles may not benefit from this approach as much as subjects who have these skills.

Training activities in spatial disorientation usually begin with teaching the subject to orient to different parts of his body and then to his environment. Strategies for handling spatial problems are introduced whenever possible.

Kephart (1960) writes:

> The early motor or muscular responses of the child, which are the earliest behavioral responses of the human organism, represent the beginning of a long process of development and learning * * *. To a large extent, so-called higher forms of behavior develop out of and have their roots in motor learning. (p. 35)

Kephart (1960) believes that perceptual skills and motor skills should not be considered as two separate activities. Since perceptual skills provide continuous feedback for coordinating motor movements, he believes that perceptual-motor ability should be considered a combined activity.

There are several assumptions which have been made about the interrelationship between visual perception and motor ability. The first assumption is that visual perception is dependent upon learning gross motor skills. This implies that disorders in gross motor skills should be corrected before training in visual perception is undertaken. Another assumption which has been made with respect to the development of perceptual-motor skills is that if a stage of the developmental sequence is not attained, failure will be experienced at the higher stages. Brain-injured children who have failed to develop motor abilities, for example, are believed to have gaps in their developmental patterns.

There is little empirical evidence, however, supporting the hypothesis that basic perceptual-motor training leads to improvement in perceptual-motor abilities or to better academic performance.

There has been an interest in sensory-motor training for many years. As early as 1846, Seguin developed an educational approach which was based on physiological and neurological hypotheses. Seguin divided the nervous system into two parts: the peripheral and the central nervous systems. Disorders in each of these systems would result in isolating the individual and "locking his learning processes."

Seguin attempted to ameliorate these deficiencies through muscular and sensory training. Deficiencies in the peripheral nervous system were trained through sensitivity of the receptors. If the problem was assumed to be in the afferent pathways, the subject was given a series of quickness exercises based upon imitation. If the problem was central, Seguin tried to develop sensitivity by stimulating the cortex into activity with contrasting stimuli. He hypothesized that the stimuli were more apt to be received if they were presented successively at fast rates.

Basic motor skills were taught which began with gross muscle movements and progressed to fine muscle movement. Immobility was taught first, followed by balancing, which was thought to be the primary pivot skill for other movements. Seguin placed great importance on the tactile function, and trained activities such as seizing, holding, letting go, and handling objects appropriately. He also attempted to train taste and smell.

Seguin taught passive, receptive vision of general impressions, and active meaningful perception of seen events. He began by training attention to the stimuli. He used cards, balls, ribbons, fruit, and other objects to train appreciation of color. Awareness of distance, form, and spatial planes was also taught. Listening skills included the passive reception of auditory sounds into meaningful perception of selected sounds and avoidance of other sound impressions. Seguin also provided training in speech, reading, and writing. These activities were primarily done through imitation techniques aided by the sense of touch and the use of flashcards and concrete objects.

More recently, Kephart (1960) has developed a training program for developing perceptual-motor abilities in children who have "suffered breakdowns in perceptual-motor development at one of the earlier stages." Kephart's method is concerned with sensory-motor abilities which are basic to visual-perceptual abilities. Training procedures are based upon specific diagnosis of perceptual-motor development, and are directed at the most basic area of weakness. As performance improves, instruction is shifted to "higher" activities. Kephart emphasizes the importance of developing generalizations, especially motor generalizations, as soon as possible. In order to do this, he has designed activities which appear to transfer to other situations. Although Kephart's program is concerned primarily with perceptual-motor development, it includes verbal language activities of comprehension and expression. For example, he sometimes requests that the child state what he is going to do, tell what he is doing, and afterwards, tell what he has done. Kephart repeats activities which have been mastered in order to reinforce and integrate these activities with new ones.

The sensory-motor training program trains gross motor skill and involves such activities as bounce-to-rhythm, whole body movement, balance-on-board, and movement of differentiated body parts. Chalkboard training improves the development of eye-hand coordination and directionality through scribbling, pursuit, drawing, and copying tasks. Ocular control is developed through ocular pursuit activities, binocular and monocular training, and games which involve a visual component. These activities are designed to establish muscular control of eye movements and to coordinate these movements with other body movements. Form perception training is intended to develop discrimination between object shapes and figure-ground relationships by putting puzzles together, making stick figures, and forming designs. Kephart focuses attention on what the child is doing and the process which he is using. He describes each task in terms of the terminal behavior, the operations necessary to accomplish it, and the rationale of the activity.

It is interesting to note the similarities between the approaches taken by Seguin and by Kephart. Both are concerned with the problem of ameliorating disabilities in the perceptual-motor processes, both approaches are based in part on neurological and psychological hypotheses, and both stress importance of differential diagnosis and the principles of child development. Many of the activities and equipment are similar, such as the springboard—trampoline; nails in a board—pegboard; footprints—stepping stones; and candle—penlight.

The major difference between these two approaches is that Seguin directed his method toward severely mentally deficient children, whereas Kephart has developed his program for children with less severe problems. Because of the severity of the cases with which he worked, Seguin placed less emphasis on the verbal aspect of the program than did Kephart.

Painter (1966) studied the effect of a rhythmic and sensory motor-activity program on the perceptual-motor spatial abilities of kindergarten children. The purpose of this study was to investigate the effects of the program on body image, perceptual-motor integration, and the psycholinguistic competence of kindergarten children. Twenty-one half-hour training sessions were given to the experimental group extending over a period of 7 weeks. The children were seen three times a week. The program was carefully sequenced using theoretical constructs suggested by Barsch (1963) and Kephart (1960). Thirty-eight activities were related to nine of 12 movement areas of Barsch's Movegenic Theory. The nine included: Visual dynamics; auditory dynamics; dynamic balance; spatial awareness; tactual dynamics; body awareness; rhythm; flexibility; and unilateral and bilateral movements. These activities involved: See and move; hear and move; balancing for both sides of the body; awareness of one's body in space; feeling and moving; being aware of, identifying and localizing body parts; movement to auditory rhythmic patterns, change in tempo and movement patterns; and moving one side or two sides of the body.

In addition to the Barsch theoretical constructs, some of Kephart's procedures were used. These included: generalization of rhythmic patterns; the sequencing of unilateral, bilateral, and cross-lateral movement; and the changing of uncoordinated or jerky movements to large, sweeping movements, in which the entire musculature of the body was used. The activities were sequenced so that they would progress from the very simple to the more complex as the children developed skills.

The results of the study demonstrated that a systematic program of rhythmic and sensory activity will: (1) affect the level of ability to draw a human figure; (2) ameliorate the apparent distortion of body image concept; (3) improve visual-motor integrity; (4) improve sensory motor spatial performance skills; (5) improve psycholinguistic abilities; and (6) improve the ability to express ideas motorically. Because a small number of subjects were utilized over a short period of time, Painter considers this investigation as a pilot study. The significant aspect of this study is that a carefully designed program was developed and applied under controlled conditions to bring about significant gains in specific learning and skills, such as body image, perceptual-motor integration; and psycholinguistic competence. The implications of the study may be generalized to preschool children or to children who present problems created by minimal brain dysfunction.

The Frostig Program for the Development of Visual perception (Frostig and Horne, 1964) attempts to develop proficiency in visual perceptual abilities. The authors state that the program is designed to be corrective and preventative. Remediation is based on each of the five areas measured by the Frostig Developmental Test of Visual Perception (1963), i.e., position in space, spatial relationships, perceptual constancy, visual-motor coordination, and eye-hand coordination. The program consists of work sheets and exercises designed to ameliorate any dysfunction in visual perception. The exercises include games and physical activities designed to facilitate visual perceptual development. Physical activities include: (*a*) awareness of body parts; (*b*) right-left differentiation; (*c*) eye-movement exercises; and (*d*) gross and fine motor activities. The five areas of visual perception are trained concurrently.

The efficacy of the Frostig remedial program has yet to be evaluated in its entirety. Rosen (1966) investigated the effect of the worksheets in the remedial program. He compared groups of first grade children. Subjects were tested on the Metropolitan Readiness Test and the DTVP at the beginning of the school year, and retested on the DTVP later in the academic year. The experimental group received 29 days training on the Frostig material (30 minutes per day). The control group received 15 minutes extra reading time, while the experiemental group had 15 minutes subtracted from their daily reading period. Results showed that additional reading time was more important than perceptual training, that improvement in perceptual skills was not reflected in later reading ability, and that perceptual training showed increased perceptual ability as measured by the CDVP. Additional research is needed before the results of this study can be accepted or rejected. It is likely that individual gains in perceptual ability may have been obscured by other factors in the experiment. It should be noted that teaching reading itself is perceptual training. Those who teach children to discriminate an A from a B may have more transfer to reading that those who teach children to discriminate a square from a triangle.

While certain training procedures have been developed and clinical reports of progress have been made, specific training programs have not been related to the various behavioral syndromes characterizing spatial disorders.

2. *Visual Discrimination.* There are several kinds of visual discrimination tasks. In the first, the subject is typically presented with several discrete stimuli, usually

differing in one specific stimulus element or quality of the object, and is required to respond to that quality. This task will be referred to as an object-quality or prominent-feature discrimination task. The second kind of visual discrimination task is one in which a complex stimulus is presented and the number of stimulus elements is increased. When the number of stimulus elements is increased, usually by the addition of irrelevant elements, the task is called "figure-ground differentiation." In the third type, the number of stimulus elements is decreased by omitting a portion of the visual detail of the object. This task is called "visual closure."

Visual discrimination is involved in tasks in which the child is to fit three-dimensional forms into holes (Stanford-Binet Intelligence Scale, 1960), point to the pattern which is different (Columbia Mental Maturity Scale, 1954), draw a circle around the letter form which is different (reading readiness tests), copy designs (Bender Visual-Motor Gestalt Test, 1938).

It is unfortunate that so few studies of "disorders" have reported the procedural details of the tasks and the behavioral responses of the children in performing these tasks. It is not uncommon to read inferences such as "poor visual perception" based on performance on a single task wherein the required response was to draw or reproduce a picture or a pattern. Further, there is confusion with respect to the names given to these tasks. In some instances, two different names have been given to the same task. In other cases, the same name has been applied to two different tasks.

Visual discrimination tasks are operationally defined by the stimuli which are presented, and the response which is required. Visual stimuli can vary along different presentational dimensions including: (*a*) number of visual stimuli which are presented; (*b*) rate of presentation; (*c*) duration of presentation; (*d*) color-hue; (*e*) brightness; (*f*) contrast; (*g*) size; (*h*) shape; (*i*) sequential order; and (*j*) motion. Various combinations of presentational aspects define different visual discrimination tasks. Visual stimuli may be presented either at the same time (simultaneous), or at different times (successive). Discrimination becomes more difficult as the total number of visible units in the stimuli increases. The discrimination task is made easier if the subject is familiar with the set of significant features, and if both members of the pair are presented at the same time.

A. Selection on the Basis of Dominant Features: Children have been shown to discriminate dominant features (object qualities, attributes) such as: color and form (Corah, 1964); shape (Ling, 1941); pattern (Dornbush and Winnick, 1966); letter-like forms (Gibson, Gibson, Pick, and Osser, 1962); Greek letters (Shepard, 1957); size (Kagan and Lemkin, 1961); position (Lubker, 1964); brightness (Clifford and Calfin, 1958); area (Welch, 1939); and horizontal versus vertical direction of a stripe (Jeeves, reported in Munn, 1965).

The amount of time it takes an individual to perceive visual stimuli is another variable which affects visual discrimination. A discrimination task usually becomes more difficult as the presentation time of a stimulus item decreases. The effects of intervals shorter than one-half second are complex due to the time needed for the human eye to fixate on more than one point to gain sufficient visual information (Gibson, 1966). A child may be able to successfully complete the tests provided he is given time to study and examine the stimulus material. When the stimulus is presented for only a brief time, as in tachistoscope, he may be unable to perform the task.

A dysfunction in perceptual speed is characterized by extended examination of pictures, perception of only one element at a time, and difficulty in selecting and relating the necessary identification signs. It may be accompanied by an ataxia of gaze and uncertain conclusions about what is seen. These symptoms may be due to lesions of the occipital lobes.

The discrimination of objects differing in one dominant feature may be the first step in the complex task of processing visual stimuli. Simple discrimination is also one of the first steps in assessing performance in visual processing tasks in order to determine which aspect of the complex process is disturbed.

Pictures are presented to the subject and he is asked to name them. This approach is useful in identifying subjects who: (*a*) recognize objects or pictures; (*b*) perceive only one cue; (*c*) identify and synthesize the essential cues of a picture; (*d*) relate them to other signs; and (*e*) draw conclusions from the single cue which has been perceived. Teuber (1962) found that certain visual symptoms appear to be more marked after right than left hemispheric involvement. This suggests that many of the visual perceptive skills are mediated in the right hemisphere.

There are few procedures which have attempted to train discrimination activities. Montessori (1964), for example, developed a set of didactic materials for educating the sense of vision. These materials include a set of objects which differ in size, thickness, length, form, and color. The purpose of the exercises using these materials is to train discrimination of objects and forms. Montessori states that by utilizing the tactile modality, visual recognition of forms is greatly improved.

The application of operant techniques and the use of programmed instruction has been used to ameliorate visual-perceptual disorders. A fading procedure was used by Moore and Goldiamond (1964) to establish visual discrimination in preschool children. Staats and Staats (1963) describe the use of reinforcements to improve discrimination of visual verbal stimuli and reading ability. Programming a task according to operant principles may involve the following steps:

1. Select a form or class of behavior that seems essential to the performance of some everyday (academic) task.
2. Describe the behavior in detailed, objective terms, that is, establish a reliable set of clearly specified criteria.
3. Prepare a sequence of materials and establish a procedure aimed at enabling the individual to perform such a task.
4. Find children who cannot perform as required (even though they possess the necessary biological equipment) or who perform it poorly, and give them training on the sequence.
5. Modify the sequence systematically until the subjects perform according to criterion.

Seguin (1907) attempted to ameliorate visual perceptual deficiencies through muscular and sensory training. Deficiencies in the peripheral nervous system were trained through sensitivity of the receptors. If the problem was assumed to be in the afferent pathways, the subject was given a series of quickness exercises based upon imitation. If the problem was central, Seguin tried to develop sensitivity by stimulating the cortex into activity with contrasting stimuli. He hypothesized that the stimuli were more apt to be received if they were presented successively at fast rates.

There have been a few studies which have attempted to differentiate how the visual-perceptual performance of brain-injured persons is distinguished from the performance of non-brain-injured individuals. Many of these studies, however, attempted to compare brain-injured subjects with familial retardates rather than with normal subjects (McMurray, 1954; Halpin, 1955; Hunt and Patterson, 1958). Total score on a test or error scores are often reported, obscuring qualitative evidence. There is a need for more detailed information which describes the nature of visual-processing performances required in the tasks. Elkind, Koegler, Go, and Van Doorninck (1965) studied the effects of perceptual training on unmatched samples of brain-injured and the familial retarded children. Both groups improved in the perception of ambiguous figures; however, the brain-injured group required more trials and reached a lower level of performance than did the familial retarded group.

B. Figure-Ground Differentiation: The concept of figure-ground differentiation refers to the distinguishing of an object from its general sensory background. According to Rubin (1921) the figure appears to be in front, and the ground consists of those stimuli which are behind the figure. This represents a special type of visual discrimination task. The subject must attempt to locate a stimulus, which has been identified as the figure, despite the distracting effects of competitive visual stimuli which are seen simultaneously by the subject. In order to accomplish this task the subject must attempt to form and retain an image of the figure while he is scanning the total stimulus pattern. Children have been shown to perform this type of task (Munn and Steining, 1931; Gellermann, 1933).

The response modes which are required of subjects in figure-ground tasks vary from task to task. Superimposed figure tasks may require the subject to indicate his choice of figure by drawing around it or on it with a pencil. Some tasks require counting the number of times a certain object occurs. Luria (1966a) describes a task in which the subject is shown pictures which have been scribbled over or superimposed on one another, and is asked to identify the outlines. Luria cites Poppelreuter's (1917, 1918) tests for superimposed figures as examples of early tests for figure-ground discrimination.

The Frostig Developmental Test of Visual Perception (Frostig, 1963) contains a figure-ground task. The remedial program based on the test (Frostig and Horne, 1964) contains especially developed sequentially ordered tasks which presumably train the performance.

More recently, Metzger (1953) has developed stationary optical designs in which searching and scanning for a given figure is made difficult by additional lines.

Some researchers have related poor performance in figure-ground tasks to damage in certain parts of the brain. Strauss and Lehtinen (1947) hypothesized, and Teuber and Weinstein (1956) found that damage to the frontal lobes results in figure-ground confusion, distraction by irrelevant stimuli, and a return to the most prominent element of the stimulus field. Because the figure-ground tasks in the classroom have not been carefully identified and described, little effort has been made to develop training programs to improve performance on a variety of these tasks.

C. Visual Closure: A visual closure task is another special kind of visual discrimination in which the subject is asked to recognize or identify an object, despite the fact that the total visual stimulus is not presented.

The significant features which define and allow recognition of an object or picture are typically given, but not the entire set of features or the entire pattern. He may be required to demonstrate his recognition of it by naming; pointing to incomplete forms of a specified object among a variety of figures; or making the form complete. This task is found in the "Incomplete Man" item on the Stanford-Binet Intelligence Scale, in which the child is asked to complete the picture by drawing. The "Visual-Closure" subtest of the revised Illinois Test of Psycholinguistic Abilities (Kirk, McCarthy, and Kirk, 1968) is another example of a test measuring recognition of incomplete objects. There is need to develop and evaluate training programs to determine whether or not dysfunctions in visual closure can be ameliorated.

3. *Object Recognition* (*Visual Agnosia*). The behavioral phenomenon called "central blindness, mental blindness, or visual agnosia" was described nearly one hundred years ago. Case studies of animals and humans were reported in which the subjects were no longer able to recognize objects, despite the fact that the elementary functions of seeing objects, describing parts of objects, reproducing objects, and avoiding obstacles remained intact (Jackson, 1876; Munk, 1881; Charcot, 1886, 1887; and Lissauer, 1889). This condition was linked with lesions of the occipital and parietal regions of the brain. More recently, animal studies have supported earlier findings that damage to the occipital cortex disturbs the processing of visual stimuli. While the discrimination of shape and color is impossible, the elementary visual functioning such as the gross recognition of light is not so severely affected (Lashley, 1930, 1942; Kirk, 1936; Chow, 1952; Mishkin, 1954; and Mishkin and Pribram, 1954).

In the history of disturbances of visual processes, disagreement existed as to whether visual imperception represented a complex symbolic dysfunction, or a disturbance in visual memory. Recent research suggests, however, that visual agnosia is a dysfunction of the higher cortical analysis and synthesis of visual images.

While the recognition of objects through the visual channel may be impaired, a child may be able to recognize objects through the sense of touch. In cases where damage to the occipital lobes is less severe, tasks which require the recognition of simple objects are completed more easily than are complex visual tasks which are composed of many visual stimuli. For this reason it is necessary to assess the range of tasks from simple to complex.

The underlying disorder seems to be one in which visual processing is incomplete, because the subject is unable to synthesize visual stimuli and integrate them into a unified whole. Instead, the subject focuses on one dominant visual stimulus and guesses. Attempts to integrate two or more stimuli are usually unsuccessful. Birenbaum (1948) found that it is not uncommon for subjects with language ability to attempt to compensate for visual agnosia by converting their visual analysis into a verbal analysis. Subjects were as effective in interpreting parts of pictures as they were in interpreting complete pictures. Narration was used as the mode of compensation.

In mild cases of occipital and occipito-parietal involvement, few signs of visual agnosia appear. For example, the child may be able to distinguish between objects and pictures. In these cases the child may have difficulty perceiving more than one object at a time, thus affecting the integration of elements into groups. Difficulty in shifting the gaze from one object to another is another symptom of mild involvement (Holmes, 1919; Hécaen and Ajuriaguerra, 1952; Yarbus, 1961).

Pavlov (1949) hypothesizes that failure to deal simultaneously with two or more stimuli may be due to an inhibitory effect that occurs when one stimulus creates a point of excitation which in turn inhibits the excitation of the second stimulus.

A number of behavioral symptoms have been associated with lesions of the frontal lobes. These include: (*a*) inability to inhibit reactions from irrelevant stimuli; (*b*) failure to restrain automatic movement; (*c*) apathetic, dull visual investigatory activity; (*d*) failure to select essential cues; (*e*) an inert and immobile gaze; and (*f*) failure to combine details into a whole. In these cases, the visual field is narrowed, and although objects can be seen in the midline or central field of vision, they cannot be seen on the periphery.

With the exception of being able to distinguish color and shape (Pribram, 1959, 1960; Mishkin, 1957), the behavioral symptoms of occipital and frontal lobe involvement appear to be similar. The major difference between the two is that frontal lobe disorders represent dysfunctions of active investigatory activity, whereas, occipital dysfunctions reflect deficits in the analysis and synthesis of visual stimuli.

Luria (1966a) indicates that frontal lobe damage and true optic agnosia may be distinguished by

"* * * careful observation of the passive character of the perceptual activity (in frontal lobe damage) and of the presence of the syndrome of generalized inertia and lack of critical attitude toward performance * * *." (p. 364) The deficit may appear to be the same inability to recognize an object. However, the etiology of this disability is more likely related to a lack of control over the voluntary scanning movements of the eye. In this case, failure to recognize the figure is not an agnosia but is instead an inability to control impulses regulating the eye movements. Scanning is erratic and incomplete. This "frontal syndrome" seems to represent a disturbance in purpose of behavior. This description closely resembles the stereotype of the hyperactive "Strauss Syndrome" child who exhibits impulsivity and perceptual disorders.

There are a number of tests which are currently being used to assess visual processing operations. The Bender Visual-Motor Gestalt Test (1938) was one of the first tests of visual stimulus processing. The designs were adapted by Lauretta Bender from those used by Wertheimer to demonstrate the principles of Gestalt psychology. The Bender test requires the subject to copy designs from a pattern. Failure to copy a design correctly may be due to a deficit in either visual processing or motor performance. It may be necessary, therefore, to assess the visual (perceptual) component separately from the motor reproduction, especially, if a child appears to have a motor problem. In addition to its use as a test of visual-motor perception, the Bender Gestalt has been used for a variety of other purposes, e.g., to diagnose brain injury, emotional disturbances, and as a predictor of school achievement. Noting that between 1938 and 1964 more than 130 publications have been written concerning the test, Koppitz (1964) has integrated the research on children (CA 5–7) into one volume and presents guidelines for objectively scoring the test.

The Frostig Developmental Test of Visual Perception (1963) assesses five areas which the authors consider to be related to academic skills: Figure-ground relationships, eye-hand coordination, form constancy, position in space, and spatial relationships. Motor skills are necessary for adequate performance in each subtest. The DTVP yields a "perceptual quotient" with norms for children from ages 4 to 7. Frostig and Horne (1964) have developed a remedial program for ameliorating deficits in each area.

Several tests require copying a form, using a pencil. The Graham Kendall Memory-for-Designs Test (1960) requires the reproduction of 15 geometric designs from immediate memory. The Developmental Test of Visual-Motor Integration by Beery and Buktenica (1967) requires the copying of a series of forms, with the model at the top of the page and the space for reproduction at the bottom. The Stanford-Binet Intelligence Scale, Form L–M (Terman and Merrill, 1960) contains several copying items: A circle at "Year III," a square at "Year V," a diamond at "Year VII." The Purdue Perceptual Motor Survey (Roach and Kephart, 1966) also includes several coyping items, such as a series of loops, circles, and scallops.

Several standardized tests have visual components and varying degrees of motor responses. Most reading readiness or school readiness tests include sections on finding similarities and differences in sets of pictures and forms (Gates, 1939; Hildreth and Griffiths, 1949; Murphy and Durrell, 1965).

Some scales purporting to measure cognitive abilities or intelligence have sections involving visual stimuli. The Columbia Mental Maturity Scale (Burgemeister, Blum, and Lorge, 1954) is a series of visual discrimination items. The so-called performance sections of the WISC (Wechsler, 1949) contain subtests requiring the child to put together flat cut-up drawings (object assembly), indicate missing features (picture completion), arrange pictures in a story-sequence (picture arrangement), copy a geometric design (block design), and copy a different arbitrarily designated symbol underneath a series of random numerals, 1 through 9 (coding). An alternate test is the drawing of a line through a printed linear box maze (mazes).

A recent addition to the test repetoire is the Wechsler Preschool and Primary Scale of Intelligence or WPPSI (Wechsler, 1967) which is similar in content to the WISC, with the exception of the coding task which has been changed somewhat to suit the less skilled motor performance of children 4 through 6½. The Animal House subtest requires the child to associate a different color peg with an animal picture and place a peg of the appropriate color in holes marked with animal pictures. The Goodenough Draw-a-Man Test (Goodenough, 1926) requires the child to draw human figures. The Peabody Picture Vocabulary Test (Dunn, 1951) requires the child to listen to a spoken word and indicate, usually by pointing, the one picture of four presented which was named. In contrast, the Picture Vocabulary item on the Standford-Binet requires the child to name each of a series of pictured objects.

Some tests have been developed with a view toward eliminating both the motor production (copying) of a stimulus and the producing of a free response. The colored Progressive Matrices (Raven, 1956) consists of a series of items, each arranged in matrix form, usually two by two. In each item some progressive feature can be distinguished, and one cell is missing. It is the child's task to indicate which one of four possible cell-fillers offered to him is appropriate. The Illinois Test of Psycholinguistic Abilities, revised edition (Kirk, McCarthy, and Kirk, 1968) contains five subtests with visual stimuli and motor responses. "Visual sequencing" requires the replacing of form chips in a specified sequence. "Visual reception" requires the subject to attend to one stimulus picture, then choose without the model, the one picture of four which is similar in function. "Visual Association" requires the choice of the one in four pictures which is most closely associated with the stimulus picture, which remains in view. "Visual Closure" requires the subject to point to partially hidden figures such as dogs, shoes, and fish. "Manual Expression" requires the use of gestures to illustrate the use of pictured objects, e.g., hammer, comb, and mirror.

There are a number of disorders which interfere with the processing of visual information. The behavioral symptoms of these disorders, for the most part, are varied and represent different kinds of cognitive operations. For this reason, a differential approach to treatment and compensation is indicated.

In cases of central blindness, where vision is completely lost, it is necessary to intervene with teaching approaches which are used for the blind. If there is partial damage to the occipital lobes resulting in hemianopsia, training manual and ocular sensitivity may help compensate for the visual perceptual deficit.

Case histories report wide differences in the quantity and quality of information reported by subjects with visual processing disorders (Gelb and Goldstein, 1920; Goldstein, 1948; Nielsen, 1962; Luria, 1966a). An attempt should be made, therefore, to ascertain, as accurately as possible, whatever it is that the subject reports he sees, i.e., nothing, blurred objects, outlines, or individual elements of an object. Also, any failure to integrate the elements of the object for purposes of recognition, and the degree of confidence or insecurity with which he reports his impressions should be noted. Self reporting has obvious limitations for use with younger children, as well as older children who have limited expressive language. In any event, an attempt should be made to list the visual processing tasks with which the child is successful, as well as those tasks with which he is unsuccessful.

The number of compensatory modes are limited. Improvement in supplementing visual information through tactile and kinesthetic hand and eye movements is one approach. Training the child to study the outline of an object with hands and/or eye movement may help him in distinguishing the elements of the object, and integrating them into a meaningful recognized whole (Fernald, 1943).

If an individual with a visual processing dysfunction attempts to recognize an object by using language as a compensatory mechanism, he may arrive at an incorrect conclusion, because his verbal reasoning is based on incorrect, incomplete, and unintegrated visual information.

There is need to develop more precise methods for assisting the subject to search for and obtain visual information which, for the most part is correct; as well as develop specific strategies to prevent guessing or drawing of hastly conclusions.

Compensatory mechanisms also may be developed for specific tasks such as reading. For example, alphabet letters can be associated with meaning such as telling the child that "the letter S looks like a snake." This takes advantage of general information possessed by the child to help compensate for a disability in visual processing. Another compensatory method is to teach the child to assemble alphabet letters by showing him the letter or number, analyzing it into its parts, and teaching him to reassemble the parts into the whole. This method also takes advantage of the child's ability to learn, remember, and apply principles as well as become familiar with the motor-kinesthetic sequence of disassembling and assembling the elements of the alphabet letters or numbers.

When the visual perceptual field is narrowed as a result of hemianopsia, the number of visual units which can be seen may be increased by teaching the subject to utilize the residual visual fields by employing active systematic scanning procedures. If, on the other hand, the visual field is narrowed because of simultaneous agnosia, the subject can only process one or two visual units at a time. This disorder is extremely disruptive to the act of reading which requires the rapid analysis and synthesis of words, phrases, and sentences.

Shif (1945) studied subjects with simultaneous visual agnosia, who had a narrowed field of reading. Shif found that in addition to two or three clearly perceived elements, the remainder of the visual field was not entirely empty. Peripheral vision included several poorly differentiated signs. In order to teach the subjects to read, Shif wanted to widen the perception of letters and shift the focus of reading to the right, so the right side of the visual field would become a clear and independent center for reading. He did this by: (*a*) introducing certain groups of letters as single visual units; (*b*) requiring practice on distinguishing the groups of letters from words; and (*c*) using the groups to produce new short words with the same beginning. This procedure enabled the patients to perceive the fixed groups as a simultaneous entity and the patients ceased to analyze the structure of the word. Instead, the patients were able to concentrate on the right half of the word. Reading became possible and was supplemented by perimetry training.

Most of the research on dysfunctions in the processing of visual stimuli has been done with the adult population. Comparatively little work has been done with children. An important issue which needs to be resolved through future research is whether or not certain dysfunctions can be ameliorated through remediation as opposed to providing compensatory mechanisms for adjustment in the subject's areas of strength. There is need for interdisciplinary idiographic ($N=1$) research between educators, pediatricians, neurologists, ophthalmologists, and psychologists to resolve many of these questions.

Directions for Future Research

The traditional distinction between peripheral and central disorders is often confusing and ambiguous. An effort should be made to clarify this distinction in terms of a continuum of interaction among the three components of the visual processing mechanism: The eye, the ocular musculature, and the brain. A better understanding of the tasks involved in visual stimulus processing will hopefully lead to quicker and more successful educational, psychological, medical, and surgical intervention, as well as preventive measures.

A more accurate description of the ocular-motor tasks known to be related to the processing of visual stimuli is needed. There is need to investigate and identify the more subtle ocular-motor tasks which may be involved such as distinguishing light from no-light, seeing fine detail, binocular fusion, convergence, scanning and tracking, developing spatial relationships, discriminating object qualities, differentiating figure from ground, completing visual wholes, and recognizing objects. The relationships of fine and gross ocular motor tasks to cognitive tasks and to the continuum of visual stimulus processing tasks has not been made clear in the present literature.

Cognitive tasks should be thoroughly investigated along broad types of parameters: stimulus, organism, and response. These investigations should be sequentially programmed so as to bring maximum information from a series of studies. Research is needed to develop different procedures for assessment and training in visual investigatory activity and in improving operations in visual analysis and synthesis.

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CHAPTER 4

HAPTIC PROCESSING

The human body provides several sensory avenues through which information can be obtained about the environment as well as the state of the body itself. Information may be obtained through the senses of hearing, sight, taste, smell, touch, and body movement. While the average person uses all sensory avenues, the auditory and visual systems seem to be the major input systems for acquiring information. In the absence of sensory impairment or excessive stimulation, sight and sound seem to dominate sensory awareness.

Children who can hear and see sometimes demonstrate a preference for using one system more than other systems. Children who are blind depend chiefly upon audition, while children who are deaf rely heavily upon vision. Touch and body movement are incorporated in educational programs for both the deaf and for the blind. Unfortunately, touch and body movement represent the main avenues of informational input for those children who are both deaf and blind.

While a great deal of information pertaining to the auditory and visual input channels is available, there is comparatively little information concerning the processing of cutaneous (touch) and kinesthetic (body movement) information. Also, the information which is available is widely scattered in various medical, child development, and psychological journals. Comparatively little information is found in most educational journals.

This situation is particularly distressing because experience in teaching deaf, blind, and deaf-blind children has clearly demonstrated the usefulness in using touch and body movement as a means of conveying information to children. Only a few teaching methods have emphasized touch (tactile) and body movement for teaching seeing and hearing children. Fernald's (1939) method of teaching remedial reading, writing, and spelling is a classic pattern of tactile-kinesthetic tracing technique. Gillingham and Stillman (1960), Strauss and Lehtinen (1947) and Montessori (1912) have also developed tactile-kinesthetic methods of teaching. There is need, however, to investigate the potential value of touch and movement for teaching children who can hear and see. Similarly, there is need to learn more with respect to dysfunctions in the processing of cutaneous and kinesthetic information.

The purposes of this chapter are to discuss: (*a*) the central processing mechanism for obtaining information from the cutaneous and kinesthetic systems as they operate independently and simultaneously; (*b*) the kinds of sensory information which can be acquired; (*c*) the nature of dysfunctions in this processing system; (*d*) the procedures for assessment and treatment; and (*e*) the future research needs.

The Haptic Processing Mechanism

It is important to distinguish between vital sensations, gnostic sensations and haptic sensations. Vital sensations are largely unconscious and have to do with the automatic regulation of visceral events. Gnostic sensations are those such as vibration and position which require analysis and interpretation. For the purpose of this report, "haptic processing" refers to the integration of cutaneous and kinesthetic information. "Haptic perception" willl be used to denote information which is acquired as a result of the central processing and synthesis of cutaneous and kinesthetic information.

According to Gibson (1966) the haptic system is composed of different subsystems: (*a*) cutaneous touch gives perceptions of the skin and deeper tissue without movement; (*b*) touch-temperature refers to the combination of skin stimulation and vascular dilation or constriction; (*c*) touch-pain refers to the registration of pain; (*d*) haptic touch is the movement of the joints along with stimulation of the skin and deeper tissues; and (*e*) dynamic touch is muscular exertion in combination with stimulation of both the skin and the joints. Gibson also refers to "oriented touch" which is the continual feedback from the inner ear about the body's relationship with gravity and the ground.

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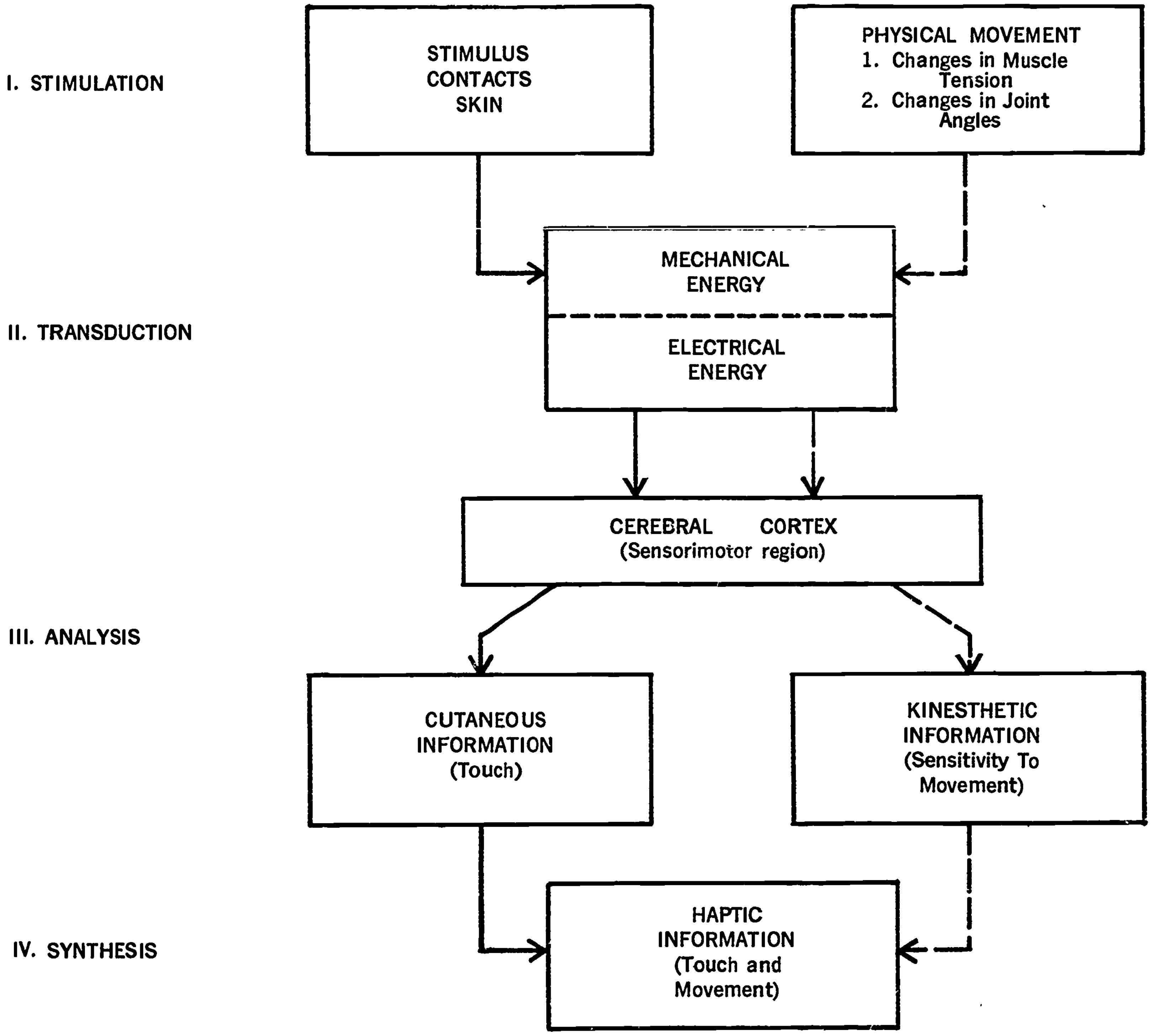

Figure 4.—The Haptic System

The haptic system is activated when external stimuli come in contact with the skin and when muscular or skeletal movement occurs (see fig. 4). It should be noted that stimulation might be imposed on a passive subject or stimulation might be self initiated. Regardless of the active or passive nature of the stimulation, sense organs in the body are activated. These sense organs are named "mechanoreceptors."

According to Gibson (1966) mechanoreceptor cells are located throughout the body in the: (*a*) skin and deeper underlying tissue; (*b*) muscles and tendons which attach muscles to bone; (*c*) skeletal joints and connecting ligaments between all moveable bones; (*d*) blood vessels; and (*e*) hair cells located in the semicircular canals, utricle, saccule, and cochlea of the inner ear. These receptors convert the mechanical energy created by the stimulus into electrical energy which is transmitted along the neural pathways to the brain (see fig. 4).

The sensorimotor region of the brain, which is located in the parietal area or postcentral gyrus, serves as the analyzer for cutaneous-kinesthetic sensory information. The simultaneous input of cutaneous and kinesthetic information is integrated into haptic information or haptic perceptions about the body, its environment, and their interrelationships.

There is need to learn more about the nature and functioning of the haptic processing system and its various sybsystems. Gibson (1966) highlights this need: "More than any other perceptual system, the haptic apparatus incorporates receptors that are distributed all over the body and this diversity of anatomy makes it hard to understand the unity of function that nevertheless exists." (p. 134)

Kinds of Information Obtained by the Haptic System

Most school tasks, as do most acts in everyday life, require both touch and movement. The haptic system is important for obtaining information about object qualities, bodily movement, and their interrelationships. The simultaneous input of cutaneous and kinesthetic preception not only provides more informational input than either system alone, but by combining movement and touch it is possible to physically obtain various combinations of stimulus cues which would not be encountered if each system were used successively or independently of the other.

The haptic system provides two major kinds of information. The first category includes information about the environment such as: (*a*) geometric information concerning surface area or size, shapes, lines, and angles; (*b*) surface texture; (*c*) qualities of consistency such as hard, soft, resilient, or viscous; (*d*) pain; (*e*) temperature; and (*f*) pressure.

In the second category, bodily movement provides information about the body itself such as: (*a*) dynamic movement patterns of the trunk, arms, legs, mandible, and tongue; (*b*) static limb positions or postures; and (*c*) sensitivity to the direction of linear and rotary movement of the skull, limbs, and entire body. Body movement also provides information about the location of objects in relation to the body itself.

Duration of body movement through space supplies information about the areas where objects are not encountered. This is accomplished by physically seeking out and contacting the concrete boundaries of an area.

Muscular effort and tension or strain in the joints, ligaments, and tendons provide information about weight or resistance to gravity. Pushing and pulling an object in the horizontal direction or lifting and lowering objects in the vertical direction give information about the relative weights of objects. Muscular effort and strain also supply information about the relationship of one's own body to gravitational pull.

Description, Assessment, and Treatment of Cutaneous Processing Dysfunctions

As early as 1874, Wernicke reported case studies in which pain and tactile sensation remained intact, but in which complex discriminatory sensation was affected. Since that time several cutaneous dysfunctions have been identified. These include failure to: (*a*) identify the presence of pressure on the skin; (*b*) localize the point of mechanical stimulation; (*c*) differentiate two or more stimuli which are applied simultaneously; (*d*) indicate the direction of an object moving over the surface of the skin; and (*e*) register sensitivity to pain and temperature.

A number of case studies have been reported which have shown that the synthesis of tactile stimuli may be disturbed by lesions in the parietal areas of the cerebral cortex (Luria, 1966). Lesions in the posterior central gyrus region on one side of the body were found to be accompanied by absence of cutaneous sensation on the opposite side of the body (Head, 1920). Semmes, Weinstein, Ghent, and Teuber (1960) also found that lesions in the sensori-motor or postcentral region of the left hemisphere may reduce tactile sensation in the right upper limb. Their studies suggest that the cerebral localization of the higher tactile functioning is more highly concentrated in the dominant hemisphere. The significance of these areas is further emphasized by Luria (1966) who reports that lesions outside the sensori-motor postcentral and posterior parietal regions of the left hemisphere usually cause no disturbance of tactile sensation.

Single-Point Discrimination and Localization (Touch versus No Touch)

A common procedure in the investigation of tactile functioning is to exclude sensory input from the visual and/or kinesthetic receptors by screening and immobilizing the limb. The threshold of tactile stimulation can be studied by applying tactile stimuli to the subject's fingers, palm, forearm, and shoulder with increasing pressure. The frequency intervals with which stimuli are applied are varied to allow for the aftereffects of sensation and fatigue. When a point stimulation increases in intensity, the cutaneous deformation becomes enlarged and deeper and a greater number of receptors are activated.

Gibson (1966) mentions several instruments which are used to create mechanical energy, mechanically displacing or deforming the skin, and activating the mechanoreceptors in the skin. These stimuli include a rounded wedge for rubbing, a sharp wedge for scraping, a small cylinder for rolling, and tufts of hair for brushing. Each of these instruments can be used to apply different kinds of pressure. Torsion of the skin can be produced by twisting a rubber stimulator clockwise or counterclockwise to see if the subject can indicate the direction of the torsion. Forceps are used to test sensitivity to stretching or pinching. Sensitivity to motion over the surface of the skin, lateral traction, is measured by drawing a long rod over the skin region (Gibson, 1962). Thermal sensitivity can be tested by applying metallic objects which have been heated or cooled to different temperatures.

Several studies have used surface texture to assess tactile discrimination in the absence of vision. Rough and smooth paper, commercial grades of sandpaper (Stevens and Harris, 1962), and fleece and untwisted rope fibers (Binns, 1937) were used to study tactile perceptiveness. It is interesting that little tactile information was obtained by mere touching. In order to discriminate, it was necessary to rub the stimulus object or pull the stimulus object through the fingers. Mechanical friction seemed necessary in order to obtain sufficient information about subtle differences in surface texture so that comparative judgments could be made.

Classifying the intensity of two, three, or more stimuli which have been applied in random order requires greater discrimination than does differentiating between touch and no touch. Diminution of sensitivity on one side of the body usually indicates lesions in postcentral divisions of the contralateral hemisphere or of the corresponding conductive tracts.

Tests for tactile localization can be administered by simply having the subject indicate the part of the skin touched by the instrument. The task can be made more difficult by asking the subject to point to the corresponding point on the opposite limb. This requires the subject to preserve the tactile localization and then to identify the symmetrically opposite area of the skin. Error can be measured in millimeters or centimeters.

Sensitivity to pain is the consequence of excessive or intense mechanical, thermal, electrical, or chemical stimulation. According to Geldard (1953) pain is usually sharply localized and tends to elicit prompt withdrawal reactions. Pain has value as a carrier of useful information because it produces withdrawal reactions to environmental conditions which may be injurious. Contact with an object in the environment, such as a pin or a hot stove, is often the only way a child is able to learn whether a physical contact is injurious or not, Sternbach (1963, 1968) reviews the clinical and experimental literature on pain and concludes that otherwise "normal" individuals are apparently insensitive to pain, yet have acquired all the expected social behaviors without the assumed negative reinforcement, assumed necessary to learning such avoidance behaviors, such as avoiding fires and sharp objects. Great individual differences in sensitivity to and awareness of pain are found in randomly-sampled populations. Gibson (1966) points out the need to learn more about the nature of pain and how it is perceived.

Multiple-Point Discrimination and Tactile Recognition

The touch compass test is useful in investigating the threshold at which the subject is able to differentiate between one-point and two-point stimuli. Two points are placed in contact with the skin as closely as possible and then gradually separated until the subject is aware of two-point sensation. In cases where the parietal region has suffered damage, the subject often has difficulty perceiving when two stimuli are applied simultaneously to the skin (Head, 1920; Bender and Teuber, 1947, 1948; and Bender, 1952).

The two points of the compass can be presented simultaneously or successively. For example, Teuber (1959) found that subjects with lesions of the parietal cortical region are able to distinguish tactile stimuli on both the right and left sides of the body, provided the stimuli are applied to the skin surface separately. In the event one stimulus is applied to the right side of the body and a second stimulus is applied, simultaneously, to the left side of the body, the individual with damage to the right hemisphere will notice only the stimulus on the right side. He will fail to notice the stimulus on the left side. This phenomenon represents a breakdown in the discrimination of multiple-point stimuli.

The movement of an object across the skin's surface triggers a temporal sequence of successive sensations. Failure to process this tactile information results in failure to indicate the direction of the object moving across the skin's surface. This phenomenon represents a dysfunction in synthesizing successive multiple-point stimulation. An extensive discussion of the skin senses has been conducted by Kenshalo (1968).

Procedures for assessing the processing of complex cutaneous information have been developed by Strauss and Werner (1938), Strauss and Lehtinen (1947), Hauessermann (1958), Benton (1959), Kinsbourne and Warrington (1963–1964), and others. Hauessermann's (1958) tests of tactual sensitivity provide a basis for the diagnosis of tactile agnosia in children from the ages of 4 to 6 years. The tests determine if the subject is able to use tactile scanning for the perception of slight differences in texture, and the recognition of familiar objects by touching their form and texture without seeing them.

Kinsbourne and Warrington (1963–1964) used three separate tests to assess the ability to perform discriminations based on the classification of sensory input from the fingers in terms of the individual fingers which were stimulated in their correct spatial arrangement. Two of the tests require verbal responses. The subjects ranged in age from 4½ years to 7½ years. Results of their tests indicated that the acquisition of "finger sense" is a maturational process. The ability to differentiate sensory input from the fingers was acquired by the approximate age of 5½ years in 50 percent of their group of normal children. Kinsbourne and Warrington's procedures for evaluating "finger sense" are described as follows—

A. Finger Differentiation Test: In the finger differentiation test, the subject faced the examiner with his eyes closed. One hand was positioned with the palm down and the fingers spread. Two points were touched simultaneously on the fingers, sometimes both on the same finger and sometimes on two adjacent fingers. The examiner then asked the subject how many fingers he was touching. He maintained contact until an answer was given by the subject and long enough after the answer to permit the subject to verify the answer under direct vision.

B. The "In Between" Test: In the "in between" test the subject's hand was positioned with the palm down and the fingers spread. The examiner touched two fingers simultaneously and asked the subject to tell how many fingers were in between the ones he was touching. The examiner maintained contact until answered and long enough to permit the subject to verify the answer under direct vision.

C. The Finger Block Test: Four wooden blocks with distinctive shapes were utilized in the finger block test. The subject's fingers were molded around one of four corresponding test blocks while his eyes were closed. The subject was then directed to open his eyes and without looking at the block in his hand, pick out the corresponding one on the table. After making his choice, the subject was allowed to verify his answer by direct visual comparison.

Recognizing objects by touch and distinguishing shapes, letters or numbers drawn on the skin require integration of sensations from a series of points on the skin's surface. Wernicke (1874) and Nielsen (1946) believed that failure to recognize objects and shapes represents a symbolic disorder. In contrast, Bay (1944) and others have viewed tactile processing dysfunctions as more elementary sensory disorders which may manifest themselves as the tactile task becomes more complex. Failure in object recognition may be due to a basic sensory dysfunction in synthesizing complex cutaneous information (Luria, 1966). There is need to question, study and clarify the traditional distinctions which have been drawn with respect to higher symbolic tasks and complex sensory integrative tasks.

The lack of information about cutaneous processing suggests the need for further research in this area. Anderson (1966) suggested several possible research directions: (1) isolation of research variables relating touch to learning; (2) increased work with clinical populations; (3) study of developmental trends in touch perception with clinically defined groups; (4) exploration of the extent to which enrichment or deprivation of tactile scanning experiences influences the development of symbolic skills; and (5) selection of diagnostic data which is more directly related to training procedures.

Description, Assessment, and Treatment of Kinesthetic Processing Dysfunctions

The kinesthetic sense makes little demand on our attention. Yet, simple acts such as lifting the foot from the ground, reaching for an object, or sitting down are continuously monitored by incoming signals from the mechanoreceptors. According to Wyburn, Pickford, and Hirst (1964), even without seeing movement we are aware of positions taken by different parts of the body. Tissue deformations, tensions, flexion and extension stretching, compressions, and changes in length of muscle or ligaments all generate kinesthetic information which aid in controlling movement. The positioning and movement of the joints, muscular contraction and tension resistance of the tendons trigger kinesthetic feedback. Breakdowns in kinesthetic processing can interfere with the feedback of several different kinds of kinesthetic information.

Joint and Muscle Sensitivity to Movement

The importance of joint sensitivity to the perception of space and movement has not received sufficient attention. Contrary to widespread belief, "* * * muscle sensitivity is irrelevant for the perception of space and movement, whereas joint sensitivity is very important for it. In short, we detect the angles of our joints, not the length of our muscles" (Gibson, 1966, p. 109).

The amount of information which is obtained from muscles and tendons is limited. Nerve endings in the muscles and tendons are triggered by tension. The muscle fibers register the stretch of fibers, and the tendon receptors register strain. Resistance to gravity is obtained through muscular effort. Since muscle length is not correlated with muscle effort, the muscle itself provides comparatively little information. Muscular effort in combination with mechanoreceptors in the skin, joints, ligaments, and tendons yields the most information.

In addition to the function of permitting mobility of the articulated bones, the relative position and movement of the bones is registered by the receptors in the ligaments and the receptors in the capsules of the joints. Consequently, awareness of position and movement of the joints depends solely on the receptors in the joints themselves. Reference to some mysterious "muscle sense" to explain kinesthetic sensation is unnecessary and runs contrary to all known facts concerning the muscle-stretch receptors (Rose and Mountcastle, 1959).

The joint receptors discharge at a given rate for a given angle of a joint. When the angle changes, the rate of discharge changes. Sensitivity to these changes was demonstrated in studies by Goldscheider (1898) and Geldard (1953), who found that subjects could detect the bending of a single joint as little as a fraction of 1°. The angle of one joint has little meaning, however, unless it is related to the angles of all mobile joints in the body of which there are approximately one hundred. The angular position of every bone of the body is articulated with the body frame which is anchored in the direction of gravity pull. The sensory feedback from angle changes and rotations of the joints provide perception of space and movement, particularly in the absence of vision. Motor behavior consists, in part, of a succession of angular changes which give the impression of continuous sensory feedback. Troland (1929) has described movement as a succession of many different postures.

All five fingers of each hand are frequently used to provide sensory information (Kohler and Dinnerstein, 1949). Finger span, the dimension in space between the thumb and index finger, is often a source of information concerning the dimensions of small objects (Katz and MacLeod, 1949; Kelvin, 1954). The angular position of the bones in the fingers is also used to help determine geometrical information such as the shape of surfaces and the arrangement of objects in space. Similarly, sensory information about the size of large objects may be obtained by extending both arms, thus rotating shoulder, elbow, and wrist joints, thereby determining kinesthetically the span or distance between the hands. There is need to develop procedures for training increased joint sensitivity to joint and muscular movements.

Linear and Rotary Movement

Kinesthetic information which is registered by the inner ear includes sensitivity to linear movement, acceleration, deceleration, directional changes, falling, and clockwise or counterclockwise rotary motion or spin. Information is obtained about the vertical and horizontal axes of the world, the gravitational point of reference and an awareness of the posture of the body. The vestibular apparatus in the inner ear registers stops, starts and changes in direction but it is not sensitive to uniform movement in a constant (straight-line) direction. The vestibular apparatus is defined as the utricle with the three semicircular canals and the saccule. These enclosures are filled with fluid into which the hairs of the receptors penetrate. The fluid moves with movement of the body and the receptors are stimulated by the motion of the fluid.

Movement Patterns and Static Postures

For voluntary controlled movement to occur, it is necessary to receive continuous feedback from the kinesthetic system. The mechanoreceptors which are distributed around the ligaments, joints, and deep tissue normally provide this feedback (Gibson, 1966).

Lesions in the postcentral divisions of the cerebral cortex have been found to be related to motor disturbances in which the power of the muscle remained unimpaired but voluntary movements could not be performed (Foerster, 1936). The motor impulses lost their selectivity and produced simultaneous contraction of both the agonistic and the antagonistic muscles. In less severe cases, subjects experience difficulty in reproducing finger position. Foerster also found similar problems arising from damage to the parietal area.

Recent thinking has emphasized the importance of the preparatory process for motor behavior. Before a voluntary motor act can be executed, cortical areas in the sensori-motor region (postcentral and precentral regions) must simultaneously organize the movements in the system of external spatial coordinates and analyze impulses arriving from the muscles and joints. During the early stages of motor development, both kinesthetic and optic afferent impulses play an important role in developing voluntary movement (Zaporozhets, 1960). As further development takes place, however, language is used as a mediator for planning voluntary action and kinesthetic and optic afferent components of movement assume a supporting role (Bernshtein, 1947).

Head (1920) and Denny-Brown (1958) found that a lesion of the posterior divisions of the sensori-motor region (area 4) results in disturbances of spatial integration or to kinesthetic schemes of movement upon which motor behavior is based. Motor impulses lose selectivity and go to agonists and antagonists at the same time.

The work of Piaget (1935) and others shows that kinesthetic visual and vestibular analyzers are responsible for processes of inspection, palpation, head orientation, eye movement, and the development of spatial relationships. "Before a voluntary motor movement can be carried out, the visual, vestibular, or acoustic impulses must first be recoded into a definite system of kinesthetic signals." (Luria, 1966, p. 174) The kinesthetic basis of movement has been placed in the postcentral divisions of the cortical nucleus of the motor analyzer. Exteroceptive signals are recoded into kinesthetic combinations and impulses integrated into simultaneous groups.

Failure to process information about movement patterns can be investigated by having the subject reproduce various movement patterns or postures with his limbs. Before administering such a test, however, a neurological examination should be given to provide information about manifestations of muscle power, accuracy of movement, disturbances of muscle tone, ataxia, and hyperkinesis.

Luria (1966) describes a procedure for assessing optic-kinesthetic organization of a complex movement. The subject is asked to reproduce different finger positions demonstrated by the experimenter. Visual input is blocked by placing the subject's hand through a hole in a screen. Failure on this test is noted by diffuse movements or the inability to achieve the necessary selection of movement. Mirror-image reversals of movements are not necessarily connected with kinesthetic disturbances. They may be eliminated if the examiner either sits beside the subject or asks the subject to reproduce with his left hand, movements presented by the right hand. The tendency to perseverate a movement may be an indication of a lesion of the anterior division of the cerebral cortex. Pathological inertia of motor acts accompanied by postural praxis is usually a sign of a lesion (Luria, 1966).

The examiner may vary the test by positioning one of the patient's hands and asking him to reproduce the position with the other hand while keeping his eyes shut, or asking the subject to execute a movement from a verbal command. This removes the optic afferent component of the motor analyzer. Luria (1966) also discusses tests which help identify defects in the optic-spatial organization of the motor act.

Several tests help identify the presence of defects in the kinesthetic basis for accomplishing hand movements. The examiner places the subject's hand or fingers in a certain angle or position and asks him to reproduce this angle with the same hand and with the opposite hand. Then the examiner asks the subject to shut his eyes and reproduce the angle with the same hand and with the opposite hand. Poor performance on these tasks or the gradual increase of errors as fatigue develops suggests that there is a deficit in kinesthetic analysis in the opposite hemisphere.

There are a number of procedures which are used to assess the functioning of deep muscle and joint sensation. The subject usually sits upright, with his eyes covered, and his arm, hand, and fingers in a fixed position. The examiner then moves the subject's arm, hand, or fingers up, down, and to the side. The subject is asked to indicate the direction of movement. Subjects are also asked to reproduce the position of a limb independently, or move the opposite limb to a corresponding position. The angle or the forearm may be moved passively from one angle to another to determine if the subject is able to: (*a*) Determine if the two movements were the same or different; (*b*) repeat those consecutive movements; or (*c*) reproduce the movements with the other limb.

Disturbances in deep muscle and joint sensations, particularly in the upper limb, tongue and lips have been found to arise from lesions in the postcentral and posterior parietal regions of the cortex of the opposite hemisphere. Disturbance of kinesthetic sensation is found mainly in the contralateral upper limb. These conditions lead to evaluative errors.

The reproduction of actions may be severely impaired when the object is not visibly present. When the object is present, vision may help support the subject's attempt to reproduce actions. This suggests that the kinesthetic organization of action is a basic element of symbolic actions.

The disturbance of the kinesthetic basis of speech has been classified as "afferent kinesthetic motor aphasia." Disruption of the coordinated movements essential for the kinesthetic basis of motor acts results in failure to organize and execute articulation in speech (Liepmann, 1913).

As early as 1861, Broca (1861a, 1861b) described motor aphasia for the motor images of words as distinct from all other sensory and motor disorders. Further, he localized this disorder within the third frontal gyrus. Nissl von Meyendorff (1930) found that motor aphasia also resulted from lesions in the Rolandic area and involved the inferior portions of the postcentral kinesthetic region of the cortex as well.

Lesions of the inferior divisions of the postcentral region of the left hemisphere have also been found to result in apraxia of the tongue, lips, and palate (Luria, 1966). While the subject can produce sounds, he is unable to select the correct positions of lips, tongue, or palate. This requires concentration and results in frequent sound substitutions while speaking because the subject is unable to assume the correct position with the articulators in transferring from one sound to the next. In contrast, the condition of dysarthria is characterized by the inability to produce individual sounds and by slurred speech and monotonous speech patterns. In some cases entire phrases may be produced easily while great difficulty is experienced in articulating specific sounds. Such abnormalities of speech should be followed up by an investigation of the articulatory mechanism and how it functions.

Many tests for oral praxis usually require the subject to reproduce movements of lips, tongue, and face, such as stretching lips; baring teeth; extending tongue flatly; folding it up; puffing out cheeks; and, placing tongue between teeth. While the subject is performing these acts, his lips, tongue, palate, and facial muscles (controlled by the inferior portion of sensori-motor zone and adjacent parieto-temporal areas) should be observed for symptoms such as protruding lips; asymmetry of movement when showing teeth, puffing cheeks, wrinkling the brow, frowning, squinting, or positioning the tongue; limited range of tongue movement; excessive salivation; smooth movement substituted by tremors, spasms, or tension; and paresis of the soft palate or facial muscles. These all represent peripheral disorders of the articulatory act.

The subject is asked to reproduce two or three movements in succession either from demonstration or verbal command. These may be the same or different movements. Rapid performance of the first movement followed by the inability to switch movements or a fixation on one movement may be indicative of a lesion in the anterior divisions of the motor cortex. The examiner may gain further information by contrasting the subject's natural performance of an action with his performance upon request. The inability to act on command, while able to function in the real situation is characteristic of those with brain lesions.

Writing and reading activities are often affected by the kinesthetic form of motor aphasia. A study by Nazarova (1952) demonstrated that when first and second grade pupils were not permitted to articulate, the number of errors in writing increased five to six times. Children use articulatory movement as a mediator to analyze the sound composition of words during the initial stages of learning how to read and write. Thus, difficulty in organizing and producing speech sounds, whether or not due to lesions in the postcentral cortical divisions, may interfere with learning how to write. The inability to organize and produce appropriate sounds may interfere with reading, particularly in words which have complex sound sequences requiring rapid transitions. Sound substitutions and sound distortions resulting from failure to produce the correct auditory language signals for their graphic representations will interfere with comprehension of what is to be read.

Future research is needed to provide a more thorough description of these disorders and to develop more effective procedures for their assessment. Causes for failure to produce complex voluntary movement must be differentiated, such as: (*a*) faulty kinesthetic processing; (*b*) inadequate muscle power and tone; (*c*) dysfunctions in the optic-spatial afferent system; and (*d*) failure to inhibit one set of muscle groups while exciting other muscle groups.

There is need, also, to determine if training can improve the selection and organization of kinesthetic impulses for bringing about increased control over voluntary movement.

The literature reveals that special teaching procedures have been developed for training cutaneous-kinesthetic abilities in normal young children (Montessori, 1912; Scagliotta, 1967). Remedial training in the tactual-kinesthetic mode has also been recognized by educators as a means of reaching children with special learning problems. Monroe (1932), Fernald (1939), Strauss and Lehtinen (1947), Gillingham and Stillman (1960), Kephart (1962), and Frostig (1964–1965) all suggest methods of remedial reading, writing, spelling, and arithmetic which employ cutaneous-kinesthetic training techniques. The Hegge, Kirk, and Kirk (1948) remedial reading drills uses a graphovocal method for teaching reading.

These procedures have been used for amelioration of the basic disability as well as for improving the functioning of one modality to compensate for the dysfunction of a second modality. A major issue in training is whether or not haptic processing disabilities can be influenced by various forms of training exercises or whether it is necessary to work with the residual abilities and teach the subject to compensate by utilizing his assets.

A review of the research reveals that there is little known about either the restoration or the compensation of haptic processing dysfunctions in children. It is very likely that the training programs devised for deaf, blind, and deaf-blind children have the greatest applicability for teaching hearing and seeing children who have difficulty processing and integrating cutaneous-kinesthetic information.

Further research should investigate the amelioration of haptic processing dysfunctions, as well as the ways in which the haptic modality can be used to reinforce the learning of children who have other kinds of disorders. Increased attention should be directed toward haptic input as a compensatory source of information for children whose auditory or visual processing mechanisms are impaired.

Directions for Future Research

There is need for research on the processing and integration of cutaneous and kinesthetic information. In addition to acquiring more precise behavioral descriptions of the dysfunctions in the haptic system, there is need to: (*a*) develop more systematic assessment procedures for describing deviant behaviors; (*b*) devise more effective diagnostic procedures for linking specific behavioral symptoms with the causal factors; and (*c*) study the effectiveness of different treatment procedures with specific dysfunctions.

Most of the literature has been concerned with utilizing the cutaneous-kinesthetic processing to reinforce other sensory modalities which may be defective in children. A major issue which needs to be resolved is whether or not it is possible to improve tactile-kinesthetic abilities in children whose tactile-kinesthetic sensory modality is distorted or deficient. Research is needed, also, to explore the compensatory advantages of using the haptic modality to compensate for children who have dysfunctions in auditory or visual processing.

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DYSFUNCTIONS IN THE SYNTHESIS OF SENSORY INFORMATION

CHAPTER 5

MULTIPLE STIMULUS INTEGRATION

In view of the limited research which has been conducted on the processing of multiple stimuli, this chapter rightfully belongs in chapter 11, "Directions for Future Research." Despite the fact that few research studies have been reported, the significance of this concept and its implications for education warrant its inclusion as a separate chapter in this report. In almost all daily activities, particularly in school related tasks, children must process multiple-stimulus information. It is the purpose of this chapter to describe the few research studies which are to be found in the literature and to highlight the urgent need for future research in this important problem area.

What Is Stimulus Integration?

The term "integrative processing" refers to the central synthesis of multiple stimuli which are presented to the same sensory modality or different sensory modalities. The term "integration" suggests the presence of additive or incorporative elements. One type of integrative task is matching information between auditory and visual sense modalities (e.g., /k aet/= cat? or tac?). "Differentiation" refers to the reception, analysis, and selective organization of competitive stimuli, or the separation of revelant from irrelevant stimuli. Finding a hidden figure in a pattern is an example of figure-ground differentiation or discrimination. A child who is easily distracted by irrelevant visual or auditory stimuli may be reflecting a breakdown in his ability to differentiate, which may in turn cause difficulty in the ability to integrate.

The independent integrity of the auditory, visual, and haptic processing systems is necessary for simple sensory functioning. There is clinical evidence, however, that the simple sensory functioning of one sensory system is affected or modified by the functioning of other sensory systems, both as they function independently and in coordination with other sytems (Birch, 1954; Myklebust, 1964). As processing tasks become more complex, the number of sensory systems needed increases and their inter-relationships become more complex.

The concept of intra-sensory integration refers to the processing of multiple stimuli which are being received through the same modality. Relating the words "tap-tap-tap" to the equivalent sounds made by a hammer is one example of an intra-sensory task. Table 6 outlines intra-sensory integration systems which require the selection and organization of multiple input through the same channel.

Table 6.—Intrasensory Integrative Systems

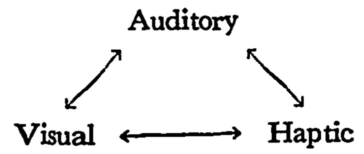
Input	Input
Auditory ⟶	⟵ Auditory
Visual ⟶	⟵ Visual
Haptic ⟶	⟵ Haptic

Intersensory integration is the processing of multiple stimuli which are being transmitted through different modalities. Relating the auditory word-name /kæ t/ with the visual graphic word "CAT" is one example of an intersensory task. Other terms such as "intersensory translation," "cross-modal coding," and "association" have been used to refer to the process of relating information which has been received through one modality to information which has been received through another modality. Table 7 presents basic intersensory integration systems.

One major research question which must be resolved is, "What are these systems?" Do simple one-channel systems combine to produce more complex, higher-order two-, three- or four-channel systems? These systems must be identified more clearly and their functioning described in greater detail.

Table 7.—Intersensory Integrative Systems

Input		Input
Auditory	⟶ ⟵	Visual
Visual	⟶ ⟵	Haptic
Haptic	⟶ ⟵	Auditory



How Do Integrative Systems Develop?

There is very little information about the growth and development of sensory integrative systems. Researchers in this area appear to have made several assumptions with respect to the development of integrative processes. Chief among these are: (a) the nervous system develops in a given hierarchy; (*b*) certain senses and combinations of senses are relied upon more heavily than others at different developmental stages; (*c*) integration is the synthesis of elementary sensations which occur repeatedly; and (*d*) the appearance of complex adaptive functions depend, to a great extent, upon the gradual development of integration between the sensory systems (Birch and Lefford, 1963). Whether or not these assumptions are correct is open to question, and each assumption represents a potential research area.

Theories

According to Munn (1965), organisms differ phylogenetically in their reliance upon different types of stimuli. In infants, the development of tactual and kinesthetic activities precedes the development of other modalities. The very young child acquaints himself with objects in his environment by feeling them and perhaps by tasting or smelling them. As the child develops more reliance is placed upon auditory and visual channels. Man, at the highest level of phylogenetic development, relies most heavily upon his visual and auditory channels.

Luria (1966) views the higher human mental functions as "* * * complex reflex processes, social in origin, mediate in structure, and conscious and voluntary in mode of function" (p. 32). With respect to the possible development of the higher mental functions, Luria believes that they are widely represented throughout the cortex as systems of functional combination centers. His second conclusion is that the higher mental functions are neither preformed nor do they mature independently, but are formed in the process of social contact and objective activity which gradually acquire complex intercentral connections. During the early stages of development, the sensory and motor basis for learning is very important, but during the later stages of development, the higher mental functions develop from more complex systems of connections.

Hebb's (1949) neurophysiological theory of cell assemblies also emphasizes the successive integration of cell assemblies into phase sequences, phase sequences into phase cycles, and phase cycles into series and classes of phase cycles. The gradual integration of cell assemblies into more complex sequences results in the continued development of higher order cerebral organization, and thence in cognitive growth.

The theory of "neurological organization" described by Delacato (1959, 1963), hypothesizes that each individual passes through all stages of man's neurological evolutionary development. More specifically, neurological development is believed to occur first in the medulla, then the pons, the midbrain, and finally in the cortex. The operation of the lower cortical levels is of an automatic nature. This theory suggests that a disruption at any level will interfere with the development of successive stages.

According to Piaget (Flavell, 1963), cognitive growth is dependent upon the continued formation of new, higher order, intercoordinated "sensori-motor systems."

> Observation shows that very early, perhaps from the very beginnings of orientation in looking, coordinations existed between vision and hearing * * * subsequently the relationships between vision and sucking appear * * * then between vision and prehension, touch, kinesthetic impressions, etc. These intersensorial coordinations, this organization of heterogeneous schemata will give the visual images increasingly rich meaning and make visual assimilation no longer an end in itself but an instrument at the service of vaster assimilations. (Piaget, 1952, p. 75.)

Piaget believes that the development of these intercoordinated systems are necessary to the development of intelligence, and that any distintegration in intersensory coordination will interfere with the normal development of intelligence.

In studying the relationship of the environment with the development of processing systems, Hunt (1961) concluded that the individual's interaction with the environment affects the quality and style of informational processing. Hunt writes:

> Perception is a synthesis of elementary sensations, for perception may also be conceived as a system of relations with

each relation itself being a whole. From such an assumption Piaget derives the notion that complex perceptual structures are the product of progressive construction arising from "adaptive differentiations and combinative assimilations." Perceptual constancies arise as central processes, derived from the aspects of objects that provide the most redundant patterns of input, become sufficiently autonomous to be evoked as a whole when the input concerned involves only small portions of the total pattern (p. 254).

According to Hunt's theory of behavioral development: (*a*) stimuli must be integrated into the organism before they can trigger automatic habit-chains; (*b*) repetition seems to be the mechanism by which information-processing strategies are acquired; and (*c*) habit-chains are built from infancy.

Bruner (1964) describes cognitive growth as the gradual development of representational systems which are useful for dealing with the environment. According to Bruner, this development passes through three stages: an action pattern representation; an iconic or imagery system; and a symbol system. This theory suggests that deficits in an earlier stage may affect the development of later stages.

Research

A number of studies have reported that intrasensory systems develop before intersensory systems. Research by Sherrington (1951) and Birch (1954) suggests that the integration of information arriving through a single sense modality is phylogenetically more primitive and appears earlier than does the capacity to integrate information arriving through two or more sense modalities.

The development of sensory capacities by stages is supported by age-related performance on standard psychometric tests. Young children, for example, are more likely to perform successfully on test items which make fewer demands on the sensory integrative systems. Belmont, Birch, and Karp (1965) found that the intramodal visual-visual demands of the Seguin Form Board Test and of the Three-Hole Form Board (2½-year level) subtests of the Stanford-Binet Intelligence Scale are much easier for younger children than are subtests which require multimodal interaction.

Studies by Birch and Bortner (1960) and Bortner and Birch (1960) reported that young children and brain-damaged adults show similar discrepant abilities: accuracy in the perception of shapes, and gross inaccuracy in their reproduction. This discrepancy may be accounted for by the empirical fact that the control of visual-kinesthetic input modality develops before the control of visual-motor response systems necessary for the accurate production of forms.

A study of intersensory development in children ranging in age from 5 to 11 years with a mean IQ of 115 was conducted by Birch and Lefford (1963). The experiment, exploring the relationships among visual, haptic (active manual exploration) and kinesthetic (passive arm movement) sense modalities for recognition of geometric shapes, found that the ability to make various intersensory judgments (same-different) follows a general law of growth and improves with age. For judgments of both identical and nonidentical forms, the least number of errors was made in visual-haptic judgments. Seventeen percent of the 5-year-olds made no errors in judgment using visual and haptic information, while no 5-year-olds performed perfectly with haptic-kinesthetic or visual-kinesthetic information.

Five-year-olds also had difficulty integrating both visual and haptic information with stimuli transmitted through the kinesthetic mechanism. According to Birch and Lefford, the integration of the kinesthetic modality with visual and haptic modalities does not take place until the children are 7 or 8 years of age. In judging nonidentical forms, haptic-kinesthetic judgments were less difficult than visual-kinesthetic judgments. In judging identical forms, visual-kinesthetic and haptic-kinesthetic were equally difficult. At 11 years of age, there were almost no errors under all experimental conditions. "The evidence for normal children strongly confirms the view that the elaboration of intersensory relations represents a set of developmental functions showing age-specific characteristics and markedly regular curves of growth" (Birch and Lefford, 1963, p. 59).

Birch and Belmont (1965b) studied 220 elementary schoolchildren on the Auditory Visual Pattern Test. They found that the most rapid improvement in auditory-visual integration of temporal and spatial patterns seemed to occur between 5 and 7 years of age and reached an asymptote by the fifth grade. This time period coincides with the ages at which Birch and Lefford found the most rapid development of competence in making equivalence judgments of visual-haptic, visual-kinesthetic, and haptic-kinesthetic forms. It may be significant that the rapid improvement in integrative abilities occur at about the same time the child goes to school. One might wonder whether this rapid improvement is due to "maturation" or to instruction and practice in the school which may make demands on the integrative processes.

Meuhl and Kremenak (1966) investigated the ability of first grade children to match information within and between auditory and visual sense modalities. Matching visual pairs was easy for most children. Matching auditory pairs was the most difficult task. Matching visual to auditory and auditory to visual pairs was intermediate in difficulty. Ability to match visual pairs did not contribute to the prediction of reading achievement, while ability to match visual to auditory, auditory to auditory, and auditory to visual pairs made significant contributions to predicting reading success.

Luria (1963) has reported studies which have been concerned with verbal-motor control. These dual-response studies reveal a phenomenon which is similar to multistimulus integration. Luria theorized that until approximately age 4, a child's motor responses are not under control of the verbal signaling system. The studies which he reported show that it is difficult for the mentally retarded to integrate the verbal and motor signaling systems. On a simple task involving bar-press to a light, for example, one finds that young or retarded subjects below MA 4 find it difficult to add a verbal self-command to the motor sequence.

Hermelin and O'Connor (1960) tested Luria's theory with normal and retarded subjects on what they termed "cross-modal coding." The subjects heard either one or two pencil taps and responded with an indication of the opposite number of taps. The response was either tapping, counting, or a combination of the two. In the cross-modal condition, for example, if the child heard one tap he was to respond by counting "one, two." Results showed that cross-modal stimulus and response (tap-count) produced more correct response patterns and higher scores, whereas intramodality stimulus-response conditions (tap-tap) led to stereotyped imitative or perseverative behavior.

What Are the Correlates to Stimulus Integration?

There is relatively little information with respect to the specific nature of integrative disorders and the etiological correlates of these disorders. There is some evidence that individuals who function normally when receiving stimuli through a single sensory modality sometimes perform differently when the task involves the simultaneous or successive functioning of several modalities, or when several stimuli are received through the same modality. A breakdown in the ability to integrate multiple input from two or more modalities may be described as an intersensory integrative disorder. On the other hand, failure to organize and select multiple input through the same modality may be called an intrasensory integrative disorder.

There is need, then, to study the factors which might either retard the development of integrative abilities or cause breakdowns in integrative functioning. There are several questions which need to be answered. What is the relationship between intelligence and integrative ability? What effect does brain damage have on different kinds of integrative abilities? To what extent do biochemical imbalances contribute to this problem area?

Intelligence.

Few studies on integration have reported data on the intelligence of the subjects. Birch and Belmont (1964a) found a significant relationship between IQ and auditory-visual integrative ability, as measured by the Auditory Visual Pattern Test. This study indicates that auditory-visual integration may be one of the processes that underlies adaptive behavior and IQ.

There is evidence from recent Russian and English studies that the severely mentally deficient, in addition to suffering from a deficient verbal production and reception system, also lack flexible connections between words and motor behavior (Luria, 1956; Hermelin and O'Connor, 1960). According to Vygotsky (1934), speech normally tends to provoke motor activity until children are approximately 3 years of age; then the speech becomes regulative and is used to inhibit behavior. Speech directs perception as well as motor behavior and words may activate and support an otherwise deficient motor system.

The lack of control of the integration between speech and motor behavior in mentally retarded children frequently results in the excitatory impulse from words which trigger a motor response, or a motor response setting off verbal behavior or babbling. Two Russian studies placed imbecile childen in conflict situations in which responses required by verbal instructions were contradictory to responses arising from impulses set off by direct stimuli. Both studies found that retarded children will usually respond to the direct stimuli rather than verbal signals (Nepomnyashchaya, 1956; Tikhomirova, 1956).

Luria (1963) has reported studies of verbal-motor control. These dual response studies reveal a phenomenon which is similar to multiple-stimulus integration. Luria hypothesized that until approximately age 4, a child's motor responses are not under control of the verbal signaling system. The studies of retarded subjects, which he reports, show that it is difficult to investigate the verbal and motor signaling systems. On a simple task involving bar-press to a light, for example, one finds that it is difficult for young or retarded subjects below MA 4 to add a verbal self-command to a motor sequence.

Does a low intelligence level necessarily mean that a child will be deficient in integrative ability? The relationship of intelligence, whether it is conceived as learning rate (IQ) or amount learned (MA), to integrative functioning needs to be clarified through research.

Brain Damage.

Higher mental functions may be disturbed by lesions affecting the parts of the cerebral cortex which make up the integrative system. According to Luria (1966), the functioning of higher mental systems requires interconnected, but highly differentiated cortical zones, and the integrity of the whole brain.

Integrative systems may be disrupted by lesions in widely separated areas of the cortex. The resulting disorders may be quite different depending upon the parts of the cortex which are affected. The intact areas tend to compensate for the pathologically changed system. For diagnostic purposes, one must look beyond the function that has been lost. It is necessary to identify the factor or factors responsible for the disturbance because identical symptoms may be the result of entirely different pathological factors and, therefore, may require different remedial treatment, and have different prognoses.

Luria points out that "* * * a lesion of a single, circumscribed area of the cerebral cortex often leads to the development, not of an isolated symptom, but a group of disturbances, apparently far removed from one another" (p. 74). Because higher mental functions often share common links, the impact of primary defects may result in disturbances of several different systems, manifested by symptoms which may seem unrelated. In other cases, the higher function is simply depressed and is reflected by weakening or inadequate mobility of the nervous processes. If the cortical intercentral relationships are different at different stages of development, then a lesion will have different effects at different stages of functional development.

The literature is filled with clinical observations and references to the "behavioral inflexibility" and "rigidity" of brain-damaged individuals. Mettler (1955) reports animal studies which demonstrate that experimentally produced lesions in the "stratum" (i.e., caudate nucleus and putamen) result in the incapacity to react appropriately to changing environmental events.

Benton, Sutton, Kennedy, and Brokaw (1962) attempted to determine whether brain-damaged and nonbrain-damaged adult patients demonstrate changes in reaction time as a function of changes in the stimulus. Both groups showed slower reaction times to stimuli that had been preceded by a different stimulus in the same sensory modality than to stimuli that had been preceded by an identical stimulus in the same sensory modality. Both groups were found to have similar reaction times in changing from visual to auditory stimuli. When auditory stimuli preceded visual stimuli, however, the retardation in reaction time to the visual stimuli was significantly greater in the brain-damaged than in the controls. Patients with more diffuse cerebral diseases showed significantly larger intersensory retardation than the controls or patients with focal lesions.

Disturbances of intersensory systems in brain-damaged children have been reported by Birch and Belmont (1965a). Brain-injured subjects had greater difficulty in using multisensory information for making judgments than did normal subjects. When given a choice, brain-injured subjects preferred to use more intact unisensory information (visual-visual) than less intact multisensory information (visual-auditory) as a basis for organizing behavior. A study by Belmont, Birch, and Karp (1965) supports the hypothesis that cerebral damage is associated with marked disturbances in both intersensory and intrasensory integration. The more marked disturbances, however, were in intersensory integration.

Birch and Belmont (1965b) used the Auditory Visual Pattern Test to analyze the development of intersensory relations of 88 cerebral palsied children and 220 normal children of school age. Their results support the view that cerebral palsied children differed from normal children in the ability to integrate auditory and visual information. The difference was sustained when groups of comparable mental age or general intellectual functioning were compared. A study by Birch and Lefford (1963) also found differences in intersensory integrative ability between normal children and neurologically impaired children.

Birch and Belmont (1964b) investigated the effect of brain damage on perceptual analysis and sensory integration by testing 18 left hemiplegic adults. The task, adjusting a luminous rod within a tilted frame in a darkened room, could be performed by using visual-visual (intrasensory) or visual-somesthetic (intersensory) relationships. They reported that brain damage has more effect on intersensory than intrasensory integration. This study led to the hypothesis that more complex abilities are disordered more readily than are simple abilities which are assumed to be acquired early in life. The effects of cerebral damage before, during, or shortly after birth probably have far different consequences than damage to the brain of an adult. The development of the intersensory processes, therefore, may be more severely affected in the developing brain.

The few studies performed specifically on the effects of brain damage on the integrative processes have indicated that brain damage may well be a factor in integrative disorders. Research efforts to relate behavioral functioning to organic damage are handicapped by the inaccessibility of the brain and the technological limitations for diagnosing brain damage.

Biochemical Imbalances.

The behavioral impact of biochemical imbalances on integrative disorders represents a potential area for collaborative research between educators, psychologists, and the medical profession. There is very little information relating to this problem area. The complexity of the problem and the obvious technological limitations in measurement have undoubtedly limited research efforts.

How Can Stimulus Integration Be Assessed?

Evaluation of a child's performance in the reception and processing of stimuli in single modalities should precede any attempt at measuring integrative functioning. There is, at present, no standardized set of clinical or experimental procedures for assessing either single sensory functioning or multiple-stimulus integration. This section will present techniques that have been used and suggest others that are presently available.

Tests which have been used for the auditory channel, for example, include auditory discrimination tests (Templin, 1943; Wepman, 1958), the Auditory Decoding, Auditory Closure, and Sound-blending subtests of the Illinois Test of Psycholinguistic Abilities (Kirk, McCarthy, and Kirk, 1968). The Seashore Pitch and Rhythm Tests could be used. A test involving tapped auditory patterns may be useful to determine the ability to decode complex auditory patterns on a nonmeaningful basis.

Assessment of the visual channel might include such tests as the Auditory Visual Pattern Test (Birch and Belmont, 1964a, 1965b), the Bender Gestalt Test (1938), the Visual Sequencing, and Visual Closure subtests of the Illinois Test of Psycholinguistic Abilities (Kirk, McCarthy, and Kirk, 1968), or the Developmental Test of Visual Perception (Frostig, 1964).

The assessment of the strengths and weaknesses of auditory, visual, and haptic-kinesthetic perception appears to be a necessary antecedent to testing multiple-stimulus integration. Little attention has been given to the assessment of kinesthetic and tactile perception.

There is need to develop standardized tests for multiple-stimulus integration. At the present time, the only tests which are available are those tasks which have been developed by researchers actively investigating this area. It is possible to gain insight into the practical problems of measuring integrative functioning by studying the methodology of research studies. Reaction time to flashing colored lights, dot patterns, pure tone stimuli, and tap patterns have been used in attempting to measure visual-auditory integration. A second approach has been to test for recognition after training the subjects using different combinations of modalities.

A reaction time apparatus was used to investigate intrasensory and intersensory integration (Benton, Sutton, Kennedy, and Brokaw, 1962). The four stimuli used were: a red light, a green light, a 1,000 cycles-per-second (c.p.s.) tone, and a 400 c.p.s. tone. The subjects were asked to press the key as quickly as possible when any of the four stimuli were presented. Sixty-four stimuli were presented in a sequence which systematically varied light versus tone and "same versus different" within light and tone.

Belmont, Birch, and Karp (1965) tested simple reaction time to auditory (tone) and to visual (light) stimuli. Intrasensory integration was measured by requiring the subjects to make reaction responses to a series of intramodal stimuli (tone-tone or light-light). Intersensory integration was measured by interpolating a different kind of auditory stimulus, a metronome beat. The intrasensory sequence was tone-beat-tone; the intersensory task was light-beat-light. The difference in reaction time between first and third stimulus was considered evidence of intersensory or intrasensory integration.

The Auditory-Visual Pattern Test (Birch and Belmont, 1964a, 1965b) was developed to explore the relationship between a temporally structured set of auditory stimuli and a spatially distributed set of visual stimuli. The examiner taps patterns (tap, tap, tap). The subject is shown three visual patterns (...) (..) (.) and is asked to "pick out the dots which look like the taps you hear." This test was found to successfully differentiate subjects with lower and higher reading scores.

Hurley (1965) investigated the performance of children on a battery of tasks requiring the integration of multiple stimuli in auditory, visual, and haptic modalities. Scheffelin (in press) compared the effects of intrasensory and intersensory paired associates on the learning performance of young children and found that learning all-visual pairs, and mixed auditory-visual pairs, was easier than learning all-auditory pairs.

Another technique for exploring intersensory integration is to measure the effect of exercise in several modalities. Postman and Rosenzweig (1956), for example, trained subjects in nonsense syllables and then tested them for recognition in another modality.

At the present time, there are few procedures or instruments for measuring multiple-stimulus integration. The lack of reliable and valid testing procedures may be attributed, at least in part, to the complexity of the processes which are involved. In order to develop more sophisticated tests, there is need to determine what kinds of responses serve as the best indicators of the different kinds of multistimulus functioning, and what kinds of stimuli best elicit these responses. The assessment of multistimulus integration must take into consideration three important parameters: (*a*) the stimulus which is presented; (*b*) the organism to which the stimuli are presented; and (*c*) the response which is required. It is important to identify the variables which are related to the stimulus, organism, and response param ers. Unless these variables are identified, it will be exceedingly difficult to build tests, or to relate results from one situation to another.

Table 8 presents a list of variables which should be considered in the assessment of integrative functioning. The variables which have been listed under the stimulus, organism, and response parameters are meant to be suggestive of the kinds of considerations which must be made in developing assessment procedures and in studying integrative disorders.

What Factors Should Be Considered in Developing Remedial Procedures?

Because most teaching procedures utilize two or more sensory modalities, one might conclude that all remedial procedures can be considered as effective techniques for developing integrative abilities or ameliorating integrative disorders. This kind of thinking, however, represents a naive approach to this complex problem area. If effective remedial programs are to be devel ped, it will be necessary to resolve several basic questions.

Should educators attempt to remediate integrative problems only in relation to specific tasks? This represents a content orientation, as contrasted to a process

Table 8.—Significant Variables Which Should Be Considered Under SOR

Mode of stimuli	Organism	Mode of response
Intramodal	Sex	Intramodal
Intermodal	C.A	Intermodal
Simultaneous presentation	MA	Symbolic
Successive presentation	IQ	a: Motor
Symbolic stimuli	Organic involvement	b: Vocal
Nonsymbolic stimuli	Prior experience or training	Nonsymbolic
Intensity		a: Motor
Number of units		b: Vocal
Rate		Production
Duration		a: Latency of response
Interval		b: Duration of response
Instructions		c: Frequency of response
Order		d: Intensity of response
Complexity		Imitative responses
Distortion		Judgmental response
		a: Same
		b: Different
		c: Recognition
		d: Recall
		e: Equivalence
		f: Correspondence
		g: Recoding to a rule

orientation which asks the question, "Is it possible to ameliorate a basic integrative deficit, so the ability can be transferred to a variety of different tasks?" There is need to determine whether or not integrative disorders can be ameliorated and under what kinds of conditions.

The presentation of experiences during the teaching process requires the teacher to make many decisions about the content and mode of presentation. Table 8 lists some of the variables which should be considered in the selection and presentation process.

First, it is important that the teacher determine, as accurately as possible, which integrative systems are involved in each activity or experience. Second, the nature of the stimuli must be determined. Is it to be symbolic or nonsymbolic? Are stimuli to be presented simultaneously or successively? What is to be the intensity, number, rate, and duration of stimuli? Third, is it necessary to give the child prior instructions before he can engage in the activity? Variables such as these must be considered in developing remedial approaches to intersensory and intrasensory integrative disorders. At present, there is little information with respect to the selection and presentation of stimuli for remedial purposes.

Modality choice and sequence are critical factors in programing remedial procedures. A study by Pimsleur and Bonkowski (1961) found that college students took fewer trials to learn verbal material both visually and aurally when the material was presented first aurally and then visually. The learning task consisted of 10 paired associates (di-syllables as stimuli and color names as responses). Half the subjects learned the list first through the visual and then through the auditory modality. The other half learned the list in the opposite order. Positive transfer was found in both conditions, but the initial aural presentation had a greater effect on the visual presentation than did the visual on the aural. Similar results were found in a study on transfer from auditory training to visual discrimination in adults by Weissman and Crockett (1957).

Postman and Rosenzweig (1956) reported on a study which varied modality and integrative systems. The effects of practice were greater in intrasensory tasks when the same modality was involved in training and testing than the intersensory task when there was a change in modality. The transfer from visual training to auditory discrimination is greater than the converse. This finding was based on the recognition of nonsense syllables after varying frequencies of exercise by 150 undergraduate students. There are several alternative explanations for these results. During the visual training, subvocal repetitions may help mediate the recognition of verbal stimuli in the auditory discrimination task. Auditory training, on the other hand, may not produce corresponding visualizations which would similarly mediate during the visual discrimination task. There was a tendency for auditory stimulation to produce more complete responses than did visual stimulation. Vision may be more closely related to visual perception, whereas audition may be more closely related to the conceptual language system.

As present, little is known about the ways in which modality choice and sequencing influence integration. There is even less information about the ways in which disorders further confound the situation and interfere with modality sequencing in remediation.

The individual characteristics of each child should determine the appropriateness of specific remedial approaches and procedures. (See table 8.) There is need to consider the child's sex, mental age, chronological age, intelligence level, motivation, presence of organic damage, as well as the child's previous experience and training. Individual differences between children may explain why a remedial procedure may work with one child but not with another. The graphic description of individual cases is essential if educators are to understand the nature of intrapersonal variables and their implications for remediation.

An important aspect of any teaching situation is the response required of the learner. A learning situation can be very complex if the responses required of the child are beyond his ability. Table 8 lists different kinds of responses which can be built into a remedial program.

One critical variable in attempting to ameliorate an integrative disorder may be the frequency and duration of instruction. Perhaps of even greater importance is the age of the child when remedial intervention occurs. There are few studies concerned with the frequency and duration of remedial teaching for integrative disorders. Postman and Rosenzweig (1956), for example, found that speed of recognition varied directly with the frequency of exercise. The more frequently an auditory or visual stimulus item is encountered, the smaller the fragment necessary for identification of the whole item. The frequency and duration of teaching sessions may be a critical variable in determining whether or not the child progresses. The amount of training necessary to improve integrative functioning remains a major research question.

Directions for Future Research

To summarize, the area of multiple stimulus integration is a comparatively new area of study. The complexity of the process for integrating multiple-stimulus information has been a major factor which has contributed to the lack of research in this interesting problem area. At present, the status of knowledge about sensory integrative functions is limited.

There are a number of research areas which should be systematically explored. There is need, for example, to obtain a more thorough understanding of the intersensory and intrasensory processing systems which form the basis for processing multiple-stimuli. There is need to do basic programmatic research in determining what these systems are, how they function, and how they develop. Also, it is necessary to identify the psychological, neurophysiological, and biochemical correlates which are related to these systems.

In addition to the need for basic information about multiple-sensory integration, there is need to develop procedures for measuring or assessing behavioral performances on integrative tasks. These instruments can then be used to assess the nature and severity of dysfunctions of integrative processing. There is need, also, to develop instructional methods designed to ameliorate dysfunctions in integrative tasks or to provide a means of compensating for the dysfunction. These procedures should take into account different combinations of stimuli, the characteristics of the organism, and the various response modes which may be used. A critical issue is the extent to which it is possible to train multiple-stimulus integration. If so, how specific is the effect of such training and is there transfer from simple tasks to more complex tasks such as reading?

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CHAPTER 6

SHORT-TERM MEMORY

A review of the research on the storage of information reveals that children who have been classified as having brain damage frequently have an accompanying deficit in retention, recall, and recognition. Most research efforts have been directed toward what is commonly called short-term memory. Short-term memory is usually defined as recall within seconds, as opposed to long-term memory in which the retention is a matter of hours (Scott and Scott, in press). This chapter, therefore, will attempt to present theories and summarize the research related to this broad class of phenomena.

Children, as well as adults, are familiar with the concepts of remembering and forgetting. To the average man, memory is the power or process of reproducing or recalling what has been learned or retained; an image or impression of someone or something remembered. The term "memory" is often applied to the process of remembering as well as to the product, or that which is remembered. This concept views memory as one of man's basic and fundamental abilities to retain, recall, and recognize the representations of past experience.

Despite the popular use of the term "memory," little scientific evidence has been gathered which reveals what goes on in the brain to cause information to be stored or forgotten. In the absence of adequate information about the psychological, neurological, and biochemical factors which contribute to memory, several views have emerged which attempt to provide an explanation of the memory phenomenon and the processes which are involved.

According to Koffka (1935), "memory is but a word which labels a great number of achievements without explaining them" (p. 424). According to Hunter (1957), memory consists of four basic processes: learning; remembering; forgetting; and retaining. Both Hunter and Koffka view memory as a term used only to designate, collectively, a wide and somewhat heterogeneous range of processes. Moore (1939) also pointed out that memory can be viewed in different ways. "The word 'memory' can be taken in three different senses: (*a*) the function of the mind by which experience is stored and recalled for use as occasion may arise; (*b*) a state of awareness with constant reference to past experience, a revived picture or concept, a memory; (*c*) a mental disposition, that is to say, a modification superimposed on a fundamental ability of the organism" (p. 411).

The behaviorist point of view holds that any learned act reflects changes in the nervous pathways over which sensory stimuli travel. "Behaviorally, a memory is nothing more than a response produced by a stimulus" (Osgood, 1953, p. 550). There are two important questions which then emerge from the behavioristic view of memory. First, what are the conditions under which stimuli lose their capacity to evoke previously associated responses? An additional question which may well be asked is, what are the conditions under which the stimuli gain their capacity to evoke associated responses? In other words, why do we forget on some occasions and remember at other times?

The movement in factor analysis has advanced the theory that there is no general memory, only a number of special memories. The individual may perform well on one kind of memory task and perform inadequately on a task of a different sort. This view suggests that some of these memory functions have little or no relationship to each other, but neglects the integrative aspects of memory.

Drees (1941) makes the distinction between memory process and memory product. According to Drees, the process of memorizing leaves physiological and psychological traces. The physiological traces are in the nervous system, whereas the psychological traces are the images, meanings, and insights in the mind. In order for recall to occur, the memory trace must be activated. Viewed in this way, memory is a process which leads to a particular product: the item which is remembered. Drees also makes the distinction between sensory and intellectual memory. Sensory memory consists of sensory images, whereas intellectual memory is mainly meanings or insights into relationships. Moore (1939) points out that intellectual memories are acquired more rapidly than are sensory memories.

The classical view of memory holds that all inputs are stored in a form such that they are retrieved as stored. Thus, the classical view of memory has been that of a direct, one-stage storage and retrieval process. This has resulted in emphasis being placed upon structuring the properties of the stimulus and preserving the representation of the stimulus trace. Cohen, Stolurow, and Johnson (1967) offer a contrasting view which assumes a central processing function which scans all new material so that the important parts can be identified readily. Only part of each new input is stored. By storing elements in combination with overlearned skills which are already in the learner's repertoire, the learner is able to remember and retrieve the material at another time.

Man's concept of memory has changed over the years. There has been a gradual shift from a global memory to a molecular concept of memories. Recent research has demonstrated that memory can neither be explained by a single organic unit or function, nor can it be explained by chemical changes in the nervous system. Perhaps a complete conception of memory will eventually emerge from the different theoretical approaches.

The Storage and Retrieval Process

"In an organism endowed with memory, the acquisition of information leads by definition to storage" (Pribram, 1968, p. 1). Two major approaches have been pursued to study the processes through which information is stored. Neurophysiologists study the physical activity of cells and attempt to account for the phenomena of learning and memory in terms of cellular changes. These changes are thought to be either structural, functional, or both. In the stimulus-organism-response paradigm, neurophysiologists study the effects of manipulated aspects of the organism in terms of cellular changes and motor responses. Psychologists study the activity of organisms and attempt to account for phenomena of learning and memory through manipulating stimulus variables and by requiring the organism to exhibit various response classes. Psychologists then make inferences about the state or states of the organism from observed responses.

A fruitful convergence of the two disciplines is noted in recent years, with psychologists developing neuropsychological theories and neuorologists performing psychological experiments. Improved methods of studying phenomena of brain malfunction and atypical development have given impetus to the convergence. This section summarizes the views about the neurological basis for informational storage.

According to Hilgard and Bower (1966), two basic opposing views have been held about the neural basis for storing information and/or experiences. According to the "dynamic" view, stimuli initiate continuing electrical activity in the appropriate neural circuits and memory exists as long as these circuits remain active. The "structural" view of memory hypothesizes that learning consists of structural changes in the nervous system, and that memory will persist even though the original neuronal circuits are no longer active. It may be that short-term memory represents the continued activation of the appropriate neural circuits, whereas long-term memory depends upon some structural change in the nervous system.

According to the dynamic neural basis for memory, loss of memory will result when the electrical activity in the neural circuits is discontinued. Hilgard and Bower reject the dynamic view and cite two examples where learning has occurred and memory was not lost despite the fact that the neural circuits were disrupted. The first example is an animal study. A hamster was cooled down to 5° C. causing the hamster to hibernate. Very little neuronal brain activity was recorded during the hibernation period. When the hamster was brought back to its normal body temperature and tested, it still retained the habits which were taught before the neural circuits were deactivated by hibernation. Grand mal epileptic seizures are another example of extreme electrical disruption in the brain. According to the dynamic view, these electrical brain storms would disrupt the neural circuits and result in memory loss. After recovering from seizures, however, the victims are not devoid of memory. For these reasons, Hilgard and Bower take the position that memory represents a relatively permanent or structural change in the nervous system.

The "structural" view of memory as a consolidation of memory traces was initially proposed by Müller and Pilzecker (1900). Their hypothesis suggested that the storage process is the result of neural processes which persist for some time after the experience. The longer the neural activity continues, the more permanent the physical changes become. It follows, then, that if the neural activity is interrupted, the physical changes would be of a lesser magnitude and the retention reduced.

Hebb (1949) also developed a neurophysiological model to account for the memory phenomena. According to Hebb, immediate or short-term memory is simply the reverberation of neuronal circuits which are initiated by sensory input. These neuronal circuits can be called upon for immediate recall but if the trace decays before there is some kind of structural change immediate recall will dissipate. In contrast, strengthened traces result in more permanent structural changes in the neural pathways which in turn result in long-term memory.

Most of the research which has been gathered to support the hypothesis of the consolidation of memory traces consists of inferences from behavioral studies. Some support, however, comes from clinical experimentation with animals which allows more direct observation of events or changes within the central nervous system. A procedure which has been used widely consists of registering an experience and then intentionally traumatizing the brain. Theoretically, disruption of this kind should disturb the memory trace and interfere with recall in later retention tests.

Electroconvulsive shock and drugs have been used in experimental work on induced amnesia in animals. Rats, for example, are given learning trials on a specific behavior and then are given an electroconvulsive shock. In subsequent testing, the rats' performance is disrupted most when the electroconvulsive shock is given almost immediately after the learning trials (Duncan, 1942). Stimulation of the central nervous system by drugs may tend to either increase the consolidation rate, or perpetuate short-term activity of neural circuits, either of which would result in more learning per trial. Drugs such as strychnine, diamantan, and picrotoxine tend to speed up the maze learning of rats (McGaugh, 1965). McGaugh studied genetic constitution of rats and found that two genetic strains of "maze-dulls" and "maze-brights" differed in their rates of memory consolidation.

Memory may involve the entire central nervous system in storing and retrieving information and experiences. There are a few studies which suggest that different areas of the brain may contribute in some specialized way to the memory process. Most of the inferences which have been made about the function of different areas of the cerebral cortex are based upon either the results of electrical stimulation of the cortex or studies of brains which have been damaged. Both animal studies and research with human subjects have attempted to link the loss of memory function to brain damage in a particular area of the cerebral cortex. It should be noted that the frontal lobes and the temporal cortex have been identified as having an important function in the memory process. The nature of this relationship, however, is not clear.

According to Penfield and Rasmussen (1952), the temporal cortex is involved in the act of remembering and making comparisons between present sensory perceptions and past experience. Case studies are cited in which the temporal cortex is stimulated by electrodes. The hallucinations which result from this kind of stimulation are viewed by the patient as a memory which he has summoned. He is aware of it and is able to think about it. It seems, therefore, that the activity of the temporal cortex has a function in remembering or interpreting things seen or heard. Penfield and Rasmussen (1952) point out that the two temporal lobes probably have equal value because one lobe can be removed on either the dominant or the nondominant side without evidence of marked memory loss or interference with the capacity for perceptual interpretation. Of the thousands of visual impulses sent to the occipital cortex, a few are stored in the temporal cortex as memory. According to this view, the experiences on which man has focused his mind are stored in the temporal cortex; and these auditory, visual or combined memories may be brought forth to consciousness by either minor seizures or electrical stimulation. Unquestionably the temporal lobes are involved in the process of remembering. However, few people would take the position that the memories are actually all stored in this area. More likely, the temporal lobe has some function in referring memories to other parts of the brain for storage, or in the recall process.

How are the frontal lobes related to memory? The organism that has experienced damage to the prefrontal lobes is less attentive, less vigilant, and perhaps more distractible than before. These characteristics indirectly affect the symbolic functioning of the organism (Shure and Halstead, 1958). Perhaps it is the distractibility resulting from frontal lobe damage which interferes with the storage process.

At the present time, there is very little definitive evidence about the process by which memory is stored in nervous tissue (Hilgard and Bower, 1966). There are two approaches to the explanation of the nature of these long-term changes. There are those who consider that they represent physical changes in the neural structures, especially the synapses. There are others who are postulating molecular biological changes in the large molecules of the cell, somewhat related to the genetic alterations of the DNA–RNA structure of the cell.

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. Are there anatomical or biochemical changes at the synapses along the neural pathways? Will study of the single neural cells develop proof of the hypothesis about physical changes in learning? To what extent does the amount of the chemical composition of the brain affect the rate of learning? Is the ratio of one chemical to another an important factor? Do chemical imbalances in different areas of the brain create problems in learning? For example, what is the importance of acetylcholine and cholinesterase and cellular neural chemistry with respect to memory functions?

There is need to determine the functions of anatomical structures which are involved in the memory process. If, for example, damage occurs to one structure, is it possible for another structure to assume part of this function, or is the function permanently lost? Another area for further research is the relationship between genetic memory and genetic constitution.

Assessment

The assessment of short-term memory has been performed both for normative and for clinical purposes. Assessment procedures have relied upon recall, recognition, and reproduction tasks. Only a few procedures have been developed for studying afterimages, memory span, the effects of aspiration level and delayed responses.

Afterimage

Basic to the assessment of short-term memory is the study of the stimulus afterimage. When a stimulus is presented, the excitation of the neurones may continue after the stimulus itself has been withdrawn. The "aftereffect" or "afterimage" of a stimulus can be considered as the first impression of a memory trace. A common procedure for studying visual, auditory, or kinesthetic afterimage is to measure the duration of the direct retention of a series of concrete stimulus items. This kind of assessment is concerned with the most elementary processes involved in memory. It should be noted that most of the research has been done in the visual area because of the technical problems in studying auditory and tactile images (Osgood, 1953; Hilgard and Bower, 1966).

A typical procedure for the clinical assessment of memory traces is described by Luria (1966):

Visual traces.—Present three or four visual images (simple geometric figures) for 5 to 10 seconds. The figures are then covered and the subject is asked to draw as many of them as he can remember.

Acoustic traces.—Present series of rhythmic notes or beats for the subject to reproduce.

Kinesthetic traces.—Present a series of positions of the hand for the subject to reproduce. The subject should have as little visual information as possible concerning his hand.

Verbal traces.—Dictate or present in writing a series of three or four words or figures for immediate vocal repetition.

There is little information about how to assess the kinds of learning strategies people employ in order to remember. There is need to describe these strategies and to relate their effectiveness to the intellectual activities required for specific kinds of memory tasks. Luria (1966) describes a procedure to investigate logical memorizing. The subject is asked to memorize a series of 12 to 15 words. A card for each word is used as an aid. The cards establish a chain of meaning between the word and the pictorial representation but the cards do not depict the meaning of the word. A card with a picture of an umbrella, for example, would be used as an aid to remember the word "rain." The subject either may be told that a particular picture is an aid for a particular word or he may be asked to choose the most suitable picture for each word. Each time he is asked how to memorize a particular word. The group of cards is shuffled and presented in random order. The subject must select the correct picture. The process of using logical connections for memorizing begins to develop in children before they reach school age, and is finally established at the beginning of the school period after which it becomes progressively more complex.

Memory Span

The most widely used measure of memory span is the number of items, e.g., digits, objects, designs, words, and narratives which an individual recalls after a single presentation. By increasing the number of stimuli presented to the subject, the examiner is able to test the range of elements that the subject is able to retain and retrieve. The stability of direct retention may be assessed by lengthening the interval between presentation of the stimuli and the beginning of reproduction. Several factors have been shown to affect retention: Number of units previously learned; number of units to be learned; practice; rate of presentation; pronounceability, recodability, familiarity; meaningfulness of units; duration of the retention intervals; and activities during the retention interval

(Blankenship, 1938; Van De Moortel, 1965; Scott and Scott, in press).

Aspiration Level

The subject's aspiration level in relation to the failures he experiences during the learning process is an important dimension which is frequently overlooked. Luria (1966) presents a procedure for assessing the effect of the aspiration level upon volume. A list of 10 to 12 words, or 8 to 10 numbers is presented to the subject. The words should be unrelated and the list should be longer than the subject is expected to memorize. The subject is asked to memorize the sequence and reproduce it in any order. After he has written down the elements he has retained, he is given the series again and the results are recorded. This procedure is repeated 8 to 10 times. Each time the results are plotted on a memory curve to gain a better idea of the order of memorization. The investigator denotes each reproduced word by numbers corresponding to the sequence of their reproduction. The subject who has just memorized a certain number of words is asked how many words he feels he will be able to memorize when the sequence is next repeated. He then proceeds to learn the words and the results are plotted on a learning curve.

Delayed Response

A clinical procedure developed by Hunter (1957) utilized the delayed response to measure higher learning processes involving the application of symbols. A test for delayed reaction requires a response to an absent stimulus. In order to respond correctly, the child must recall what the stimulus was or where it was. Delayed reactions elicited without external guidance from any cue are considered to be mediated by symbolic processes. After the delay and at the time of response, the internal symbolic processes must substitute for the stimuli. Two important questions are: (1) How long can a symbol be retained in order to mediate recall? and (2) How many items can be recalled after a delayed reaction? The interval between the presentation and the test for recall may be increased until the subject fails the test.

Tinklepaugh (1928) tested delayed reaction in monkeys. An object was placed under one or two cups, then the subject was taken away from the situation. Upon his return, the subject was observed to see whether he would lift the cup which has the object beneath it. This is a spatial memory test. Another variation of this test is to substitute something for the original object. When the correct cup is turned over something other than the original object is found. Some subjects may search the vicinity for the desired object. A nonspatial delayed reaction test can be given by requiring the subject to recognize several test objects which have been presented some time earlier. The subject must demonstrate his recognition of an object through a matching task. The object itself must be remembered and its position disregarded. Although few recent studies report data on the delayed response procedure in assessing the memory of children, it appears to offer distinct possibilities for research, especially among language-handicapped children.

Disorders of Storage and Retrieval

Most of the research on memory disorders has been directed toward the loss of memory through trauma in adult subjects. There are several reasons which may help explain why adult subjects are used so frequently in the study of memory. First, the symptoms of memory loss in an adult are obvious. Second, memory is difficult to measure in young children with little language. In contrast, the adult subject may retain partial ability to demonstrate retention either through words or gestures. Third, maldevelopment is difficult to identify and measure. Failure in retention may lead to failure in performance on psychological test items which require some degree of retention for success. Low scores on tests sometimes lead to the classification "mental retardation." Inconsistent performance may lead to the classification "brain damage." Due to the sparse research on children, therefore, many inferences about children continue to be based on the study of adults.

A dysfunction in memory might occur at a basic neurological level. Several studies have demonstrated that pathological conditions of the brain change the basic excitability of the cerebral cortex. Research studies on the elementary processes involved in memory trace, for example, have found that pathological states of the brain alter afterimages (Bogush, 1939; Kaplan, 1949; Balonov, 1950). Luria cites a study by Zislina (1955), in which tumors of the occipital lobe were found to cause a reduction in the brightness and duration, or total disappearance of afterimages. This may be an early symptom of the presence of a lesion and may occur before any disturbance in direct visual perception is demonstrated. Most of the research on afterimage has been done in the visual area. Auditory and tactile afterimages are even more difficult to study.

According to Luria (1966), patients with general cerebral changes in cortical activity show many of the same qualitative features of the learning process which are found in normal subjects. In setting levels of aspiration, these patients appear to consider results obtained in preceding trials. The level of aspiration, however, is usually higher than the number of elements that the patients are capable of memorizing. They attempt to learn the words in a particular order and to attend to words that they were unable to remember during previous trials. Few mistakcs were made, and the same mistakes were not repeated many times in succession. Pictures aided in the recall of associated words.

There are differences between normal subjects and patients with lesions of the posterior divisions of the brain. Individuals with posterior brain damage tend to learn slowly. The volume of material which they are capable of learning is somewhat smaller, and many subjects cannot memorize more than five or six words. Another characteristic is that they may demonstrate the ability to reproduce a group of newly presented words, but in doing so forget the group memorized previously. The learning curve reaches a peak during the fourth or fifth repetition, begins to decline and then becomes dome-shaped.

Patients with frontal lobe syndromes, however, do not demonstrate this pattern of behavior (Luria, 1966). They tend to set their predictions of the number of elements they will memorize on the next series at a low level and keep that level regardless of the number they did memorize.

According to Luria (1966), damage to the frontal lobes often results in gross memory defects in the selection of images. Recognition tends to be more intact than does reproduction or recall. Old verbal associations appear to be less affected than more recent associations, and sometimes, voluntary memorization of new material is made more difficult by interfering old associations. There tends to be some perseveration of behavior. Some subjects may continue to perseverate an action rather than change to a more appropriate form of behavior. The subject with a frontal lobe lesion also has difficulty in recognizing mistakes that have been made or in correcting these mistakes. In memorizing a series, words are often reproduced in random order. Mistakes which have been made once are repeated with no attempt at correction. The learning curve does not rise above certain limits and assumes the shape of a plateau. These individuals are unable to select and use logical corrections as an aid to memorization. Pictures offered as aids often trigger independent associations which are unrelated to the corresponding word. When word and picture are joined by some kind of logical connection, the connection is not used for the subsequent reproduction of the word. Independent associations continue to be aroused. Failure to develop an afferent feedback mechanism for active memorization is an important symptom of disturbance in higher mental processes associated with lesions of the frontal lobes.

According to Munn (1965), performance on delayed reaction tests is generally impaired by lateral lesions involving the frontal lobes of the cerebrum and in cases of prefrontal surgery, in which the tips of the frontal lobes are removed. Munn notes that when comparable amounts of tissue from other regions of the cerebrum are removed, the delayed reaction is generally not affected. This finding holds for a variety of organisms such as rats, monkeys, chimpanzees, and human beings (Loucks, 1931; Morgan and Wood, 1943; Jacobsen, 1931; Pribram, Mishkin, Rosvold, and Kaplan, 1952; Jacobsen, Wolfe, and Jackson, 1935).

Luria (1966) observes that frequent repetition of the stimulus does not result in an increase in the number of elements reproduced by an individual with a pathological condition of the cerebral cortex. Difficulty in changing from one series or sequence to another leads to perseveration on the original sequence and is a sign of pathological inertia of the nervous system which is characteristically found in individuals with organic brain damage.

Considerable attention has been given to the learning processes and their modification by pathological states of the brain. Investigation of these processes may provide valuable results for the clinical study of brain lesions. It is interesting to note that Luria (1966) considers the most important aspects of the learning process in an individual to be: (*a*) the analysis of methods used during the process of learning, (*b*) the ways in which the volume of retained material increases, and (*c*) the patient's reaction to any mistakes he might make.

A study by Hutt, Lee, and Ounsted (1963) investigated whether evoked bioelectric paroxysms, not accompanied by clinical seizures, may have an effect on recall of digits presented at the rate of 1 per second. Two children with epilepsy showed impairment of recall whenever bioelectric paroxysms were evoked by stroboscopy, in contrast with two other epileptics who, under similar conditions, did not. Hutt et al. suggest that at least two physiological subsystems are required to account for the results. Hutt et al. cite Olds and Travis (1960) on the effect of chlorpromazine upon memory in rats and suggest that the drug may be acting on one of the postulated subsystems.

In reference to subclinical epilepsy, Masland (1969) points out that mental confusion in epileptics may occur under several circumstances.

1. A period of confusion frequently follows a severe seizure, and might be looked upon as exhaustion of brain cells. Such exhaustion rarely lasts more than 1 or 2 days after a severe seizure.
2. There are certain types of seizures which are relatively inapparent, and which may be mistaken for mental sluggishness or deliberate disregard of instructions. I refer to the absences or "petit mal" type of seizure. They consist of a momentary lapse of consciousness with little outward movement.
3. In many epileptic patients, there occur random electrical discharges in the disturbed area of the brain which occur between seizures and of which there is no outward manifestation. Such subclinical discharges are thought to interfere with normal brain functioning, and to be associated with confusion or personality changes. Such discharges are thought to interfere with proper storage of memory traces. (Masland, 1969.)

Improving Memory

Can memory be improved? According to Hunter (1957) at no time in the history of psychological investigation has there been the slightest evidence to suggest that improvement of retention could be brought about by practice. While it may not be possible to train an intangible ability such as memory, it does seem possible to expedite the storage and retrieval of specific kinds of information through improving techniques of selective observation, organization of materials, and repetition.

Practice

An early experiment by Sleight (1911) gave three groups (average age 12–8) different kinds of practice over a 6-week period. Group I memorized poetry; group II memorized quantitative facts such as scientific formulas and geographical distances; group III memorized selections of prose passages and immediately wrote them. A fourth group had no practice. Despite the fact that each of the four groups were equal on a pretest of 10 different types of memory, the post-test showed no general improvement in learning as the result of any of the three forms of practice.

Bradford (1939) investigated the effect of practice on variability in memory tests. Bradford found that with college students and 10th grade students, practice did not increase trait variability in the various memory tests. Bradford gave his subjects separate forms of seven memory tests on each of 9 successive days. Digit span appeared to be the test on which they improved the least with practice. Recognition and recall tests were given for nonsense syllables and digits. Digit recognition gained the least. Digit recall gained between 30 and 60 percent for all the subjects. Nonsense syllable recall improved much more than did nonsense syllable recognition. This is perhaps a function of the fact that recognition usually exceeds recall on first retention trial for any learning task. An earlier study by Gates and Taylor (1925) showed that 78 days of practice in repeating digits resulted in the gain of almost two digits but the improvement disappeared by the end of 4 months.

A specific instance of experimental teaching or training auditory memory deficits is reported by Kastein and Trace (1966). The child with whom this method was used was a 5½-year-old girl with delayed language. In order to remediate auditory memory, the speech pathologist had asked the mother to train the little girl in the task of repeating a series of nonsense syllables. They began with two syllables; then as the child was able to repeat two correctly, the number of syllables was gradually increased to three, four, and five. At this time the child was also being taught to speak in complete thoughts, albeit in the telegraphic style, such as, "Eat green beans" and "Jean play ball." The next type of memory training was that of repeating nursery rhymes. Individuals in the little girl's environment were instructed to ask her to repeat each statement or request that was made to her. Slow but sustained improvement, lasting over years, was reported.

Hilgard (1933) gave two 4½-year-old twins practice in repeating digits and found a temporary improvement in performance. Hilgard also developed an object-memory test. The object-memory test consisted of placing a combination of small toys or objects in front of the subject at the same time. Each toy was presented for approximately 2 seconds and removed. The child was then asked to recall which toys she had seen by naming them. Two toys were presented to the child. If the child recalled them correctly, three were presented. If those were correct then four were given. Seldom was there success in naming four. Practice was found to improve object-memory, but this improvement tended to decline after a period of no practice. The object-memory task required more concentration and attention and appeared to be more easily affected by fatigue than did the task of repeating digits. It will be noted that this task differs from the delayed response task in which the subject is expected to move or point toward the place of concealment of the object. In Hilgard's object-memory task the subject is expected to recall and name the objects which have been presented.

Drees (1941) investigated the effect of practice upon memory performance in school children. He presented eight cards with a name and a numeral on each card and read the material to the children. The children wrote the material in a booklet. An experimental group received 3 months of practice, one period every school day. A 4-month rest period followed the practice period. There were five tests: At the beginning of the experiment, at the end of the 3-month practice period, at the end of 4-month rest period; then both groups received practice and were tested again 2 weeks later. There was an additional retest at 4 weeks after both groups had received additional practice. Results showed that the experimental group improved as a result of their daily practice and lost this improvement after a no-practice period of approximately the same length. The experimental group did not differ from the control group at a later practice time. It is important to note that the children were not instructed in the techniques of memorization.

Organization and the Application of Rules

Perhaps more efficient learning is the only way in which memory can be improved (Hunter, 1957). Organizing material seems to be one of the best devices for remembering things. An experiment by Katona (1942) gives an example. He presented adult subjects with a series of digits. One group of subjects was given 3 minutes to discover the principle involved in this series of digits, while another group attempted to memorize the digits in groups of 3's. Three weeks later, each group was asked to recall the digits. Twenty-three percent of the principle-seekers reproduced the digits perfectly while none of the memorizers could. The memorizers had to learn 24 separate numbers and their locations but those who discovered the principle for the series had to remember only two units, the number which began the series and the principle for expanding the series.

Woodrow (1927) formed groups and provided different kinds of practice. A group of university students practiced memorizing poems and nonsense syllables. The training group had practice in memorizing poems and syllables, and received instruction in methods of efficient memorizing. The rules taught to the training group were: (1) be alert; (2) concentrate on learning; (3) have confidence in your ability to memorize; (4) learn by wholes rather than by parts; (5) use recitation; (6) organize the material in terms of its rhythm and its meaning; and (7) practice using or making secondary association to nonsense syllables. The control group received only the pretest and the posttest. This experiment showed different results from that of Sleight, because the training group which learned rules were better on the posttest than either the practice group or the control group.

Programmed Presentation

The sequence in which experiences and/or information are presented and the mode of presentation may have an effect on the child's retention and recall. The research literature on interference, for example, points out that the amount of forgetting which occurs is dependent upon the kinds of intervening activities (Bruning and Schappe, 1965; Peterson and Peterson, 1959). According to Whimbey and Leiblum (1967), the interspersing of activity between presentation and recall does not change the psychological processes which are involved—only the difficulty of the task. If learning or memory tasks can be simplified through careful programming, the learner should become more efficient in accomplishing that particular task.

There are a number of task variables which have been found to affect memory span. These include: Rate of presentation, presentation mode, list length, syllabic length of words, nature of the material used, rhythm of presentation, rate of presentation, method of scoring, time of day, fatigue, attitude, distraction, practice, drugs, and pathological states (Lumley and Calhoon, 1934; Underwood, 1964).

Memory Monitoring

Hart (1965, 1966, 1967) has conducted a series of experiments on memory monitoring. Hart employed a recall-judgment-recognition paradigm to assess the accuracy of the memory-monitoring process. This approach makes use of the fact that recognition usually is an easier task than recall. The subjects are asked to recall memory items. For those items which they are unable to recall the subjects are asked to give a memory-monitoring judgment about whether or not they feel that they know the correct answer well enough to recognize it among wrong alternatives. After completing the recall task, the subjects are given a multiple-choice recognition test. The accuracy of an individual's memory monitoring system can be assessed by comparing the proportion of correct recognitions on "feeling-of-knowing" items with the proportion of correct recognitions on the "feeling-of-not-knowing" items.

This process seems to be a fairly good indicator of memory storage. It can be applied to the prediction of recognition successes and failures and somewhat less accurately to the prediction of second attempts at recall. Generally, when people feel that they know something, they usually know it. Similarly, if they feel that they do not possess the information the probability is great that they do not possess it. When an individual fails to remember, he must then determine whether or not the item is possibly stored but not retrieved in his memory bank. A monitoring process is used to make judgments as to whether or not the subject has the information and should make an attempt to retrieve the information. Inefficient memory monitoring can result either in futile attempts to retrieve information which is not stored or in failure to attempt the retrieval of items which are in storage.

The memory monitoring process may have implications for remediation in a number of different areas. Children who do not have confidence in whether or not the information for a specific item is in their storage banks could be given confidence in a concrete way through training in memory monitoring. It may be possible to adapt the memory monitoring process for specific content areas such as reading, writing, arithmetic, or spelling. Research should be conducted to determine whether different sensory modalities play prominent roles in memory monitoring systems. One individual, for example, may rely upon auditory recall or recognition; whereas, another individual might rely entirely or almost entirely upon visual recall or recognition. It may be necessary, therefore, to train a memory monitoring process for each specific modality. The basic concept provides an interesting approach to the problem of improving memory.

Biochemistry

There is little information about relationships between the biochemical makeup of the brain and memory. Hilgard and Bower (1966) discuss the importance of cellular neurochemistry to learning. Recent studies have investigated the effect of drugs upon performance in learning tasks. The effect of the drug Thiopental upon learning and retention of pictures and pairs of letters and words by normal subjects was explored by Osborn (1967). Both recognition of letters and recall of words and letters was decreased by amounts correlated with the concentration of Thiopental in venous blood at the time of learning. Talland and McGuire (1967) investigated the effect of the drug Cylert upon learning and retention. The drug did not improve new learning but it did improve maze relearning and reproduction of a line drawing. The area of biochemistry may prove to be one of the most important areas for developing techniques to modify learning processes.

Directions for Future Research

Little is known about the neurophysiological, biochemical, and psychological basis for memory. There is need for the medical, psychological, and educational disciplines to clarify the conceptual distinctions which have been made about memory, such as: the physiological and psychological basis for memory; the global and molecular aspects of memory; sensory versus intellectual memory; memory process and memory product; and storage, scanning, and retrieval.

There are several theories which attempt to explain the storage and retrieval process but there are only a few studies which have attempted to observe events in the nervous system. There is need to conduct basic research with both animals and humans to determine the neural basis for memory. Drugs, surgery, electroconvulsive shock, and cellular chemistry should be used to study the memory process in different areas of the brain, as well as their interrelationships. Any statement about the relative value of this kind of basic research for the educator should probably be reserved until data have been gathered and educators have had the opportunity to relate their application in the teaching situation.

The few procedures which have been developed for assessing memory 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 are needed which take into account the nature and quantity of the material to be learned, the meaningfulness of the material, 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.

There is need to obtain detailed descriptions of memory disorders in children. If a child has a specific, rather than a general memory problem, it might be helpful for planning purposes to obtain descriptions of memory performance in the areas which are not affected. Another issue which should be explored is whether or not memory disorders in children represent the same kind of memory disorders which have been described in adults. A child may function normally at a concrete, sensory level but as the same child grows older he may experience great difficulty in acquiring, retaining, recalling, or recognizing spoken or written symbols. When a child has been diagnosed as having organic brain damage, the behavioral manifestations should be described. Remedial efforts should also be described and the child's progress carefully recorded. Through careful description of organic involvement, behavioral symptoms, and remedial intervention, it may be possible to make statements about etiology, prognosis, and treatment. At the present time, however, the status of description of memory disorders remains at a gross conceptual level.

The research which has been conducted on the remediation of memory dysfunction is limited. The facilitating effects of practice usually disappear when practice is discontinued. Several attempts to improve memory through organization and the application of rules have met with limited success. The application of learning principles in programmed presentation has made retention more efficient. Improving the memory monitoring process is another intervention technique which may have some value. Although memory appears to develop along with physical growth, there is no evidence that memory can be improved through outside intervention. Improvement through biochemistry may be possible at some future time. Until then, educators must pinpoint the specific memory problem with which they are concerned and intervene with specific techniques designed to improve initial learning (Pribram, 1968).

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DYSFUNCTIONS IN SYMBOLIC OPERATIONS

72/73

CHAPTER 7

AUDITORY LANGUAGE

This chapter reviews the problems in assessing and treating central processing dysfunctions which interfere with the acquisition and use of a first language. Major issues are discussed and future research needs identified. Also included in this chapter is a preliminary task analysis that describes, in behavioral terms, the various subtasks which must be attained in order to develop facility in understanding and using auditory language.

Because of the wide scope of language study, it is not possible to comprehensively treat all aspects of language in this chapter. The chapter, therefore, has several limitations. First, only a minimal description of the linguist's conception of language as a system will be included. Theory concerning the acquisition of language in children is in a state of controversy. In the absence of research studies to support various theoretical positions, particularly with respect to children with brain dysfunctions, it is not possible to make definitive statements about the many aspects of language study which have been or are being raised by Skinner (1957); Carroll (1964); Chomsky (1959, 1965); McNeill (1966); Osgood (1966); and Lenneberg (1967). A second limitation is reporting research which focuses on disorders in children, excluding the adult population. Third, the psychologists' and philosophers' concern with "thought" is not treated here. A fourth limitation is the deemphasis on language dysfunctions which have occurred after language has been attained.

There are several reasons for the focus on dysfunctions which have been found to interfere with the initial acquisition of a first language. Although definitive epidemiological studies have not been conducted, it is generally agreed that there are more children who do not develop language by age 4 than there are children who develop and then lose language performance. Since more is known about the etiology and treatment of conditions relating to loss of language performance, the reader can find adequate discussions on loss of language elsewhere (Head, 1926; Weisenburg and McBride, 1935; Goldstein, 1948; Nielsen, 1946; Wepman, 1951; Schuell, 1953; Myklebust, 1954; Berry and Eisenson, 1956; Wepman, Jones, Bock, and Pelt, 1960; Wood, 1960; Luria, 1963; Osgood and Miron, 1963; Van Riper, 1963; Mecham, Berko, Berko, and Palmer, 1966; Carterette, 1966). Multiplicity of terms applied to children who do not develop language such as asphasic, childhood aphasic, word-deaf, receptive or expressive aphasic, autistic, mentally or socially retarded, and dysacoustic, indicates a need for clarification in description of behavior and diagnosis. Finally, the prediction of language rehabilitation after language loss depends not so much upon the extent of the loss, or the extent of the lesion as upon the age of the child and the degree of his language acquisition at the time of loss (Lenneberg, 1967). Thus, even in cases of language loss it is necessary to have information concerning the initial acquisition of language. For these reasons, the focus of this chapter will be directed toward central dysfunctions which interfere with the acquisition of the auditory language code.

Acquiring the Auditory Language Code

It is generally agreed that in acquiring auditory language, the child acquires an auditory-vocal communication system, a code used by his speech community (Carroll, 1964; Chomsky, 1965). The terminal behavior of the child is agreed to be the comprehension and production of complex and highly structured utterances which conform to the code, the content and form of which are relatively well known (Jakobson, Fant, and Halle, 1963).

Menyuk (1967) summarizes the current state of thinking about the universal components of language:

> The syntactic component contains rules for defining the classes of the language and their functional relationships. The semantic component contains rules for interpreting the meaning of lexical items and the underlying syntactic structures of the sentence. The phonological component contains rules for defining the classes of sounds of the language and translating the underlying structure of the sentence into a sequence of sounds (p. 313).

Menyuk (1967) is conducting a series of investigations to ascertain the sequence in which the universals in the general American language code are acquired. Several studies present descriptions of children's utterances which show that they appear to come closer and closer to adult production with advancing age (Brown and Bellugi, 1964; Weir, 1962, 1966). Also, there seem to be obvious regional variations in pronunciations as well as regional differences in meaning for the same word.

What is not generally agreed upon is the manner in which children acquire the code. The technique of linguistic analysis has been applied recently, with mixed results (Ervin and Miller, 1963). The linguist in the field employs a procedure involving the use of "native informants" who are asked to judge the appropriateness of certain utterances in his own language. The use of native informants presupposes the prior acquisition and retention of the language elements about which judgments are sought. This technique has obvious limitations when the native informant is a young child or infant, not given to making judgments and responding to judgmental tasks. Therefore, the appropriateness of the informant technique is open to serious criticism when dealing with the acquisition of a first language in a young child, or with a child who has not acquired language to the extent that is expected, and a person of any age who has acquired language but lost the facility.

How then is the acquisition of a first language investigated? Myklebust (1954, 1960) discusses a developmental sequence for language acquisition consisting of inner language or meaningfulness, receptive language, and expressive language. Rarely does a child acquire the total performance of one language task before demonstrating acquisition of any part of another language task (Fraser, Bellugi, and Brown, 1963). It is more consonant with the data on language acquisition to postulate that there is a spiral effect, in which some aspects of reception are learned before any aspect of expression is learned. Lenneberg (1967) points out that it is possible to acquire the receptive aspects without any vocal-motor behavior. Without adequate motor control of the delicately balanced sequential system of the speech motor mechanism, however, the acquisition of expressive vocal language may be greatly impeded. The usual order is random vocal-motor behavior, receptive, and then expressive language.

It should be noted that some aspects of phonology may not be acquired in an expressive way until several years after receptive learning has occurred. Some persons have difficulty in producing sounds in their native language of English, especially the consonants /r/ and /s/. Many persons report difficulty in acquiring new phonemes in a second language (Fries, 1963), but young children under 4 apparently have a plastic phonological system which acquires new phonemes easily. Whether there is an upper age limit to the acquisition of a first language is still open to question.

Many discussions of language acquisition are confusing because little distinction has been made between the three major aspects of language performance: Receptive auditory language, expressive auditory language, and vocal-motor production. Few attempts have been made to identify the various central processing functions which are required in the attainment of receptive language or expressive language (Myklebust, 1954). A large body of literature exists, however, concerning the acquisition of vocal-motor production (Travis, 1957; Van Riper, 1963; West, Kennedy, and Carr, 1947; and Berry and Eisenson, 1956).

Gagne (1965) presents a theoretical hierarchy of learning tasks for acquiring language skills. These include: (1) signal learning; (2) stimulus-response learning; (3) chaining; (4) verbal association; (5) multiple discrimination; (6) concept learning; (7) principle learning; and (8) problem solving. There is need to investigate the ways in which these eight different types of learning are employed by normal children as they develop language skills. There is need, also, to study the ways in which central processing dysfunctions affect the employment of these learning strategies and interfere with the acquisition of language.

For purposes of organization, this chapter includes task analyses of the subtasks which may be involved in the decoding, encoding, and production of auditory language. These task analyses represent a very arbitrary distinction between the auditory, motor, and cognitive aspects of langauge acquisition. Language typically develops as an integrated pattern involving the sounds, the motor act of moving the vocal organs, and the kinesthetic concomitants of those movements. As mentioned in table 11, the act of babbling is one of the earliest elements in language acquisition, which must be quite closely related to the acquisition of auditory receptive language outlined in table 9. It should be emphasized that these functions proceed concomitantly, and what is much more important, interact with each other.

It is very difficult to discuss, at the same time, the many interrelated facets of auditory, motor, and cognitive aspects of language acquisition. For this reason, and for purposes of organization, this chapter includes three admittedly primitive task analyses, which are intended to help make several important distinctions and emphasize the major concepts related to auditory language dysfunctions among children. Although the acquisition of receptive auditory language, vocal-motor production, and expressive auditory lanaguage is generally believed to be interrelated and may occur at the same time, there is little research as to how much vocal-motor behavior and receptive language is necessary for adequate expressive functioning. This is a fertile area for future research. For purposes of organization and clarity, the decoding, encoding, and production of auditory language will be discussed separately.

The acquisition of receptive auditory language behavior is analyzed in table 9. The child first attends to vocally produced sound units, then must discriminate between them. A reciprocal association is formed between the sound unit and an experience. This association allows the child to interpret the vocal sound unit as a meaningful language signal which is stored for retrieval at a future time. The child improves his receptive langauge by analyzing more complex signals and by increasing the speed and accuracy of interpretation. Finally, with sufficient practice the child can shift attention from the vocal-language signal to the meaning carried by the signal sequence. Thus, he will be able to respond appropriately to verbal commands, instructions, explanations, and questions.

Table 10 presents a task analysis for acquiring expressive auditory language. First, the child must possess the need to communicate, and make the decision to send the message. Second, he must formulate the message by retrieving and sequencing the appropriate language signals. The third stage consists of organizing the vocal-motor sequences for producing the desired auditory-vocal signal and producing that vocal-language signal. (See table 11.) Simple vocal-language signals are combined to form more complex vocal-language signals. In time, the child gradually increases the accuracy, length, number, and types of vocal-language sequences to the point of automatic production. Finally, the child shifts attention from the mechanical aspects of sound production to the content of the message to be sent. This enables him to produce appropriate verbal instructions, commands, explanations, descriptions, and questions.

The acquisition of vocal-motor production has been analyzed in table 11. First, random movements of the vocal-motor apparatus produce random vocal-sound units. The child attends to the kinesthetic stimulation of the vocal-motor movements and the audi-

Table 9.—Acquiring Auditory Receptive Language: A Task Analysis

I. Attention: Attend to vocally produced auditory sound units, i.e., noises, speech sounds, words, phrases, sentences.

II. Discrimination: Discriminate between auditory-vocal sound units.

III. Establishing correspondences: Establish reciprocal associations between the auditory-vocal sound units and objects or events:
   - A. Store and identify auditory-vocal sound units as meaningful auditory-language signals: Substitute auditory-language signals for actual objects and/or events.
   - B. Establish word order sequences and sentence patterns.

IV. Automatic auditory-vocal decoding:
   - A. Improve interpretation by analyzing increasingly more complex auditory-language signals.
   - B. Increase the speed and accuracy of the reception of auditory-language signals through variation, practice, and repetition to the point of automatic interpretation.
   - C. Shift attention from the auditory-language signals to the total meaning that is carried by the signal sequence.

V. Terminal behavior: Respond appropriately to verbal commands, instructions, explanations, questions, and statements.

Table 10.—Acquiring Expressive Auditory Language: A Task Analysis

I. Intention:
   - A. Possess the need to communicate.
   - B. Decide to send message vocally.

II. Formulate message by retrieving and sequencing the appropriate vocal-language signals.

III. Organize the vocal-motor sequence:
   - A. Retrieve the vocal-motor sequence for producing the selected vocal-language signals.
   - B. Execute the vocal-motor sequence for producing the vocal-language signal.

IV. Automatic vocal encoding:
   - A. Combine simple vocal-language signals to form more complex vocal-language signal sequences.
   - B. Increase the rate, accuracy, length, total number, and types of vocal-language signal sequences to the point of automatic production.
   - C. Shift attention from the mechanics of producing vocal-language signal sequences to the contents of the message to be sent.

V. Terminal behavior: To produce appropriate verbal instructions, commands, explanations, descriptions, and questions.

tory stimulation of the vocal sounds produced by himself and by others. As the child begins to repeat vocal-motor movements, vocal-sound units are reproduced. He also begins to discriminate between different sounds and movements and to associate vocal-sound units with the appropriate vocal-motor movements which produce them. The correspondences which are established between vocal-motor movements and the vocal-sound units are stored for retrieval at a later time. The speed and accuracy of vocal-sound production is increased until the child can automatically produce the appropriate vocal-sound unit. A complete treatment of the complex and finely tuned mechanism for vocal-sound production may be found in Lenneberg (1967).

Methods of assessing children's performance on various subtasks of acquiring auditory language have been developed through the years. A comprehensive review of representative measures can be found in Spradlin (1967). Analysis of these published test batteries show that they have been developed, with few exceptions, from existing tests, and not from a task analytic approach such as is espoused in this chapter. There is need to conduct future research on the specific subtasks involved in decoding, encoding, and producing auditory language among the normal preschool population. Also, there is need to task-analyze the conditions of acquisition in cases of dysfunction in processing auditory language.

Perhaps the most effective procedure for studying the acquisition of language in children with auditory language dysfunction is to adopt an idiographic (N=1) research design. The behavioral symptoms and etiological factors of auditory language dysfunctions are so diverse, it may be necessary to approach the problem by studying one case at a time (Dukes, 1965). Such a procedure would require longitudinal research on individual children for periods of time up to 6 or 12 years. Data would be recorded including comprehensive case histories and physiological and psychological information. Standardized data-gathering procedures would enable a number of researchers to collaborate and place data in a data bank. The use of computers will make it possible to process the data in a comparatively short time, and identify behavioral syndromes as well as the psychological and neurological correlates to these syndromes.

Brain Mechanisms Underlying the Language Function

Most of the research focused on auditory language dysfunctions has been conducted with adult aphasics and not with children. Masland (1967) has reviewed and summarized a number of experiments which have contributed to our understanding of how language functions are related to the structures and activities of the brain.

The research literature suggests that the left cerebral hemisphere plays an important role in the language function (Masland, 1967). The superior temporal divisions of the left hemisphere, which is responsible for the analysis and synthesis of auditory stimuli seem to be closely related to the sensorimotor divisions which are responsible for articulation. Because these two systems interact a deficiency in one may cause effects in the other. It is pointed out that adults often suffer severe and permanent loss of language due to injury of the left cerebral hemisphere. In children, however, cases have been reported in which the left hemisphere has been removed, but language functioning remains normal (Lenneberg, 1967). Masland offers three alternative explanations for the presence of language dysfunctions in children. First, the damage might be bilateral. Second, the defect may be located in the brain stem or basal ganglion through which information is relayed to the higher cortical centers. Third, there may be genetically or constitutionally determined organizational defects or peculiarities of the brain which

Table 11.—Acquiring Vocal-Motor Production: A Task Analysis

I. Motion: Random movements of the vocal-motor apparatus produce random vocal-sound units.
II. Attention:
   A. Attends to kinesthetic stimuli produced by movement of the child's own vocal-motor apparatus.
   B. Attends to vocal-sound units produced by himself and by others.
III. Repetition: Begins to repeat vocal-motor movements which result in the repetition of vocal-sound units.
IV. Discrimination: Discriminate between different vocal-sound units and between different motor movements.
V. Establishing correspondences:
   A. Establish a reciprocal association between a vocal-sound unit and the motor movement which produces that sound unit.
   B. Store and retrieve vocal-sound units and motor movements.
VI. Automatic vocal production: Increase the speed and accuracy of vocal-sound production through variation, practice, and repetition, to the point of automatic reproduction.

Terminal behavior: To deliberately reproduce the appropriate vocal-sound unit.

interfere with the associations necessary for language acquisition.

According to Zangwill (1960), partial left-handedness or ambidexterity are more frequent than is supposed. Evidence of overt dominance may be obtained by observing the subject perform tasks requiring both hands. Clapping, interlocking the fingers, crossing the arms over the chest, pressing the hands together, width of the nails on the little finger, kneeling, jumping, listening, sighting with one eye can be used to determine handedness, eyedness, and footedness. The hand or arm in the uppermost position has the greatest strength, is the most active, or takes the lead, and is a reflection of dominance.

In studying the age of lateralization of speech functions in the brain, Basser (1962) found that there is a period of infancy when the hemispheres have equipotential. In approximately half the children with brain lesions sustained during the first few years of life, the onset of speech development was delayed. The other half of the subjects began to speak at the usual time. The distribution was the same for children with either left or right hemispheric lesions. This study suggests that cerebral dominance is not yet well established during the first 2 years of life. Lenneberg (1967) points out that both hemispheres seemed to be involved in the initial acquisition of language, and dominance seems to evolve through a progressive decrease in the involvement of the right hemisphere. In the event the left hemisphere is impaired before dominance is established, the right hemisphere persists in its function.

Another topic under current investigation is the question of cerebral dominance or localization of function. The left hemisphere has been found to be most often dominant for language functioning, even for left-handed or left-preferring individuals. Penfield and Roberts (1959), for example, found that surgery of the left hemisphere produced aphasia in 115 of 157 right-preferring persons, and in 13 of 15 left-preferring persons.

The significance of the dominant and subordinate hemispheres for auditory-vocal language functioning is not clear. For example, recent research on left-handed individuals has indicated that lesions in the left cerebral hemisphere (supposedly the subordinate hemisphere) has also produced auditory language disturbances (Chester, 1936; Luria, 1947; Humphrey and Zangwill, 1952; Ettlinger, Jackson, and Zangwill, 1955; Ajuriaguerra and Hecaen, 1960; Zangwill, 1960). Many individuals have left dominance for one task and right dominance for other tasks. It is necessary to determine the significance of dominance and the importance of the left hemisphere.

The general consensus at this time is that the speech centers are in the left hemisphere in the vast majority of individuals. This is true even in left-handed individuals, although in left-handed individuals there are more individuals who are right-brained (possibly up to 30 percent) than is the case with the right-handed. The other point is that there appears to be a greater degree of bilateral representation of language in most left-handed individuals (Carterette, 1966; Mountcastle, 1962).

Wernicke (1874) and Broca (1861 a and b) pointed out that the two cerebral hemispheres were not of equal importance. Their research led them to the conclusion that in right-handed individuals, the left cerebral hemisphere is the dominant hemisphere and is the most important for auditory-vocal language functioning. Jackson's (1867) work, however, suggested that both hemispheres were involved in auditory-vocal language. Jackson believed the dominant hemisphere was responsible for complex language acts and that the subordinate one was responsible for simple actions.

Masland (1967) identifies two possible explanations for the consistency with which the left hemisphere subserves the language function. First, research findings suggest that the left hemisphere seems to be more effective in processing auditory stimuli in temporal sequence. In contrast, the right hemisphere seems to be related to spatial rather than temporal relationships. Second, the left hemisphere may be related to differences between the recognition of learned symbols as opposed to nonmeaningful objects.

Penfield and Roberts (1959) hypothesize that the three cortical speech areas, Broca's, Wernicke's, and the supplementary motor-speech area are coordinated by projections of each part to the thalamus. This hypothesis is supported by the behavioral defects which result from both superficial and deep trauma. Permanent aphasia does not result from superficial excisions of the cortex, but deep trauma or cerebrovascular accidents affect the subcortical structures and do cause aphasia. The precise relationships between the cortex and the thalamus have not been identified (Walker, 1938; Feremutsch, 1963). Much of the research has been done with adult subjects, monkeys and apes, but not with children.

The role of the central nervous system in the development of auditory language, while generally agreed to be extensive, is the subject of much controversy. There is need for further research to clarify the issues and to provide a more accurate understanding of the brain mechanisms which serve as the basis for language functioning. At present there is little information which relates the scope, direction, and sequence of treatment procedures to demonstrable or suspected brain dysfunction. In order to relate the treatment of language functions to brain dysfunctions, educators and members of the medical profession must collaborate and attempt to relate the contributions from both professions.

Description, Assessment, and Treatment of Auditory Language Dysfunctions

Receptive Auditory Language

Many terms have been used to describe disorders of auditory receptive language. Failure to comprehend the spoken word has been called "word deafness," "sensory aphasia," "receptive aphasia," and "auditory verbal agnosia" (Orton, 1937; Goldstein, 1948; Wepman, 1951; Myklebust, 1954; and McGinnis, 1963). The terms "childhood aphasia" and "developmental aphasia" perhaps need to be defined and differentiated (Rappaport, 1964). According to Osgood and Miron (1963):

> Aphasia in children often does not resemble adult aphasia either in symptoms or treatment. By developmental aphasia (sometimes called congenital aphasia) one refers to a condition in which either poor endowment or brain injury occurring before, during, or after birth prevents the child from acquiring language. By childhood aphasia one refers to language impairment occurring after language has been acquired in the normal manner (p. 21).

Wood (1958), in Osgood and Miron, raises the question of whether aphasia in the usual adult sense actually exists in childhood in children who have never developed language. Difficulty in translating experience into spoken words has also been called "a deficiency in inner language" (Werner and Kaplan, 1963). The concept of inner language is not clearly understood and needs further investigation (Myklebust, 1954; Johnson and Myklebust, 1967). The work of Penfield and Roberts (1959), Russell and Espir (1961) and Geschwind (1967), however, has contributed to the understanding of the central processing functions which may be related to inner language. This section will summarize the research needs in acquiring auditory receptive language.

1. *Attending to Auditory Language:* The reception of auditory language requires that a person have sufficient auditory acuity to attend to speech sounds (see chapter 4). Assessment of auditory acuity for school-age children typically includes an audiometric evaluation, tests of speech-sound discrimination, psychological tests, a case history of medical and social development, and informal observations (Berry and Eisenson, 1956; O'Neill, 1964). Fry (1966) presents evidence that infants failing to respond to sensitivity tests and fitted with powerful amplification, especially if the condition is ascertained while under 1 year of age, do then begin to respond to sound. Preschool children and children with language problems, however, may not perform reliably on such measures, perhaps because of failure to attend to the appropriate auditory stimuli. The psychogalvanic skin-reflex test may be of value in testing these children. The children who are not deaf but who do not seem to attend to auditory stimuli, particularly speech sounds, may benefit from auditory training (Berry and Eisenson, 1956; Van Riper, 1963; Mecham, 1966). Reinforcement techniques have been successfully employed to train "attending behavior" (Sloane and McAulay, 1968). As described by Bijou and Baer (1965), observable "attending behaviors" may be regarded as "* * * operant responses whose only function is to either maximize or minimize stimulus input to the child" (p. 144).

Mecham, Berko, Berko, and Palmer (1966) believe that the amelioration of problems in attention is a prerequisite to all habilitative programs. After observing several thousand cases, Berko's staff noted that many "signs" of "brain damage," such as "abstracting problems" and some so-called "perceptual difficulties" seemed to disappear once stable patterns of action were established.

Future research should determine the effectiveness of various intervention techniques for improving attention to auditory stimuli. This would require investigations of both organic and functional disorders and include behavioral intervention as well as drug therapy. There is need, also to develop diagnostic procedures for differentiating between organic and nonorganic problems in attending to auditory stimuli.

2. *Distinguishing Between Auditory-Vocal Units:* In learning the auditory language code, the child must distinguish between sounds, words, and groups of words. There are, of course, many other cues from the physical environment to let the child know which word is being signaled. In the presence of a table set for a meal, the sound c-u-b /kub/ may be interpreted by the child as signalling the word "cup." Likewise, when looking at a picture of a bear family with three small bears at the mother's feet, the child may hear /kup/ c-u-p but interpret the meaning as "cub." Failure to discriminate differences between rhythm patterns, pitch and melody also may interfere with the discrimination

of different sounds and sound patterns, particularly in rhythmic patterns (Kleist, 1934).

Difficulty can also be experienced in selecting the relevant from the irrelevant auditory stimuli. Distractibility due to competitive auditory stimuli may interfere with performance in sound discrimination. Differentiating speech sounds, distinguishing phonemic signs and separating them from insignificant auditory-vocal sound units requires systematized hearing.

Luria (1966) states that the auditory cortex of the left hemisphere is responsible for the "* * * analysis and integration of the sound flow by identification of the phonemic signs of the objective system of the language" (p. 103). Damage to the auditory cortex will not result in the loss of auditory acuity, but may disrupt the analysis and synthesis of auditory sound units. Damage to the superior temporal region of the left hemisphere may result in both phonetic and conceptual disturbances of discriminative hearing. Lesions of the superior temporal region may interfere with identifying sounds from complex sound units, differentiating phonemes, and maintaining sound order. A more detailed discussion of the auditory processing mechanism may be found in chapter 2.

According to Luria (1966), the analysis and synthesis of speech sounds in the superior temporal divisions of the left hemisphere is closely related to the sensorimotor divisions, which are responsible for articulation. A dysfunction in one of these two areas, therefore, will affect the functioning of the other. The interrelatedness of these two areas complicates the task of identifying the primary and secondary cause of a disturbance in receptive or expressive language or in speech production.

The assessment of sound discrimination performance must be preceded by an assessment of auditory processing as a whole (see chapter 2). This includes a test of hearing acuity. Tests such as repeating simple sounds, distinguishing between similar and dissimilar sound pairs should be supplemented by testing the retention of sound sequences. First, the subject is asked to repeat isolated sounds, then dissimilar sounds (o-t), and finally similar sounds are introduced (p-b). The task is made even more difficult by increasing the number of sounds which are presented.

If the vocal-motor response system is impaired, the examiner must substitute an alternative nonvocal mode of response. Older children who can read and write might be asked to write the letters, print the letters, raise one hand or the other, or respond with "same" or "different," "yes" or "no" by a nod of the head. Chapter 2 discusses the various acoustic dimensions along which performance in auditory discrimination can be assessed.

According to Van Riper (1963), auditory discrimination, or the comparison and contrast of sounds, is the final step in training children to analyze speech sounds. This is to be preceded by presenting the sound in isolation, providing stimulation, and helping the child to identify the sound in his own speech by familiarizing him with the auditory and mechanical characteristics of the sound. Utley (1950), Miller (1951), Berry and Eisenson (1956), Mecham (1960), Mecham et al. (1966), and Luria (1966) describe various approaches for training auditory discrimination performance. In the event the subject is able to analyze and synthesize visual information, these functions may be used to help the subject compensate for his deficiency in processing auditory stimuli (Luria, 1966).

Research is needed to evaluate the efficacy of remedial approches for ameliorating auditory dysfunctions as well as for developing compensatory mechanisms for deficits in these problem areas.

3. *Establishing Correspondences:* The process of linking auditory language signals to objects, actions, or experiences is a complex intersensory task. The child must integrate certain auditory information (the sequences and patterns of sounds, and his knowledge of the recurrence of these sequences and patterns) with objects and events in the world about him. These events and objects can be observed by him through any of his sensory information pickup systems. He must relate and recombine the information together with the vocal sounds produced by another person. The vocal sounds do not have to be produced by a person who is physically present with the child. The sounds can come from many sources: Television, phonographs, telephone, from another room.

The child must establish a correspondence between the recurring patterns of sounds and the object or event. In order to learn that the word name "apple" stands for a specific object (an apple), the auditory language signal must be linked with the stimulus qualities of the object.

Auditory language provides a means for naming or labeling objects and actions, distinguishing between their properties, and describing their interrelationships. Words can stand for an object when the object is not present. Research has demonstrated that certain learning principles, such as frequency and contiguity, are important for learning, but the physiological process by which auditory and visual information is integrated has not been clarified (Hilgard and Bower, 1966.) There is need for research to determine how these correspondences are established and stored. Research needs which are related to intersensory integration are presented in chapters 5 and 6.

Future research should be directed toward the syntactical or automatic sequential aspects of receptive language. For example, comprehension of syntax and morphology was investigated in normal preschool children by Fraser, Bellugi, and Brown (1963). Pairs of pictures were shown to children, illustrating a contrast such as "the sheep is jumping" and "the sheep are jumping." One sentence was spoken aloud, and the child pointed to one picture. Templin (1966) used their procedures to collect normative data on children.

Failure to develop correspondences is often reported in case studies of children. Ajuriaguerra (1966) reports the results of clinically training 40 children who had failed to acquire speech in spite of sufficient intelligence and adequate hearing. At first the children were classified either as group I "expressive audimutes" (seriously deficient linguistic expression) or group II "congenital word deaf" (failure to understand speech and disordered verbal expression). This twofold classification had to be dropped, because it did not correspond with the observed facts about the children and their performances. Mainly, for children in group II, noncomprehension of speech took many different forms. Two main forms were finally distinguished: (1) children with normal auditory perception but with serious difficulties in the organization and performance of complex motor tasks such as vocal-motor production, and (2) children presenting complex problems of auditory perception.

Ajuriaguerra reports that all 40 subjects improved, regardless of the degree of intensity of reeducation, but that some of the symptoms remained. The majority of the children showed progress in auditory reception of language, in the comprehension of words, the expression of narratives, and syntax. Those children who were classified as "audio-verbal perception" problems showed little improvement.

Understanding simple sentences requires knowledge of grammatical structures, short-term auditory storage, and the control necessary to postpone premature conclusions about what is being said until the communication has been completed. Lesions in the temporal cortex may limit the number of auditory-vocal signals which can be processed and thus reduce understanding of what is said. If the processing of the sound structure of speech is disrupted, then the more complex auditory language signals, words, phrases, and sentences will probably be disrupted as well. Lesions of the left temporal lobe also may result in failure to establish word name associations with objects, actions, qualities, and events. In these cases, the series of words are not retained. As the length of the series increases word meaning is lost.

Damage to the middle portions of the left temporal region has been associated with the inability to obtain meaning from a word after it has been repeated. An inhibition seems to occur with repeated presentations. Comprehension of complex grammatical units such as sentences may be assessed by asking questions or giving a series of verbal instructions. In cases of temporal lobe damage, the sentence may not be perceived as a whole and the subject might react to only one aspect of the sentence. Impulsive responses are sometimes noted.

The effect of temporal lobe lesions upon abstract intellectual activity is not clear. Goldstein (1948) stated that sensory aphasics are unable to classify objects or carry out abstract operations. However, others have found the opposite. Studies by Luria (1947) and Bein (1957) found that sensory aphasics can grasp ideas, understand the proper meaning of metaphors and allegories, and that the conceptual substitutions often have an abstract basis. This would appear to refute the position that the most abstract concepts, which were last to develop, are the most seriously affected. Prepositions, conjunctions, and connecting words constitute a large portion of the residual speech of the sensory aphasic (Lotmar, 1919, 1935; Ombredane, 1951).

Dysfunctions in the middle segments of the temporal region do not disrupt phonemic hearing, but do result in failure to reproduce a series of words or phrases which have been given orally. The subject's response is often confused and the last segment is frequently forgotten. Difficulty is often encountered in reproducing the sequence in the proper order. Luria (1966) cites cases in which word meaning is retained for one or two words, but in which the patient is unable to retain word meanings when he is presented with several words at the same time.

In another type of temporal lobe involvement, pronunciation of words may remain adequate, while the subject is unable to remember word meaning. Luria (1966) believes that this reflects a dysfunction in establishing auditory-visual correspondences between objects and their word names. This integrative disorder may be due to interrelated temporal and occipital involvement.

Occipital-parietal damage has been shown to affect simultaneous synthesis and orientation in space, and is closely related to difficulty in naming objects or actions (Head, 1926; Conrad, 1932; and Luria, 1947). Occipital-parietal lesions often affect the use of words connoting time, direction, position, and the relationship of objects in space, including adverbs and prepositions such as "up, down, on, under, above, after, beside, right, and left" (Bubnova, 1946).

The problem, however, is not that the subject has failed to attach labels or word names to objects or events which are spatially related. The basic problem is the reasons why the subject fails to grasp these spatial relationships because once they have been grasped, the corresponding label can be attached in a relatively short time.

Complex word constructions which can be reversed, or transformed, such as active and passive voice, may also be affected (Luria, 1945, 1947, 1948). There is little information about the specific cause of these problems. They may represent integrative dysfunctions of the parieto-occipital systems. This kind of dysfunction may interfere with the integration of visual information into a single whole, which can be labeled or related to a specific auditory-vocal language signal. For purposes of training, explanation of the meaning of these words, development of grammatical rules, and use of external aids may help the subject establish functional use of spatial concepts (Bubnova, 1946; Luria, 1948).

Subjects with lesions in either the frontal lobes or the frontal-temporal area may understand the meaning of words which are presented in isolation, but have difficulty understanding the meaning of several words. The degree to which comprehension is affected varies widely from slight to severe. Metaphorical and allegorical meanings may not be understood and cases have been reported where the meaning of words is narrow and rigid (Zeigarnik, 1961; Kogan, 1947, 1961). Disorders of memory may interfere with the selectivity of auditory images. These disorders may be associated with auditory, occipital, parietal, and frontal lobe regions. In cases of frontal lobe involvement, voluntary memorization is involved (Luria, 1966). Disorders of memory are discussed in chapter 6. Impulsivity for premature response also has been found to result from frontal or fronto-temporal disturbances, or generalized brain damage.

Dysfunctions of any of the lower levels of analysis and synthesis will probably disrupt the rapid and automatic decoding of auditory information. There is need to identify the psycho-neurophysiological correlates to establishing correspondences between auditory-vocal language signals (words, phrases, sentences, etc.) and experiences. The assessment of whether the meaning of a word is understood requires either a verbal or motor response. The subject may be asked to describe or to point to the object named. If two or three words are presented sequentially, the subject may respond by referring to previous words. This behavior has been associated with frontal lobe and fronto-temporal lesions (Luria, 1966).

There is need to investigate the application of learning theories, such as Gagné's (1965) eight stages, to establishing correspondences between auditory-vocal signals and experiences. The field of behavior modification and reinforcement theory offers an exciting approach to teaching. The use of operant procedures in remedial speech and language training by Sloane and MacAulay (1968) is an example of putting theory into practice.

4. *Increasing the Speed and Accuracy of Decoding:* In order to understand sentences, it is necessary to become familiar with the fundamental grammatical structures. As the speed and accuracy of processing complex auditory language signals is increased through repetition and variation, attention may be directed toward the content of a vocal message. At present, there is little information about the development of the automatic-sequential aspects of receptive language. The transformations of basic assertions (active-passive, positive-negative, question-statement) seem to be acquired by age 4 (Lenneberg, 1967).

It is necessary to understand the meaning of individual words, but it is even more important to relate the meaning of one word to another. The individual who has acquired logical grammatical units for various combinations of individual words has fewer discrete auditory-language units to process. Future research should investigate the kinds of combinations which are most troublesome for atypical children.

A common procedure for testing the understanding of complex grammatical structures is to present the subject with a series of vocal requests which require a response by pointing, naming objects, or following increasingly complicated directions. Lesions in the temporal lobe or the parieto-occipital systems of the left cerebral hemisphere, and the anterior divisions of the brain have been related to difficulty in understanding logical grammatical structures (Luria, 1966). Behavioral symptoms include the inability to understand the meaning of object words, action words, words which represent spatial orientation or temporal-spatial relationships, difficulty in following complex directions, and a lack of awareness of the implications of changes in word order resulting in perseverative responses.

There is need to investigate the automatic-sequential aspects of language. How is it developed? What are the behavioral characteristics of disorders of automatic-sequential receptive language? How can these disorders be assessed? What kinds of developmental, instructional, or remedial procedures are needed to ameliorate dysfunctions in automatic-sequential receptive language? Little research has been done in this problem area.

Expressive Auditory Language

There are children who have no difficulty understanding what is said to them, but who are unable to use spoken language as a means of communication. Johnson and Myklebust (1967) point out that combinations of deficits may cause disorders of auditory expressive language. But they identify three kinds of disorders which seem to be most prevalent. First, children who have difficulty in reauditorization and word selection typically experience problems in remembering or retrieving words for spontaneous usage. Yet, these same children are often able to understand and recognize words. The second problem consists of failure to execute motor patterns for speaking. Failure to voluntarily initiate movements of the articulators in the absence of paralysis is called apraxia. The third problem is failure to acquire syntax. This is characterized by difficulty in organizing words in their proper word order, using appropriate verb tenses, and making other grammatical errors. For purposes of organization, these three kinds of disorders will be discussed in the framework of the analysis of tasks thought to be related to the acquisition of auditory expressive language.

1. *Deciding to Communicate:* The first step in using expressive auditory language is the intention to communicate. The child must have sufficient motivation to produce vocal instructions, commands, explanations, descriptions, or questions. Without this motivation, no deliberate effort is made to send information through expressive speech. The child must also make the decision to communicate. Despite the felt need to communicate with another person, the child may decide not to send a message. Because this report is concerned with central processing dysfunctions which interfere with expressive auditory language, problems related to motivation are only mentioned here.

It should be noted, however, that the clinical assessment of a child who demonstrates no expressive language typically begins with ascertaining the possibility that the child may not need to talk. It is helpful to set up a situation in which some desirable event is made contingent upon the performance of an expressive language act by the child (Schiefelbusch, Copeland, and Smith, 1967). While this situation may be only an approximation of the terminal behavior desired by the therapist (the spontaneous decision by the child to send a message), it does represent a link in a behavioral chain.

2. *Retrieving Vocal-Language Signals:* In some cases, children can understand and recognize the words that they hear, but experience difficulty in retrieving or remembering these words during spontaneous speech. Johnson and Myklebust (1967) refer to this retrieval process as "reauditorization." Berry and Eisenson (1956) refer to failure in evoking words as an "amnesic" type of aphasia. Children who are unable to retrieve words may convey an idea by using sound effects; gesture or pantomime; delaying their responses; describing the word by use or by definition; or substituting words within the same general category (Johnson and Myklebust, 1967).

Designating objects, actions, and experiences by spoken words is a complex process. A word or words stand for each of the individual stimulus qualities of an object (red, hard, moist). A word used as a name (apple) also stands for the combined stimulus qualities of an object. During the speaking act, a child may fail to retrieve the appropriate word. Instead, he may retrieve a word which is closely associated with the desired word. During the retrieval process, a large number of associations may come to mind (apple, fruit, red, moist, hard, good, pear), and the child must scan and select the most appropriate alternative (apple). A child may retrieve an inappropriate word because it sounds like the desired word (phonological similarity), or it may have a similar meaning (semantic similarity).

Disturbances of the nominative (naming) function have been found to accompany lesions of the auditory divisions of the left temporal lobe, parieto-occipital systems, tempero-occipital systems, the frontal lobes, the fronto-temporal area, and from lesions affecting the brain as a whole (Luria, 1966; Lenneberg, 1967; Salzinger and Salzinger, 1967; Carterette, 1966.) Lesions of the anterior temporal lobe in the left hemisphere have been found to interfere with the organization of a long series of auditory-vocal signals.

Subjects with frontal dynamic aphasia, resulting from lesions of the anterior divisions of the left hemisphere, can repeat individual words and phrases, name objects, pronounce speech stereotypes, but experience difficulty in sequencing elements of a series, or in composing their own scheme of expression for spontaneous speech. Vocal responses are short, passive, and echolalic. They can give a response if it is embedded in questions, but have difficulty initiating a system of speech connections (Kleist, 1934).

Children may be able to recite a well established automatic series, such as numbers or the alphabet, but have great difficulty altering the established order. Luria (1966) describes several direct approaches to the assessment of nominative functions, such as asking the subject to name single objects, pictures, or parts of the body. Several objects may be presented at the same time which may inhibit the retrieval of a word name in the presence of other word name alternatives. The subjects's ability to categorize can be tested by presenting a series of objects or procedures and asking the subject to say a single word which is appropriate or is characteristic of all the objects.

Naming an object from its description is a more complex task because the object is not physically present, and the subject must store the verbal description while attempting to retrieve the desired name. Prompting the subject by saying the first few sounds of the word may elicit the correct word. In cases where the retrieval problem is due to auditory disturbances of phonetic structure, prompting will not help the subject retrieve the appropriate word. Occipital involvement may be suspected if retrieval is facilitated by presenting more obvious pictures of the object or actual tactile contact with objects. Subjects who can name concrete objects but have difficulty in spontaneous-speech production of sentences may be affected by lesions of the frontal lobes. In these cases there is some difficulty inhibiting irrelevant words.

Luria (1966) discusses the investigation of narrative speech. Disturbances in narrative speech are characterized by lack of intention, extinction of word meaning, and loss of the higher automatisms. An important question to answer is whether the subject can produce automatized series of numbers, alphabet letters, days of the week, and months of the year. Failure in producing automatized series and the perseverative reproduction of a part of a series has been related to lesions of the anterior divisions of the brain. The subject is frequently requested to repeat the series forward and backward. Failure to reproduce a series in reverse order has been related to lesions of the frontal lobes (Luria, 1966.) Response to simple questions can be used to study the speed of response, repetition of the question, and flexibility of response. Describing pictures or telling stories is another widely used procedure for studying narrative speech. Substituting stereotyped expressions and phrases is a common mode of compensation for difficulty in composing spontaneous speech.

Instructional procedures in expressive language training are usually designed to cause a desirable event to occur when the child produces a vocal request. The supposition is that the reward received by granting the request will increase the probability of the child formulating a similar spontaneous message on future occasions. Prompting may be necessary if the child indicates that he wishes to say something but does not remember the way to say it. Ambiguous messages are sometimes sent because word order in English determines the meaning of many messages. A young child may retrieve the appropriate words for a message, but produce the words of the message in a nongrammatical manner. The task of the language therapist becomes that of re-forming the message to determine whether or not he is interpreting it correctly and to teach the subject how to formulate messages. This entire subtask merits intensive research effort, on both the content and form of messages, word meaning, and sentence and phrase structure.

Many tests have been developed to measure aspects of expressive language. In contrast, there are comparatively few tests for measuring receptive language. Similar observations can be made about training programs. The expressive "cart" has been put before the receptive "horse." As a result many children may have been trained to imitate or echo spoken language. According to Peterson (1968), imitative behavior is an important step but certainly not the last step in training.

Programs intended to train expressive language usually take the form of building upon whatever performance the child exhibits in receptive language and vocal-motor production. If a child demonstrates no vocal-motor production, the instructor must teach the necessary vocal-motor skills. If the child demonstrates imitation, the emphasis should shift to building intentional speech. Risley and Wolf (1968) present a detailed plan using operant procedures for establishing functional speech in children who imitate inappropriately. McGinnis (1963) and Barry (1961) have developed systematic training procedures for use with deaf, hard of hearing, and aphasic children which may have wider application for children with language dysfunctions.

Research is needed to: (*a*) determine the causes of dysfunctions in retrieving and formulating auditory messages, (*b*) develop assessment procedures, and (*c*) formulate instructional techniques.

3. *Executing the Vocal-Motor Sequence:* Vocal-motor behavior depends upon a certain degree of control over the mechanisms of the body which work together to produce vocal sounds. The mechanism which produces sounds is commonly termed the "speech apparatus," and is generally considered to include the musculature of the diaphragm; lungs; throat; and oral cavity, including the tongue, lips, and cheeks. One should also include the central processing mechanism which regulates and directs the sequences of events in the musculature (Lenneberg, 1967). Before phonation occurs, muscles in the abdominal and thoracic wall and in the larynx have to assume certain positions. Further, the laryngeal muscles have to be coordinated with the oral muscles. Hundreds of muscular adjustments are made every second. The complex ordering and timing of these articulatory events can be disrupted in a number of ways.

This report is concerned with central disorders in which there is difficulty organizing the motor acts necessary for speech and in receiving kinesthetic feedback from the speech mechanism.

For example, efferent or kinetic motor aphasia is chracterized by difficulty in articulating words and coherent speech. While subjects may be able to repeat separate sounds or words which have been overlearned, difficulty may be encountered in inhibiting a preceding speech movement and making the transition from one phoneme to another, repeating a series of words or phrases, reproducing melodies, or changing the order of word sequences. Speech is often characterized by a slow, arhythmical, telegraphic style in which only the key words are spoken. These disorders have been related to lesions in both the superior and inferior divisions of the premotor areas of the left hemisphere (Luria, 1943, 1947). Lesions in the inferior divisions have been found to be associated with the more pronounced disturbances.

Failure to analyze and integrate kinesthetic feedback from the speech mechanism contributes to problems in speech as a means of communication. Articulatory defects arising from lesions of the inferior divisions of the postcentral region of the left hemisphere have been found to result in a disturbance of the kinesthetic organization of motor acts necessary for articulation (Luria, 1966). Difficulty is typically encountered in attempting to place the tongue and lips in the proper position for producing speech sounds. In kinesthetic motor aphasia, the speech sounds are not slurred or characterized by monotonous patterns as in dysarthria. Speech sounds tend to be clear, but many sound substitutions occur during speech. Sounds which are similar tend to be substituted for one another (t/d, l/r, b/p). Repetition of words or phrases is disturbed, but vocal sound units which have been overlearned can be produced correctly. The most prominent behavioral symptom of kinesthetic motor aphasia is the difficulty in seeking and producing the appropriate speech sounds. While entire phrases may be produced easily, it is difficult to produce individual sounds.

There are several simple procedures for identifying disturbances affecting the lips and tongue: "* * * protracted extrusion of the tongue and observation for signs of tremor, deviation, or general inability to maintain this position; protrusion of the lips and consideration of the tone of the appropriate muscles; etc." (Luria 1966, p. 336). Tremor of the lips, paralysis of the facial muscles, and salivation are other symptoms which should be noted.

Defective innervation to the lips, tongue, and cheeks may be determined by asking the subject to bare the teeth, puff the cheeks, wrinkle the brow, frown, squint, and place the tongue in different positions and maintain a single position with the tongue. The examiner should observe for evidence of tension, mobility, asymmetry of movement such as diminished ranges of movement, deviations to one side, and difficulty in imitating movement. The subject is then asked to repeat specific motor acts several times in succession to demonstrate the smoothness of movement and to see if he is able to inhibit other facial muscles during repetitive movement. A slight paralysis of the soft palate results in excessive nasal resonance because of the flow of air through the nose. A poorly modulated and weak voice results from paralysis which involves the larynx.

A comparison should be made of the natural performance of a motor action with performance upon request. For example, a child may be able to move his tongue quickly to lick honey placed on his upper lip. This same child, however, may find it difficult to place the tip of his tongue on his upper lip upon command, even if he is sitting before a mirror. Children should be examined for the presence of apraxia or the inability to organize and perform voluntary motor acts with the articulators.

Because this report focuses on central processing dysfunctions, the treatment of vocal-motor disturbances of speech production will not be discussed here. Detailed descriptions of training procedures for vocal-motor dysfunctions are described by Van Riper (1963); West, Kennedy, and Carr (1947); Berry and Eisenson (1956); Travis (1957); and Goldstein (1948).

4. *Automatized Vocal Encoding:* In table 10 three subtasks have been tentatively identified as part of the automatization process: (1) combining simple vocal-language signals to form more complex signals; (2) increasing the range, rate, and accuracy of production; and (3) shifting attention entirely away from the mechanics of decision on production aspects of the message to the mechanics of decision on the content of the message. Automatization enables the person to participate in conversation, in which he alternates between listening and speaking, and in which he is simultaneously processing the other person's message and formulating his own reply.

The central nervous system structures involved in the development of automatic language expression have not been identified, nor is there agreement concerning the processes by which sentences are generated and produced. Lashley (1951) demonstrated the inability of a stimulus-response behavior chain to account for sentence and phrase production. Chomsky (1957) and Lenneberg (1967) also dispute the possibility of chaining simple word structures into complex syntactic structures. Not even the sequence of automatization of certain structures is known. Investigations such as research on the development of the negative construction in English will add to the store of knowledge. Normative data has been collected on a cross-sectional basis, but there is need for longitudinal data on the acquisition of language patterns for both normal and atypical children.

Mere parroting or reproduction of adequately formed sentences is not the aim of instruction at the level of automatization. What is desired is the spontaneous production of relevant statements, questions, and requests.

There is need to develop and test procedures for facilitating automatic functioning in children. The literature on second language acquisition might provide some useful models for determining the optimum procedures for presenting and eliciting combinations of words, phrases, and sentences. The use of electronic reproduction equipment, such as magnetic tape recorders, may be beneficial in providing auditory feedback to the learner, as well as preserving the ordinarily transient speech signal for later examination and pretraining and posttraining comparisons. Instruction should be accomplished by the careful collection of data so that the efficacy of various training procedures can be evaluated.

Menyuk (1967) points out that the child who is in the process of acquiring language often hear nongrammatical language signals, sometimes mixed with half-sentences, and heard against much background noise. The child who successfully performs acquisition tasks evidently makes sense out of the "jumble." For the deviant child who fails some of the acquisition tasks, the sounds may have remained a "jumble." The linguistically significant contrasts must be identified and defined for this child. Menyuk describes four aspects of language which can be considered as variables to be investigated: structural description (syntax, semantics, and phonology); input/output (grammatical, nongrammatical, and agrammatical); grammatical capacity (addition, deletion, and permutation); and embedding and general capacity (perception, discrimination, identification, memory, and induction). The last aspect, general capacity, includes many of the factors which have been included in the task analysis of receptive language which is presented in table 9.

A major research question is: What are the principles and guidelines for programming the systematic instruction of a first language? This question can only be answered by research in the clinic and classroom—by controlled evaluation of educational techniques.

Directions for Future Research

At present, the status of knowledge with respect to dysfunctions of auditory language is, for the most part, based on work with adults who have acquired language and lost it. There is need to conduct basic research with children to determine how a first language is acquired. There is need, also, to determine how central processing dysfunctions can affect the acquisition of a first language in children. In order to accomplish these research objectives it will be necessary to devise more effective methods for investigating language acquisition in children. Longitudinal study of individual children provides a clinical approach to the problem. Detailed descriptions of specific language behaviors are needed and an attempt should be made to determine if these behaviors are correlated with other observable problems.

Research is needed to clarify the role of different areas of the brain and their interrelationships with respect to language acquisition. What is the difference in hemispheric functioning? What are the implications for language functioning when dominance is not established at an early age? What is the comparative impact of brain damage on language acquisition when it occurs at different age levels? What kinds of procedures are available for assessing brain dysfunction? Research which attempts to link behavior to brain mechanisms should be conducted by interdisciplinary teams.

361-752 O—70——7

Future research areas include investigation of inner language, receptive language, and expressive language. Problems in vocal-motor production arising from central dysfunctions should also be studied. There is need to develop clear behavioral descriptions of receptive language dysfunctions and to refine the terms which are intended to represent these behavioral syndromes. Research should systematically develop procedures for assessing and ameliorating dysfunctions in attention, discrimination, establishing correspondences, and increasing the speed and accuracy of decoding auditory language units.

Research is needed in describing expressive language disorders as related to central dysfunctions. Procedures and techniques for assessing and ameliorating problems in initiating expressive language, retrieving vocal-language signals, executing vocal-motor sequences, and developing automatic aspects of language represent future research areas.

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CHAPTER 8

DECODING WRITTEN LANGUAGE

Three children are sitting at a library table. One child is blind. A book rests on the table and he is feeling the embossed dots of the braille code with his fingertips. The second child is deaf. He has his eyes focused on the page of a book. There is ordinary English print in this book. Despite the fact that the second child has never heard spoken language, he is looking at the graphic representations of spoken words. The third child is also focusing his eyes on the pages of a book. This child is neither blind nor deaf. He sees the print in the book and he has heard spoken language throughout his life. One might say that all three children are reading, but are they? What constitutes the reading process? What must a child do in order to read?

Two basic approaches have been taken to answer these questions. Theoretical definitions have been proposed to describe or define the reading process. Harris (1961) has defined the reading process as "* * * the meaningful interpretation of verbal symbols" (p. 8.). Myklebust and Johnson (1962) have defined reading as "* * * a visual symbol system superimposed upon a previously acquired language system" (p. 15). Fries (1963) defined reading as "* * * a type of linguistic performance depending first of all upon the language control achieved by each individual reader" (p. 186).

More recently the theoretical approach for describing the reading process has been supplemented by operational definitions. Fries (1963), for example, presents several operational definitions such as:

> Responding to language signals represented by patterns of graphic shapes (p. 119).
>
> Developing a range of habitual responses to a specific set of patterns of graphic shapes (p. 121).
>
> Responding to contrastive spelling patterns (p. 187).
>
> Developing habits of hi-speed recognition responses to the identification features of the spelling patterns that represent the word patterns that he knows (p. 183).

It is interesting to note that theoretical definitions best fit the reading of the adult or practiced reader, while operational definitions represent the processes which operate in the individual who is learning to read, as well as in the individual who knows how to read.

To answer the question, "What is reading?", this chapter will attempt to provide an organized structure to which the signficant research on reading and reading disorders can be related. The specific kinds of tasks which are involved in the reading process will be analyzed and the correlates to reading will be discussed. A discussion of assessment procedures for reading disorders will be followed by suggestions for training procedures to ameliorate these problems.

The Reading Act

Although the act of reading has been defined, the component aspects of the reading process have not been clearly identified. A thorough analysis of the reading act should: (*a*) describe the terminal behavior and the conditions under which it occurs; (*b*) identify the specific subtasks which are necessary to achieve the terminal behavior; and (c) arrange the substasks in sequential order.

In discussing the act of reading, it is important to distinguish between beginning and advanced reading. Beginning readers must learn a new code of graphic representations for the previously learned code of auditory language signals. According to Fries (1963), the first stage in learning to read is the transfer stage. The child learns to transfer from auditory language signals, which he has already learned, to a set of graphic language symbols. Beginning readers generally may be expected to learn to decode graphic language symbols as well as they have learned to decode auditory language signals. While beginning reading focuses on the problem of decoding, advanced reading is primarily concerned with comprehension and reading rate.

A task analysis of beginning reading is complicated further by the fact that two methods for teaching reading may require two different sets of substasks. Thus, different methods of teaching reading make different demands on the beginning reader. In order to provide a framework for this chapter, task analysis of two representative approaches to beginning reading have been included. The first emphasizes "meaning" and the second stresses "code breaking."

Table 12 represents an attempt to task analyze a whole-word system of reading. The first subtask requires the reader to attend to the visual stimuli, then the visual stimuli must be identified as a graphic word unit. Finally, the reader must then be able to retrieve the auditory language signal for the graphic word unit and respond by saying the word name.

Table 13 represents a task analysis of a sound-symbol system of reading. The first step in this system of reading requires the reader to attend to the visual stimuli as a graphic word unit. Second, the visual stimuli are identified as discrete letters in a sequence. The reader must then retrieve a phoneme(s) for each grapheme and place these phonemes in a temporal sequence. Last, the reader must blend the phonemes into a familiar auditory language signal and respond by saying the word name. Research is needed to provide a more thorough analysis of both beginning and advanced reading tasks.

Table 12.—A Whole-Word System of Reading: A Task Analysis

I: Attends to visual stimuli..........	cat
II: Identifies visual stimuli as graphic word unit....................	*cat*
III: Retrieves auditory language signal for graphic word unit..........	*cat* → (/kaet/)
IV: Responds by saying /kaet/.........	/kaet/

Terminal behavior: Given a graphic word unit such as "cat," the reader says the word name "/kaet/" within 5 seconds.

Legend:

cat.....	Visual stimulus.
cat.....	Graphic word unit perceived as a whole visual image.
→......	Association in the direction indicated.
(/kaet/)..	Recalled auditory language signal.
/kaet/...	Spoken word or auditory language signal.

The Elements of the Graphic Code

Various codes, using visual representation, have been developed to record speech. Not all languages, however, have been reduced to graphic codes. According to Fries (1963), writing systems or codes have been developed for approximately one-half of the world's languages. Furthermore, not all the elements of speech are represented by any system of writing, whether by

Table 13.—A Sound-Symbol System of Reading: A Task Analysis

I. Attends to visual stimuli......		cat	
II. Recognizes stimuli as graphic word unit........		cat	
III. Identified stimuli as sequence of discreet letters..................	1st c	2d – a –	3d t
IV. Retrieves phoneme for each grapheme.	c → (/k/) a → (/ae/) t → (/t/)		
V. Recalls phonemes in temporal sequence corresponding to graphic sequence in step III......	1st (/k/)	2d – (/ae/) –	3d (/t/)
VI. Blends phonemes into familiar auditory language signal..		(/kaet/)	
VII. Responds by saying /kaet/......................		/kaet/	

Terminal behavior: Given a graphic word unit such as "cat," the reader says the word name, /kaet/, within 5 seconds.

Legend:

cat..........	Visual stimulus.
c – a – t..	Discrete letters in sequence (graphemes).
(/k/).........	Recalled auditory sound signal (phoneme).
——→......	Association or correspondence in the direction indicated.
(/kaet/)......	Discrete sounds blended into word.
/kaet/........	Spoken word or auditory language signal.

pictures, words, syllables, or letters. Historically, writing began with a picture to represent a situation; then a picture or sign was used to represent each word. Next, a picture or sign was used for each syllable. Finally, the separate phonetic units of syllables were symbolized by signs. A list of such signs is called an alphabet.

Unfortunately, many teachers and basal reading series intentionally emphasize only the alphabet letters and punctuation marks, along with an emphasis on the meaning of the word or words. Acquisition of the entire code is not stressed or taught. When this happens, instruction is often inefficient and ineffectual, and may cause children to experience unnecessary difficulty in learning the code. While considerable attention has been given to children's performance on standardized silent reading tests, comparatively little attention has been directed toward the fundamental elements which compose the graphic language code. For many people, the graphic language code consists of two elements: alphabet letters and punctuation. It should be noted, however, that there are other significant elements which make up the graphic language code. With the recent emphasis on acquiring the "code" (Chall, 1967), future research should be directed toward studying the significance of all the fundamental elements of the graphic language code. This would include the graphic shapes of individual alphabet letters and nonalphabetic signs; the space-direction sequence; and English spelling patterns.

Graphic Shapes.—The beginning reader of English must learn to identify and distinguish to types of graphic shapes, the English alphabet and nonalphabet signs. The graphic shapes called the English alphabet consist of a set of 26 letters. Each letter has an upper-case form and a lower-case form. Any letter can be printed in typographic, manuscript, or cursive style. Thus, there are at least six possible graphic forms for each letter, depending on the style.

All letters are made from curved and straight lines. Depending on the style, some letters are all curved (O, C) others are all straight (T, E, N) and still others are partly curved and partly straight (D, G, P). Capital letters have distinctive features by which they can be differentiated: The number of strokes; the position of the strokes, horizontal, vertical, or slanting; the left-right position of the stroke; the relative size of the curved portions and position as combined with the strokes.

The beginning reader must learn that some aspects of the letters are not distinctive features. Size is not distinctive: An *A* can be a half-inch high, an inch high, or in the case of a billboard, 4 feet high; yet its signal is the same regardless of its size. Color is not distinctive, nor is material. The child must learn the distinguishing characteristics. For example, what distinguishes the letter *H* from the letter *A?* This is the kind of question the child must learn to answer. The differences between letter *H* and *A* (in the capitals) are that in the *H* the two vertical lines are perpendicular to the base reference line and the two lines do not meet at the top. The *A* on the other hand must have the two vertical lines meeting at the top of the letter. In the letter *A* some portion of the vertical lines must be nonparallel, that is, the portions of the lines that are to meet at the top can never be parallel. Note that visual discrimination, visual auditory integration, and memory are involved.

The nonalphabetic signs consist of three types: Word signs, abbreviations, and punctuation marks. One set of word signs comprise what we call numerals. These shapes are not alphabetic signs, but rather word signs. For each numeral or word sign in the Arabic system (0, 1, 2) there is a corresponding word which can be spelled (zero, one, two). The other set of word signs are those signs for mathematical processes. The $+$ represents "plus or add." The $-$ represents "minus, subtract, or less." The $=$ represents "equals or are." The $\times$ represents "times or multiply." The $\div$ represents "divided by." The second type of signs the child must learn are the abbreviations of various sorts, acronyms such as "U.S.S.R." and short forms of words such as "Mr." The third type of nonalphabetic graphic marks do not appear in vocal-auditory language signals. Punctuation marks such as capital letters, periods, exclamation marks, question marks, colons, semicolons, commas, and quotation marks exist in auditory language only as pauses or as vocal inflections. However, some linguists consider these pauses as suprasegmental phonemes.

Space-Direction Sequence.—Vocal-auditory language signals are produced in a sequence with a time dimension. Writing systems must represent this sequence by means of a directional sequence in space. In the English writing system, the space-direction sequence is a horizontal sequence of graphic shapes in parallel lines, read from left to right. Vertical or right-to-left sequences are used in some Eastern and Middle Eastern language systems.

In the transfer from a succession of sound patterns in a time dimension, to a succession of graphic patterns in space direction, there are many arbitrary features that must be specifically and thoroughly learned. This orientation toward sequence (in English, left-to-right) is significant not only for word order (*John loves Mary—Mary loves John*), but also for words (*saw—was*) and for individual letters (*b—d*), some of which have a definite directionality. In many instances a change in word order or direction changes the meaning with the exception of the letter *O*, which can be on the horizontal line in any rotation. The other 25 letters all have constraints of left-right, top-bottom, and vertical-horizontal which must be observed. Some lowercase letters have structurally significant constraints. If the left-right direction is changed, another letter is formed: *b—d, g—p*. If the top-bottom direction is changed, another letter is formed *u—n, b—p, d—g*.

Spelling.—Although the English alphabet is phonemically based, the individual letters have never stood in a one-for-one correspondence with the separate phonemes of the English language. Consequently, it is impossible to match an English phoneme with each letter of the alphabet as they occur in the graphic representation of English word patterns.

Modern English is not hopelessly chaotic. Most of the spelling is patterned. It is basically phonemic in its representation. Patterns of letters, rather than single letters, may serve as the functioning units of the representation. Patterns of letter sequences have represented those patterns of contrastive differences of sound that identify word patterns. For example, it is the total sequence of all the letters in the spelling pattern that signals "hat" or "hate." Reading must rest upon automatic, well-practiced identification responses to the visual stimuli.

Just as the process of talking rests essentially upon responding to the significant bundles of contrastive sound features, so the process of reading rests essentially upon responding to the significant bundles of contrastive graphic features that represent those contrastive bundles of sound features. (Fries, 1963, p. 125)

Some language signals are not represented in writing, but must be added to the printed word or words in order to convey the proper meaning or the intended meaning. In most graphic representations of language there are left out such language signals as intonation, stress, and pause. With continued practice, the responses to visual patterns become habitual. Accumulative comprehension of the meanings which are signaled enable the reader to supply those portions of the signals which are not in the graphic representation themselves. In oral reading this process of supplying the omitted signals and meanings is what has been called reading with expression. It will be noted that this stage of reading corresponds to the highest stage of receptive and expressive auditory language.

If children are to be taught the effective use of the graphic English code in reading and writing tasks, it is important that (a) the code be analyzed carefully; (b) the elements of the code be included in reading programs; and (c) that teachers and children are taught the subtleties which are found in the English code.

Correlates to Reading Failure

Failure in reading has been attributed to a number of different physical and psychological factors including: sensory deficiencies; low intelligence; low verbal ability; auditory, visual, and kinesthetic perceptual dysfunctions; memory disorders; integrative dysfunction; poorly developed laterality; biochemical imbalance; emotional disturbance; and genetic factors. Early researchers such as Dejerine (1892), Hinshelwood (1917), and Orton (1937) were among the first to investigate correlates to reading failure.

It should be noted that in some cases observable behavioral symptoms which have been related to failure in reading may result from either functional or organic causes. Also, several correlates may be affected at the same time. In some cases, however, more obvious behavioral symptoms of one correlate may mask or conceal the involvement of other correlates whose symptoms are less obvious. For the purpose of this report, this section will attempt to identify and discuss those correlates which are believed to arise from within the child and are thought to have something to do with failure in reading.

Sensory Deficiencies

There seems to be a difference of opinion concerning the extent to which visual and hearing deficiencies affect the acquisition of reading skill. Bateman (1963) found that legally blind children with 20/200 vision after correction were reading up to grade level. Despite the lack of evidence for a cause and effect relationship between visual acuity and reading proficiency, the visual correlates having implications for reading may be more subtle than suspected. Tests such as the Snellen Chart, the Massachusetts Vision Test (MVT) and other screening devices are not designed to identify specific visual disorders such as in eye coordination, depth perception, visual fusion, or lateral and vertical eye-muscle imbalance. Research attempting to correlate ocular factors to reading retardation has shown conflicting results and currently, the role of ocular factors is refuted by scientific interdisciplinary studies (Lawson, 1968).

Most of the research which has attempted to correlate hearing loss with reading disorders has found that retarded readers have a high incidence of hearing loss. The presence of a hearing loss, however, does not necessarily result in a reading problem (Vernon, 1957).

A study by Reynolds (1953) found the relationship between hearing acuity and reading to be reduced when allowance was made for intelligence which was correlated with both the auditory and reading test. Caution should be used, however, in interpreting experimental findings which are based on the statistical partialling out of variables such as mental age, auditory memory span and word discrimination.

There is a need to conduct detailed studies of both normal and retarded readers who have certain types of hearing losses. A careful study of individuals may reveal the critical variables which compensate for low hearing acuity, and thereby enable an individual with a hearing loss to function as a normal reader. The age of onset, the severity of the hearing loss and language involvement are only a few of the variables which should be studied with respect to success or failure in reading. Hearing loss may be significantly related to reading only if it has interfered with language acquisition.

Intelligence

There is some evidence that a positive correlation exists between measured intelligence and reading, particularly with younger children (Roebeck, 1964; McDonald, 1964; Lovell, Shapton, and Warren, 1964; Belmond and Birch, 1966). Children who obtain high scores on intelligence tests usually, but not always, learn to read earlier and make greater progress than do children of lesser intelligence. As chronological age increases, there seems to be a decline in the correlations between measured intelligence and reading. Bond and Tinker (1967) also cite studies which show higher correlations between reading and intelligence at the elementary level (0.80 to 0.84) than at the ninth grade level (0.69). The magnitude of the correlation, however, may depend in part upon the content of the intelligence test which is administered.

Luria (1966) cites several case studies which describe how lesions of the frontal lobes can affect understanding of printed tests. The resultant intellectual dysfunction seems to be "* * * an inability to remain within the limits of the selective system of connections, and an inability to inhibit these irrelevant connections." (p. 286)

Rather than study intelligence as a global correlate to reading, it might be more productive to study the individual factors which are thought to constitute intelligence, and try to determine the extent each factor or various combinations of factors are related to reading.

Verbal Ability

Since written or printed language is a graphic reproduction of the spoken language system, many of the same disorders which cause difficulty with spoken language might also be expected to contribute to disorders in reading. A review of the research revealed only one highly speculative report by Burroughs (1912) where a child learned to read prior to the acquisition of a verbal language system. In order to understand the significance of verbal ability as a correlative to reading, it will be necessary to direct research toward those disorders which limit verbal functioning. A more detailed discussion of receptive and expressive disorders of auditory language can be found in chapter 7.

Visual Perception

According to Goldstein (1948), primary reading disturbances are related to the analysis and synthesis of visual stimuli. While damage to the occipital lobes may cause visual disorders which interfere with reading, the resulting behavioral disturbances are varied and complex. Luria (1966), for example, describes several kinds of optic alexias which might occur as a result of occipital lobe damage.

> In cases of literal (printed letters) alexia, the integrated perception of graphemes and the visual differentiation of those of their signs with cue value are so disrupted that either the letters lose their meaning altogether, or their identification becomes highly unstable (p. 426).

The child with literal alexia confuses letters which have similar shapes or outlines. He may be able to recognize printed letters, for example, but if the letter is crossed out or written in an elaborate way, the child is unable to analyze it.

In contrast, individuals with verbal alexia may be able to recognize individual letters, but are unable to recognize whole words. Their word attack system for identifying words consists of putting a word together letter by letter. Difficulty is experienced in identifying familiar as well as unfamiliar words. According to Luria (1966) this disorder is based "* * * on the unique phenomenon of a pathological narrowing of visual perception, in which the capacity of the weakened visual cortex becomes so limited that it can deal with one point of excitation at a time." (p. 427) Another characteristic of verbal alexia is difficulty in selecting elements from a word and in controlling the gaze so the subject remains on the appropriate line.

In the condition of left hemianopsia, the child may not be aware that he has lost the use of the left field of vision and, therefore, makes no attempt to compensate for this loss. In these cases, children completely ignore the left-hand side of the text. If, however, the child has no difficulty reading a word printed vertically, the presence of hemianopsia is confirmed. This disorder is usually associated with lesions of the parieto-occipital or the temporal-parietal-occipital divisions of the brain, particularly when both hemispheres are implicated.

There is a difference of opinion concerning the nature of visual perception and its significance for success in reading. One point of view maintains that visual perceptual skills are specific, while a second point of view believes word perception to be a factor that is quite different from the ability to perceive numbers or geometric figures. The question of whether or not there is a common visual perceptual factor or several 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 processing mechanism for visual stimuli. There is also a difference in the response required. Perceiving a visual geometric form is typically measured by naming it, drawing it, or finding it. Perceiving a printed word is typically measured by saying the spoken word it represents. There is some evidence that children tend to see visual forms as vague wholes and then in increasing detail. Goins (1958), for example, found that children tend to focus on significant physical aspects of a word more than do adults who have developed perceptual ability for dealing with print and who know how to read.

Tests of visual perception were found to correlate with reading ability (Goins, 1958). Goins found visual closure and perceptual speed or the ability to perceive visual stimuli rapidly to be the most significant factors. It should be noted, however, that a wide range of differences existed between the average ability of the children used in the two schools under investigation. It should be noted that comparatively little information exists with respect to the development of visual perceptual skills. If visual perception is a factor in learning how to read, then failure to develop visual processing abilities by school age could cause difficulty.

A study by Kass (1962) found that children with reading disabilities differed from the normal in certain psycholinguistic abilities. They had greater difficulty: (*a*) reproducing a series of symbols presented visually; (*b*) predicting a whole from a part; (*c*) manually representing a visual image from memory; and (*d*) visually comparing detailed figures rapidly. The research needs for this area are discussed in detail in chapter 3.

Auditory Perception

Difficulty in phonetic analysis and synthesis may result from lesions in the auditory cortex (Luria, 1966). Literate adults with damage to this area of the brain may have no difficulty perceiving or recognizing the meaning of familiar words but will have problems in perceiving or recognizing printed words which are unfamiliar. In other cases, the subject may be able to recognize individual words but is unable to read whole sentences or deal with the phonetic content of the word. The discrepancy between true reading ability and the ability to reorganize a few printed letters or words is one of the characteristics of individuals who have difficulty establishing grapheme-phoneme correspondence because of a dysfunction of the temporal region. A person who is unable to discriminate between simple and complex auditory stimuli, blend sounds or deal with the phonetic values of words will have difficulty utilizing a phonic approach to reading. A more detailed discussion of disorders of auditory stimulus processing may be found in chapter 2.

Kinesthetic Perception

Lesions of the inferior divisions of the postcentral region of the left hemisphere have been found to disturb the kinesthetic organization of motor acts (Luria, 1966). A dysfunction in this area results in either motor aphasia or apraxia of the oral apparatus and interferes with the production of the coordinated motor acts which are necessary for articulated speech. Because the subject has lost his selectivity in innervating lips and tongue, he has to concentrate in order to produce sounds or words. In reading, disturbances which are associated with a defect in the kinesthetic basis of the speech act and the direct recognition of well established words may not be affected, but the true analytic-synthetic process of reading may be impaired.

An impairment in articulating sounds distorts the pronunciation of words and interferes with the auditory analysis and decoding of the complex sequence of sounds which form spoken words. Articulatory problems due to motor aphasia may cause difficulty in reading. Not only is the ability to read aloud likely to be affected, but the reader may experience difficulty in phonic skills as blending letter sounds into syllables. Syllables are read as separate letters because of difficulty in sound blending. With the defects occurring at this level, it is not surprising that children are unable to read whole words. Even when individual letters can be identified, a deficiency in kinesthetic synthesis makes word recognition difficult if not impossible, and many children may guess at word meanings or try to succeed on the basis of individual word fragments. The end result is an interference with phonic word-attack skill. Research needs in kinesthetic processing are discussed in chapter 4.

Memory

The ability to recall or reproduce what has been learned is a necessary behavior in learning how to read. The learner must: (*a*) retain impressions or traces of visual and auditory stimuli; (*b*) make comparisons with past auditory and visual experiences; and (*c*) store and retrieve grapheme-phoneme correspondences. A deficiency in the storage and retrieval process will interfere with or retard progress in reading. A more detailed discussion of memory as a correlate to learning is presented in chapter 6.

Integration of Multiple Stimuli

All approaches used for teaching reading to hearing and seeing children require the visual and auditory systems to function both semi-independently and in coordination with other systems. The integration of stimuli which are being transmitted through different modalities require the learner to relate information which has been received through one modality to information which has been received through another modality. In learning how to read the printed word "cat," for example, the learner must relate the word-name /kaet/ to the printed word "cat." In learning to use phonic word-attack skills, the learner must associate a set of printed symbols with a larger set of auditory sounds, or graphemephoneme correspondences. These tasks require intersensory integrative processing. A more detailed discussion of integrative processing is presented in chapter 5.

Laterality

There is a large body of research literature which indicates that many inadequate readers are left-handed, or have failed to exhibit a consistent preference in and between hand, foot, and eye (Monroe, 1932; Orton, 1937; Bakwin, 1950; Burt, 1950; Harris, 1957; Vernon, 1957; Zangwill, 1960; Kephart, 1960). In contrast, both Hallgren (1950) and Hermann (1959) failed to find a correlation between poor laterality and low achievement in reading. This situation is confounded by: (*a*) those individuals who seem to have failed to develop cerebral dominance, as reflected in hand, eye, and foot preference but have learned to read; and (*b*) backward readers who appear to have developed cerebral dominance.

There is need to study cerebral dominance as it occurs in combination with other behavioral problems. It may be possible to identify several different syndromes which may have different effects on reading, speech, and language performance. Moreover, there is need to study and analyze the quality or nature of the reading disorders in those individuals who have not exhibited consistency in hand, foot, and eye preference.

Genetic Factors

Hermann (1959) has related reading disabilities to a single factor, "word blindness." He defines word blindness as:

> * * * a defective capacity for acquiring, at a normal time, a proficiency in reading and writing corresponding to normal performance; the deficiency is dependent upon constitutional factors (heredity), is often accompanied by difficulties with other symbols (numbers, musical notation, etc.), it exists in the absence of intellectual defect or of defects of sense organs which might retard the normal accomplishments of these skills, and in the absence of past or present appreciable inhibitory influences in the internal and external environments (pp. 17–18.)

More specifically Hermann identifies the basic condition as an inherited undervelopment of directional function. This "primary" form of reading handicap is distinguished from a "secondary" form of reading disability in which the development of reading ability is hampered by environmental circumstances such as poor teaching, inadequate school attendance, lack of interest, low intelligence, physical and mental illness, and sensory defects.

In reviewing the difficulties in reading and writing in congenital word-blindness Hermann discusses certain "primitive errors" which give the word-blind individual's performance a distinctive character. These errors include rotations (b/d), reversals (calm/clam), and uncertainty over letters and numbers of similar shape.

Hermann (1959) states that it is usually easy to demonstrate the genetic factor. In reviewing materials at the Word-Blind Institute, he found information relating to heredity in more than 90 percent of the cases. In order to investigate this "inherited" defect, Hermann turned to parallel disturbances of function which are found in organic brain disorders. By studying disorders of acquired language such as aphasia, Hermann sought to understand the functions which make up the process of reading and writing. He pointed out the similarity between dyslexia and Gerstmann's Syndrome (disorientation for right and left, finger agnosia, acalculia, and agraphia). Because of the similarities between Gerstmann's Syndrome and dyslexia, Hermann theorized that a fundamental disturbance is common to both, and related to a defect of directional orientation.

The disturbance of the directional function in Gerstmann's Syndrome is related to a failure of lateral orientation with reference to body schema and spatial orientation. This difficulty of orientation has consequences for the ability to operate with symbols such as letters, numbers, and notes. The directional uncertainty is shown by right, left, up-down, backward-forward, confusions, reversals, rotations, and disfigurements of letters.

In Sweden, Hallgren (1950) conducted genetic studies with 276 cases of specific dyslexia. From a genetic-statistical analysis Hallgren concluded that there is a hereditary type of dyslexia. He also indicated that it is difficult to clinically differentiate this hereditary dyslexia from a secondary type. A study by Eustis (1947) suggests that an inherited slow tempo of neuromuscular maturation is a fundamental cause of word-blindness. Drew (1956) found that inherited delayed development of the parietal lobes disturbs Gestalt recognition of visual patterns and results in word blindness.

In summary, future research in genetics might examine the neurophysiological and biochemical conditions which seem to interfere with reading and which may be transmitted genetically. There is need for family studies including studies of siblings, or fraternal and identical twins who have been reared together or apart. One of the major research questions is: What is transmitted genetically and to what extent are these conditions influenced by environmental factors?

Emotional Factors

There are a number of clinical studies which show a high incidence of emotional problems among clinical cases of disabled readers (Monroe, 1932; Gates, 1936; Witty and Kopel, 1936; Gates, 1941; Robinson, 1946; and Harris, 1961). Introversion, lack of self-confidence, shyness, fear of reading, overdependence upon approval, withdrawal, truancy, tenseness, and obnoxious behaviors have been related to individuals with poor reading ability. Differences in definitions of reading disability, emotional disturbance, age of children, and the source for sample selection may help account for the wide disparity in incidence estimates.

There is need to identify the relationship between reading disorders and emotional disturbance. Under what conditions does an emotional disorder of either functional or organic origin cause reading disabilities? Under what conditions does reading failure result in an emotional disorder? Are most cases those in which the emotional disorder and the reading disorder interact, each intensifying the other (Monroe, 1932; Gates, 1941, Robinson, 1946; Harris, 1961)?

Assessment and Treatment of Reading Failure

In this report, a distinction has been made between the child who has failed, the child who is in the process of failing, and the child who might be expected to fail prior to instruction in reading. Consequently, it seems logical to discuss the assessment and treatment of reading failure under the first two categories and the prediction of reading failure under the third category.

The Child Who Has Failed

Kirk (1962) describes a widely used five-step procedure for diagnosing children who have failed to learn to read: (1) estimating reading potential or capacity; (2) determining reading level; (3) determining behavioral symptoms of faulty reading; (4) analysis of correlated factors; and (5) recommending remedial procedures. This section will summarize the literature under these five steps.

(1) Estimating Reading Potential: Individual intelligence tests which estimate mental age provide both a quantitative and qualitative estimate of a child's presumed capacity or potential for learning to read. Since verbal understanding is closely related to both intelligence and reading capacity, vocabulary tests may provide supplementary information with respect to reading capacity. The use of arithmetic computation tests which do not require reading or verbal understanding often show that a child is capable of learning and that the child's disability is specific to reading (Monroe, 1932; Kirk, 1962). However, this suggests that a person can learn to read with the same degree of competency as he already demonstrates in auditory-vocal language. This suggestion puts much emphasis on language development which is more observable than is the vague term "intelligence."

Estimating how well a person should learn to read is currently based on performance on an individual intelligence test. Since one of the corollaries to reading is auditory-vocal language, an appropriate approach would be to develop procedures to assess language performances more completely.

(2) Determining Reading Level: Traditional methods of assessing reading level have used standardized tests. These standardized achievement tests vary in the kind and amount of reading behavior sampled. Typically, they include sections on word analysis, vocabulary, recognition, comprehension, speed of reading, and study skills (Strang, McCullough, and Traxler, 1961). The standardized achievement test will identify the child who is failing.

Oral reading ability may be assessed by a standardized oral-reading test such as the Gray Oral Reading Tests (Gray, 1963) or an informal reading inventory. According to Chall (1967) some measures of reading performance can be taken only by listening to the child read aloud. On an oral reading test the teacher or examiner notes such aspects of reading as word pronunciation, connected oral reading, letter-sound correspondences, fluency, and expression. It is possible, also, to note the specific reading errors that are made: Reversal of letters, omission of phonemes, addition of phonemes, and substitution of one phoneme for another. Betts (1958) used oral reading performance to determine various reading levels. Basal reading level, independent reading level, and frustration level are based on the child's performance on comprehension and word recognition.

Chall (1967), recently commented on standardized reading tests.

I found, however, that most teachers and principals have little faith in the standardized tests now given periodically in every school. The results of these tests are not used, as they might be, as a basis for instruction and for decisions on methods and materials. Further, the standardized reading tests often mask some of the important outcomes of reading instruction because they measure a conglomerate of skills and abilities at the same time (p. 312).

What are standardized reading tests like? They can be analyzed according to the stimulus-processing model used in this report. Most reading tests administered to groups of children present various units of visual stimuli. These units can be letters, words, phrases, sentences, or paragraphs. The typical response required is that of marking another word or words chosen from several alternatives. Only a meager analysis of errors can then be performed because of a limited observation of a limited set of performances. According to Chall (1967):

The teacher needs simple diagnostic tests, while the researcher needs more complex ones * * *. We also need tests that provide absolute measurements—that tell us how much of each component of reading a child has mastered at a given time. Such tests can also tell us how well 8-year-old children, say, are doing in 1965 as compared with 8-year-olds in 1975, thus avoiding the periodic accusation that too many Johnnies can't read (p. 313).

(3) Determining the Behavioral Symptoms of Faulty Reading: An important part of the diagnostic process is to observe the child during the reading act and analyze the child's reading process. How does he attack unfamiliar words? How does he blend sounds? Does he use contextual cues? Does he read slowly, word by word? Does he understand what he has read? Are there reversal errors? Which words and sounds are omitted, added or distorted? Can he read silently? Observation of the reading process combined with a detailed error analysis will provide a symptomatic behavioral description of the reading problem and give directions for further analysis of those factors which might be associated with the problem.

Reading diagnosticians often employ the Informal Reading Inventory (IRI) which is intended to permit an estimation of the child's reading at three performance levels so as to determine the grade level at which instruction should begin (Betts, 1950). Recently, the criteria for determining the "independent, instructional, and frustration" levels has been questioned. Powell (1968) suggests that a reevaluation of the fundamental assumptions underlying informal reading inventories should be made. Research is needed for performances on reading tasks which will result in tests that specify the terminal behavior and the subperformances involved in acquiring reading proficiency.

(4) Analysis of Correlated Factors: The fourth step of the diagnostic process is to determine why the child has failed to learn how to read. Assuming the child has had adequate instruction, the first correlates which should be examined are medical problems including sensory deficiencies and intellectual retardation. If a severe emotional disturbance is present, it may be necessary to deal with the emotional and behavioral disorder before a major effort can be made with reading activities.

Furthermore, central processing functions underlie both reading and language. Dysfunctions in the analysis and synthesis of auditory, visual and haptic information, which may be accompanied by memory and integrative dysfunctions, will affect the acquisition of prerequisites to reading. Perhaps these prerequisite correlates can be considered as determining the basic potential for reading. Future research is needed to develop specific tests and procedures for measuring perceptual problems as they specifically relate to reading tasks. It is necessary, also, for the medical profession to improve and develop techniques for examining biochemical functioning, neurophysiological disorders and genetic factors. There is need for educators to improve procedures for systematic screening, referral, and diagnosis of these problems. At present, many teachers and physicians may be aware of the existence of these correlates, but have few concrete alternatives for identification, referral, or treatment.

(5) Recommending Remedial Procedures: The final step in the diagnostic process is to prescribe specific remedial or treatment procedures. These should be based on the child's estimated capacity, behavorial symptoms, and suspected cause or causes of this problem. Such recommendations should include methods, materials, and sequence of tasks in which the child is to become competent.

Research on the efficacy of assessment methods should follow guidelines for good research design such as control over the situation, allowance for such possible confounding factors as age, sex, teacher bias, and Hawthorne effect (Campbell and Stanley, 1963).

The five-step procedure for diagnosing severe reading disabilities presents five interrelated problem areas in which research should be conducted. There is need to develop more precise procedures, methods, and equipment with which to conduct a thorough differential diagnosis.

What intervention procedures are available for children who have failed to learn how to read? The educator has developed three basic approaches to the teaching of reading: Developmental reading, corrective reading, and remedial reading.

A common approach to teaching children who have failed is to give them increased attention by placing them in a smaller group or working with them on an individual basis. In these cases, children often receive "more of the same" developmental approach under which they have already failed. The efficacy of the "more of the same" approach is questionable.

A second approach to teaching the child who has failed is corrective intervention. Corrective procedures often individualize the regular reading program by using a different developmental approach in an individual or tutorial situation. They frequently utilize the child's assets and interest areas and are often erroneously called remediation. An auditory approach to reading might be recommended for a child who has not learned to read through a visual whole-word approach. What often happens is that a basal reader is selected which employs the opposite assumptions about the reading process. Historically, this suggests that reading teachers were using one method, while reading clinicians tend to "gravitate" toward the opposite method. Since some children seem to improve under different reading systems, much of the research has tended to support the use of an "opposite" approach.

Because many of the corrective approaches to reading were not successful in teaching reading to children who had failed, remedial procedures were devised for ameliorating the psychological deficits thought to underlie poor reading. Remedial approaches are intended to remedy or ameliorate the underlying factor or factors which are contributing to the problem. While this approach may utilize the child's assets, the deficient areas are the target of instruction. If a child has poor auditory memory or visual discrimination, for example, a remedial approach might include procedures designed to improve these areas.

No remedial method was found which emphasized the acquisition of sight vocabulary alone. While most methods include some phonic work, there are those methods which emphasize the visual aspects of reading by having the child focus on the whole word. This is sometimes called the "look-say" method because the child is required to look at the word and say it until he can recognize the word at sight. Attention is usually called to such aspects of the word as length and shape. Gray (1960) proposed the teaching of the whole word followed by a phonic analysis of sound-letter correspondences. However, no provision was made for the direct learning of sound values of letters or sound blending. Kirk (1940) also recommended that the child acquire a basic sight vocabulary before phonic instruction is initiated.

The approaches which emphasize phonics are primarily concerned with teaching the child a procedure for "decoding" written language. Systematic instruction in grapheme-phoneme correspondences, blending, and rhyming provide the child with a method of word attack. These skills make it possible to determine the pronunciation of an unknown visual word. Although comprehension is not ignored in most remedial programs, the emphasis of phonic work is on analysis of the spoken form of the printed word apart from its meaning.

One of the earlier attempts to employ a systematic method of word attack was espoused by Monroe (1932) who stressed the use of synthetic phonics, pointing with fingers, and saying the words in working with poor readers. Her rationale for stressing observable motor movements was that: (*a*) such a response is more easily observed by the teacher and child; (*b*) they are probably part of the normal reading process; and (*c*) such responses may assist in discrimination and attention. Monroe noted that typically the overt motor responses gradually disappeared except when the child was confronted with an unfamiliar word. At that time the child would employ his overt attack on that word. Orton (1937) also recommended a systematic phonics approach to remedial reading which stressed overt motor activities such as tracing, copying, and writing.

Another phonic method of remedial reading is that developed by Hegge, Kirk, and Kirk (1940). Their remedial reading drills begin by teaching or reviewing the sounds of the short vowel "a" and most of the consonants. Sound blending is also taught. The authors recommend the use of a grapho-vocal method in which the child writes a letter or word from memory and says the sound of the letter or word at the same time.

English does not have a consistently written and phonetic language; that is, one letter does not stand for one and only one sound (phoneme), nor is one phoneme represented by one and only one letter or set of letters (grapheme). Consequently, the phonic approach to reading sometimes causes confusion. The difficulties posed to the beginning reader are supposedly made easier if the auditory-visual correspondences are one-for-one. To this end, various systems of notation have been devised to be used in conjunction with the English alphabet as it is commonly printed.

The initial teaching alphabet (i.t.a.) is one modified alphabet scheme being offered as a reform in beginning reading. A study by Downing (1962) showed i.t.a. trained children tested better on oral word recognition than children using traditional orthography. Later studies (Downing, 1964a and 1964b) indicated that most i.t.a. trained children have little difficulty transferring to the traditional orthography. Because of weaknesses in Downing's studies, inadequate information about the subject tested, and confusion in reporting, his results cannot be taken as conclusive. Also, there is some indication that a small number of children experienced much difficulty in transferring to the traditional system (Downing, 1964b).

Other attempts to simplify the inconsistent auditory-visual correspondences of English have been concerned with color coding. In a phonic system employing color, a difference in color is used to indicate differences in sounds. Gillingham and Stillman (1940) and Norrie (1959) use different colors to identify vowels and consonants. A further classification employed by Norrie involves different colors to signal voiced and unvoiced consonants. Gattegno and Hinman (1966) and Bannatyne (1966) use color coding to further differentiate the various graphemes used to represent phonemes.

The integrated multisensory approaches have several strengths. It is often difficult to identify the cause of failure in reading; thus, a procedure which uses several input channels may be effective. Furthermore, these methods tend to stress word-attack systems while basal readers often rely on comprehension. They also frequently use color, motor, or kinesthetic cues to supplement the usual visual and auditory cues. Monroe (1932), Orton (1937), and Fernald (1943) all emphasized the use of haptic cues by tracing letters and writing letters in their remedial strategies.

Gillingham and Stillman (1940) accept the theory of incomplete cerebral dominance as a factor in the letter reversal so commonly seen in some poor readers and developed remedial methods for reading and spelling based on the systematic development of increasingly complex phonetic units. This method attempts to establish associations between visual, auditory, and kinesthetic records or memory traces within the child. At first, Gillingham presents one letter at a time and has the child learn one and only one visual-auditory association, either letter-sound or letter-name. Later, the child will learn multiple associations, for example, the sounds represented by the letter *c*: /k/ and /s/.

Fernald (1943) combined the visual emphasis with kinesthetic activity and vocalization. Her method consisted of four stages: (1) the child traces the letters of the word with his finger, saying each part aloud and then attempting to write it; (2) he learns a new word by looking at it, saying it, writing the word while saying it; (3) the child looks at a new word, says it once or twice and writes the word without saying it; (4) the child generalizes from words he knows to new words and can say the words without writing them.

While the integrated remedial or corrective procedures have many strengths and are often successful, they have several weaknesses. They usually do not identify the type of reading problem for which their method is appropriate. The teacher may choose a method for a particular behavioral symptom; but the method may be inappropriate because several different causes may create the same symptom. Many of these methods do not get at the basic physical and psychological correlates which are involved. For example, a child may be limited to a purely visual approach because his auditory skills in auditory memory, discrimination, and sequentialization may be inadequate and seem to prohibit a phonic approach. It is possible, therefore, that no attempt will be made to ameliorate these weaknesses.

Some corrective or remedial reading methods tend to accept the theory that a child who is deficient in one channel should be taught to read by those procedures which emphasize his strong channel. For example, a child with poor visual ability would be taught to read by an auditory method while a child with poor auditory ability would be taught to read by a visual method. Johnson and Myklebust (1967) accept this principle when they say, "The visual dyslexic * * * cannot retain the visual image of a whole word and consequently needs a more phonetic or elementary approach to reading" (p. 156). They have found that the most successful remedial approach with this kind of dyslexic child is that described by Gillingham and Stillman (1940). Isolated sounds are taught, then they are blended into meaningful words. On the other hand, the auditory dyslexic has difficulty in relating the temporal sequence to a visual-spatial sequence (Johnson and Myklebust, 1967). Problems in the auditory area may result in an inability to learn through the phonic approach. Therefore, they recommend a whole-word approach including tactile and kinesthetic methods. Training is initiated in visual memory and sequentialization. General form and configuration discriminations are trained by various matching activities. Training in perception of detail and orientation of letters is also included. While Johnson and Myklebust (1967) tend to emphasize teaching through the strong channel, they also make recommendations for strengthening the weak channels. Silver, Hagin, and Hersh (1967) reported that boys gained in reading from a program of perceptual training in deficit areas. For purposes of remediation, however, it is necessary to go beyond the superficial visual aspects of reading, identify the correlates which are contributing to failure in reading, and intervene with the most appropriate remedial procedures.

The Child Who Is Beginning To Fail

At present, there are no systematic procedures for identifying the child who is beginning to fail in reading. The usual sequence of events begins with the child experiencing difficulty in the early reading tasks. Because a certain amount of difficulty is expected of most students who are beginning to read, the errors made by the child who is beginning to fail may not attract undue attention. As times passes, however, most of the class acquires increased proficiency in reading skills. Meanwhile, the child who is beginning to fail may be acquiring these skills at an abnormally slow rate or not at all. Teachers sometimes explain the child's retardation in reading as temporary. The child is sometimes called a "late bloomer" and many classroom teachers believe that they can teach the child with a little "extra work and individualized attention." For some children this is all that is needed. The occasional successes teachers experience with such children serve as intermittent reinforcement and help maintain continued attempts to assist the child through "extra help" programs. In cases where central processing dysfunctions are involved, however, a tutorial program with emphasis on word recognition or word meaning may not be successful.

As the child who is beginning to fail continues to fall behind, skill by skill, page by page, book by book, it becomes obvious that "extra help" is not a sufficient condition to alter the pattern. When this happens, the child is no longer beginning to fail. He has failed.

At present, the alert teacher classifies good readers and poor readers by observing their reading performance and placing them in appropriate reading groups. There is need, however, to develop systematic procedures for teachers to use for measuring progress so that they can more readily identify the child who is beginning to fail. Checklists consisting of detailed steps for progress under each reading task may help teachers objectify children's progress and to identify as quickly as possible the children who are beginning to fail. Such a checklist will help the teacher make judgments about the behavioral symptoms of failure so the most appropriate intervention procedures may be introduced at the earliest possible time.

There is need to develop techniques which will help maintain the children's interest in reading during the period of early failure. Della-Piana (1968), for example, presents techniques which have been successfully employed: use of content in child's area of interest (Harris, 1961); use of materials concerning human values (Crosby, 1965); use of child's personal experiences (Moss, 1961); use of rewards (Clark and Walberg, 1966); making a pleasurable activity contingent upon the performance of a less pleasurable activity (Premack, 1959, 1962, 1965; Addison and Homme, 1965); making a systematic presentation of the desirable reward of the student's choice contingent upon good performance (Della-Piana, Stahmann, and Allen, 1968).

Predicting and Preventing Failure in Reading

Educators and researchers are becoming increasingly aware of the need for methods of assessment which will lead to early identification of children who run a high risk of reading difficulty. Early identification should lead to the establishment of programs and instructional procedures which will hopefully prevent reading disabilities.

Parents and pediatricians often can provide information which may help identify preschool children who, after they enter school, may fail in reading. Indications such as late attainment of developmental milestones such as lifting and turning the head, visual tracking, crawling, walking, understanding, and using spoken language may help identify high-risk children prior to their entry into school (Shirley, 1931, 1933). The kindergarten provides another means of studying children's behavior in different learning situations. There is need, however, to identify the psychological correlates to beginning reading and to develop procedures for early assessment. The research which has been done on reading readiness, however, provides some information with respect to these correlates. This section will review the research which is related to the concept of reading readiness and the development of readiness tests.

The Concept of Reading Readiness: The concept of reading readiness has a variety of meanings. It is viewed by some as the chronological age necessary for the child to learn how to read. For others, readiness for reading consists of a complex combination of social, emotional, mental, and psychological factors. There are a number of research studies which have been conducted to identify the factors involved in reading readiness. Most of these studies have attempted to identify the correlates to reading readiness by comparing the characteristics of good and poor readers after a period of instruction.

Russell (1961), for example, found that reading readiness is dependent upon four general factors: Physical, mental, social-emotional, and psychological. Other research studies have attempted to isolate more specific correlates which would be of value to educators in planning reading readiness programs. A study by Karlin (1957) was conducted to ascertain whether certain measures of physical growth were related to success in beginning reading. This study showed that the measures of physical maturation had little correlation to reading readiness test scores, but that the reading readiness test scores were related to skeletal development. Carroll (1948) found that learning facility in the preparatory period for reading was affected by sex differences in favor of girls.

Bond and Wagner (1961) state that the degree and extent to which speech defects cause difficulty in learning to read is uncertain. However, if the reading method emphasizes phonic instruction and oral reading, the child with a speech problem might experience difficulty in learning how to read. Maddox (1957) found a correlation to exist between reading readiness and the ability to produce consonant sounds. Children with articulation errors had low scores on readiness tests; older children made fewer articulation errors; girls had acquired more consonants than had boys; and the higher the IQ score, the fewer the articulation errors.

Factors such as emotional adjustment, auditory readiness, physical condition, and the time which reading instruction should begin, were identified by Williams (1958). A study by Natale (1959) found that intelligence, giving opposites to vocabulary words, memory span, and word discrimination were related to reading readiness. Intelligence test results and readiness test results were identified by Stephey (1957) as valuable criteria for teacher use in determining reading readiness. McMillan (1960) also found positive relationships between intelligence and reading readiness, between intelligence and use of context; and among intelligence, use of context, and auditory discrimination.

Probably one of the most comprehensive studies of the correlates of readiness has been done at the Gesell Institute. Ilg and Ames (1965) provide an extensive list of developmental behavior tests to aid in determining a child's readiness for school.

In summary, lists of factors thought to be related to reading readiness have been generated by comparing certain characteristics of good and poor readers. These lists include such factors as: Physical growth, speech defects, sex differences, visual and auditory discrimination, chronological age, intelligence, emotional adjustment, physical condition, abilities required for completing vocabulary opposites, memory span, word discrimination, and use of context. Because most of these lists are long and cumbersome, it is difficult to use them for assessment purposes. The extent to which these variables are interrelated and contribute either singly or in combination to reading disorders is not clear. Finally one might raise the question: Are the correlates for reading readiness the same for each child in light of individual differences, both strengths and weaknesses?

Both Gagné (1962a, 1962b) and Ausubel (1963) present an alternative approach for identifying the correlates to reading readiness. Gagné hypothesizes that no individual can perform a final task such as reading without having the subordinate capabilities or appropriate learning sets already established. Thus, by analyzing the reading task itself, identifying and rank ordering the component tasks in their proper sequence, it may be possible to identify the correlates to reading readiness.

Ausubel (1963) defines readiness as "* * * the adequacy of existing cognitive equipment or capacity at a given age level for coping with the demands of a specified cognitive task." (p. 29) Ausubel differentiates between readiness and the concept of maturation which is often equated with a process of "internal ripening" and has a more restricted meaning than readiness. Maturation is merely one of the two principal factors, maturation and learning, that contribute to the child's readiness to cope with new experiences. Unfortunately, Ausubel does not specify the components necessary for reading readiness beyond his two general categories. Ausubel comments on the serious dearth of research in the cognitive aspects of readiness which he obviously considers to be so crucial.

Rather than study the characteristics of good and poor readers, a more productive approach to the assessment and identification of the correlates to reading is to focus attention on the reading task itself and the processes by which this task is accomplished. Future research should concern itself with this issue.

Chall (1967), in reviewing 40 years' work reported by test authors and researchers, concludes that the concept of readiness for reading is largely determined by the definition of beginning reading. Those persons

361-752 O—70——8

using a complex definition of beginning reading (getting the meaning) tend to have a larger conception of readiness, concerning the "whole child" and favor a later start in learning to read. Those who define beginning reading as learning to translate a visual code for an auditory code favor an earlier start and have a more specific conception of readiness. Most code-emphasis persons consider readiness training as learning to identify and name the letters.

The Development of Reading Readiness Tests: One method used to predict future success or failure in reading is the reading readiness test. Since concepts of readiness for reading are largely determined by definitions of beginning reading (Chall, 1967), a variety of readiness tests have been developed. Those who define beginning reading as learning to decode a visual code of graphic letters for an auditory code of language signals are interested in the child's ability to identify and name letters. More general tests of readiness such as the Metropolitan Readiness Tests (Hildreth and Griffiths, 1949) sample a larger but less clearly defined set of behaviors. Nevertheless, general readiness tests have been found to predict success and failure in beginning reading. Some published basal reading series include their own tests of reading readiness. These tests have the advantage of being predictive of success in learning to read by the method to which the child will be be exposed. However, according to Chall et al. (1965), existing tests do not lend themselves easily to educational planning.

Various researchers have attempted to isolate the factors underlying the reading process and use these factors in development of tests which will predict reading success or failure. The factors often used are auditory discrimination, visual discrimination, language ability, perceptual-motor performance, and self-concept or personality factors. These tests are usually designed to be given in kindergarten or early first grade before reading instruction has been initiated.

Wepman (1960) found that auditory discrimination was correlated with early reading scores. With intelligence held constant, some 27 percent of 80 children in the first grade showed inadequate auditory discrimination and reading scores significantly below the reading level of the children with adequate auditory discrimination.

Although many researchers agree that visual discrimination is predictive of success in reading there is considerable disagreement on what kind of visual discrimination is most predictive. Smith (1928), Wilson (1942), and Gavel (1958) contend visual discrimination of letters is most predictive. Gates, Bond, and Russell (1939) favor visual discrimination of words, while Potter (1949) used shape matching, and Goins (1958) used four tests of visual perception of geometric figures and pictures. Barrett (1965) tested the predictive value of nine readiness factors, seven of them involving visual discrimination. He found the Gates Reading Letters and Numbers Test, the Pattern Copying Test, and the Gates Word Matching Test to be strongly predictive of reading achievement as measured later on the Gates Primary Paragraph Reading Test (Gates, 1958). However, Barrett (1965) concluded that the visual discrimination tests should not be used alone but in combination with other measures and observations. Smith and Keogh (1962) support the predictive value of a pattern copying test as they concluded that a group version of the Bender Gestalt Test was an effective screening device.

Several attempts have been made to predict reading success by assessing personality factors. Using a battery of psychological tests, teacher observations, and a play therapy session, Cohen (1963) determined the child's level of anxiety and depression in various situations. He found that excessive anxiety in a low ability child was predictive of failure while moderate anxiety in a child of average ability sometimes led to overachievement. He also found that the kindergarten teachers had a high degree of accuracy in prediction. Wattenberg and Clifford (1964) measured two aspects of kindergarten children's self-concepts: feelings of competence and feelings of personal worth. These measures were obtained from an analysis of tape recordings of each child's utterances while drawing pictures of his family, and his responses to an incomplete sentence test. They found self-concept to be significantly predictive of progress in reading.

Because of the large number of factors involved in reading, some researchers have developed tests which measure skills in several areas. Weiner and Feldman (1950) included language, perceptual discrimination, and beginning reading skills. Their Reading Prognosis Test had subtests of word meaning, story telling, visual similarities, visual discrimination, auditory discrimination, small letter recognition, capital letter recognition, and sight vocabulary. Preliminary validation studies showed that scores on the Reading Prognosis Test were highly correlated with those on the Gates Primary Word Reading Test of 1958.

DeHirsch, Jansky, and Langford (1966) who now view failure in reading as part of a more comprehensive language problem, contend that deviations in perceptuo-motor and behavioral organization underlie difficulty in the decoding and encoding of verbal symbols, delayed speech, and disorganization of written and spoken language. They attempted to determine "whether a distinct and identifiable pattern of perceptuo-motor and oral language deficits at preschool age is predictive of difficulties with visual language * * * in subsequent years." (p. xv)

DeHirsch et al. administered 37 tests of perceptuomotor and language ability to kindergarten children. Ten of these tests were found to be predictive: Pencil Use, Bender Visuo-Motor Gestalt, Wepman Auditory Discrimination, Number of Words Used in a Story, Categories, Horst Reversals, Gates Word-Matching Subtests, Word Recognition I and II, and Word Reproduction. The authors found that this battery of tests identified 10 of the 11 children who failed in reading on the second grade testing. Five of the 10 tests involved printed words. One of the advantages of a diagnostic test like the Predictive Index is that it suggests specific areas for prevention and remediation as well as being predictive. It can be concluded that the more the proposed predictor task resembles the criterion task, in standard reading tests, the better the proposed task will predict. Of the remaining five tests, two involved visual-manipulative activities and the remaining three required some type of verbal response.

In comparing the predictive ability of the revised Stanford-Binet Intelligence Scale and the Illinois Test of Psycholinguistic Abilities, Hirshoren (1969) found the Visual-Motor Sequential subtest had predictive ability for school achievement as measured by the California Achievement Test.

As the status of knowledge is increased with respect to the factors which constitute reading readiness, it will be possible to develop even more effective assessment instruments. The identification of the correlates of reading at an early age and the development of measurement procedures appears to be a promising area for future interdisciplinary investigation. Armed with this information, it should be possible to develop intervention techniques which will ameliorate these correlates or help children compensate for their deficits.

Preventive Training: Instructional programs designed to prevent failure in reading should probably be directed toward the remediation of deficits in reading readiness. It is somewhat difficult to plan an instructional program because the correlates to reading readiness are not always clearly identified and are sometimes difficult to measure. Often it is not known how deficient a correlate must be before there is an effect on reading. In order to remediate the deficiencies in the high-risk child, it will be necessary for the schools to operate preschool programs with special emphasis on readiness activities. Different types of programs should be studied to determine the efficacy of various methods.

Directions for Future Research

For the purposes of this report, reading has been analyzed as a series of acts for obtaining meaning from graphic symbols. Also, a distinction has been made between the child who has failed, the child who is beginning to fail, and the child who might be expected to fail in reading even before he goes to school and receives instruction in reading. There are several major areas in which research is needed.

The Graphic Code

Research in reading is needed concerning the language code itself, the characteristics and abilities of the person learning the code, the measurement of these characteristics and abilities, and the efficacy of various remedial methods. Linguists have done a fairly good job of analyzing language but there is need for research on the significance of all the fundamentals of the graphic language code. It is known that shape and directional orientation are crucial discriminative aspects of a letter while size is not. Future research should study the learning of graphic shapes of individual alphabet letters and nonalphabetic signs; the space-direction sequence and English spelling patterns.

Task Analysis of the Reading Act

Research on reading and reading failure should proceed from an analysis of the reading act along two dimensions: time phases and tasks. The time phases are the prereading, beginning to read, and advanced reading stages through which children must pass if they are to become practiced, efficient readers of the graphic language code. The main task is breaking the graphic language code. The subtasks are automatically recognizing the units of graphic language, combining those units into their corresponding auditory language signals, adding those elements of auditory language not found in the graphic language code, and relating past experiences to that which has been read and adding to the store of one's knowledge by reading new information.

Analysis of the reading act into component and possibily hierarchical tasks will produce a checklist of observable behaviors found necessary to perform the reading act. Research can help determine: (*a*) the amount of practice necessary to attain competence in each component; (*b*) the alternate methods of presenting the tasks to children who differ in their initial behavioral repetoire; (*c*) the selection of approaches to beginning reading; and (*d*) the decisionmaking process for selecting the remedial method on the basis of critical characteristics of failing readers.

Correlates to Reading Failure

Present research indicates that visual and auditory acuity, intelligence, verbal ability, visual, auditory and kinesthetic perception, integration, laterality, biochemical functioning, genetic factors, and emotional factors are related to reading failures. In each case the exact nature of the relationship is not clear. Attempts to demonstrate the correlations between these variables and reading failure have had conflicting results. There is need to determine the extent to which a deficiency in any area affects the acquisition of reading skill as well as determining the results of various combinations of deficiencies. With respect to sensory acuity, it is necessary to study specific visual conditions and the degree of severity necessary to disrupt or interfere with the reading process. In the case of a hearing loss, such variables as age of onset, severity of the loss, and the language involvement should be studied with respect to success or failure in reading. Other critical variables related to loss of hearing need to be identified.

Research is needed to determine whether each identified correlate to reading is composed of one or several factors. Intelligence, for example, has usually been treated globally with respect to reading but it might be more productive to study the individual factors thought to constitute "intelligence" and try to determine the extent to which each factor or various combinations of factors are related to reading. Verbal ability, for example, has been found to be related to intelligence, and is thought to have significance for reading. Basic research should be directed toward disorders which limit verbal functioning. There is also a question of whether there is one common visual-perception factor or several separate factors. Visual processing is difficult to study because each different visual task makes slightly different demands upon the processing mechanism for visual stimuli. Research is needed, also, to describe the development of visual perceptual skills.

Several theories have tried to link cerebral dominance to the difficulty in learning to read. There is need to study cerebral dominance as it occurs in combination with other behavioral problems. Syndromes which may have different effects on reading, speech, and language should be identified. Also, there is need to analyze the exact nature of reading disorders in individuals who do not exhibit consistency in hand, foot, and eye preference.

At present, there is little evidence concerning biochemical functioning as a correlate to learning disorders. However, this area may be a productive avenue for future research. Future work in genetics might examine the neurophysiological and biochemical conditions which seem to interfere with reading and which may be transmitted genetically. Studies should include siblings, or fraternal and identical twins who have been reared together or apart. There is need to determine just what is transmitted genetically and to what extent these conditions are influenced by environmental factors.

Confusion exists over the relationship between reading disorders and emotional disturbance. Research is needed to identify the conditions under which emotional disorders cause a reading problem and the conditions under which a reading problem creates an emotional problem. If emotional disorders and reading disorders interact, each intensifying the other, it is necessary to define the nature of this interaction.

There is need to determine if the correlates to readiness and the correlates to reading are the same and if the correlates to reading readiness are the same for each child. Although some of the motoric correlates to reading readiness have been identified, there is a lack of research on the cognitive aspects of readiness.

In addition to studies concerned with the language code and the neurophysiological correlates to reading, research is needed to develop procedures for measurement and remediation. Better methods of assessment are needed for each of the correlates to reading. Procedures need to be developed for assessing language performance more completely. Tests are needed to measure perceptual problems as they specifically relate to reading tasks. Although teachers and physicians may be aware of the existence of correlates, there are few alternatives for identification, referral, or treatment. Thus, it is necessary for the medical profession to develop techniques for examining biochemical functioning, neurophysiological disorders, and genetic factors, while educators need to improve procedures for systematic screening, referral, and diagnosis of these problems.

Diagnostic and Remediation Procedures

The need for procedures leading to early identification and diagnosis is especially crucial. The identification of correlates to reading at an early age and the development of procedures for measuring these correlates appear to be promising areas for future interdisciplinary investigation. The identification of correlates to reading and the development of assessment procedures should lead to remedial programs which include training in specific correlates and the reading process itself. Special attention should be given to develop programs designed to improve a child's readiness to read. Furthermore, there is need to develop techniques which will help maintain the child's involvement in reading during a period of early failure. The efficacy of various assessment and remedial methods should be studied. Testing of procedures for training the correlates should include the effect of training versus no training and the effect of instruction in the reading process in conjunction with specific remedial measures for particular correlates.

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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.

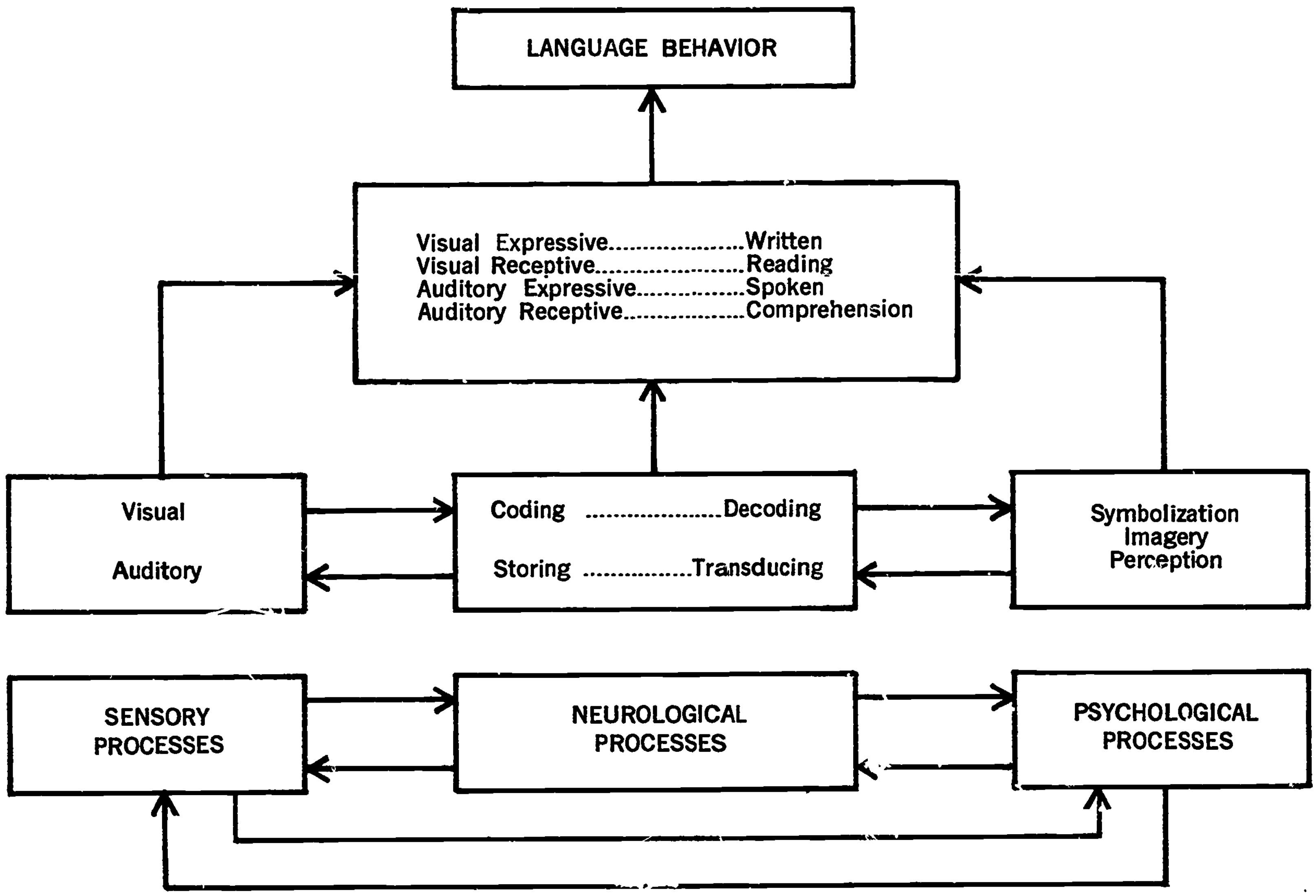
There is some evidence to support the view that the physiological mechanism for writing seems to involve the complex interaction of different areas of the brain. According to Penfield and Roberts (1959), writing is carried out by the dominant hand which is controlled through the motor-hand mechanism 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. Myklebu:t, H~'mer 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 movemen'; 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 ocess, 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 th se. (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 tim 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;

361-725 O—70——9

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 infero-parietal 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

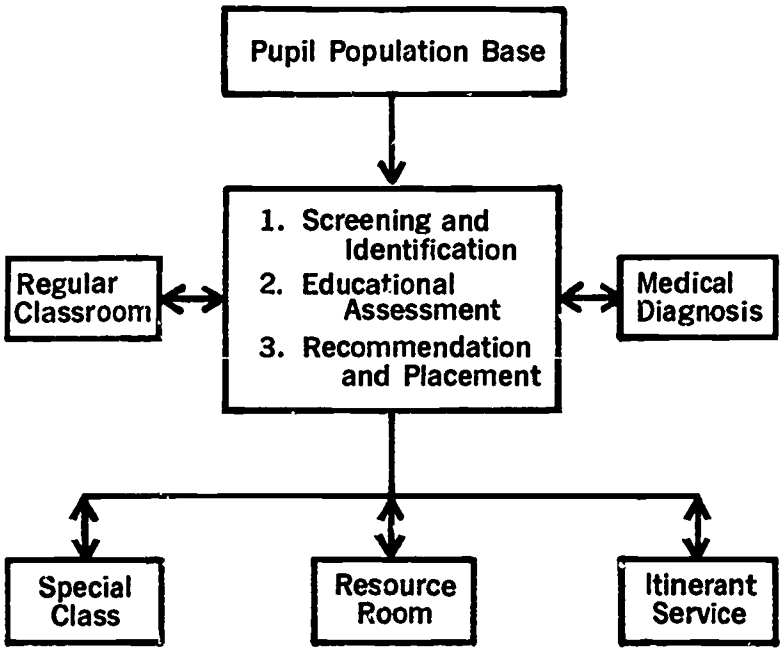

Figure 6.—Flow Chart for the Identification, Assessment, and Referral of Children Who Have Difficulty in School

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 popul tion in question. This confusion is reflected by the terminology and definitions 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

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"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."

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"* * * 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 psychologic. 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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