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CENTRAL PROCESSING DYSFUNCTIONS IN CHILDREN:

A Review of Research

U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
Public Health Service National Institutes of Health

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A Review of Research

Phase Three of a Three-Phase Project

by

James C. Chalfant, Ed. D.
and
Margaret A. Scheffelin, Ph. D.

Institute for Research on Exceptional Children
University of Illinois
Urbana, Ill.

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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.

*"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.

RICHARD L. MASLAND.

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James C. Chalfant
Project Director

University of Illinois
Urbana, Ill.
March 1969

TASK FORCE III—PROJECT CONSULTANTS

DOUGLAS L. CROWTHER, M.D.
Department of Neurology
University of California Medical Center
San Francisco, Calif.

RICHARD L. MASLAND, M.D.*
Chairman, Department of Neurology
College of Physicians and Surgeons, Columbia University
New York, N.Y.

JAMES W. MOSS, Ph.D.
Director, Division of Research
Bureau of Education for the Handicapped, United States Office of Education
Washington, D.C.

HELMER R. MYKLEBUST, Ed. D.
Director, Institute for Language Disorders
Northwestern University
Evanston, Ill.

RICHMOND S. PAINE, M.D.**
Children's Hospital and George Washington School of Medicine
Washington, D.C.

CHARLES R. STROTHER, Ph. D.
Director, Mental Retardation and Child Development Center
University of Washington
Seattle, Wash.

*Formerly Director, National Institute of Neurological Diseases and Stroke, National Institutes of Health, Bethesda, Md.
**Deceased.

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Samuel A. Kirk
Professor Emeritus
University of Illinois

and

Severina Nelson
Professor Emeritus
University of Illinois

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	Biological events:
		Prevention:	Genetic events:
		Medical treatment:	Neurophysiological events:
		Changes in function and structure:	Structure and function.
Psychology	Psycho-educational correlates to learning:	Measurement	Cognitive development:
		Cognitive development.	Pyschological events:
		Remedial treatment:	
Education	Behavior	Prevalence	Educational consequences:
		Classification:	Social-emotional behavior:
		Management:	Motivation:
		Behavior modification:	Observable behavior:
		Developmental methods.	
		Corrective treatment:	

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.

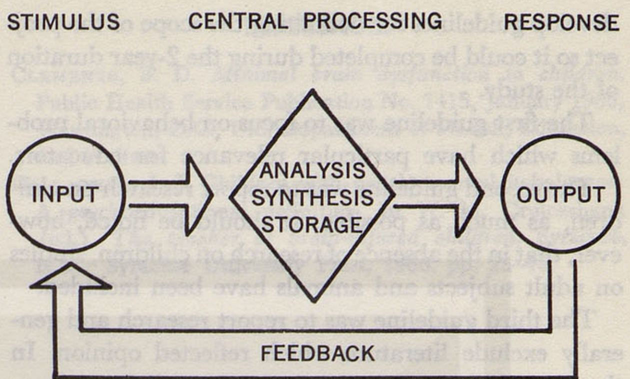

Figure 1.—Computer Model for Information Processing

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

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

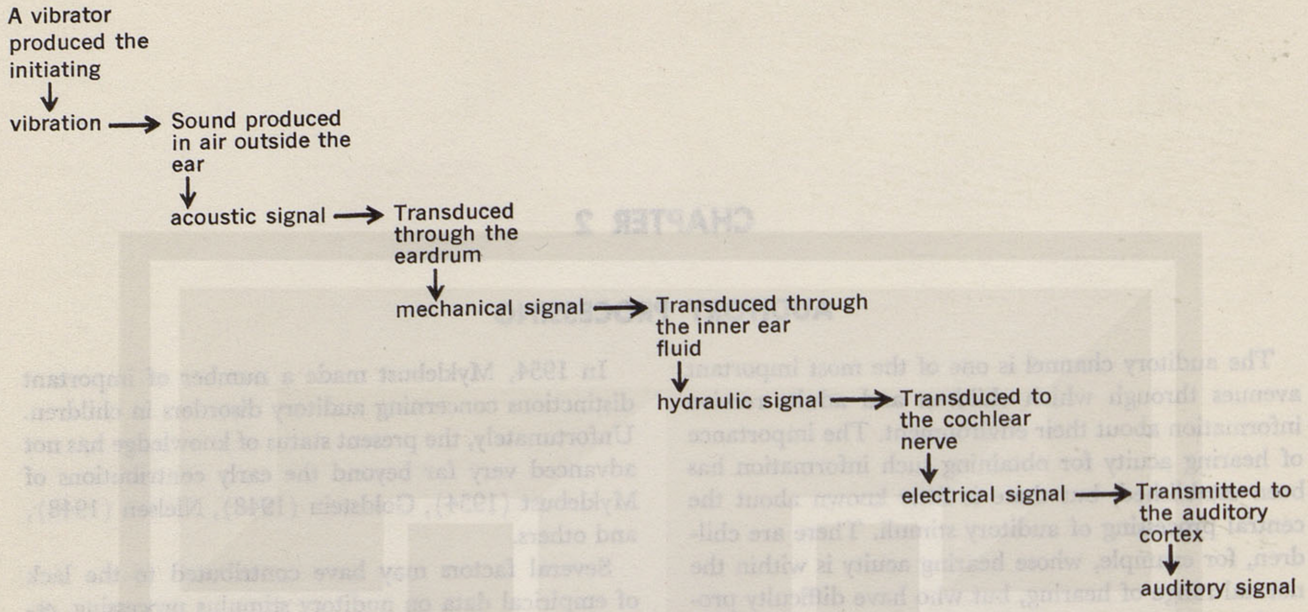

Figure 2.—The Transduction of Auditory Stimuli

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 arise 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.

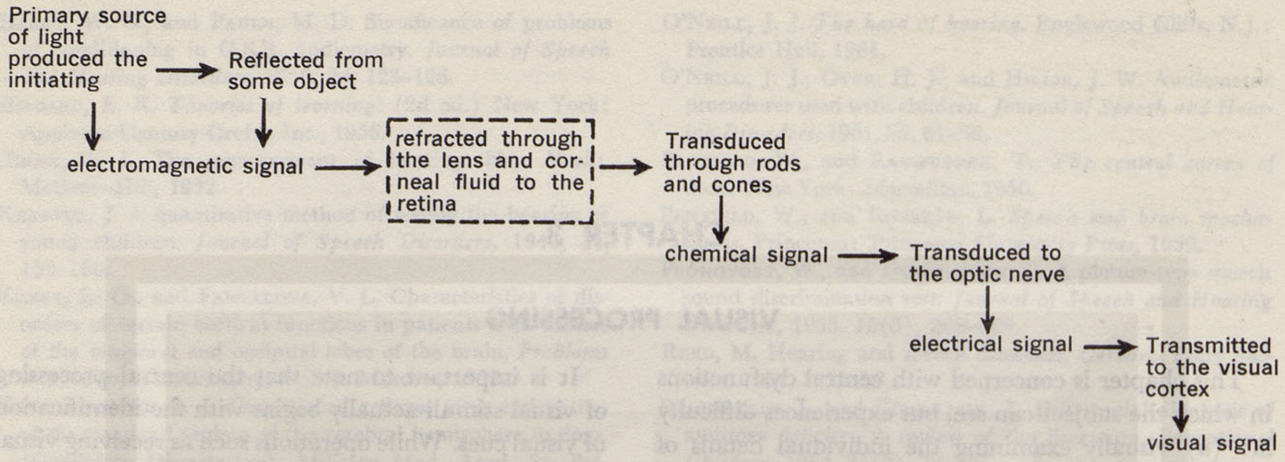

Figure 3.—The Transduction of Visible Stimuli

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 fi.st 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.

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 of 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