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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Directions for Future Research

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

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

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

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CHAPTER 4

HAPTIC PROCESSING

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

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

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

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

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

The Haptic Processing Mechanism

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

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

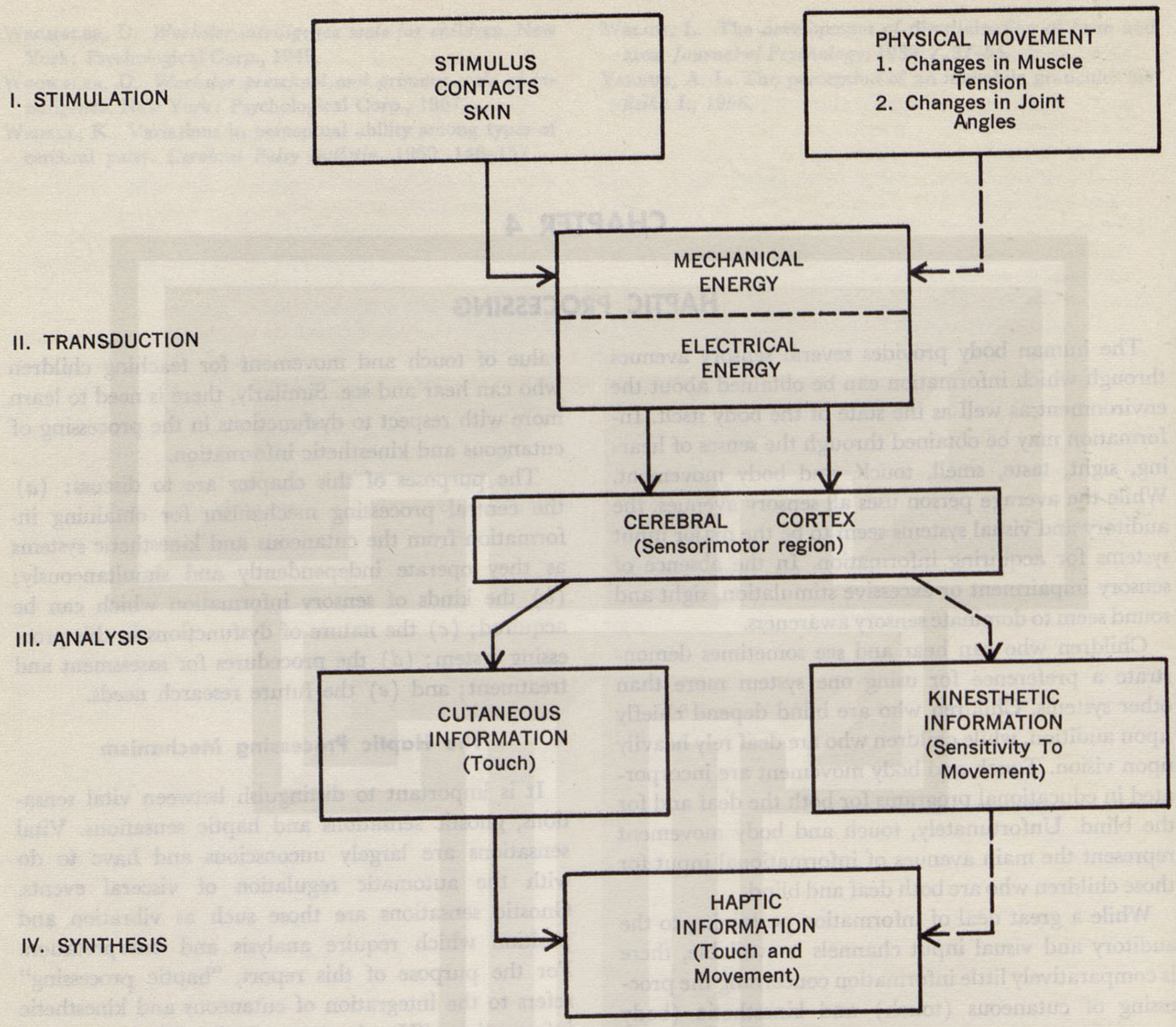

Figure 4.—The Haptic System

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

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

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

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

Kinds of Information Obtained by the Haptic System

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

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

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

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

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

Description, Assessment, and Treatment of Cutaneous Processing Dysfunctions

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

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

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

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

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

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

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

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

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

Multiple-Point Discrimination and Tactile Recognition

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

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

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

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

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

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

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

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

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

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

Description, Assessment, and Treatment of Kinesthetic Processing Dysfunctions

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

Joint and Muscle Sensitivity to Movement

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

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

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

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

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

Linear and Rotary Movement

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

Movement Patterns and Static Postures

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Directions for Future Research

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

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

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DYSFUNCTIONS IN THE SYNTHESIS OF SENSORY INFORMATION

CHAPTER 5

MULTIPLE STIMULUS INTEGRATION

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

What Is Stimulus Integration?

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

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

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

Table 6.—Intrasensory Integrative Systems

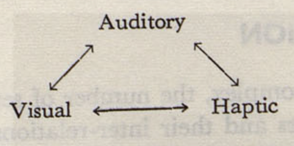
Input		Input
Auditory	⟶ ⟵	Auditory
Visual	⟶ ⟵	Visual
Haptic	⟶ ⟵	Haptic

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

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

Table 7.—Intersensory Integrative Systems

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



How Do Integrative Systems Develop?

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

Theories

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

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

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

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

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

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

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

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

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

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

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

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

Research

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

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

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

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

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

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

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

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

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

What Are the Correlates to Stimulus Integration?

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

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

Intelligence.

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

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

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

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

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

Brain Damage.

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

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

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

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

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

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

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

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

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

Biochemical Imbalances.

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

How Can Stimulus Integration Be Assessed?

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

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

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

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

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

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

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

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

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

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

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

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

What Factors Should Be Considered in Developing Remedial Procedures?

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

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

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

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

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

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

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

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

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

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

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

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

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

Directions for Future Research

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

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

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

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CHAPTER 6

SHORT-TERM MEMORY

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

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

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

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

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

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

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

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

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

The Storage and Retrieval Process

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Assessment

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

Afterimage

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

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

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

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

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

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

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

Memory Span

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

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

Aspiration Level

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

Delayed Response

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

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

Disorders of Storage and Retrieval

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

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

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

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

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

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

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

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

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

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

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

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

Improving Memory

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

Practice

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

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

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

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

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

Organization and the Application of Rules

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

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

Programmed Presentation

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

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

Memory Monitoring

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

This process seems to be a fairly good indicator of memory storage. It can be applied to the prediction of recognition successes and failures and somewhat less accurately to the prediction of second attempts at recall. Generally, when people feel that they know some-