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The Development of Perceptual–Motor Abilities: *A Theoretical Basis for Treatment of Dysfunction*

A. Jean Ayres, OTR, PhD

Central to the concept of occupational therapy are the evaluation, enhancement and use of skilled motor actions. While many central nervous system processes are involved in skilled movement, one aspect of sensorimotor function has come under particular attention lately as a large determinant of fine motor facility. That aspect is perceptual–motor functions, formerly called “eye–hand” coordination. Deficits in this domain are most easily and frequently observed in the patient who can accomplish simple grasp and release with apparent ease yet who cannot accomplish with comparable dexterity such tasks as tying shoes, handling tools or manipulating objects. The possible nature of that dysfunction is described in this paper and hypotheses presented regarding related developmental processes.

One of the more generally accepted postulates on which treatment of motor dysfunction is based is the recapitulation of the sequence of development. Accordingly, theories regarding the ontogeny of perceptual–motor abilities provide a basis for treatment of dysfunction in this area of human behavior. The data to which the theoretical system is anchored come largely from a research project conducted at the University of Southern California. (This investigation was supported in part by PHS research grant MH06878-01 from the National Institute of Mental Health, Public Health Service.) Results of published research by neurophysiologists have served as additional sources of knowledge. Although well supported with scientific facts, the highly provisional nature of the theoretical framework must be kept in mind. It has been necessary to force considerable structure onto the data (largely by omission of detail) in order to make them manageable. As our conceptual formulations become more familiar and secure, we will undoubtedly find that they have oversimplified the true nature of perceptual–motor function and it will be necessary for us to restructure them on a more complex basis.

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Method of Obtaining Information

A brief review of the method by which the major research data were gathered is needed for their interpretation. One hundred children of approximately six and seven years of age who were suspected of having perceptual deficiencies were administered a battery of tests covering visual, tactile, and proprioceptive perception and some motor skills. Auditory and language functions were not included. None of the children carried a medical diagnosis of cerebral palsy; all of them had or had had learning or behavioral problems. The battery of tests was selected on the basis of descriptions in the literature of areas of perceptual–motor dysfunction. The scores made by the children on the tests were correlated and then subjected to R-technique factor analysis in order to determine the possible existence of associations among symptoms that would justify hypothesizing the presence of taxonomic categories or syndromes of dysfunction. Establishment of factors is a means of summarizing and simplifying masses of confusedly interrelated observations, a function not possible by the human brain alone. A factor is a process which accounts for differences in a domain of behavior under observation—the domain in this case being perceptual–motor function. For example, among cerebral palsied children, certain neurophysiological processes account for the behavioral manifestation called spasticity, different processes determining athetosis, and another type of dysfunction causing ataxic behavior. These different neurophysiological processes are used to identify the neuromuscular problem of the patient. Understanding the process has served as a basis for establishment of treatment procedures.

In essence, this study has attempted a comparable categorization of a domain of neurological dysfunction, with reliance not upon subjective human judgment, but the objective accuracy of statistical computations. Nevertheless, a major limitation to this type of study lies in the fact that the emergence of a syndrome and its nature is dependent upon the type of data gathered. A serious omission in data collection will result in a gap in the results. Consumers of the information must be alert to this limitation.

Since the data were gathered from children with learning or behavioral disorders, we can expect to find similar syndromes of dysfunction among other children with comparable difficulty. Although cerebral palsied and definitely mentally retarded children were not included in the sample population, it is not unreasonable to expect these data to apply to children with those disorders. Caution must be used, however, in assuming that comparable clinical syndromes might be manifested in the individual sustaining brain injury as an adult.

Areas of Perceptual–Motor Function

Some of the types of perceptual–motor functions covered in the test battery are shown in Figure 12.1. In some instances, an area of function represents several tests. In these cases the mean factor loading of a group of tests was obtained by taking the square root of the mean of the squares of the factor loadings of several tests, all of which had significant loadings on that factor.

Motor planning was evaluated by (1) how well a child could draw a line with a pencil on top of another line, (2) the degree of quickness and accuracy with which the child could assume a posture demonstrated by the examiner and (3) the ability to manipulate an object. Finger identification was evaluated by the identification by the child of which of his fingers the examiner touched. Tactile perception was based on (1) the accuracy with which the subject could localize a tactile stimulus on hand or forearm, (2) his ability to discriminate between one and two tactile stimuli in the finger tips, (3) the degree to which he could perceive two simultaneously administered tactile stimuli to cheek and/or hand, and (4) his accuracy in identifying simple figures drawn on the back of the hand. Manual perception of form was tested by visual recognition of a geometric form held in the hand. The accuracy with which the child could return his hand to a position previously assumed with the help of the examiner was the basis for the score on kinesthesia. Visual perception of form and space included Frostig's tests of form constancy, position in space, and space relations. Ability to identify superimposed and imbedded pictures of objects made up the test of figure-ground perception. Right-left discrimination refers to the child's identifying his right and left sides as well as those of the examiner. Reluctance to cross the mid-line of the body was evaluated by whether or not the child would spontaneously put his hand on a part of the body on the opposite side and, in addition, pick up objects placed on the other side of the body's mid-line. Hyperactive, distractible behavior is self-explanatory.

The Major Syndromes and Their Hypothesized Development

The statistical analysis of the data gathered by the method described above (and to be described in statistical detail elsewhere) leads to postulating the existence of five major syndromes of perceptual-motor dysfunction. These syndromes, which emerged from the analysis as factors, and the mean or actual factual loadings of the tests of perceptual-motor function on each factor are shown in the diagram. The most important general observation to make is that different syndromes are represented by different constellations of deficits of function. This fact provides the basis for categorizing symptoms into syndromes. The structure of the constellation of areas of dysfunction also directs our reasoning in theorizing about the nature of perceptual-motor development and dysfunction. Each factor will be discussed individually.

Apraxia

Because a deficiency in the ability to motor plan is the primary characteristic of one of the categories of dysfunction, it is suggested that it be called "apraxia" or "developmental apraxia." A child with this disability has difficulty directing his hands or his body in performing skilled or unfamiliar motor tasks. His major perceptual deficiency lies quite clearly in tactile functions. According to the data gathered, kinesthetic and other proprioceptive sources of information play a less important role in apraxia than do tactile sources. Of the conditions which are usually considered aspects of body scheme disturbance (which is often considered to be associated with apraxia) only diminished finger identification appears closely linked with apraxia, as defined here.

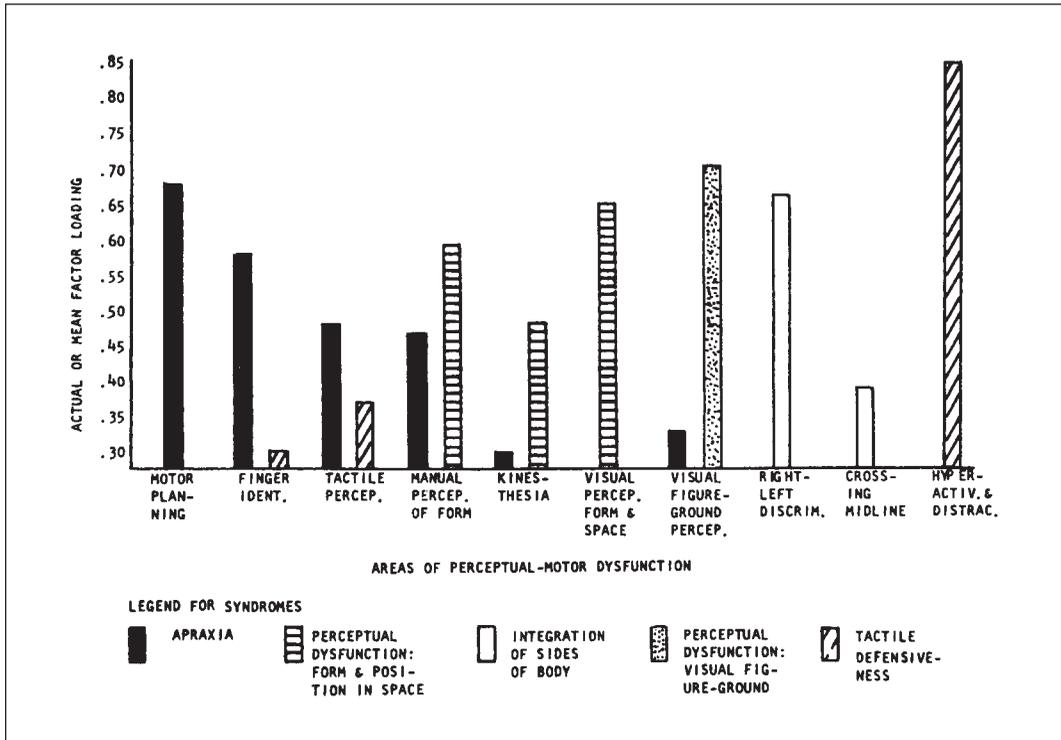


Figure 12.1. Factorial content of five major clinical syndromes of perceptual-motor dysfunction.

The close relationship between deficits in motor planning and tactile perception suggests the primacy of tactile functions in the maturation process. It is hypothesized that the development of central nervous system processes of organizing, inhibiting, and augmenting tactile impulses in association with meaningful experiences must precede the ability to perform skilled motor tasks. Emphasis is placed on the word “precede,” for concomitant tactile perception during a motor task is not a sufficient basis for motor planning. It seems that the continuous flow of tactile sensations, if meaningful, lay down in the brain the body scheme upon which all future motor planning is based.

Skill in all motor activity involving the hands is dependent upon finger gnosis. The close linkage between finger identification and tactile perception has invited the hypothesis that finger agnosia is, at least partially, a function of a disordered tactile system.

Our approach to treatment of the child with apraxia must focus on normalizing the tactile functions as well as training in motor skill.

Perceptual Dysfunction: Form and Position in Space

Another important syndrome reflects a deficit in perception of form and position in two-dimensional space. As shown in the diagram, perception refers, here, not only to visual perception, but also to tactile perception of form and kinesthetic perception of the position of

the hand in space. It is the grouping of these three sensory modalities that provides us with a major clue regarding the development of visual perception. It is hypothesized that the visual perception of form and position in space is preceded developmentally by the purposeful response to tactile and kinesthetic sensations carrying information about form and space. If a child feels with assurance where his hand is, how his fingers are positioned, and what they are holding, he will be better able to visually cope with form and space, such as is required in tasks as simple as setting a table or as complex as drawing designs, reading, or assembling an object on the production line. The relationship may not be an inevitable one, however, for relationships among perception of form and space in the three sensory modalities may be a function of a common neurological process.

The implication for treatment, again, is to first normalize, as much as possible, tactile and kinesthetic sensation, followed by the enhancement of perception in these modalities and of visual stimuli.

Deficit of Integration of Function of the Two Sides of the Body

From the research data emerged a syndrome with characteristics to which reference has been made in the literature for many years. However, the grouping of symptoms into a single dimension of central nervous system development and organization appears not to have been suggested prior to this time. The two most distinguishing aspects of behavior of this syndrome are a tendency of the hands to avoid crossing the mid-line of the body when engaged in motor tasks and difficulty in learning to discriminate and identify the right and left sides of the body, the latter type of behavior being the best representative of the syndrome. It is possible that there are other, more effective means of identifying this type of dysfunction. Studying those aspects of perceptual-motor dysfunction which showed close association with crossing the mid-line and right-left discrimination suggests a basic clinical syndrome of inadequate integration of the two sides of the body. Whenever the motor function of one side of the body is related to activity of the other side, the function of the two sides requires coordinating by a central nervous system mechanism of unknown type which is clearly vulnerable to disorder. Thus, successful participation in rhythmic activities requiring a temporal interrelationship of the two hands or two feet is partially dependent upon this central nervous system mechanism even though the mid-line is not crossed. Similarly, jumping with both feet simultaneously and performing reciprocal motions with the extremities are affected. It even seems likely that having to draw on one side of a page a duplicate of a design appearing on the other side of the page involves integration of the two sides of the body. The ability of the eyes to cross the mid-line of their respective ranges of motion is part of this behavioral dimension.

The sensory component of the syndrome is obscure, but, again the significant correlations between scores on tests of tactile perception and crossing the mid-line or right-left discrimination suggest the importance of tactile stimuli in the developmental process. It is hypothesized that crawling or creeping has found favor among therapists and psychologists as a therapeutic process partly because it is one of the most basic and ontogenetically early sensorimotor patterns requiring and enhancing integration of function of the two sides of

the body. It is interesting to note that at the age of six or seven years, the degree to which the right and left sides could be correctly identified was apparently a function of the maturation of a specific area of sensorimotor development, as contrasted with verbal skill. This syndrome is deserving of much attention from the occupational therapist. As in the case of most of the other syndromes, it requires treatment with controlled sensation and bilateral motor activity. The effect of some of our bilateral activities begins to take on new significance.

The fact that diminished body balance is associated with poor integration of sides of the body leads to wondering whether there is a neurophysiological deficit basic to both balance and body side integration or whether balancing on one foot involves the kind of neuromuscular integration diminished in children with inadequate functional interrelationship of the two symmetrical halves of the body.

Identification of the pattern of dysfunction in the cerebral palsied child may be very difficult. It is not likely that it would have been detected statistically in a cerebral palsy population. Our inability to detect it does not preclude its presence, and we must be alert to its manifestation and response to treatment.

Perceptual Dysfunction: Visual Figure-Ground

Deficiency in visual figure-ground perception has been identified as a clinical condition for many years. The disability emerged from the research data as a specific and independent syndrome, although some of the children with apraxia also demonstrated disturbance in figure-ground perception. Inspection of correlations between scores on tests of visual figure-ground perception and other perceptual-motor tests suggests that the neurological process basic to figure-ground perception is also basic to all other types of perceptual-motor ability. Somatic perception is closely associated with visual figure-ground perception, the latter even appearing within the apraxia syndrome. The relationship may lie in mutual dependence upon the discriminatory functions of the non-specific processes of the reticular formation and thalamus. The developmental process underlying visual figure-ground perception is far from clear.

A neurophysiological approach to treatment of this syndrome remains to be investigated. The most fruitful approach will likely be through influencing the function of the non-specific reticular system by control of sensory input. If we can enhance the discriminatory function of the general system, figure-ground perception will likely improve. The area is a fertile field for investigation by therapists.

Tactile Defensiveness

The last major syndrome to be described is one brought to our attention for the first time by our research at the University of Southern California. It is characterized by deficit in tactile perception, by hyperactive, distractible behavior, and by a defensive response to certain types of tactile stimuli. It is interesting to note that hyperactive and distractible behavior carried a significant loading on only one syndrome, suggesting that this troublesome behavior problem may, in these children, be linked to a specific neurophysiological mechanism. The

syndrome is closely and directly associated with emotions. These data, when taken into consideration with other neurophysiological information, have led to a fruitful theory described in detail elsewhere. In essence, the developmental process suggested by the syndrome reflects the phylogenetic primacy of tactile stimuli as messages warning the organism of danger and to prepare to flee or fight. This type of interpretation of tactile stimuli leads to the over-alertness of distractibility, the flight-like behavior of hyperactivity, and a tendency toward negative affect (fight). The presence of the syndrome interferes with the development of perceptual-motor ability. It was found primarily in association with the other syndromes and not as an isolated condition.

Identification, at least hypothetically, of a neurophysiological basis for certain types of hyperactivity gives us a cue for another approach to treatment of the dysfunction—the approach being a normalizing of tactile functions.

General Discussion

Attention must be drawn to the fact that the five syndromes may not be expected to appear in pure states in any child. Correlation among scores on perceptual–motor tests warrants the expectation that a child who is perceptually deficient in any one area is likely to be deficient in all other areas but he is not necessarily so. From the statistical analyses emerged many other syndromes of lesser clarity and accounting for less of the source of variance among the children. Additional research may indicate their significance.

Although tactile functions emerged as highly significant, the apparent comparative lesser role of the proprioceptors may be purely a matter of inadequate evaluation of their function or an inability to interpret the results.

While emphasis has been placed on a neurophysiological understanding and approach to treatment, the cognitive approach is certainly not excluded as an important aspect of treatment. The two approaches are really ends of the same continuum. It is strongly suggested, however, that treatment based primarily on influencing basic neurophysiological integration, through control of sensorimotor behavior, and secondarily on intellectual processes will be the most effective approach. There is a long gap between these basic research data and the assurance that a treatment procedure is effective. We need many studies to test, scientifically, the hypotheses suggested by the theories.