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Visual-Spatial Thinking

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THE THEORETICAL BASIS OF VISUAL-COGNITIVE INTELLIGENCE

Jean Piaget and Hans Furth subdivided intelligence into three categories: (1) biological intelligence (Furth's term), (2) sensorimotor intelligence, and (3) operational intelligence (Furth, 1986).[1] Biological intelligence is prewired in utero and is manifest after birth in the form of developmental reflexes. Sensorimotor intelligence can be referred to as "action knowing," and continues throughout adult life. When Piaget discovered object permanence (which occurs developmentally in a child around 2 years of age and involves the ability to do things at a mental level—"in the child's head"—rather than solely to know them through physical action), he became more fascinated and involved with what he termed operational intelligence. Although Piaget delved very little into sensorimotor intelligence beyond object permanence, he did not imply that sensorimotor intelligence stopped at object permanence. Operational intelligence can be described as reasoning or thinking by a child, which usually starts around age 2 and matures around ages 5 to 7, but continues to be embellished throughout life.

To these three categories, Furth and I added a fourth—*body and sense thinking*—to describe sensorimotor development in a child between the ages of approximately 2 and 7 years of age (Furth & Wachs, 1974). Extending Piaget's theory from object permanence through concrete operations—the period when a person can use reasoning to tap sensorimotor intelligence—the term describes the child's ability to apply reasoning to sensorimotor experiences once the child can mentally manipulate his or her visual-spatial world. During this period, the child's action knowing can be enhanced by reasoning or operatory thought.

Piaget's theory can be applied to all individuals, impaired or nonimpaired. Its application includes the autistic spectrum, from pervasive developmental disorder (PDD) to severe autism, as well as attention deficit disorder (ADD) and the more common learning disabilities (LD) and dyslexia (Wachs, 1980, Vol. 2, pp. 51-78). In my research on the application of Piagetian theory, I have worked with children from Europe, Asia, and North and South America, as well as with many indigenous groups—Africans, South American Indians, Bedouins, Aborigines, Eskimos, Native Americans, mestizos, and hill tribes in Thailand—with similar results on sensorimotor and body and sense thinking tasks.

[1] The term "operational" describes intelligence, whereas the act of doing something operational is described as "operatory."

The word "intelligence" is often misused in common speech, as in statements like "Scott is intelligent" or "Cathy is not very intelligent." In fact, "intelligent" should not be used to describe a person, but rather what a person does or is involved in. "Scott is doing this intelligently" would be a better use of the word.

This chapter deals with visual and spatial intelligence and spans the child's development from birth to approximately age 7. All the developmental visual-cognitive hallmarks are stages of growth and should not be misconstrued as age-related norms (Wachs & Vaughn, 1977). Some children with special needs have difficulty developing intellectually, even up to the level of an average 7-year-old. A negative outcome, however, should not be assumed, as I have seen many children develop far beyond their prognoses. A distorted body does not necessarily imply a distorted mind.[2]

Furth and I have coordinated our work to follow the general principles of Piaget's constructivist theory in both diagnosis and intervention. For all children, especially those with special needs, we assign tasks chosen from a repertoire of probes and interventions designed to diagnose, elicit, and foster cognitive understanding. All our probes and interventions are hierarchically based. They are not designed solely to achieve the "right answer" from the child, but rather to lead the child to construct cognitive understanding by developmentally raising or lowering the demands of the tasks.

The following brief outline lays out our developmental approach for developing the visual-spatial aspects of body and sense intelligence:

I. General Movement

- Reflexes (e.g., obligatory arm movements when head or feet move)
- Mental map of body (e.g., awareness of joints and body dimensions)
- Integration of body sections (e.g., creeping-crawling, "angels in the snow")
- Integration of body axes (e.g., rolling, bimanual circles on chalkboard)
- Rhythm (e.g., moving or tapping body parts to the accompaniment of a metronome)
- Coordinated actions (e.g., skipping, hopping, jumping rope)

II. Discriminative Movement

- Fingers (e.g., crumpling or tearing paper)
- Eyes (e.g., focusing, tracking, fixating on an object)
- Lip, tongue, and vocal chords (e.g., tongue motility, making funny faces, gargling)

III. Visual Thinking

A. *Matching* (e.g., household items, blocks, pegs)
- Coincident (reconstructing a given model with some part of each block touching other blocks)
- Separated (matching items spread apart)
- Negative space (placing items in spaces purposely not filled in)
- Recalling (reconstructing a given model in a distant part of the room)

B. *Transposition* (coordinated with body axes)
- Horizontal (toward and away)
- Vertical (right and left)
- Transverse (rotations)

[2] In this context, see Furth, H. (1991). Life's essential: The story of mind over body. *Human Development,* for a discussion of the 1989 memoirs of Ruth Sienkiewicz-Mercer.

– Analysis (determining how a given design was transposed)
– Positions (constructing from a different viewpoint; that is, north, south, northeast, etc.)

"Vision" is another misused word. A parent who says, "My child's vision is 20/20," really should be saying, "My child's *sight* is 20/20." The difference is tremendous. We look with our eyes (looking); we see with our brains (sight); and we understand with our minds (vision). Here is where Piagetian theory is so valuable. Piaget's theory of constructivism holds that knowledge is not neurally constructed; instead, neural connections are built through mental constructs. In other words, the retina and the brain are used to construct, not evoke, new knowledge.

Piaget's theory of sensorimotor intelligence lays the foundation for visual intelligence. The determining factor for visual intelligence is not what passes through the eye but rather what a person can understand from a particular visual experience and eventually coordinate with other aspects of body and sense thinking. Thus, a partially sighted child may have well-developed visual intelligence and a child with acute 20/20 sight may have poorly developed visual intelligence. The foundation for visual intelligence is developed through sensorimotor intelligence in the first few years of a child's life, even during the neonatal period when the child is nonmobile. This does not imply that visual intelligence cannot be developed in the movement-impaired child, but rather that the more developed the child's movement (or sensorimotor) intelligence, the better the opportunity for the child to develop visual intelligence. In addition, even in the nonmotorically impaired child, a lack of movement intelligence development could confuse and inhibit the development of visual intelligence. My experience has shown that most children with cerebral palsy have inadequate visual intelligence, and also that many children with inadequate visual intelligence have inadequate movement intelligence, despite being neurologically intact (Fraiberg, 1977).

DEVELOPMENTAL REFLEXES

For biological intelligence, Furth uses the phrase "biological knowledge" to describe the intelligence the child is born with. Modern neuroscientists refer to this knowledge as "pre-wiring," observable in the many developmental reflexes in a healthy, intact newborn (Goddard, 1996). Clinical experience has shown that the existence of these primitive reflexes can inhibit sensorimotor function and that removal of the reflex obligatory responses actually can aid the efficiency of such sensorimotor functions as ocular motility and general body motility.

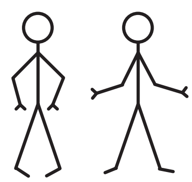
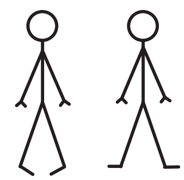
British neuropsychologist Peter Blythe has made an exhaustive study on the diagnosis and treatment of such reflexes sustained beyond their useful years (Blythe, 1990; personal communications with H. Wachs, 1995-1999). His work shows that children who retain primitive reflexes often show the following dysfunctional traits (this list is not all-inclusive and does not imply that primitive reflexes are the sole factors involved):

- Rigidity of movement
- Poor handwriting
- Gaps in athletic performance, especially in throwing or catching
- Clumsiness
- Bumping into things
- Dis-coordination
- Poor ocular tracking
- Poor rhythm
- Difficulty in showing usual expected response to intervention procedures

Though I have not been trained in Blythe's methods, I have incorporated three

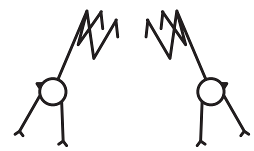
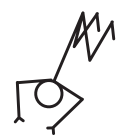
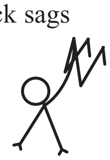
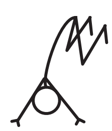
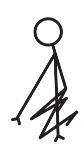
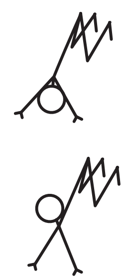
Tables 1A. Primitive Reflexes Adopted into Vision and Conceptual Development Theory

Table 1A. Feet

Observed Reflex	Diagnostic Procedure	Clinical Picture, if Sustained	Clinical Picture, if Reabsorded
FEET (exact origin still undetermined, possibly caused by the amphibian, labyrinthine, or Moro reflex)	Stand erect, hands hanging by side. Turn feet inward in “pigeon-toed” position, then outward in “Charley Chaplin” position.	With feet pointing inward, the child thrusts elbows and arms backward in “scarecrow” position, hands rotated with palms facing away from body. With feet pointing outward, the child moves elbows toward body and rotates hands so that palms face forward. Thus any movement of feet triggers an obligatory movement of arms. This could be very confusing and disturbing, especially to an already confused child. 	The child does not move arms in either feet position, even when marching in place. 

NOTE: Some individuals have such severe gaps in sensorimotor development that they are unable to rotate their feet in either one direction or both directions. These individuals require specific therapy procedures (see treatment section for more information). Other individuals show no reflexive arm movement until asked to turn their feet in or out while marching in place and swinging their arms accordingly. The sustained reflex inhibits and sometimes actually stops the arm movements. I am presently treating a young Mennonite child in rural Maryland who is so reflex-bound that every time she attempts to turn her feet inward, even when seated, her left arm shoots straight up in the air. How can she possibly participate successfully in daily activities at home and in school?

Table 1B. Asymmetric and Symmetric Tonic Neck Reflexes

Observed Reflex	Diagnostic Procedure	Clinical Picture, if Sustained	Clinical Picture, if Reabsorded
Asymmetric Tonic Neck Reflex (ATNR)*	With hands and knees on the floor in a creeping position and head hanging downward, rotate head right and left.	Elbow on opposite body side of head rotation bends; i.e., rotate head to right and left elbow bends, etc. Occasionally only one side is affected. 	Neither elbow bends. 
Symmetric Tonic Neck Reflex (STNR)**	Ask child to get down on hands and knees (or place child in creeping position), and to drop head downward. Repeat, alternately raising and lowering head. This could cause poor posture, with all its visceral and skeletal problems, or dysfunctional results when working at a desk or reading in a chair.	Sitting back on heels indicates retention of STNR. Collapse (flex) of elbows and/or humping of back when head is lowered (and collapse of back when head is raised) indicate existence of STNR. Elbows collapse  Back sags  Back arches  Sitting on heels 	Back stays straight; elbows do not bend. 

* An occupational therapist (OT) told me that she felt the ATNR was responsible for some auto accidents. The driver's head turned to the right caused flexion of the left arm and the resultant swerving of the car.
** Imagine trying to learn to swim, ski, or play a sport if your symmetric tonic neck reflex is severe and inhibitory.

of the primitive reflexes identified by him and some of his teachings in my therapy procedures. Tables 1A and 1B list the identifying features (diagnostic procedure) of each reflex and its clinical picture if sustained or reabsorbed as a result of therapy.

Treatment for Children Who Retain Primitive Reflexes

My approach to therapy for children who retain the reflexes just described is twofold. I have the child (1) work through sensorimotor experiences that in normal development precede cessation of the reflex and (2) participate in sensorimotor experiences that contradict the obligatory movements of the reflex in question.

For step 1, my therapists and I use such early sensorimotor experiences as rolling, crawling and "starfish." Starfish is a simulated in utero procedure borrowed from Peter Blythe in which the child, in a sitting position, first crosses the right leg over the left leg and the right arm over the left arm, with body and head leaning forward. The child maintains this position for a count of ten. The child then thrusts both arms and legs apart and leans body and head backward, again for a count of ten. The child repeats this two-step procedure several times, alternating right over left and left over right (Blythe, 1990).

For step 2, we use animal walks (e.g., bear walk, crab walk, duck walk, inchworm, crawling on the belly) to contradict the FEET and ATNR reflexes. In each of these actions, the hands and feet must coordinate, though they each play an independent but supportive role in the activity. The wall walk and feet-in-and-out have also proved helpful in eliminating the FEET reflex. In the wall walk, the child stands more than an arm's length from a wall, the distance forcing a stretch to reach the wall. With feet stationary, the child walks both hands up and down the wall, as high and as low as possible. The wall-walking procedures can be made more complex by having the child

- place hands alternately on either side of a vertical line,
- move hands rhythmically to a metronome,
- turn hands and feet outward and inward opposite to the assumed position of the feet reflex, and
- turn the head right and left opposite to the ATNR.

For treatment to eliminate the symmetric tonic neck reflex, I use two procedures adopted from yoga practice. In the "turtle," the child sits erect on heels with toes bent under, hands resting on thighs, and back straight. After staying in this position for a count of five, the child leans forward and, supported by the arms, straightens toes (toenails toward the floor) and again sits back on heels with arms resting in the lap for a count of five. The child then grasps the back of the neck with both hands and tucks the head downward between knees, again for a count of five. This is repeated several times. In the yoga technique of "cat and cow," the child—on hands and knees—tucks head down and between arms while arching the back upward, and then bends head backward and arches back downward. This, too, is repeated several times. Eventually, the child performs this procedure rapidly and vigorously.

Readers can add to these examples of treatment activities or use them to build procedures of their own. After the child is free from obligatory reflex movement, the therapist can employ procedures to construct sensorimotor knowledge that will eventually lead to the child's spatial knowledge of the construction of his own body. This is known as endogenous spatial constructs, and is analogous to the knowledge of a car's construction that is required by a person to parallel park the car (Furth & Wachs, 1974, pp. 71-110).

SENSORIMOTOR

My format for addressing sensorimotor growth and endogenous spatial constructs leading to exogenous spatial constructs follows a proven hierarchical developmental plan:

1. Developmental absorption of primitive reflexes
2. Mental map of the body
3. Integration of body sections
4. Rhythm
5. Coordination of body axes
6. Coordination of body actions

Occupational therapy procedures are a valuable adjunct to movement development prior to the body and sense activities just listed. Occupational therapy should be used for children with vestibular (balance) needs and lack of motility or muscle joint adequacy (Furth & Wachs, 1974, pp. 94-107). Perceptual-motor procedures are also a valuable adjunct at the level of coordinated actions. Ocular, digital, and oral discriminative movements also play important roles in spatial constructs in that each has a component of right-left, up-down, and forwards-backwards. This discussion, however, relates only to ocular discriminative movement.

Before discussing interventions for sensorimotor growth, it is necessary to clarify the major difference between development and externally imposed learning. Development implies new mental constructs leading to Piaget's object concepts (mental awareness of an item in the absence of that item) (Ginsberg & Opper, 1979). Externally imposed learning could be conceptual if it were based on solid mental constructs, or solely content learned if the child did not have the prior mental constructs to understand that which was being taught. Children with special needs are particularly prone to such memorized or rote learning. Excessive content learning can actually thwart development and make intervention more difficult because such rote learning encourages the child to memorize and not search for understanding.

The following traits can be observed in children with gaps in sensorimotor development:

- Clumsiness
- Bumping into things
- Inability to ride a bicycle
- Inability to skip
- Poor performance in sports
- Inability to catch or throw, or awkwardness or poor institution of these actions
- Poor handwriting
- Tendency to lose place when reading or when switching fixation from far to near
- Carsickness, especially in the back of a car
- Preference for verbal or manual activities
- Difficulty using scissors
- Difficulty staying within borders—coloring or walking
- Difficulty drawing geometric forms
- Moving of head rather than eyes
- Inability to maintain personal space

The next section briefly discusses probes and interventions for gaps in body and sense thinking, which could well be the cause of the preceding traits.

GENERAL MOVEMENT

Mental Map of Body

The body is a physical construction in which the person resides. The person, or the self, is that unique property that characterizes one as an individual. At death, the person leaves; but the body, as a construction, remains. The person has to develop an understanding of the width, height, and breadth of the body, as well as its hinges and rotary components. Mobility through space requires knowledge of the extensions and limitations of the spatial components of the body, just as parallel parking requires knowledge of the extensions and limitations of the spatial components of a vehicle. Any dysfunctional movement warrants suspicion of an inadequate mental map of the body. A therapist can determine if a child has an adequate mental map of the body through the following probes (Furth & Wachs, 1974, pp. 77-83).

Mental Map of Body Probes

Body lifts. The child lies prone (face down) on the floor, feet extended and arms at sides on the floor. The therapist touches each of the child's limb individually; then two limbs of the same side of the body; then two limbs on opposite sides of the body; then three; then in sequence; then in sequence asking for a response in reverse order; then touching specific parts such as shoulder or elbows; and so on. If the child does not respond while in a prone position, the therapist starts with the child in a supine position (face up), but switches the child to a prone position as soon as possible.

Observations:

- Does the child move only the limb that is touched?
- When the lower leg is touched, does the child lift the whole leg?
- When the elbow is touched, does the child raise the whole arm?
- When the head is touched, does the torso remain stationary?
- Does the child move several parts before deciding on the proper part to move?

Dimensions. The child stands facing the therapist, who is about 6 feet away. The therapist holds a pole (or thick dowel) horizontally and perpendicular to the vertical axis of the child, and asks the child to indicate, either verbally or through gestures, whether the pole should be raised or lowered until it is the same height from the floor as the specified body parts of the child (e.g., eyes, knees, shoulders). This procedure is performed sideways—right and left—as well as frontward. In another task, the therapist asks the child to estimate how far to walk forward or sideways to be at arm's length or foot's length from a wall. At that point the child, with eyes shut, extends a limb to check body judgment. The therapist uses similar techniques to elicit a response for torso dimensions, height, and movements required to get under a stick. Various other tasks can be assigned to encourage body spatial judgment.

Observations:

- Is the child unable to make a judgment? (If so, the therapist works closer to the child, or moves rather than asking the child to move.)
- Does the child seem to be confused, guessing rather than making judgments? (If so, the therapist has the child walk under the stick, try to touch the stick while seated, or walk between two chairs while varying the spatial requirements.)

Joints. The therapist moves a pole or stick toward various parts of the child's body, and the child stands "glued" to one spot and bends the body at the joints to avoid being touched by the stick. Another adult can first demonstrate (but not teach!) how to avoid the stick.

Observations:

- Does the child bend only at the waist?
- Does the child have to move feet from the "glued" spot?
- Are there any joints that seem confusing to the child?

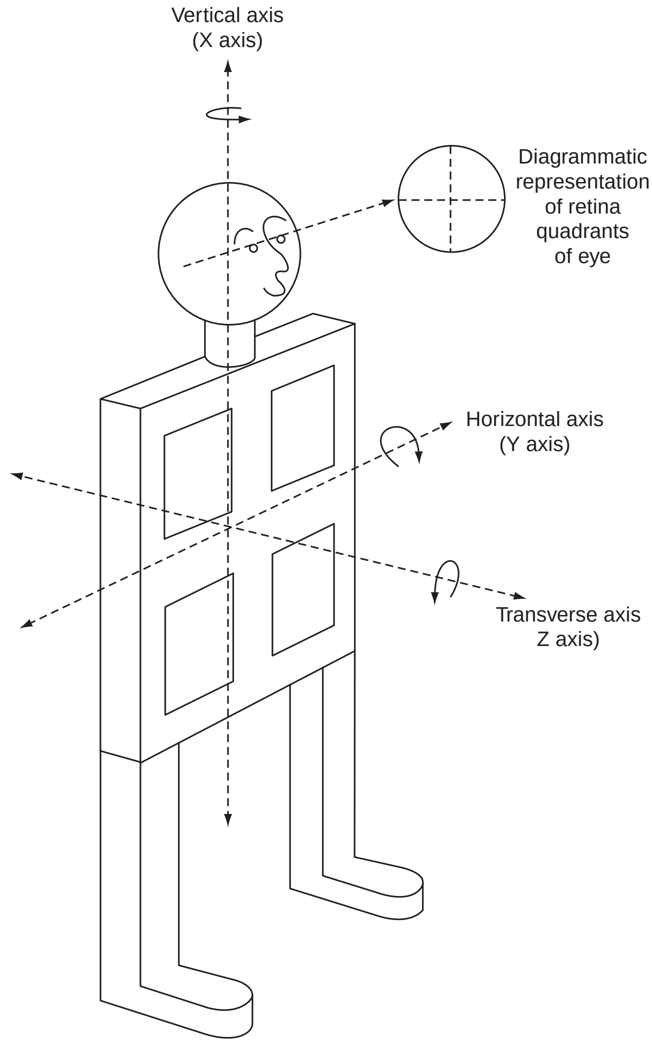


Figure 1. Schematic Representation of Body Axes

Integration of Body Sections and Axes

The body, which is the container and vehicle of the person in all of us, is divided into a right and left half and an upper and lower half. These sections rotate around three axes—vertical, horizontal, and transverse. The axes remain constant in all body positions. The person inside must manipulate the body (the container) for effective, efficient movement. The midline of the body, which lies along the vertical axis, is the longitudinal center of the container and the spatial reference center for the inside person's orientation in space and self (see Figure 1). The ear is thus further from "the person" than the nose. The eye can focus more easily on an object held temporally than on an object held nasally under binocular exposure because the object held nasally is closer to the person's center of reference.

The three axes interact to develop endogenous spatial coordinates and are our internal reference for three-dimensional space. Thus an object moving from right to left moves toward us until it reaches our body's midline, where it begins to move away from us. As evidence, try this simple exercise. Keep both your eyes shut. Hold your right hand level with your face but off to your right. Slowly move your right hand toward the left. As you cross your body's center line, you will feel that your arm and hand have shifted direction and are moving away from your body—even though they are still moving in the same direction, leftward.

The construction of this internal directional focus depends on physiological readiness and psychological awareness and motivation. To properly establish an internal directional focus, the child must develop integration and coordination of all sections of the body and coordinate all this mentally through vision, hearing, smell, and touch. Once this is established, the child is ready to develop efficient exogenous spatial coordinates, or a knowledge of the three-dimensional space of the child's external world. A child who has difficulty imitating simple body positions that involve right and left arm, or a child who is unable to walk cross-legged backward along a line on the floor, has not yet developed adequate endogenous spatial coordinates. These are usually developed around 6 years of age—prior to school entry in the United States—and are the foundation of the right-left concept important to academics.

Most children with reversal difficulties fall into the nondeveloped endogenous and exogenous visual-spatial category (Fraiberg, 1977, pp. 5, 78, 157-159, 197; Furth & Wachs, 1974, pp. 86). (Endogenous is *internal*; exogenous can be described as a baby's ability to project an internal model of space through visual, auditory, and manual appreciation of spatial relationships in its *external* world) A therapist can determine adequate integration of body sections through the following probes.

Integration of Body Section Probes

Static imitative movement. The child and the therapist (or parent) stand facing each other about 10 feet apart. The therapist raises his own right hand and instructs the child to imagine standing alongside the therapist and to raise the same hand as the therapist has raised. Keeping that hand raised, the child moves alongside the therapist and observes whether they both have the same arms raised. If not, the child is told to "fix it." The child then returns to the original position—facing the therapist from 10 feet away. The therapist again asks the child if the raised arm is the same arm as the therapist has raised.

Observations:

- Does the child then mirror the therapist (e.g., uses the left arm to imitate the therapist's right arm)? If so, no further probe is necessary—the child has not developed adequate visual-spatial knowledge.
- If the child successfully imitates the therapist, the therapist models several right-left positions but does not cross hands over the midline. The therapist's final modeling is to put the right hand on nose and left hand on right ear. This position requires a crossover of the central body locus.

Observations:

- Can the child imitate the positions modeled by the therapist? The child's successful imitation of this position indicates basic development of endogenous-exogenous, visual-spatial knowledge. An inability to imitate the position indicates that the child has not yet developed this visual-spatial knowledge.

Cross-legged walk-on-line. The therapist places a strip of tape approximately ten feet long on the floor, and demonstrates walking forward cross-legged (right foot forward over left foot, then left foot forward over right), until the entire tape is traversed. Then the

therapist instructs the child to do the same walk backward (placing the left foot backward and behind the right foot, etc.)
Observations:
- Does the child have an inability to perform the action backward? This indicates inadequate endogenous spatial development.
- Does the child have an inability to perform the action forward? This indicates a severe lack of endogenous spatial development.

Skipping. The therapist asks for and/or demonstrates skipping, having the child skip at least 20 feet (in a circle, if space is limited).
Observations:
- The child may not skip at all. (My research with Orinoco children of the Waika tribe in Venezuela revealed that skipping is not part of their culture, nor are hopping or jumping up and landing on both feet simultaneously. On the other hand, Zulu children in South Africa skip well at age three. Children in the Western world usually skip by approximately six years of age.) Skipping cannot, *and should not* be taught. Step-hop is not skipping. A sighted child who has the necessary motoric constructs will skip by observing others.

"Angels in the snow," crawling on the belly, creeping on hands and knees, human ball roll, and rolling (Furth & Wachs, 1974, pp. 84-107) all involve sensorimotor knowledge of how body halves can work together for purposeful movement. Any physical challenge that requires basic understanding of how to coordinate right and left as well as top and bottom of body sections can be used. The key is *not to teach.* Tasks can be demonstrated but not taught. If the child is unable to perform the task, the demands and complexity of the task should be simplified, but not taught.

RHYTHM

Rhythm adds a temporal component to body and sense thinking. Though often categorized as an auditory function, rhythm is really internal timing with an auditory, visual, and tactile component. In half a century of clinical experience, I have seen very few children in need who have adequate, if any, rhythm constructs. The following three probes can be used to test rhythm constructs.

Rhythm Probes

Accompanying tapping (observed). The therapist taps rhythmically in steady beats on a table in front of the child. The child accompanies the therapist's tapping. Both child and therapist are observing.

Accompanying tapping (hidden). The child accompanies the therapist's tapping while the tapping instrument is hidden from the child.

Recall tapping. The therapist taps rhythmically and stops. The child recalls the rhythm and taps accordingly.
Observations:
- A well-developed 3-year-old can accompany rhythmic taps—hidden or visible.
- A well-developed 4-year-old can recall a simple rhythm pattern.
- By age 6, a well-developed child can maintain rhythm under various conditions with hands and feet, stopping one limb and reversing the cycle in time to the beat of a metronome.

Rhythm Interventions

Body support. The therapist stands behind the child and taps on the child's shoulder to the beat of a metronome set at about 100 beats per minute. The child taps on a table to the accompanying sound of the metronome and the therapist's tapping. The therapist gradually ceases tapping on the child's shoulder as the child's tapping on the table becomes more efficient.

Rhythm light. The child observes as the therapist flashes a light rhythmically to the beat of a metronome. This adds an additional signal to the child to reinforce the child's rhythmic response.

Puppet. The child sits in a chair with hands on the table and feet flat on the floor. To the beat of a metronome (started slowly at 100 beats per minute) the child taps, in a circular pattern, right hand, right foot, left foot, left hand, right hand and maintains this pattern. The therapist decides when the circle should be reversed—clockwise and counterclockwise. An advanced step is to ask the child to stop one limb and maintain the beat. Thus, the right hand stops but the child maintains the beat as though the right hand were moving. Eventually, two limbs can be stopped. The therapist can also ask the child to reverse the circular pattern—clockwise and counterclockwise. Another advanced procedure is "simultaneous same" (right hand, right foot, then left hand, left foot) and "not same" (right hand, left foot, then left hand, right foot). Again, stopping of limbs adds complexity. As the child improves, the speed of the metronome can be varied.

Sitting spider. This activity is similar to the Puppet, but the child sits on the floor with hands on the floor, hips and feet flat on the floor, and knees bent and raised. The same procedure is used as in the Puppet, that is, circular, same/not same, stopping of limbs, and reversing circular motion clockwise and counterclockwise.

Creeping. (Furth & Wachs, 1974, pp. 90-91). On hands and knees, the child creeps "simultaneous same" and "not same" on the therapist's command to various rhythmic beats of the metronome. Complexity can be added by placing signs printed with an "R" (for right hand) and "L" (for left hand) on the floor in varying sequences. If the child has no knowledge of the symbols, the therapist can just put blank cards on the floor or designate the hand that is to touch that card with a pattern (e.g., a red dot) and draw the same symbol on the child's hand.

Coordination of Body Actions

Coordination of body actions is a very high phase of sensorimotor intelligence. At this point, the child's sensorimotor development is fairly well established. Too early involvement in coordinated action activities can mask, or even thwart, development of the basic sensorimotor foundation for well-developed sensorimotor intelligence. Jumping rope, sports, gymnastics, rope and monkey bar activities, and walking rails and balance boards are all physical skill activities that require total body coordination.

OCULAR SENSORIMOTOR DISCRIMINATIVE MOVEMENT

The four basic movements of ocular sensorimotor intelligence are:

- Tracking
- Fixation
- Focus
- Convergence

Tracking is the ability to sustain fixation on a moving object. An intact, well-developed 4-year-old child should have adequate tracking. A 3-year-old can fixate, or move the eyes to point to a specific exogenous spatial object. Focusing is the ability to see an exogenous object clearly, and is not well developed until a child is 4 or 5 years old. Convergence is the ability to bifixate (point each eye at) an object as that object moves toward the eyes. A well-developed 3-year-old should be able to converge on a target held 2 inches from the eyes. An intellectually healthy, well-developed 5-year-old can perform adequately in all these areas (Furth & Wachs, 1974, pp. 71-110). The following probes can be used to test the basic movements of ocular-sensorimotor intelligence.

Tracking Probes

The therapist asks the child to fixate (look at, point their eyes at) a penlight or other attention-getting object while the therapist moves the object horizontally, right to left and back to the right. Observing the ocular movement and, if possible, reflection of the object in the center of the child's eyes, the therapist then moves the target up and down vertically, with the child fixating the target. The therapist follows this with irregular, reverse motion movement of the target while the child tries to fixate and follow the target.
Observations:

- Is the child able to fixate on even a stationary target?
- Does the child move the head rather than the eyes?
- Does the child lose fixation?
- Do the child's eyes cross in the attempt to follow the target?
- Does the child track horizontally but not vertically?
- Does one eye stop while the other continues tracking?
- Does the child track if the therapist uses slow, steady motion, but lose fixation when the tracking pattern is irregular?

Tracking Interventions

Pen stab. The child holds the top cover of a felt tip pen. The therapist holds the pen itself and moves it in various directions at various heights while the child tries to put the cover on it.[3]

Paper stab. The therapist draws a bull's-eye target on a piece of paper and ascribes various scores to the rings on the bull's eye (the center area has the highest score and the area outside the bull's eye has a minus score). The paper is moved on the table with the bull's eye in view, and the child uses a felt tip pen to stab at the bull's eye as in a game of darts. After a specified number of stabs, the therapist adds up the score . The child tries to better the recorded score during the next session.

Washer or ball stab. The therapist suspends a metal or wooden washer (or other device with a hole in the center) from a rope. The child tries to stab the hole in the washer with a pencil or stick as the washer swings to and fro (Furth & Wachs, 1974, pp. 111-128).

Fixation

Tracking is dynamic fixation. Since a person who has difficulty tracking has difficulty fixing, the probes for tracking will also indicate the adequacy of fixation.

Focus

Focusing requires optometric evaluation. Asking a child whether she sees something clearly is far too subjective to indicate adequate focusing. However, looking far to near and back to far, and having to identify the target used, is the treatment of choice.

Convergence

Convergence is the ability to turn each eye inward to bifixate a near vision target. A well-developed 3-year-old should be able to converge on a target held 1 inch from the

[3]Dr. Arnold Sherman, O.D., of New York, first invented this simple procedure.

eyes. Two basic probes can determine the adequacy of convergence.

Convergence Probes

First, the therapist brings a fixation object forward from over the child's head to approximately 1 inch in front of the bridge of the child's nose while the child bifixates the target. Second, the therapist holds the fixation object from above about 8 inches from, and aligned with, the bridge of the child's nose, and then moves the object toward the child while the child tries to bifixate on the target.

Observations:

- Do the child's eyes remain looking straight ahead—no convergence?
- Does one eye fixate the target while the other remains looking straight ahead, turns in, or turns out?
- Does the child try to fixate by thrusting the head forward rather than converging the eyes?

Convergence Intervention

Convergence is a complex function and often requires professional intervention. If not, the simple procedure called "push-ups" can be used. The therapist has the child bifixate a target while moving the target toward and away from the child. If this does not help, the parents should enlist the aid of a visual-cognitive or developmental optometrist.

VISUAL THINKING

Visual thinking is making sense out of the sense of sight. As described earlier, the eye's role is to change photic energy into neural energy. When this energy is transmitted to the brain, a child with the requisite mental construct will either understand the photic event or develop a new scheme to enhance knowledge of that photic event. Visual thinking is involved in all performance testing as well as academic and intelligence testing. Visual thinking also is involved in mathematical thinking, especially in geometry. Visual thinking is involved in viewing and understanding molecular structures in organic chemistry. In short, visual thinking is visual intelligence.

To explore visual thinking, the therapist can best do probes using parquetry blocks, pegs, form boards, and sticks (Furth & Wachs, 1974). Most children in need start by matching patterns of blocks placed before them. Some can only stack blocks. The following outline illustrates a hierarchy of actions using parquetry blocks. At any step, time can be introduced as a factor (e.g., speed, time limits, tachistoscope). A minimal clue also can be introduced, such as blurring the child's vision, camouflaging the model with overlays, and partially hiding or partially forming the model. The therapist should avoid developmentally inappropriate strategies.

A Hierarchy for Demonstrating Visual Thinking

This hierarchy (Furth & Wachs, 1974, pp. 286-287; Wachs & Vaughan, 1977, pp. 8-10) is not sacrosanct. The progression does apply generally but not totally universally. Some individuals (both child and adult) may be able to use strategies and appear to achieve a higher function but still not be conceptually solid on a lower function (Wachs & Vaughan, 1974).

A. Same/not same

A tenet basic to both learning and development is recognition of the conflict between known and unknown elements (Furth & Wachs, 1974; Wachs & Vaughan, 1977). This conflict provides the impetus for inquiry and eventual understanding. To probe a child's ability to distinguish between what is known and not known, the therapist asks the child to differentiate one color, size, or shape of block from another.

B. Stack blocks
The child is asked to duplicate the therapist's model by placing one block upon another in a balanced position, matching either the broad side or the narrow side of the blocks. (See Figure 2.)

C. Build a bridge
The therapist makes a model by placing blocks at least one pencil width apart and spanning them with another block, and then asks the child to duplicate the model. (See Figure 2).

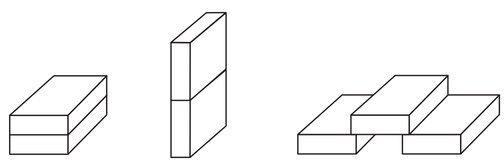


Figure 2. Illustration of Stacking Blocks and Building a Block Bridge

D. Actual match (blocks to blocks)
The therapist asks the child to reproduce a model arrangement of blocks. The reproduction should be such that the model, when placed on top of the reproduction, fits exactly. Various configurations of blocks can be made.

1. **Parallel square** - the central block (square) placed so that the sides of the square are parallel to the sides of the table. (Figure 3 illustrates the following variations on the parallel square.)

a. Juxtaposition - The sides of all blocks are coincident (the whole side of one touches the whole side of the other). The ultimate number of blocks is five—preferably two squares, one triangle, and two diamonds. The following procedures are designed to build same/not same awareness:
– take away
– add on
– substitute

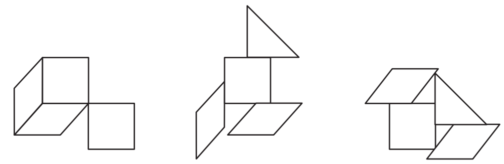


Figure 3. Three Arrangements of Blocks Around a Parallel Square

b. Off-center – The blocks are placed so that the edge of any block only meets half the edge of the central block.

c. Hole – The blocks are placed so that their edges only partially meet the edges of the central block, thus creating holes (or spaces) between blocks.

2. **Tilted square** - The central square is tilted so that the corners, rather than the sides, point to the sides of the table. The substeps are the same as those for the Parallel Square.

3. **Separation** - This activity can either be simple (i.e., blocks edges are parallel, but the blocks do not touch) or advanced (i.e., blocks edges are not parallel nor do the blocks touch). (See Figure 4.) Separation involves the following elements:
– add-on
– take away
– substitute

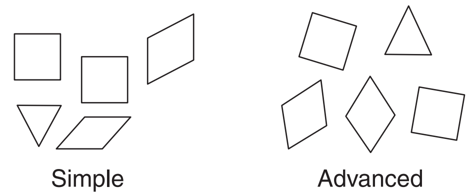


Figure 4. Simple and Advanced Separation of Blocks

4. **Recall** - The therapist presents a model, either in another room or apart and unseen in the same room. The child assembles a reconstruction of the model from memory. The therapist encourages repeat viewing until the child completes the replica, and then the therapist places the model on top of the replica to give the child visual feedback.

E. Transposition

This is the introduction to exogenous visual-spatial concepts. Flipping and rotation of blocks are simulations of the rotation around the three body axes: vertical (through the head down), horizontal (through the hips side to side), and transverse (through the navel and out the back). Knowledge of how to manipulate the body around these various axes provides our endogenous spatial concepts. Figure 5 illustrates transposition according to the following hierarchy of axes.

1. **Hierarchy of axes -**
   a. Horizontal
   b. Vertical
   c. Transverse
      – side-to-side
      – corner-to-corner
      – corner-to-side
      – side-to-corner

2. **Hierarchy of block assembly** - Using three blocks, the therapist can instruct the child to assemble the blocks according to the following hierarchy of increasing complexity. Figure 6 illustrates the final two levels of this hierarchy.

1. <u>Parallel basic</u> - center square parallel to the sides of the table and the sides of the other two blocks coincident with the sides of the square.
2. <u>Parallel advanced</u> - center square parallel, and only one of the other two blocks coincident with the square.
3. <u>Tilted basic</u> - center square tilted and the other two blocks' sides coincident with a side of the square.
4. <u>Tilted advanced</u> - only one of the other two blocks coincident with the square.
5. <u>Individual placement</u> – the therapist presents the child with the blocks one

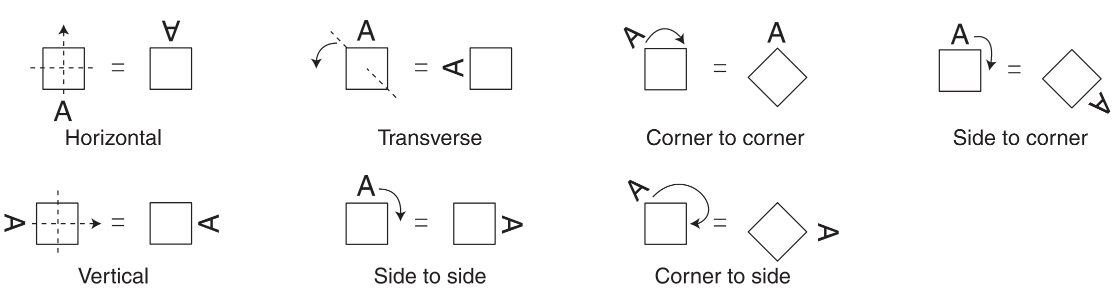


Figure 5. Transposition of One Block Along a Hierarchy of Axes

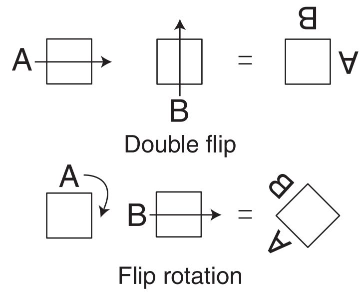


Figure 6. Illustration of a Double Flip and Flip Rotation of Blocks

at time, with the central block last. The above hierarchy is maintained, and the child or person is not to reposition the blocks until the final one is placed on the table.

6. Double flip – the therapist asks the child to flip the blocks in two directions simultaneously.
7. Flip rotation - transverse axis rotation combined with a horizontal or vertical flip.

The hierarchy of block assembly, as well as the transverse axis complexity, is maintained for both the Double Flip and the Flip Rotation.

F. Positions

The therapist's blocks remain stationary in the center of the table. The child replicates the design as it would be viewed from any of the four cardinal positions of the table (north, east, south, west), as well as from the corners of the table. In previous actions, the blocks were moved and the child was stationary; here, the child moves and the blocks remain static.

G. Analysis

The model *and* the transposed replica are both presented to the child who must determine the type of transposition (e.g., horizontal flip, double flip, flip side-to-side or toward and away, rotate from corner to side or side to corner of sheet) required to transpose the model into the replica (that is, how the model was flipped or rotated to create the replica).

H. Pictures Around the Room

The therapist places a drawing of a three-, four-, or five-piece block design in various positions around the room, and then a blank card before the child. The child is asked to duplicate the designs.

I. Outline

The therapist traces the outline of a three- or four-block design (with blocks placed either horizontally or vertically) onto a card and asks the child to visualize the component parts of the outline and construct the design alongside (not on) the card. Basic to this is placing the blocks *on* the card within the outline.

J. Positional Hierarchy (from basic to complex)

1. Coincidence
2. Off-center
3. Hole

K. Hierarchy of Media Complexity

Within each of the following elements, there is a hierarchy; that is, chips are juxtaposed, then overlap; pegs are in sequence, then in random order lying flat and diagonal. Any medium lends itself to both matching and transposition tasks.

1. Cuisenaire rods
2. Cubes or chips
3. Parquetry blocks
4. Pegs
5. Dot patterns (4 or 5 missing dots)
6. Geometric designs

7. KOHS blocks or other multicolored cubes (the position of color or block adds another dimension)

CONCLUSION

I have made no attempt to be all-inclusive in this chapter, as a full explanation of visual-cognitive development would require many pages of text. Instead, I have tried to introduce optometric, visual-cognitive therapy in the hopes of encouraging parents of children in need to seek the help of a visual-cognitive optometrist. The consequences of well-developed visual thinking are manifold. Academic subjects such as geometry (a visual mathematics), biology (with its visually presented experiments), geography (requiring the visualization of graphically presented symbols), and organic chemistry (demanding visual organization of molecular structures) are some of the visually dependent tasks students are required to perform. Such vocations as architectural design, engineering, surgery, dentistry, sculpture, and painting are visually dependent. The congenitally totally blind person can learn to do many things that sighted people can do, but are restricted when the activity is solely visually demanding, as in dentistry or restoration of a painting.

My research has shown that mathematical thinking is very visually dependent. A small study I conducted at West York School District in Pennsylvania demonstrated that second-grade pupils who scored high in state-level math competency tests had well-developed visual thinking, visual-logic, and numerical literacy, whereas children who scored poorly were inadequate in these functions. Because mathematics is a visual-related child, the use of manipulatives to teach math in normal and remedial settings has long been the method of choice.

In essence, visual-spatial knowledge plays a major role in our intellectual growth and everyday existence. Children have a right to every opportunity to develop this knowledge to their fullest capacity. This tenet guides the work of visual-cognitive optometry, which is a necessary link in the chain of total development.

CASE STUDIES

Case One

M. was 11 years old when I met him. His father was a teacher in rural Maryland, and his mother a college-educated homemaker. M. had received occupational therapy and countless hours of remedial reading. He had also been seen by several outstanding opthamologists. He was a large boy, affable and cooperative. His verbal ability was superior, and all previous mentors and testers had assured his parents that he was of superior intellect. Nevertheless, M. still could not read. He had trouble even with the words “the” and “and.” The boy’s most serious problem was his lack of development in ocular sensorimotor schemes. He measured slight hyperopia (far-sightedness) and had severe esophoria (overfocus) bordering on intermittent esotropia (crossed eyes). M. could not see near objects clearly, and glasses alone could not solve his problem. He was so uncomfortable trying to perform near vision tasks that he had simply stopped trying by the time I met him. One helpful “eye doctor” had actually suggested that M. learn Braille. M. also had developmental gaps in general movement as well as operatory thought. I worked with M. in my home office for about one hour weekly for nearly a year. Since M.’s most serious problem concerned his poor ocular sensorimotor schemes, I first concentrated on developing his skills in tracking, fixation, focus, and convergence. We then worked on general movement to improve his mental map of his body and on visual thinking to help him make sense out of what he could now see. M. did not complete as much of the visual-cognitive therapy as I would have liked, but he did complete enough of the sensorimotor (ocular and body as well as visual thinking) therapy to begin reading. His reading proficiency was sufficient to enable him to finish high school in the upper part of his class and attend college. The last I heard, M. had moved up in the corporate world to a position as assistant director of a major museum in Washington, D.C. From an illiterate, "pseudo-blind" school failure, this boy became a literate, successful person.

Case Two

Y. first came to my office when she was almost 8 years of age. Her early developmental milestones were severely delayed. She had received speech therapy and special education in her native Middle Eastern country, but she spoke very few words and was extremely withdrawn. All testing had resulted in a clinical developmental age of 3 to 4 years. When I first met her, Y. did not respond to anything. She would not, or could not, interact in any way. Her social and societal dysfunction, together with her major cognitive deficits, had resulted in a guarded and unfavorable prognosis.

Upon testing, I found her visual acuity to be 20/20 at distance and near, but she had considerable sensorimotor confusion when attempting near vision fixation. She was under such stress and visual confusion at near that she actually crossed her eyes from the distress of near vision binocular fixation. I prescribed glasses with special lenses to relieve her near vision distress. When I offered to work with Y., her parents moved to Washington, D.C., and were totally cooperative and consistent, both with her therapy in our office and with other therapies in the Washington area. Treatment continued for a 3-year period. I worked with Y. on an optometric, visual-cognitive regime consisting of general body and ocular sensorimotor development as well as very basic body and sense thinking. I paid special attention to Y.'s receptive-expressive language, having her stay focused on a task, and improving her ability to follow verbal and gestural instructions. For example, I had Y. place inch cubes (or other objects) on designated locations, as well as walk to specific locations or mark specific locations on a chalk board or table top. To do this, I had to ascertain her level of development in each task on each day as it varied quite often. I then presented each task at a slightly more challenging complexity, being certain that the new task was not too high for Y. to comprehend. As Y. grew cognitively and new tasks became more complex in minute steps, I introduced new aspects of intelligence. Other therapists addressed her speech, her neuro-physiology, and her special education needs. The family lived in Washington, D. C. from September to June every year and returned home for the summers, during which they maintained a home therapy program.

The results of these efforts have been outstanding. Y. is now a gregarious and talkative girl, attends a local public school, and reads adequately. Her eyes are straight and her parents are delighted. At 11 years old, Y. functions at about age 8. She may never perform at an age-appropriate level, but her prognosis for a normal, intellectually competent adult life is now excellent. ■

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