Sensory Integration

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Alma Jean Ayres Baker

"Jean Ayres (pg 21) had conceived what she believed was a deceptively simple and yet frustratingly entangled truth: that in order to fully develop both motor and cognitive skills, the human brain has to internally digest an route (process) continuing feedback from all the senses, particularly visual-perceptual and proprioceptive (including vestibular). If some of that input goes missing or is misrouted, brain circuitry becomes mixed up, and that can slow gross- and fine-motor maturation and delay cognitive development as well. These problems can manifest in many ways, from clumsiness to dyslexia to poor math skills.

Ayres had received her degree in OT from the University of Southern California (USC), and she would go on to get her master's degree there, as well as a PhD in educational psychology. It was in 1968 that Ayres began calling her theory "sensory integration."

During that era there was a general acceptance of the idea that if you pushed the body through particular movements—even passively—it would modify brain circuitry in specific ways. "Patterning" was a common practice.

Sensory Integration (pg 22) puts forth the hypothesis that if you introduce children to multiple sensory activities at once (such as having them write on a clipboard while swinging on a swing), the brain circuitry still will attempt to integrate the feedback, possibly correcting the lack of stimulation that may have caused the developmental problem. Thus the swinging equipment you find in the SI gym or clinic today.

Jean Ayres told Sieg in June 1981. "…Theory is not the facts. Theory is putting the facts together so you can pursue them, and in my case, enhance the development of children. This is always my end objective."

With great thanks to: Brown, E.J. (18 October 2004) The fight for Jean Ayres' legacy. *Advance for occupational therapy practitioners*: 21-22.

Overview of Sensory Integration

- This is not meant to be the most comprehensive lecture on sensory integration, as the body of work is too large to contemplate on one website. We hope to introduce some concepts and terminology that we frequently use when working with a child.

According to Shelly J. Lane (Bundy, A.C., Lane, S.J., Murray, E.A. (2002). *Sensory integration: Theory and practice*. (2nd 3d.). Philadelphia: F.A. Davis Company – (Pg 4):

"Ayers (1972a) defined sensory integration as "the neurological processes that organizes sensation from one's own body and from the environment and makes is possible to use the body effectively within the environment" Sensory Integration is a theory of brain-behavior relationships. Sensory integration theory has three components (pg 5). The first pertains to development and describes typical sensory integrative functioning; the second defines sensory integrative dysfunction; and the third guides intervention programs.

The three major postulates of sensory integration theory are:

1. Learning is dependent on the ability to take in and process sensation from movement and the environment and use it to plan and organize behavior
2. Individuals who have a decreased ability to process sensation also may have difficulty producing appropriate actions, which, in turn, may interfere with learning and behavior.
3. Enhanced sensation, as a part of meaningful activity that yields an adaptive interaction, improves the ability to process sensation, thereby enhancing learning and behavior.

We have identified two levels of motor planning dysfunction (pg 6): Bilateral Integration and Sequencing (BIS) and somatodyspraxia. To have sensory integrative-based dyspraxia, individuals must have deficits in processing one or more types of sensation.
Fisher and Bundy (1991b) suggested that somatodyspraxia is a more severe form of practic disorder than is BIS.

Posture (pg 7) is assumed to be the outward manifestation of vestibular and proprioceptive processing. Postural deficits are thought to reflect the basis for deficits in BIS in particular, and sometimes for somatodyspraxia.

Relevant postural indicators include:

- Extensor muscle tone (assessed by examining posture in standing)
- Prone extension
- Proximal stability
- Ability to move the neck into flexion against gravity (part of supine flexion)
- Equilibrium

Postrotary nystagmus is also often apart of this grouping, in which case the cluster may be called "postural-ocular." Deficits in tactile discrimination are assumed to be an outward manifestation of tactile processing. They are thought to be one basis for somatodyspraxia. As the name suggests (pg 8), individuals with BIS have difficulty using the two sides of their body in a coordinated fashion and sequencing motor actions. Fisher (1991) indicated that "sequencing" referred specifically to anticipatory projected movement sequences (i.e. the feed forward-dependent sequence of movements necessary to get one's limbs to a particular place in time to act). BIS is presumed to have its basis in poor vestibular and proprioceptive processing. Additionally, the visual system plays a major role in anticipating the location of moving objects and in guiding our movements to these locations.
Individuals with somatodyspraxia have difficulty with both feedback- (simple) and feed forward dependent (difficult) motor tasks. To have somatodyspraxia, an individual must

have deficits in somatosensory (usually tactile) processing. However, the individual usually also has poor vestibular and proprioceptive processing.

Sensory Modulation Disorders

Ayers (1979) defined modulation as the CNS's regulation of its own activity.

Commonly, four types of modulation disorders include (pg 9):

1. Sensory (including tactile) defensiveness
2. Gravitational insecurity
3. Aversive responses to movement
4. Underresponsiveness

Although **tactile defensiveness** was the first to be described, defensiveness is widely believed to occur in all sensory systems, with the possible exception of the vestibular and proprioceptive systems. **Sensory defensiveness** is often linked to poor limbic or reticular system processing. **Gravitational insecurity** is manifested as fear of movement, being out of the upright position, or having one's feet off the ground. Gravitational insecurity is associated with poor otolithic vestibular processing. **Aversive Responses to Movement** are characterized by (pg 10) autonomic nervous system reactions. Similar to gravitational insecurity, aversive responses to movement are associated with poor processing of vestibular information. However, rather than otolithic processing, aversive responses are thought to reflect poor processing of semicircular canal-mediated information. **Underresponsiveness to Sensation** causes individuals to react in a way that suggests they do not notice sensation, or their responses are far less than expected.

Assumptions of Sensory Integration Theory

1: The Central Nervous System is Plastic

Ayers (1989) indicated that:
…the brain, especially the young brain, is naturally malleable; structure and function become more firm and set with age. The formative capacity allows person-environment interaction to promote and enhance neuro-integrative efficiency. A deficiency in the individual's ability to engage effectively in this transaction at critical periods interferes with optimal brain development and consequent overall ability. Identifying the deficient areas at a young age and addressing them therapeutically can enhance the individual's opportunity for normal development.

2: Sensory Integration Develops (pg 11)

As Short DeGraff (1988) indicated:
…sensory integration theory assumes that the brain is immature at birth and also is immature [or dysfunctional] in some individuals with learning problems. The goal of sensory integration therapy is to provide stimulation that will address certain brain levels (primarily subcortical), enabling them to mature [or function more normally], and thereby assisting the brain to work as an integrated whole.

3: The brain functions as an Integrated Whole

Ayers believed that higher-order integrative functions evolved from, and were dependent on, the integrity of "lower-order" structures and on sensory-motor experience. She viewed higher-order (cortical) centers of the brain as responsible for abstraction, perception, reasoning, language, and learning. In contrast, she viewed sensory integration as occurring mainly within lower (subcortical) centers. Furthermore, she conceptualized lower parts of the brain as developing and maturing before higher-level structures. Systems interact, and both cortical and subcortical structures contribute to sensory integration.

4: Adaptive Interactions are Critical to Sensory Integration

An adaptive interaction represents give and take with the environment in which an individual meets a challenge or learns something new and the environment changes. An assumption of sensory integration theory is that adaptive interactions promote sensory integration and the ability to contribute to an adaptive interaction also reflects sensory integration.

5: People Have an Inner Drive to Develop Sensory Integration Through Participation in Sensorimotor Activities (pg 12)

Ayers (1972s, 1975, 1979, 1989) linked inner drive and motivation to self-direction and self-actualization. She indicated that children with sensory integrative dysfunction often showed little motivation (or inner drive) to be active participants, try new experiences, or meet new challenges. Intervention leads to a stronger inner drive to seek out, self-actualizing or growth-promoting activities, that, in turn, enhance sensory integration (Ayers, 1972a)

The Mind-Brain-Body Process

Ayers clearly cared about children's self-esteem and self-actualization (i.e., mental phenomena), she portrayed sensory integration very much as a brain-body theory.

Development of Sensory Integration Theory: History and Research Factor-Analytic and Related Studies

To analyze patterns of dysfunction among children with learning disabilities, Ayers used three statistical procedures: principal components, factor analysis, and cluster analyses.

Between 1965 and 1977, Ayers complete six factor-analytic studies of the Southern California Sensory Integration Tests (SCSIT) (Ayers, 1972 c) and related measures, using data from children with and without perceptual-motor or learning disabilities (Ayers 1965, 1966a, 1966b, 1969, 1972b, 1977)

The patterns of dysfunction that appeared most consistently included:

- Dyspraxia (i.e. poor motor planning) Associated with poor tactile discrimination
- Poor bilateral integration associated with postural deficits, thought to reflect poor processing of vestibular and proprioceptive sensation (pg 18) and commonly called vestibular bilateral integration disorder
- Tactile defensiveness (i.e., n aversive reaction to being touched) was sometimes associated with increased activity level and distractibility
- Poor form and space perception (visual and tactile)
- Auditory-language dysfunction
- Poor eye-hand coordination

The patterns that emerged from the factor and cluster analyses of the SIPT data included:

- Somatosensory processing deficits
- Poor BIS
- Impaired somatopraxis
- Poor praxis on verbal command
- Visuopraxis factor, more appropriately considered poor form and space perception and visual construction deficits, visual motor coordination deficits
- Generalized sensory integrative dysfunction.

In synthesizing the results of the many factor and cluster analyses, we find four broad groupings. One group, **dyspraxia**, includes patterns we have described earlier under practice functions. A second group reflects expression of **sensory modulation dysfunction** (i.e., sensory defensiveness, gravitational insecurity, aversive response to movement underresponsiveness). Sensory modulation dysfunction did not emerge from the SIPT data, and the SIPT data do not provide a basis for evaluating them. A third group includes various measures of **visual perception and visual-motor coordination**. Finally, some of the factor analytic studies included **auditory-language** measures.

Neuro-physiology considerations

The mechanisms (pg 36) of function that underlie processing in most or all sensory systems are:

- Reception
- Transduction and encoding of the sensory stimulus
- Receptor fields and adaptation
- Lateral inhibition
- Convergence and divergence
- Distributed processing and control
- Serial and parallel processing"

The Central Nervous System (CNS) is one of three components of the human nervous system. The peripheral nervous system (PNS) and the autonomic nervous system (ANS) are the other two. The CNS can be grossly divided into the brain and the spinal cord. The brain consists of

- The cerebrum or hemispheres
- The diencephalon
- The cerebellum
- The brainstem

The diencephalon is composed of the thalamus, epithalamus, and hypothalamus. The brainstem is made up of the pons, medulla, and midbrain.

Within the midbrain are the inferior and superior colliculi, associated with the auditory and visual systems, respectively; and the tectum.

Although the sensory receptors are different for each system, the process of changing the input from physical to electrochemical has some similarities. All cells have an "electrical potential" established by the distribution of charged ions on the inside and outside for the cell membrane. There is a receptor potential in each cell and when the stimulus is very weak, the electrical changes are minimal and the receptor potentials are not strong enough to lead to transmission beyond this level, so the input never reaches the CNS.

If the stimulus is of sufficient intensity or applied for a long enough period of time, **receptor potentials** can be added together, and the result is the production of an action potential in the sensory neuron. One action potential, in any system, generated by any input, is the same as another. (pg 40) **Discrimination** relies on specificity (pg 41) of receptors for a type of sensory input and requires interpretation within the CNS, based on pathways and connections of the sensory neurons. Some receptors are considered rapidly adapting, responding only at the onset and offset of input. Others are slowly adapting, responding in a more continual manner to ongoing input, but eventually even these will cease to produce action potentials. **Lateral inhibition** is the mechanism used by the CNS to focus input from the receptors and thereby sharpen its interpretation. It is used to focus the input, rather than allow it to be diffused over many neurons, therefore reducing background noise. This results in the ability to discriminate and localize the input we receive.

In the process of **convergence**, many cell processes synapse at one site and when this happens, a great deal of information is condensed. **Divergence**, on the other hand, occurs when one process synapses with many different cells in the CNS. (pg 43) The same information is represented at many places, repeated over and over. Thus, the potential impact of this information can be widespread. When it works well, distributed processing allows for efficient and effective interactions with the world because the load is distributed among different centers of control. In **serial processing**, things occur in sequence, one after another, in a hierarchical manner. **Parallel processing** involves the work of more than one pathway at the same time, working simultaneously."

The Somatosensory System

The **tactile system** is the first sensory system to develop in embryo. Embryos less than 6 weeks old respond to touch with motion. Touch is extremely important after birth and contributes to the maternal infant attachment, infant security and well-being, and growth and weight gain. Touch perception and discrimination develop over time. Tactile sensations arise from receptors located in the skin that fire when we touch or are touched by something. They provide the brain with body boundaries so we can differentiate "me" from "not me". They are processed in two separate and distinct touch systems that make it possible for us to differentiate light touch from pressure touch.

The hypersensitive child who shows intolerance for touch may:

- React negatively and emotionally to light touch sensations, exhibit anxiety, hostility, or aggression. He/She may withdraw from light touch, scratching or rubbing the place that has been touched. As an infant, he/she may have rejected cuddling as a source of pleasure or calming.
- React negatively and emotionally to the possibility of light touch. He/she may appear irritable or fearful when others are close, as when lining up.
- React negatively and emotionally when approached from the rear, or when touch is out of his/her field of vision.
- Prefer receiving a hug to a kiss. He/she may crave the deep pressure of a hug, but try to rub off the irritating light touch of a kiss.
- Overreact to physically painful experiences, making a "big deal" over a minor scrape or a splinter. The child may remember and talk about such experiences for days.
- Avoid touching certain textures such as certain fabrics, blankets or stuffed animals.
- Complain about the feeling of their clothing such as shirt collars, textures, turtlenecks, tags, elastic waistbands, belts, hats and sock seams.
- They may refuse to wear socks and shoes all together. Or prefer to wear sandals on a cold day or long sleeves on a hot day.
- Dislike being touched on the face or head when being washed.
- Dislike baths complaining that it is too hot or too cold.
- Dislike having fingernails cut.
- Avoid messy play activities, such as shaving cream, sand, fingerpaint, glue or mud and hurry to wash off hands.
- Avoid walking on the grass, sand or through water barefoot.
- Dislike having hair brushed or getting their haircut.

The hyposensitive child who shows an increased tolerance for touch may:

- Hurt other children or pets not realizing the pain that others feel.
- Not realizing that he/she has dropped something.
- Show little reaction to pain from scrapes and bruises.

- Seem unaware of touch unless it is very intense.
- Seem out of touch with his/her hands as if they are unfamiliar (discrimination).
- Be unable to identify which body part is being touch without looking.
- Be fearful in the dark.
- Be unable to perform fine motor and self-help tasks such as zippering and buttoning.
- Have difficulty holding and using crayons, scissors and forks.
- Have trouble perceiving the physical properties of objects, such as texture, shape, size and temperature.

The **proprioceptive system** also forms and begins functioning prenatally. By 5 months in utero a fetal response to stretching can be noted, and the system is fully functional at birth. However, between the years of 4 and 5 the development of the differentiation between visual and proprioceptive inputs develops. During preschool years the ability to use appropriate force develops. This allows a preschooler to hold and lift an object without holding so tightly as to hinder manipulation. Proprioceptive sensations arise from firing in tiny receptors located in muscles, tendons, and ligaments that surround joints. They tell the brain where body parts are and what they are doing without having to look. They also provide the sense of our body contents or body awareness.

The hypersensitive child who shows poor awareness of their body may:

- Not know where his body parts are or how they relate to one another.
- Have trouble orienting his arms and hands, legs and feet to get dressed.
- Withdraw from movement experiences, to avoid touch sensations.
- Avoid putting weight onto their joints when standing, pushing, or jumping.
- Complain about lifting heavy things.

The hyposensitive child who shows poor awareness of their body may:

- Deliberately bump into objects, seeking jumping and crashing opportunities.
- Stamp or slap his feet when walking.
- Bang a stick or other object on a wall or fence when walking.
- Rub his hands on the tables, bite or suck on his/her fingers, or crack his/her knuckles.
- Enjoy being wrapped up in a blanket or tucked in tightly at bedtime.
- Chew constantly on objects such as on shirtsleeves, pencils or toys.
- Press hard on a writing implement.
- Handle objects forcefully, and frequently breaks things.

“Receptors in the tactile system are, by and large, mechanoreceptors. Our tactile discrimination ability (pg 44) depends, in part, on the density of receptors and the associated size of the receptor field. In areas of fine tactile discrimination, receptor density is high and the receptor field is small. Areas of high receptor density are more skilled. The tactile system also capitalizes on lateral inhibition to focus input and refine discrimination. Receptors associated with the Dorsal Column Medial Lemniscal Pathway (DCML) respond to mechanical stimuli, transmitting primarily tactile, vibratory, touch-pressure, and proprioceptive (deep pressure) information. Inputs are transduced into a set of action potentials and transmitted over the axon to the cell body, which, in this case is in the dorsal root ganglion.

Proprioception involves the perception of joint and body movements as well as position of the body, or body segments, in space. It also senses the direction and velocity of movement, as well as determining the effort needed to grasp and lift objects. Proprioception informs us about the spatial orientation of the body or body parts, the rate and timing of movements, the amount of force our muscles are exerting, and how much and how fast a muscle is being stretched. Not all proprioception (pg 47) is derived from peripheral proprioceptive receptors. Internal correlates of motor signals that are sent to the muscles after an action is planned (i.e. corollary discharge) are also an important source of proprioception. Proprioceptive feedback arises primarily from muscle spindles, mechanoreceptors of the skin, and centrally generated motor commands. Joint receptors fire primarily at the extremes of range (flexion or extension) and are probably most important for preventing hyperextension and hyperflexion. Active stretch occurs when higher-level motor commands descend to produce alpha-gamma coactivation and when a muscle contracts against resistance. Therefore, evincing an adaptive behavior against resistance may be the most effective means available for generating proprioceptive feedback.

Tactile sensation (pg 48) pertains to awareness or perception of the location, or change in position, of an external stimulus applied to the skin. Also within the parietal lobe (pg 49), aspects of tactile and proprioceptive input converge and subsequent project to anterior motor planning areas of the brain. Thus, output from the DCML could be expected to have an impact on both objects manipulation and motor planning.

The decrease in sensory feedback to the motor cortex that occurs secondary to interruption of DCML is critical and interferes with the production of coordinated fine motor acts. The difficulty in perceiving the size and form of an object during the process of active manipulation results in difficulty handling the object. The DCML may also have a role in modulating arousal.

The Anterolateral System (AL) is composed of separate pathways that function primarily to mediate pain, crude touch (the detection of an object's position but not its movement across the skin), and temperature. Mediation of both neutral warmth and the "tickle" sensation are also related to transmission within these anterolateral pathways. In sensory integration theory (pg 51), the tactile system is thought to be of the utmost importance in determining behavior. The somatosensory system (pg 52) is an incredibly pervasive system from both a receptor and an interactive perspective. Given that the AL pathways project to the regions of the brain responsible for arousal (reticular system), emotional tone (limbic structures), and autonomic regulation (hypothalamus) (pg 53), we postulate that tactile defensive behaviors may be related to the connections among these systems and brain regions."

The Vestibular System

The vestibular apparatus is present and adult like in form by 10 to 12 weeks post conception. However, it takes time and the experience of more and more complex motions to master movement against gravity. Rapid development of this system occurs during preschool years, but maturation of vestibular function does not appear to be complete until age 10. Infants engage in self-stimulatory behavior that provides vestibular inputs. These behaviors may help increase motor development. Young children also actively seek out activities that provide vestibular stimulation through playground play. These activities challenge gravity and consist of swinging, climbing, running, bike riding, standing on one foot, hopping, skipping, galloping and walking and walking on a balance beam. Vestibular sensations arise from the firing of the vestibular apparatus in each inner ear. They tell the brain we are moving, surrounded by something that is moving, or on something that is moving, or a combination of all three. They also tell the brain where down is because the vestibular apparatus registers the pull of gravity.

The hypersensitive child who shows intolerance for movement may:

- Dislike playground activities, such as swinging, spinning and sliding.
- Be cautious, slow moving, and sedentary, hesitating to take risks.
- Seem willful and uncooperative.
- Be very uncomfortable in elevators and on escalators, perhaps experiencing car or motion sickness.
- Demand continual physical support from a trusted adult.
- Get carsick easily.
- Get nauseous and/or vomit from other movement experiences.
- Lose balance easily, appearing clumsy.
- Misunderstanding of the meaning of words in relation to movement or position.

The child with gravitational insecurity may:

- Have a great fear of falling, even where no real danger exists. This fear is experienced a primal terror.
- Be fearful of heights, even slightly raised surfaces. The child may avoid walking on a curb or jumping down from the bottom step.
- Become anxious when her feet leave the ground, feeling that even the smallest movement will throw her into outer space.
- Be fearful of climbing or descending stairs, and hold tightly to the banister.
- Feel threatened when her head is inverted, upside-down or tilted, as when having her head shampooed over the sink.

- Be fearful when someone moves her, as when a teacher slides her chair closer to the table.
- For self-protection, try to manipulate her environment and other people.

The hyposensitive child with increased tolerance for movement may:

- Need to keep moving, as much as possible, in order to function. The child may have trouble sitting still or staying in a seat.
- Repeatedly and vigorously shake her head, rock back and forth, and jump up and down.
- Crave intense movement experiences, such as bouncing on furniture, using a rocking chair, turning in a swivel chair, assuming upside down positions, or placing his/her head on the floor and pivoting around it.
- Be a "thrill seeker" enjoying fast moving or spinning playground equipment, or seeking the fast and "scary" rides at an amusement park.
- Not get dizzy, even after twirling in circles or spinning rapidly for a lengthy amount of time.
- Enjoy swinging very high and/or for long periods of time.
- Like seesaws, teeter-totters, or trampolines more than other children.

"The vestibular apparatus includes the semicircular canals and the otolith organs, the utricle and the saccule. Vestibular receptors are haircells located in the otolith organs and in swellings at the base of 3 semicircular canals. The otolith organs are primarily responsible for static functions. The information processed by these receptors is used to detect position of the head and body in space and control of posture. The semicircular canals are the dynamic component of the vestibular system. These structures respond to movement of the head in space. The otoliths are saclike organs oriented in horizontal and vertical plane, of which the utricle is concerned with movement in a horizontal plane. Movement of the stereocilia creates electrical discharges within the hair cell. The utricle (pg 54) responds to linear, sustained, and low frequency stimuli. The saccule is considered by some to be involved in the detection of vertical acceleration, noting that gravity is the most "ubiquitous and the most important" of vertical inputs. Together, the utricle and saccule respond to dead tilt in any direction and to linear movement.

The semicircular canals, which are actually closed tubes, detect the changes in the direction and rate of angular acceleration or deceleration of the head. With continued movement of the head (pg 56) at a relatively constant velocity, the semicircular canal receptors return to a basal firing rate. When head movement stops or decelerates, the inertia again acts on the endolymph, and it continues to move in the canals, this time in the direction of head movement.

Afferent fibers carry information from the receptors to the vestibular ganglion and from there to the vestibular nuclei. The information sent to the CNS from the two ears is different. The most efficient stimuli for the semicircular canals are angular, transient (short-term), and fast (high-frequency) head movements of at least 2 degrees per second.

The vestibular nuclei can determine direction of movement by comparing the frequency of impulse flow between left and right canals of otolith organs. Vestibular nuclei receive input from other sensory systems notably the visual system. The vestibular system (pg 57) is the only sensory system with direct connections to the cerebellum. The interconnections between the cerebellum and vestibular nuclei are important for ongoing control of eye and head movements

The vestibular nuclei have direct connections with oculomotor nuclei for cranial nerves III (oculomotor), IV (trochlear), and (VI (abducens) via the medial longitudinal fasciculus. These connections serve to fix the eyes as head and body move, providing us with an ongoing stable visual image. This constitutes the vestibulo-ocular reflex. Nystagmus is a specialized compensatory vestibulo-ocular movement. Nystagmus is named for the direction of the fast phase, which is the same as the direction of head movement. When the head stops, movement continues causing a visible post rotary nystagmus in the eyes. This phenomenon is related to velocity storage, a mechanism associated with the vestibular nuclei in which velocity information generated by movement is collected and stored, then released slowly, generating nystagmus.

Transient or angular head movements (pg 58) that stimulate the semicircular canals result in phasic (rapid, transient) equilibrium responses. Sustained head tilt or linear head movement that stimulate the utricle result in tonic equilibrium (maintained) responses. If the goal is to facilitate tonic postural or support reactions, activities that provide utricular stimulation may be more appropriate. If the goal is to encourage the use of more phasic or transient postural reactions, then activities that provide semicircular canal stimulation may be indicated. Vestibular and proprioceptive processing are hypothesized to jointly contribute to the perception of active movement; the development of body scheme; and the development and use of postural responses, especially those involving extensor muscles. Goldberg (1985) also suggested that proprioception played a role in programming and planning of bilateral projected action sequences.

Vestibular and proprioceptive inputs, together with vision provide:
- Subjective awareness and coordination of movement of the head in space
- Postural tone and equilibrium
- Coordination of the eyes, head, and body, and stabilization of the eyes in space during head movements."

The Auditory System

The Auditory system is the response to things heard. By 28 to 35 weeks gestation the fetus moves different body parts in response to different phonemes of a mother's speech, demonstrating the ability to differentiate among speech sounds.

The hypersensitive child who shows intolerance for auditory stimuli may:

- Display oversensitivity to sounds heard during typical everyday situations.
- Become overly emotional when hearing loud noises, such as toys banging, fire alarms, others screaming and babies crying.
- Become very upset as well to the sound of a vacuum cleaner, dishwasher or hair dryer.
- Cover their ears often and run away from source of noise.
- Scream or talk loudly to compete with the noise, which is uncomfortable.
- Fail to listen or pay attention to what is said to him/her.
- Fail to follow through to act upon requests to do something or to understand directions.
- Seem to be confused as to which direction sound is coming from.

The hyposensitive child who shows increased tolerance for auditory stimuli may:

- Enjoy being in loud environments with crowds of people.
- Like to make loud noises, scream or yell.
- Talk excessively.
- Like to sing or dance to music.

"Activation of the auditory system (pg 59) is a complex process because sounds waves are received by the external ear, transmitted via the middle ear, and finally transduced into action potentials within the inner ear. Receptors for the auditory system are located in the inner ear, in a membranous structure called the cochlea. The receptors are hair cells, which are components of the organ of Corti. Sound begins as sound waves, captured by the external ear and transmitted through the external meatus to the tympanic membrane. The ossicles of the middle ear act to optimize the transfer of sound energy from air to the fluid filled inner ear, where the organ of Corti lies. Because of this relationship, diseases that impede movement of the ossicles decrease energy transfer and interfere with hearing. This is what occurs with inner ear infections (i.e., otitis media). The transduction of sound into a neurochemical signal begins with movement of the tympanic membrane, which, in turn, creates movement of the ossicles in the middle ear.

The auditory system has two primary pathways to the CNS: the *core pathway*, which maintains tonotopic organization of input and transmits sound frequency with speed and great accuracy, and the *belt pathway*, which is less well organized and transmits information relative to the timing and intensity of input. This latter pathway contributes to bilateral interaction of sounds input. The inferior colliculus (pg 60) receives essentially all auditory input, both core and belt pathway input, as well as input from the contralateral auditory cortex. As such, it is a major integrating center for the auditory system. Brodmann's areas 41 and 42 are composed of the primary auditory cortex. When information reached the primary auditory cortex, a sound is heard. This cortical region is critical for the perception of speech.

Auditory association cortex encompasses areas 39 and 40, the angular gyrus and supramarginal gyrus, respectively. These areas are associated with reading and writing. Damage to area 39 leads to an inability to recognize speech. Projections from the primary auditory cortex are also found in other cortical regions associated with speech. Areas 44 and 45 have been called Broca's area; damage there results in speech that is nonfluent. There is multi-sensory interaction between other sensory systems here, and this may play a role in arousal or attention."

Auditory Processes

Pg 5
According to Pamela Gillet, "Auditory skills include the ability to attend to various sounds, to remember them, to be aware of the direction from which the sounds originates, to repeat the sound, to recall sounds to be aware of sounds in the environment, to be aware of rhythmic patterns, to isolate a sound from a variety of different sounds, to distinguish embedded sounds from background noises, to draw meaning from verbal stimuli, to fuse the sounds coming into two ears into one unified impression, and to identify a sound in the initial, middle, or ending position of a word. The auditory channel functions to keep an individual in contact with the environment at all times. It is the main mode of learning in early childhood. Through the auditory channel, language develops and matures, and shows a meaningful relation to learning and social acceptance (pg.5)

Symptomatic behavior (pg 6) of problems in the auditory processing area may be:

- Confusion in sounds/words heard
- Difficulty in spelling words that are dictated
- Problem remembering names and places that are heard
- Requests a speaker to repeat what is said on a frequent basis
- Difficulty in following directions that have been given orally
- Easily distractible by extraneous sounds
- Leaves out words and letters when asked to repeat what is said on a frequent basis
- Misinterprets one sound or word for another
- Confuses the sequence of sounds, words, and steps in a task when presented verbally
- Trouble differentiating one sound from another
- Easily distracted by noises
- Inability to select and attend to relevant auditory stimuli
- Difficulty recognizing a word when only parts are given
- Slowness to respond to questions presented orally
- Inappropriate responses to relatively simple, age appropriate questions
- Inability to gain meaning or the complete meaning form material presented orally

Auditory Discrimination

Auditory discrimination(pg 17) is the ability to distinguish similarities and differences in sounds. Before a student can respond appropriately, he/she must be able to perceive the unique qualities of a stimuli and differentiate one stimulus from another. He must be able to tell in which part of the words he hears a particular sound; the initial, medial, or final position. Inadequate auditory discrimination skills may result in defective articulation. Auditory discrimination is necessary for learning the phonemic structure of oral language. Some children (pg 18) will fail to distinguish the printed symbols *b* and *d* because their auditory equivalents are not distinguished. This confusion of letters can occur on an auditory as well as visual basis. Some children are often insensitive to rhymes and cannot pick our words that rhyme or supply words to rhyme with a given word. This ability is fundamental to the construction of "word families" in reading. Auditory discrimination is important in the sound blending areas as well (pg 19).

Auditory Memory

Auditory memory (pg 35) involves the ability to retain and recall material presented through the auditory channel. This material does not necessarily involve repetition of pattern or sequence. The degree of auditory memory of a child is generally evaluation by output: oral and written expression as well as the demonstrated ability to follow oral directions. The child with an auditory memory problem may not remember names of people or objects in the class or home. He often (pg 36) does not know rote sequences, i.e., his alphabet, counting sequence, multiplication tables, his address, or phone number. He is unable to remember several directions, or cannot supply a word to a well-known poem, greeting, story, or rhyme. Sometimes there is no difficulty remembering single words but is limited by the amount of information that can be remembered at any one time. A child with difficulty in this area may be severely handicapped in a variety of ways —in storing information, in reading, in following directions, in initiating words and sentences, and in developing language. Disorders in auditory memory also cause problems in developing a grammatical language structure and appropriate sentence patterns. In fact, all aspects of language are dependent on auditory memory.
Auditory memory problems (pg 37) can lead to faulty comprehension since the child may expend time on trying to remember words or sounds. Auditory sequencing problems may be reflected in an inability to learn the days of the week, months of the year, etc. In a series of directions, the first or last is often remembered, but not all those given. Rapid, oral math drills are very confusing and frustrating for a child with an auditory memory problem. (pg 37)

Auditory Perception

Auditory perception (pg 51) is defined as the ability to receive and understand sounds and words. Auditory perception has a key role in the development of efficient reading skills, processing incoming verbal information, conceptual development, basic communication, social relationships, and in the ability to respond in an appropriate and safe manner to the environment. Auditory perception is basic to the verbal communication skills that are integral to the development of all interpersonal relationships. Various aspects of language learning can be affected depending on the severity of the auditory perception problems. The child has a difficulty in attaching meaning to words, understanding directions that are given, deriving full benefit from group discussions, acquiring abstract meanings, understanding words showing relationships, or fully comprehending questions asked. Receptive vocabulary is poor. He frequently asks for repetition when oral instructions are given. He may be able to repeat what he hears, but understands little of what he said. The meaning of words (pg 52) that expresses a concept or an emotion are often difficult for this child. Problems can occur with quantitative terms, directional words, and prepositions.

Auditory-Vocal Association

Auditory-vocal association (pg 63) involves the ability to draw relationships from what is heard, and then to respond verbally in a meaningful way to these spoken words. The child with an auditory-vocal association disability has difficulty in completing simple sentences or responding to riddles. He also has difficulty in remembering words for use in spontaneous speech. He often does not respond accurately to a verbal question. When he does respond, he may take a long time. He needs time to "think" about the auditory stimuli presented. A child who has this disability may also have a difficult time in classifying isolates into groups, in making generalizations, and in detecting absurdities. Weak abstract reasoning and concept formation may also be in evidence. A defect in auditory-vocal association is also based on the child' inability to draw relationships from what is heard, to manipulate the symbols internally, and then, to respond verbally. He may have difficulty holding two or more concepts in mind and considering them in relation to each other (pg. 63).

Auditory Synthesis

Auditory synthesis (pg 73), auditory closure, or sounds blending, involves the ability to combine smoothly all the sounds of syllables of words to make them a whole, or the ability to analyze a word into its separate sounds. This skill, as well as auditory sequencing, is closely related to the reading and spelling process. The child may be quite familiar with the individual sound elements, but he cannot blend them to make a smooth pronunciation of the word. Auditory synthesis (pg 74) depends on such factors as" the frequency and recency with which the child has heard the expression; the number of choices possible; the position in the expression of the parts omitted; and the number and length of the parts omitted.

Auditory-vocal Automaticity

Auditory-vocal automaticity (pg 83) refers to the ability to predict future linguistic events from past experience. It implies correct and automatic grammatic and syntactic responses to our language system. A child with a deficit in this area has problems in responding to questions in a correct grammatic form. He has trouble with verb tenses, suffixes, and plural endings. He may also use small words incorrectly. This child presents relative slowness in language processing skills. His word order in sentences is frequently jumbled. Environment can have an important influence here. "What language models are available to him in the context of the home and family?"

Auditory Figure-Ground

The auditory world (pg 89) is made up of many sounds having many pitches, intensities, and meanings. The significance of these sounds is often determined by the individual as the sounds are structured to meet individual needs at particular times. An auditory process, figure-ground, relegates certain sounds into the background while selecting others as the focus of attention. An auditory figure-ground problem consists of difficulty perceiving relevant auditory stimuli in the presence of background stimuli or when there is a significant change in the intensity of the stimuli. For school success, it is not only important to screen out he distracting auditory stimuli, but the student must also learn to change the focus of attention at various times during the instructional day. An auditory/figure ground problem may be associated with inadequate discrimination due to the inability to adequately differentiate the essential from non-essential. An auditory figure-ground problem has a direct relationship to listening. Listening requires the concentration of attention and anticipatory behavior about the forthcoming auditory activity. Good listening can only take place when the auditory stimuli are properly organized and structured (pg 89). Students (pg 90) with auditory figure-ground problems cannot select the important speech sounds from the mixture of auditory stimuli and cannot structure the sounds selected so that they become ordered into units that are meaningful and distinctly different from all the other sounds.

Reading Skills: For a child with a problem in the auditory processes

Reading (pg 95) is a visual symbol superimposed on previously acquired auditory language. Before a child learns to read, language learning depends almost exclusively on the auditory channel. Therefore, the language base upon which reading skills are build are dependent on the child's ability to use auditory processes. The three aspects of the auditory processes that are most significant for reading are discrimination of particular phonemes within words, auditory discrimination of words, and auditory synthesis. These abilities are especially important to the development of word attack skills.
Auditory processing problems may affect reading in the following ways:

- Inability to hear the similarities in the initial of final sounds of words
- Cannot perceive the similarities in words, e.g., "fat" and "pat"
- Unable to hear the double consonant sounds in consonant blends
- Lack if discrimination of short vowel sounds: "ten, tin, ton"
- Cannot break words into syllables
- Cannot break words into individual sounds
- Inability to combine parts of words to form a whole
- Cannot (pg 96) remember the sounds for the printed symbols or the names for the printed word
- Inability to detect rhyming elements of words
- Difficulty in distinguishing similarities and differences in sounds
- Lack of retention of sounds or syllables long enough to make matches or blends
- Inability to relate the visual components of words to their auditory counterparts
- Does not relate a part of a word to the whole word
- Inability to synthesize or analyze unfamiliar words"

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The Visual System

The visual system is the response to things seen. Vision is the sense we use for understanding the relationships between people and objects. It puts the environment in perspective for us and precedes auditory development by building concepts and perceptual abilities.

The hypersensitive child who shows intolerance for visual stimuli may:

- Be oversensitive to light.
- Be easily visually distracted.
- Tend to avert eye contact.
- Want to wear sunglasses or a hat often.
- Cover his/her eyes often.
- Startle easily.

The hyposensitive child who shows increased tolerance for visual stimuli may:

- Seek toys which contain moving objects or flashing lights.

"The visual system (pg 61) functions primarily as an edge, contrast, and movement detector. Visual processing is complex, with at least three parallel pathways carrying information that must be integrated. The *photoreceptors*, the rods and cones, transduce light energy into electrical energy that can be transmitted to the CNS. Cones are responsible for day vision and rods for night vision.

Cones mediate color vision and provide higher acuity than do rods, which are highly light sensitive and able to amplify light signals to enable vision in dim light. In the center of the retina is an area called the fovea. In this region, light more readily reaches the receptor cells, and acuity is enhanced. There are no rods in the fovea, only a dense concentration of cones.

The retina has 10 layers. The inhibition from horizontal cells (pg 62) is an example of lateral inhibition and serves to sharpen the edges of receptive fields, allowing for great accuracy in the information that travels to the CNS. The bottom line (pg 63) with this highly complex circuitry is that a great deal of information about contrast, color, form, and movement in the visual environment is processed before information reaches the CNS."

Eyesight vs. Vision
Eyesight and vision are not synonymous. Eyesight is the sharpness of the image seen by the eye. Vision is the ability to focus on and comprehend that which is seen. Research has shown that while most children do not have eyesight problems, many have visual dysfunction. If a child has motor delays, vestibular difficulties or health problems, vision is often compromised. Vision is made up of several categories.

Ocular Pursuits
Ocular Pursuits is important for the eyes to be able to track an object or moving target.

Saccades
The ability to switch fixation from one target to another. This skills permits easy shifting of the eyes along the line of print in a book, a rapid and accurate return to the next line, and quick and accurate shifts between desk and chalkboard, or from one distance to another. By the time child starts reading his eyes are capable to read at least 11 character letters at a time before his eyes start shifting. Inadequate eye movement control may cause a child to lose his place while reading, have difficulty copying from the blackboard, and skip or omit words when reading.

Convergence and Divergence (eye teaming/focus)
In order for a child to have comfortable vision, the two eyes must work together in a very precise and coordinated fashion. When the two eyes do not work as a team, it may result in double vision, frequent loss of place while reading, headaches or eyestrain and an inability to sustain attention to a visual task for any prolonged period of time. Focusing allows rapid and accurate shifts of the eyes with instantaneous clarity from one distance to another, such as from the desk to chalkboard.

Visual-motor skills
This is affected by eye-hand coordination activities such as handling writing utensils; creating art projects; putting together puzzles; building with blocks; eating neatly; tying shoes; writing neatly and evenly; drawing geometric symbols; copying for a nearby or distant source; remaining with boundaries when writing or coloring; performing threading activities (will usually bring the needle to the thread)' performing mazes, dot-to-dot, and tracing activities; and catching or hitting a ball.

Visual Perception
Visual perceptual skills relate to the ability to understand and interpret symbols, shapes, numbers, and letters. For such skills as reading readiness, puzzle completion, and figure ground perception. In other words, it is the capacity to interpret or give meaning to what is seen. This includes recognition, insight, and interpretation. Visual perception is made up of several categories.

Visual Discrimination
This is the ability to differentiate between objects and forms. It gives us the ability to notice subtle differences and to identify if something does or does not belong. For example, this skill is important for identifying a pair of the same colored socks in a drawer filled with socks or for identifying and exchanging money. A deficit in this area may contribute to problems in dressing, correcting errors in school work, distinguishing similarities and differences in the formation of letters or objects, discriminating between size of letter and objects, and matching two dimension to three dimension such as alphabet letters. Visual discrimination is a reading readiness skill that is taught frequently in preschool and kindergarten.

Visual memory
This reflects the child's ability to store visual details of what has been seen in the short-term memory. If details aren't stored, there will also be difficulty accurately recalling, and in some instances reproducing, all of the characteristics of a given item. Functionally, a visual-memory deficit may make reproducing figures (letters, numbers, shapes or symbols) from memory difficult, causing the child to mix lower and uppercase letters. Deficits also influence copying from a text or chalkboard, replicating information on worksheets and tests, comprehending reading, dialing a phone number, remembering sight words, transferring learned words from one medium to another, remembering what was read, reproducing figures from memory. The child would tend to copy only one letter or number at a time from the board, and would benefit from a visual model of the text to be reproduced (e.g., model placed on desk or on sheet above on the page that child has to copy from, alphabet strip on desk, mini word-wall on desk, etc.). Subsequent storage of visual information in the long-term memory is important for performance areas including community mobility – identifying familiar surroundings such as a neighborhood or school campus and successfully navigating one's way through them.

Visual-spatial relations
This refers to a child's ability to orient his body in space and to perceive the position of objects in relation to himself/herself or other objects. Therefore, a child will have difficulty in determining reversals in letters or numbers, confusion in sequencing letters in a word (e.g., was/saw), writing from left to right (trouble with left/right in general), using consistent spacing and sizing of letters, aligning numbers, writing on the line, writing within the margins, adopting to space on a worksheet or on a form, scissor skills, dressing ability, skill in recognizing concepts of up and down, on top of, around, etc., copying a design, reproducing shapes in relation to one another, miscalling words when reading, and ability to make judgments in moving his/her body around a room (child may bump into objects/people or knock over items). Spatial relations also may reflect sensory integration issues. If a child has difficult with this area, they may have vestibular and body in space issues.

Visual form constancy
This reflects a child's ability to recognize forms, letters, or words regardless of their orientation (i.e., if a form were upside down, sideways, inverted, etc.). A deficit in this area would make reading difficult as the child might not recognize familiar letters when presented in different styles of print (fonts, size, or color); result in being slower to master the alphabet and numbers; lead to difficulty recognizing errors; cause confusion between "p, q and g", "a and o", "b and d"; cause difficulty transitioning from printed letters to cursive letters; assuming the size of objects regardless of their distance; looking at things from an angle; understanding volumetric concepts such as mass, amount and quantity; and recognizing things that should be familiar when environmental conditions change. An issue with visual form constancy also reflects attention and focus, which makes it difficult to complete seatwork.

Visual sequential memory
This reflects a child's ability to recall a series or sequence of forms. Functionally, this skill would influence a child's ability to sequence letters or numbers in words or math problems, remember the alphabet in sequence, copy from one place to another (e.g., from

board, from book, from one side of the paper to the other), spell, perform math, retrieve words with reversals or when out of order, and remember order of events after reading (which affects reading comprehension). The child would also tend to forget assignments and forget steps that are shown in an activity.

Visual figure-ground
This refers to the ability to locate and identify shapes and objects embedded in a busy visual environment, or the ability to attend to one activity without being distracted by other surrounding stimuli. A child with a deficit in this area may have difficulty attending to a word on a printed page due to his/her inability to block out other words around it, difficulty filtering out visual distractions such as colorful bulletin boards or movement in the room in order to attend to the task at hand, difficulty sorting and organizing personal belongings (may appear disorganized or careless in work), over attend to details and miss "big picture", or overlooks details and misses important information (e.g., word recognition, locating one object within a group, finding place on the page or skips pages and sections, noticing punctuation), difficulty copying from the board and may omit segments of words, difficulty recognizing misformed letters and uneven spacing, difficulty with hidden picture activities, may lack visual search strategies, have difficulty locating a friend on the playground or finding a specific item in a cluttered desk. An issue with visual form constancy also reflects attention and focus, which makes it difficult to complete seatwork.

Visual closure
This reflects a child's ability to look at an incomplete shape, object or amount, and fill in the missing details in order to identify what it would be if it were complete. This skill requires abstract problem solving. Functionally, visual closure impacts a student's ability to write, to use worksheets or test forms that are poorly photocopied, copy something if he/she cannot see the complete presentation of what is to be copied, complete partially drawn pictures or stencils, spell, complete assignments, complete dot-to-dot worksheets or puzzles, identify mistakes in written material, perform mathematics (including geometry), and solve puzzles. The child tends to leave out parts of words or entire words, and leaves out parts of worksheets.

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Praxis is more than just motor planning

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"Central to occupational therapy practice is the individual's engagement in meaningful occupations and ability to participate in those occupations in the context of daily life and in society at large. Occupational therapists using a sensory integration frame of reference identify dyspraxia, or a deficit in the process of praxis, as the underlying mechanism for the motor performance problem (Reeves & Cermak, 2002).

As early as 1958, Ayers laid the foundation for understanding praxis in relationship to motor performance. She described motor performance as requiring an idea and the organization of a plan of action for executing the motor act. Paillard (1982) more broadly identified praxis as "the operations that intervene between the mental representation (pg CE 2) Praxis describes a *process* of action performance and it is composed of four components: (a) **ideation**, (b) **planning**, (c) **execution**, and (d) **sequencing**. The defining characteristic of praxis is the ability to produce an adaptive response to environmental demands.

The **first level** involves the sensory and motor foundation components that occur at the subcortical and cerebellar levels of neural functioning. The **second level** is the components of the process of praxis its self, which involves integrating cognitive and subcortical functions. Lastly, the cognitive ability of planning, organization, and problem solving represent **end-product components** that allow occupational performance.

The foundations of praxis rest in the outcomes of sub cortical sensory processing functions of modulation and discrimination of inputs, and in the cerebellar functions of sequencing and rhythmiticity.

Sensory modulation skills involve the ability to assess sensory inputs for relevance and to respond appropriately. A functional state of arousal allows the individual to ace the skills and abilities available to him or her for occupational performance and is a necessary prerequisite for making adaptive responses to the environment.

Sensory discrimination skills involve the ability to identify and integrate the salient qualities of sensory inputs for skill. Praxis skills have consistently been associated with somatosensory inputs of tactile and proprioception. To a lesser degree, visual and vestibular sensory inputs have been identified as important contributors to overall praxis ability. The ability to discriminate and integrate these sensory inputs results in the development of body scheme and body awareness, postural abilities, and visual spatial skills necessary for motor performance.

The ability to sequence at multiple levels is also central to the praxis process. Sequencing of vestibular/proprioceptive inputs in the cerebellum is a primary basis of internal rhythm, timing, and simple muscle contractions. Rythmiticity affects arousal level as well. The production of corollary discharge for developing feed forward processes is dependent on sequencing at this most basic level.

Praxis is a largely cortical process that is highly dependent on subcortical processes such as sensory discrimination, body scheme/body awareness, and the ability to produce feed forward responses. Praxis involves four major components: (a) ***Ideation****,* or the ability to conceptualize and identify a motor goal and some idea of how to achieve the goal; (b) ***Motor planning***, or the ability to plan and organize a series of intentional motor actions in response to environmental demands; (c) ***Motor coordination/execution***, or the ability to perform motor responses with precision; and (d) ***Feedback*****,** or the ability to recognize and respond to the motor act and its consequences.
Within occupational therapy practice, praxis represents performance skills and forms the foundation for developing performance patterns and occupations. (Pg CE-3)

With sensory integration theory, dysfunction in praxis is manifested in one of three major groups of characteristics.

- ***General dyspraxia***, which is characterized by dysfunction in discrimination of somatosensory and vestibular inputs with performance problems in motor planning and sequencing.
- ***Somatodyspraxia***, which is characterized primarily by decreased tactile discrimination and motor planning problems, is conceptualized as a specific problem in the motor planning component of praxis and is manifested in difficulties performing actions such as imitating gestures as well as performing various motor tasks.
- ***Bilateral integration and sequencing*** dysfunction, which is characterized by primary deficits in vestibular, proprioceptive, and visual integration deficits. Deficits in this area are reflected in problem with timing, motor coordination, execution, and completing *projected action sequences*.

In addition to these three well-established problems in praxis (Reeves & Cermak, 2002), deficits in *ideation*, or the ability to generate ideas for motor actions, have only recently begun to be examined (May-Benson, 2001).

Ideation (pg CE-4) represents the first step in praxis and involves identifying a movement goal, a gestalt motor image of possible means of achieving the desire action, and the concurrent physiological preparatory motor sets. Cognitive knowledge of object functions, actions, and appropriate objects for actions is viewed as necessary to form intentions and plans to achieve desired action goals.

Motor planning refers to the ability to order, plan and sequence a series of intentional motor actions.

The concepts of **motor coordination** and **motor execution** in praxis, or in motor performance literature in general are not well defined. Whereas motor planning skills appear dependent on body scheme/body awareness sand awareness of feedback of motor actions, motor coordination skills appear more dependent on feed forward mechanisms (corollary discharge) and cerebellar sequencing and timing.

Projected action sequences involve actions that require timing and movement through space. There are four developmental levels of projected actions involving variations in the temporal and spatial aspects of the person and the environment that are largely reflected in actions and tasks such as ball skills, running, and sports-related skills (Gentile, 1987; Koomar & Bundy, 2002) These are:

- Static client/static target
- Static client/moving target
- Moving target/static client
- Moving target/moving client

Feedback processes in praxis typically rely on both internal and external inputs that reflect cortical and subcortical processes.

1. Production feedback from the body movements itself (i.e., recognition of *what* the body did)
2. Production feedback from the production of an adaptive response to the environment (i.e., recognition of *how* the action was performed)
3. Outcome feedback based on observable effects of the action on the environment (i.e., recognition of *what was done* to the environment) (Reeves & Cermak, 2002)

Repetition of motor sequences and production of corollary discharge are also important for internalizing this feedback.

Praxis provides the mechanism for organization of motor performance but also is a necessary foundation for the function of problem solving and the organization and performance of larger sequences. Problems with motor performance have consistently been associated with difficulties in play skills (Bundy, 2002), activities of daily living (May-Benson, Ingolia, & Koomar, 2001), and social participation (Chen & Cohn, 2003) as well as having long-term impact on a wide variety of other areas of function (Cantell & Kooistra, 2002).

Central to intervention for praxis (pg C5) is the ability to elicit *adaptive responses* to environmental demands. Ayers (c.1980) identified five levels of adaptive responses as being primary features for praxis versus simple motor performance. The original levels of adaptive response have been expanded on by Koomar and Bundy (2002) and include:

1. Responding to passive stimuli
2. Holding on and staying put
3. Alternating contracting and relaxing muscle groups

4. Initiation
5. Familiar activities
6. Unfamiliar activities
7. Complex activities

In addition to these levels, the ability to formulate *complex plans into the future* may be viewed as an end product related to practice function.

Bottom-up strategies emphasize remediating foundational processes, and occupational therapists using a sensory integrative approach have been viewed as using primarily a bottom-up approach. ***Top-down strategies*** involve bringing conscious cognitive attention to the learning and performance of a task and do not address remediating foundational problems. They also involve using specific types of mediational techniques by the treating therapists."

Our sincere thank you to May-Benson, T.A. (October 2004). Praxis is more than just motor planning: Clinical reasoning for understanding intervention for praxis *OT Practice*: CE1-CE7.

Oral Motor System

The primary oral motor mechanism is the suck/swallow/breath (SSB) synchrony. This involves the rhythmical, coordinated pattern of sucking, swallowing, and breathing. An intact synchrony of SSB is critical to many elements of sensorimotor and cognitive development including speech and language development, postural control, feeding/eating behavior, eye/hand coordination, and sense of well being.
Even a subtle disruption in any element of the SSB may have a far-reaching impact on development and function. The SSB synchrony often functions as an organizer for neuromotor behavior and can be used effectively in treatment to bring about more integrated behavior. Bite, crunch, chew, lick, suck, seal, vacuum, swallow, blowing and vocalization are ways to activate the SSB synergy. Suck, blow, bite, crunch, chew and lick are major components of oral motor activity, which can be incorporated into meals, snacks, and play activities. Use of these along with taste, temperature, texture, size and form will help improve SSB synergy and therefore influence sensorimotor and cognitive functioning.

Oral Motor Dysfunction:
Oral Defensiveness – is an avoidance of certain textures of food and activities using the mouth in general (such as tooth brushing). Each child differs in the types or textures or activities they find offensive.
Some common behaviors a child with Oral Defensiveness may exhibit:
- Resist brushing his teeth or going to the dentist.
- Be a picky eater and preferring only certain textures, dislike foods with unpredictable lumps, disliking sticky foods such as cake icing.
- Refuse to eat hold or cold foods.

Activities to Develop Oral Motor Integration

- Licking – Have the child lick stickers and place them in a book. They may also lick lollipops and Popsicles, or place sour drops or other foods on the child's lips and have them lick it off. Licking helps facilitate concentration. It also works on developing the tongue musculature.
- Sucking Activities – These work on developing the tongue, check, jaw, and lip musculature. They also facilitate concentration and help the child to transition between activities.
    1. Straw – Use straws for drinking liquids. There are a variety of straws that can be used which make it easier or more difficult for the child, such as crazy straws, coffee stirrers, or exer-tubing. Try attaching two straws together to make it more of a challenge for the child. Juice boxes are also great for the child. Have the child drink a variety of liquids through the straw, such as milk shakes or puddings for more of a challenge. Tart juices will encourage a strong suck.
    2. Washcloth Soaked in Juice – A washcloth may be soaked in a sour juice for the child to suck on.
    3. Suck Foods Off Finger – The child can also suck foods off of his finger, such as peanut butter, frosting, and applesauce.
    4. Sucking In – Children may suck in on a piece of Thera-band or bubble gum over the lips, sucking on a lollipop, nipple, pacifier, or finger and creating a loud pop as it is pulled out.
    5. Suckers – lollipops, caramel pops, sour hard candies, and other forms of suckers are also great for sucking. The child may also suck on Popsicles.
    6. Games – As a fun activity, have the child move small bingo chips or other small objects from one place to another while playing a game.
- Blowing Activities – These help develop the tongue, cheek, jaw and lip musculature; respiratory control (oral, pharyngeal, upper chest, and diaphragm); it opens up the rib cage; and it works on concentration and helps the child to transition between activities.
    1. Blowing Bubbles – The child may blow bubbles into a bathtub, dishpan, or sink with a few drops of liquid detergent in it.
    2. Blow Darts
    3. With a straw or tubing: blowing cotton balls, crinkled up tissue paper, ping-pong balls, or other small and lightweight object to a correct answer in a game, across a trail or road map, or in water.
    4. Blow through a straw into a thick substance, such as homemade silly putty, for increased resistance. (See appendix for recipe to make homemade silly putty)
    5. Blow Toys – Have the child play with toys such as whistles, party blowers, pinwheels, musical instruments, kazoos, etc.
    6. Blow up balloons.
- Bite/Crunch/Chew – These activities are used for developing jaw and neck stability as well as upper thoracic stability. It also decreases oral defensiveness, hyperactive gage, and tongue thrust, jaw protrusion and retraction, and teeth

grinding. In addition, it facilitates concentration. Crunchy foods are very alerting. Chewy foods are organizing.

1. Chewy Foods – Such as bagels, dried fruit; pepperoni chunks, beef jerky, licorice shoestrings, gummy worms, tootsie rolls, fruit rollups, and chewing gum.
2. Chewing Activities – Have child chew on objects such as a pacifier or teething ring, dog toys, tubing, etc.
3. Crunchy Foods – Such as Zots, Pop Rocks, and War Head candies; frozen grapes, bananas or blueberries; frozen peas or corn; corn nuts, pretzels, or tortilla chips; and carrot sticks.

- Tactile Experiences – Have the child experience a variety of textures, temperatures, and sensations. The following are types of foods that are alerting: cold foods (frozen fruit, ice, frozen teething rings, frozen toothbrush soaked in cranberry juice), Pop Rocks candy, sour drops (also encourages puckering), and hot tastes such as fireballs. Crunchy and chewy foods encourage concentration. NUK knobby toothbrush, water pick, electric toothbrush, etc., are also great tactile experiences.

Fine Motor Skill Development

Principle 1
Children develop motor skills in a cephalo-caudal direction. Head control, trunk and shoulder control precedes walking or fine motor skill.

Principle 2
Control of movements is gained in a proximal-to-distal direction. Children learn to control the joints closest to the body (proximal) before being able to control the joints farthest away from the body (distal). They learn to reach and control shoulder movement before achieving elbow, wrist, and finger control.

Principle 3
Stability must be achieved before mobility or controlled distal movements are possible. Infants gain control of their shoulders through the process of lying on their tummy and moving their weight from side to side and forward and backward. Control is further refined as the infant crawls and creeps on all fours. We know that stability is being developed because we can see the infant reaching in more and more controlled ways with arms held farther away from the midline. As the shoulders gain stability, the weight bearing and weight shifting activities in the elbows and wrists help to refine the more distal control of the hands.

Principle 4
First movements are whole body movements. Later, the child learns to disassociate, or separate the movements of one particular part of the body from another. In grasping, first the whole hand is used. Gradually children learn to move the thumb separately from the other fingers and to use fingers separately for the refined demands of precise grasping.

Principle 5
Children must pay attention to survival issues first. If they are unbalanced and feel as if they may fall off the chair, they will put their attention to their seating rather than to the fine motor task being taught. If the child is hungry, sick or uncomfortable, these sensations will require all of their attention.

Prerequisites to Writing Skill Success

Developmental Readiness
One of the earliest stages that children go through when learning to play and interact with their environment is the sensory explorative stage, in which the body itself is the child's toy. They learn how to move their body parts, to isolate reach and grasp, and to coordinate those skills with vision, such as banging objects together. Then their interest turns towards how toys work. Children develop specific cause and effect relationships such as pushing objects, pulling them apart and rolling them over. They then enter a constructive stage of play by building, stacking and putting objects together. When prewriting activities (crayons) are presented earlier than this stage the child can become frustrated.

Balance
To begin pre-writing tasks, the child must be sitting or even standing independently. Their arms must be free to interact with the crayon and not busy holding up their trunk. As pre-writing skills move from random marks on the paper to the more complicated copying of shapes and letters, balance becomes an even more significant issue. The more complicated the fine motor task expected of the child, the more balance is necessary as a basis of movement and attention will then be free to focus on the task of writing.

Shoulder Stability
The ability to stabilize and control the movement of the shoulder is important for direct reaching and to provide support for the forearm, wrist, and finger actions required in holding a pencil and using it to make complex shapes. The child must be able to control the shoulders so that the arms can perform separate actions without losing precision.

Forearm Control
The child must be able to comfortably move the forearms from a palm-down position to the thumb-up position. Not only must the child have the range of motion necessary to achieve these movements, but also the movements must be done smoothly and with control.

Wrist Stability
The child must be able to hold the wrist in a controlled position and to gradually move them into and out of that stable position. The wrists provide the proximal support needed for the distal or finger control used in writing. Without the easy stability provided by the wrist, the fingers have limited control.

Grasp
The ability to grasp the hand around the writing tool is necessary for the precision writing skills to develop. The little finger side of the hand provides the stable base from which the more active thumb side of the hands moves. The grasp needs to be firm enough to hold the pencil without being so clenched that the freedom of motion is affected.

Bilateral Hand use
This pertains to the ability the child has to use both hands together, with one hand stabilizing the paper while the other hand leads in the action of writing. When pre-writing instruction begins, interchangeable hand usage is acceptable for those children who have not yet achieved established hand dominance. As children become older, they should begin to show a hand preference. They will then consistently hold the paper with one hand and the writing utensil with the other hand.

Coordination of Arm, Hand, and Eye Movements
Coordinating the eyes with the finely graded actions of the shoulders, elbows, forearms, wrists, and fingers is required. The child develops eye-hand coordination skills from a very early age and visual motor skill in terms of pencil and paper skills is the refined form of this development. It is through visual motor skill that the child learns to color, trace, copy, draw and write.

Sensory Experiences
Through various sensory and motor experiences, children learn to handle a variety of materials. They refine the movement of their hands and fingers by manipulating puzzles and toys. They learn to pull toys, play with large and small objects, use both hands together, use a spoon at meals, and feel a variety of objects of different sizes, shapes, and textures. They play in water, sand, and powder, and they feel pebbles and feathers. They learn how to throw accurately. These indirect preparations for writing are achieved by the development and refinement of the senses of touch and sight and are experiences needed in preparation for holding and using a pencil.

Research Articles

Burden of Proof: Occupational therapists are researching the science behind sensory integration.

By Jill Glomstad

"Lucy Jane Miller, PhD, OTR, director of the Sensory Processing Treatment And Research (STAR) Center at Children's Hospital in Denver and executive director of the Littleton, CO-based Kid Foundation. Miller finally started a full-time program to study sensory processing when she took a faculty position at the University of Colorado Health

Sciences Center, where she is now an associate professor in rehabilitation medicine and pediatrics.

‘Children with Sensory Processing Disorder (SPD) have different sympathetic and parasympathetic nervous systems than children who are developing normally.” ---Lucy Jane Miller, PhD, OTR. Miller conducts her research in the STAR Center’s “space lab,” a sensory gym designed to look like the inside of a spaceship. Miller uses two outcome measures to evaluate the children who undergo testing in this psychophysiology lab: electrodermal activity, which measures the sweat response of the sympathetic nervous system: and a parent report measure, the Short Sensory Profile.

Miller, who works with a neuroscientist, a post-doctoral fellow and a research assistant, recently completed a study of 40 children with autism using this sensory challenge protocol. After analyzing the data, “we expect to find that there are two different patterns, hyper-responsiveness, and they have two different behavior patterns,” Miller said.

In addition to conducting her own research, Miller received a grant to train other labs to collect the same data. The University of Southern California, in conjunction with Pediatric Therapy Network in Los Angeles; Boston University in conjunction with Occupational Therapy Associates-Watertown; and Thomas Jefferson University in Philadelphia are receiving funding to establish labs just like Miller’s. Additionally, the Medical College of Georgia has purchased the equipment and will be sending faculty to Miller’s lab to receive a week of training.

Brain Activity and SPD

At Colorado State University, Patti Davies, PhD, OTR, is conducting research on children with SPD using electroencephalograph (EEG) measurements.

While positron emission tomography (PET) and functional MRI show where in the brain activity is occurring, EEG shows exactly when it is occurring. This allows researchers to measure in milliseconds when the processing occurs and how that differs between the study group and the control group.

Davies’ research uses a sensory gating paradigm, specifically for the auditory system. Davies chose the auditory system because, while children with SPD my have differences in multiple sensory system, the auditory paradigm has already been established in children with other disabilities and in adults.

“We think that the brain automatically suppresses the response to repetitive or irrelevant information,” a process called gating, explained Davies. “Especially for children who seem to be over responsive to stimuli, this was a possible are to look at to see if their brains were not making that automatic suppression to repeated stimuli.”

So far Davies and her colleagues have completed one study with 22 typical children and 13 SPD. Overall, the typical children as a group exhibited gating, while the children with SPD did not gate.

In addition to the auditory sensory gating protocol that Davies is currently using, EEG has several other established paradigms that look not only at the suppression of stimuli but also at the detection of stimuli and discrimination between stimuli. "The nice thing about EEG is that we can look at these different kinds of processing as well as the timing of processing," Davis said."

For more information
Lucy Miller's KID Foundation; www.kidfoundation.org
Lucy Miller's SPD Network: www.spdnetwork.org
Patti Davies website: http://brainwaves.colostate.edu/
For additional information on other research on sensor processing disorders.
http://www.spdnetwork.org/reseach/index.html

Glomstad, J. (18 October 2004). Burden of proof: Occupational therapists are researching the science behind sensory integration. *Advance for Occupational Therapy Practitioners*

Studying SPD in a Primate Model

By: Jill Glomstad

"Mary Schneider, PhD, OTR/L, professor of occupational therapy at the University of Wisconsin—Madison, is studying primates using magnetic resonance imaging (MRI), position emission tomography (PET), tests of prepulse inhibition (test which enable the quantification of sensory gating) and behavioral observation to attempt to identify the etiology and physiology of SPD.

Dopamine is a neurotransmitter, which plays a role in a number of integrative brain and body functions, including motor control, executive function, problem solving, attention as well as the experience of pleasurable and aversive sensations and sensory gating. If the release of dopamine is not being properly modulated in the brain, it could have an affect on any or all of these functions.

"It appears that altered sensory processing is accompanied by an abnormality in this important neurotransmitter system," Schneider added. "It is clear that there will be many other neurotransmitter systems that need to be examined, but this is a first step in looking at neurobiological correlates in behavioral variability in SPD."

Glomstad, J. (18 October 2004). Studying SPD in a Primate Model, *Advance for Occupational Therapy Practitioners*