Sensory Integration

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What is Sensory Integration?

Sensory integration is the ability to take in, organize, and process information from the senses for use. A person exhibits adequate sensory integration when he or she demonstrates successful adaptive (or goal-directed) responses to the environment (Ayres 1979). To achieve an adapted or successful response indicates that the central nervous system has been able to successfully organize incoming sensory information from the environment for use (Ayres 2005). Sensory integration is not a passive process. The person must be actively involved in the activity for integration to occur (Spitzer 1999). He or she uses the sensory information that is received, in an automatic way, without thinking about it (Ayres 1972). It is therefore also not a cognitive process. With sensory integration, a person responds immediately through processes wired to specifically deal with the type and amount of sensory input received (Ayres 1979). This input, which is largely unconscious, allows a person to get things done.

It has long been believed that an enriched sensory environment influences the brain, and that sensory deprivation, or an inability to process the input appropriately, may negatively impact the organization of the central nervous system and brain (Diamond 1988; Rakic, Bourgeois & Goldman-Rakic 1994). According to sensory integration theory, when an adaptive (goal directed) response occurs – a change occurs at the level of the synapses of the central nervous system (Jenkins, et.al 1990). The complexity of the sensory input can influence neurological changes, and result in more dendrites being formed. This formation of dendrites occurs because the nervous system has a quality known as neuroplasticity (Jacobs, Schneider 2001). This enables the nervous system to be changed or modified. Neuroscience research has demonstrated that when animals and humans are allowed to explore and interact with environments that are meaningful and interesting to them, there are significant increases in the formation of synaptic connections between the neurons that send messages within the brain (Volkmar, Greenough 1972; West, Greenough, 1979; Floeter, Greenough 1979). There is also an increase in their efficiency. The extent of plasticity in the nervous system has been linked with the extent of its use (Kandel, Schwartz, Jessell 1995; Kempermann, Gage 1999). Changes due to plasticity however can also occur in a relatively short period of time. Novelty in sensory input, as opposed to just receiving the same input, causes changes to occur in the brain (Kempermann, Kuhn, Gage 1997) Interaction between sensory systems is such that input to one system can influence the functioning of another.

The Three Components of Sensory Integration Theory

The first component of sensory integration theory pertains to the development of sensory integration and describes sensory integration that develops in a typical manner.
In typical sensory integration development, movement and learning depend on the ability to take in sensory information from the environment, process it in the central nervous

system, and use the environmental information to plan and organize a behavior (Bundy, Murray 2002).

Another assumption of normal sensory integration development is that sensory integration occurs in a developmental sequence (Ayres 2005) with some senses developing before others. The development of these senses has been substantiated through research of the child in utero and shortly after birth. While sensitive periods exist during which time development and changes are easier to see, changes that begin in sensitive or critical periods tend to persist.

The senses that develop early and have a major impact on an individual's development are the tactile, vestibular, and proprioceptive senses. These three senses are interconnected with one another and are connected to several areas of the central nervous system and brain. Therefore, the activation of some regions of the central nervous system can influence the function and plasticity of others.

Sensory Integration Dysfunction

Sensory integrative dysfunction is a disorder in which sensory input is not integrated or modulated in the brain in an organized manner (Kranowitz 1998). This can result in various problems with development. When a person has deficits in processing and integrating sensory input, problems can occur in learning, behaving and moving (Bundy, Murray 2002). The ability to participate in social, school, and home activities can be effected. Some individuals can have difficulty registering sensory information. This particular problem can result in delays in responding to sensory input, or in noticing it (Miller, Lane 2000). Others may engage in intense sensory seeking behaviors just to register the input, or they might self-stimulate in non-productive ways to get the sensory input they need.

Some individuals may be able to register the sensory input, but not modulate the input appropriately (Kranowitz 1998). They may be hypo or under-responsive to the sensation. If they are hypo-responsive, they may go to extremes to obtain the sensory input they need. On the other end of the sensory processing spectrum, a person may be hyper-responsive (or over-responsive) to sensory input. This suggests that there is a higher than average sensitivity of the sensory receptors. As a result, he or she may be defensive to sensory input (Dunn 1997, 1999).

Sensory defensiveness results in an over-reaction of our body's protective responses and can result in a fight or flight response (Baranek, Foster, Berkson 1997). The child who has a high activity level may be hyper-responsive to sensory input, and be dominated by their sympathetic nervous system, (Lane, Miller, Hanft 2000) which prepares them for "danger". This can result in frequent flight or fight reactions which may be interpreted by some as simply being uncooperative behavior.

Sensory Integration Intervention

The third component of sensory integration theory pertains to intervention. In sensory integration intervention, opportunities for enhanced sensory input, or appropriate sensory input, in conjunction with meaningful activity are used to improve the ability of the central nervous system to process and integrate sensory input for function (Bundy, Murray 2002). When individuals with sensory integrative dysfunction are given the opportunity to receive appropriate sensory input within the context of meaningful activity, the ability of the central nervous system to process and integrate sensory input may be improved. As a result, learning, movement and behavior can be enhanced. If the person is provided with the sensory input that he or she demonstrates a need for through their observable behaviors, their needs are addressed by providing their central nervous system with the input it requires to produce an appropriate response.

Review of the Primary Senses that Contribute to Sensory Integration

The Tactile Sense

The tactile sense is the human body's largest sensory system. Research has suggested that there is a growth gene that responds to tactile input (Schanberg, Field 1988). The tactile sense is necessary for motor skills, learning and emotional development. By 11-weeks gestation there are tactile receptors on the face, the upper and lower extremities. By 11.5 weeks gestation, the infant's chest has tactile receptors. By 13.5- 14 weeks: the entire body has receptors, except for the back and top of the head. If there is deprivation of touch, it appears to cause a decrease in the production of growth hormones and an increase in stress responses (Schanberg, Kuhn, Field, et al 1990). Tactile receptors are located on the surface of the skin, and just below the surface of the skin. The tactile sense serves several functions however in general there are two very different ways it is used.

The Discriminative Tactile System

The discriminative tactile system helps to discriminate things or objects that are touched or that touch us. There are several discriminative tactile receptors located on the skin and beneath the surface of the skin (Kranowitz 1998). One of the discriminative tactile receptors is Merkel's disc. Merkel's discs are found in the deep layers of the epidermis in hairless skin. They respond to slow movements across the skin, and generate a sustained response to touch. Ruffini's endings, another discriminative receptor, also help to discriminate tactile input. These receptors lie deep in the skin and also generate a sustained response to tactile input. Meissner's corpuscles are highly discriminative tactile receptors and are located on the bumps of the skin. They have small receptor fields and are activated very quickly. They initially are very sensitive, but will adapt and stop firing if the stimulus that is received is the same and continuous (Bear, Connors, Paradiso 2001).

The Protective Tactile System

The protective tactile system is used to protect and warn a person about something that is harmful or dangerous (Kranowitz 1998). There are several different tactile receptors that carry this type of information. Free nerve endings which are located on the skin and beneath the surface of the skin carry information about pain and temperature. Hair end organs and hair follicles on the surface of the skin and beneath the skin are activated when hair is displaced. They are stimulated by light touch and the information from them is transmitted very quickly through the nervous system (Bear, Connors, Paradiso 2001). There are discriminative tactile receptors that carry information about pain and temperature, light touch, deep touch or pressure, slow touch, and even vibration.

Processing Tactile Input

When tactile input is received on the skin, either from touching something or someone touching the person, the information travels up two different tracts of nerves in the spinal cord. One of the tracts carries protective information and the other tract carries discriminatory information. The tactile information received passes through lower areas of the brain including the brainstem (Kranowitz 1998), the thalamus - a major relay center (Bear, Connors, Paradiso 2001), and the limbic system, which is a major center for processing emotions. Finally the information gets to the highest level of the brain for tactile discrimination to an area called the somatosensory cortex. This is where the information received through the sense of touch is interpreted. Some body parts have a larger representation in the somatosensory cortex of the brain than others (Bear, Connors, Paradiso 2001). The areas of the body that have more skill are represented by larger areas. The somatosensory cortex also has nerves that project into an area of the brain that is right next to it – which is the motor cortex (Bear, Connors, Paradiso 2001). This is one of the reasons why tactile input has a direct effect on the development of motor skills (Ayres 1972).

The tactile sense is also important for our physical and emotional well-being (Wilbarger, Royeen 1987). Tactile information runs directly through the limbic system of the central nervous system which responsible for our emotions. Therefore, it has an impact on our emotional responses.

The skin is also an information gatherer. Skin receptors send information to the brain about where we have been touched, how much pressure was applied, whether the skin was hurt, and the identity of the object touching the skin. The tactile sense is also essential for learning about the environment. It also helps a person to know his or her body and its boundaries (Ayres, 1972).

Another very important function of the tactile system is to filter out some of the tactile information that is always being received. If this did not occur, tactile information could be distracting and the person would always be aware of it (Larson 1982).

Tactile Modulation and Integration Problems that Lead to Dysfunction

Individuals who have difficulty processing tactile input, can be hypo-responsive to the input, and seek it out on their own terms (Dunn 1999, Hanft, Miller, Lane 2000). These individuals will often attempt to obtain tactile input to develop their discriminative sense. At times, their tactile seeking behaviors may appear inappropriate. On the other end of the processing spectrum, a person can be hyper-responsive to tactile input (Kimball

1999). When this occurs, the person is described as being tactually defensive. This causes the person to avoid tactile input, or to respond negatively to it. With this disorder, feelings of discomfort, physical withdrawal, or the fight or flight response can occur (Kranowitz 1998). A person who is tactually defensive or hyper-responsive to tactile input is responding to the input initially received through the receptors in the skin, but the information is then transmitted through the protective tract of axons in the spinal cord. The input then travels up through the thalamus and reticular activating system which alerts the person to the tactile information. In addition, the input also runs through the limbic system which causes a quick emotional response. The brain then interprets this as pain.

The Vestibular Sense

The vestibular sense is a totally unconscious sense if it is functioning normally. It develops prenatally and tells us about changes in position and about movement. Receptors for this sense originate in the inner ear which contains fluid and hair cells. These inner ear receptors include the semicircular canals and the utricle and saccule. The utricle and saccule contain hair cells encased in fluid. On top of the hair cells, in the fluid are small crystals or stones. When a person moves his or her head, the stones move, which makes the hair cells move. The hair cells then send input to the vestibular nerve telling it that the head has moved (Bear, Connors, Paradiso 2001).

In the semi-circular canals (which are closed tubes), there are no “stones” but there are hair cells which are contained in a thick gel like fluid. When the head is turned, the gel becomes displaced. It then pushes on the hair cells which then send information to the vestibular nerve indicating that the head has been turned (Bear, Connors, Paradiso 2001).

In general, with movement, there are shifts in the fluid in the inner ear. These shifts then tell a person about where he or she is moving in space and how fast he or she is moving. It also tells the individual whether he or she is right side up, sideways, or upside down (Kranowitz 1998).

The vestibular sense is also our equilibrium and balance center. It has direct connections to the cerebellum which helps us to maintain our posture and balance (Bear, Connors, Paradiso 2001). It also helps to develop a sense of security about movement. Moving more, causes more messages to be sent. As a result, if the nervous system processes the input in a normal manner, it can become accustomed to the movement.

The vestibular sense also has a direct effect on muscle tone, especially the muscles that hold us up against gravity (Bundy 2002). This is because it has direct connections to an area of the brain called the reticular system – which keeps a person alert and ready for action.

The vestibular sense also has a direct effect on eye contact because it has direct connections to the cranial nerves (III, IV, and VI) that innervate the muscles around the eyes. This sense also contributes to the development of a person’s perception of space. In addition it serves to keep us in a calm state if the input is slow (Kranowitz 1998) and an alert state if the input is fast.

Vestibular Modulation/integration problems that lead to dysfunction

A person can be hypo-responsive to vestibular input and not get enough. He or she may therefore give it to him/herself in a self-stimulatory manner (Kranowitz 1998). This is done in order to get the input that he or she needs. If a person is hypo-responsive to vestibular input, the person may also have low muscle tone (Kranowitz 1998). He or she can have poor equilibrium and balance reactions because of the difficulty with muscle tone that cause problems with automatically keeping the body in an upright position if the center of gravity is disturbed (Bundy 2002). The child may have poor eye contact and hence poor visual motor skills. In addition, the child can have problems with their perception of space and where their body is moving in space (Kranowitz 1998). On the other end of the processing spectrum, if the child is hyper-responsive to vestibular input: he or she could be afraid of movement (Lane 2002). This is referred to as being "gravitationally insecure".

The Proprioceptive Sense

The proprioceptive sense is a discriminative sense (Ayres 1972). It unconsciously tells the person what position his or her body parts are in, and where they are. It also provides information about how the body is moving (Kalaska 1988; Matthews 1988; Kandel, Schwartz, Jessel 2000; Kiernan 1988). It is essential for an internal sense of body awareness (Kranowitz 1998). Although proprioceptive input is always being processed, the typical person doesn't think about it unless he or she is learning a new movement. Since an individual doesn't have to think about how to move, the ability to move can be more spontaneous and much less complicated.

The sense of proprioception is generated from both active and passive changes in the length and tension of muscles, joints, ligaments and even the deformation of skin (Lane, 2002). While proprioceptive input is typically unconscious, if it is conscious, it gives the person a physical sense of him or her self. An example of this is when a person maintains a position for a long period of time, he or she will often reposition themselves to regain proprioceptive input and hence an awareness of where his or her body parts are positioned.

Proprioception however is primarily unconscious because the brain takes this information in automatically. Because of this, a person can focus on what he or she wants to do, without having to consciously think about how to make the body do it.

In sensory integration, active movement is more important than passive movement. Active movement results in the formation of "neuronal models" which helps the person remember how to move in a certain way (Brooks 1986). Formation of these neuronal models also unconsciously helps us to remember how much pressure or effort it takes to use or lift an object.

Reception and Interpretation of Proprioceptive Input

Processing of proprioceptive input begins with the receptors in the muscles and joints, and then proceeds to occur at various levels of the central nervous system. Muscle spindle receptors are proprioceptors that are important for sensing changes in the length of muscles (Lane 2002) and are essential for gross motor movements. The muscle spindles are encased in a capsule that is surrounded by sensory nerves. When a muscle is stretched, the sensory axons respond to the stretch and send information that the muscle's length has changed thereby telling the person that there is a change in its position. Golgi tendon organs are another type of proprioceptor. They are located at the junction of the muscle and tendon. When a muscle is stretched, they get compressed and send information about the force in a muscle. Pacinian Corpuscles which are in the deepest layers of the skin respond to pressure. They are numerous in the palms of the hand, soles of the feet, and in connective tissue. Although they respond quickly to input, they adapt if the pressure is maintained. Other receptors called Ruffini's corpuscles lie deep in the tendons, muscles and tissues of the folds of the skin. They monitor the rate and direction of movement. Meissner's Corpuscles and Merkel's Discs which are located on the bumps of the skin, sense curvatures on surfaces and also sense vibration (Bears, Connors, Paradiso 2001)

Information from the proprioceptive receptors is sent up through tracts of the spinal cord; the cerebellum; the thalamus (relay center); and the somatosensory cortex which interprets the input. All of these structures have a role in processing proprioception.

The somatosensory cortex of the brain interprets the proprioceptive information then connects with the motor cortex which in turn tells the muscles what to do in response to the sensory input that is received (Lephart, Riemann, Fu 2000). Without proprioception, we would have to watch what each body part was doing, to know what it was doing. This would be very cumbersome and would severely affect the spontaneity of our movements and our ability to do things automatically.

The proprioceptive sense also works with the vestibular sense to produce adequate muscle tone (Gepper Coleman, Mailloux, Smith Roley 2004). It is important to know that if a person has abnormal muscle tone, he or she will most likely have abnormal proprioceptive feedback. The proprioceptive sense also forms the basis for body awareness and how the body is moving (Matthews 1998). In addition, because of the feedback it provides, it tells the person how much physical effort to put into accomplishing a task

The proprioceptive sense also has a modulating and regulatory effect. It helps to decrease over-responsiveness to other forms of sensory input and has a regulatory effect on arousal in general. It is the body's natural "tranquilizer" in that it can be used for calming a person who has a high activity level (Ayres 1972; Blanch, Schaff 2001). This calming process occurs when information to the proprioceptive system comes down from the somatosensory cortex through the reticular system in the brain. One of the functions of the reticular system is to assist in waking us up or calming us down (Noback et al. 2005). If deep pressure is received or applied to the proprioceptors of the body, a calming response occurs. The deep pressure received through the proprioceptors encourages production of serotonin, which is one of the major modulators of the central nervous system. As a result, the proprioceptive sense serves to decrease arousal and over-responsiveness to tactile and other forms of sensory input.

Proprioceptive Modulation and Integration Problems that lead to Dysfunction

If a person is hypo-responsive to proprioceptive input, movement will often be clumsy and uncoordinated because of poor body awareness. Poor muscle co-contraction and difficulty maintaining an upright position against gravity associated with low muscle tone can also occur (Blanche, Schaaf 2001). Poor righting and equilibrium reactions can be evident due to decreased input to the muscles and joints that relay information about the position of the body. A person with poor proprioceptive awareness may difficulty moving from one position to another and may be hesitant and unsure of movements because of the poor feedback. To obtain more proprioceptive information, the individual may engage in jumping or stomping of the feet (Kranowitz 1998), or may toe walk to enhance the input received. Some children, for example with autism, may engage in unusual placement or positioning of their extremities in an effort to obtain additional proprioceptive feedback. From a fine motor perspective, it may be difficult for a child with poor proprioceptive awareness to be successful in activity of daily living tasks such as buttoning, turning on faucets or manipulating objects without looking very carefully at what he or she is doing. He or she may unintentionally break things such as pencil points or toys because of a lack of awareness regarding how much pressure is being applied (Kranowitz 1998). Some individuals with poor prioprioceptive awareness may also engage in self stimulatory behaviors such as teeth grinding/biting, or bumping into things on purpose just to obtain the input they need (Blanche, Schaaf 2001).

Summary of Normal and Abnormal Sensory Integration

Understanding how a person processes sensory information is based on careful observation and assessment of the person’s responses and behaviors. Individuals can show through their behaviors, the kinds of sensory input they need, or how they are processing sensory input. When a person with sensory integrative dysfunction is given the opportunity to receive appropriate sensory input within the context of meaningful activity, the ability of the central nervous system to process the information should be improved so that learning, movement, and behavior can be enhanced.

Sensory Integration Treatment

The ability to create effective intervention for a person who needs or would benefit from sensory integration therapy depends upon being knowledgeable regarding the function and dysfunction of the vestibular, proprioceptive, and tactile systems. Most treatment activities used in the sensory integration approach provide multiple sources of sensory information. Intervention however, should be specific to the underlying sensory system deficits that are displayed. Information about the underlying sensory system deficits is obtained via an assessment by an occupational therapist trained in evaluating sensory processing disorders. In treatment, sensory modulation problems should be addressed first. In addressing sensory modulation difficulties first, the person can be prepared to respond more appropriately to the sensory input for the activities and tasks that follow. Therapists and teachers must be vigilant observers of a child's response to the sensory input that he or she is receiving and adjust the input and activity as needed to obtain an appropriate response (Spitzer, Smith-Roley 2001). This personifies the "art" of the intervention provided and should lead to the child being able to produce a meaningful and productive response.

Principles of Sensory Integration Intervention

First and foremost, as in any intervention, an interpersonal relationship between the person receiving the intervention and the person providing it must be formed. It is also important to understand that every individual's response to sensory input and to sensory integrative treatment is unique to how he or she is processing the input. It is therefore difficult to provide a "cookbook" approach to intervention.

The purpose of sensory integration treatment is to improve the efficiency with which the nervous system interprets and uses sensory information for function Schaaf, Miller 2005; Vargas, Camilli 1999). It should promote underlying central nervous system organization for the promotion of an adaptive (goal directed) response (Ayres 1972). It also should develop the necessary components needed for the desired response. The "just right challenge" should be achieved in order for the intervention to be successful. It is therefore essential that the activities that are used are appropriate for the person's developmental level. Active participation is required (Kimball 1988). If activities are provided that meet the person's sensory needs, his or her inner drive to participate in the intervention should be evident. In this way, therapeutic gains are maximized. If this is not evident, it is the therapist's job to modify the environment or activity to tap into this inner drive. In doing so, the activity is meaningful to the person, and therefore more integrating.

Summary

An outcome of sensory integration treatment can be an increase in the frequency and duration of adaptive responses. When a person is able to integrate the sensory information that comes into his or her central nervous system, increasingly complex adaptive responses should be observed that reflect better neural organization (Ayres 1979). These responses can be reflected in better regulation, an increase in attention, and improved functional behaviors and skills. The person who is able to integrate sensory information should be able to make appropriate judgments about the environment and what actions need to be taken within it. A child should have a better sense of what they can do with objects, and be able to use them with greater skill. As a person develops control over the responses he or she makes because sensory input is being processed appropriately, a belief in the skills that are able to be accomplished often develops. This contributes to making participation in tasks more meaningful, successful and satisfying. Hence, sensory integration has occurred.