

What is Neuroplasticity and Why Do Parents and SLPs Need To Know?

by Megan Hodge

What is "neuroplasticity" and why do parents and SLPs need to know?

by Megan Hodge, Ph.D., R.SLP, CCC-SLP

Neuroplasticity refers to the brain's ability to change (organize and reorganize) its structure as a result of internal (genetic) factors, as well as external (experiential) factors that lead to new learning. Examples of these kinds of changes in brain structure are increases or decreases in: 1) connections among neurons, the main type of brain cells, 2) number and size of cells that support neurons, and 3) the blood supply to brain cells. Periods of rapid change in brain structure occur when the immature brain first begins to process sensory information (developmental plasticity) and continue throughout our life when we alter our behavior based on new information (plasticity of learning and memory). Neuroplasticity also occurs as an adaptive mechanism to compensate and adjust for lost function and/or to maximize remaining functions in the event of brain injury. This capacity of the brain to change applies across all levels of its function from neurochemistry to observable behavior (see Hoiland, 2006; Stiles et al., 2005; Vanderbilt Kennedy Centre for Research on Human Development, 2006).

We learn through experiences that are gained from our actions and that are influenced by the characteristics of our environments. For a new skill to be "learned" (both acquired and maintained), there must be persistent changes in the brain's neural circuitry that represent this new learning. More specifically, our environments and activities directly affect our learning and thereby shape our brains. Learning has been defined as the ability to acquire new knowledge or skills through instruction or experience. Memory is the process by which knowledge and skills are retained over time. For many children, speech learning progresses through an interaction of internal factors and experiences gained in social interactions, as part of their daily activities, without specific instruction. For children with suspected CAS however, this same interaction of internal and experiential factors is not sufficient to stimulate typical speech development processes. To date we do not have a unified picture of the underlying impairment in CAS. However there is consensus that CAS results from brain differences due to genetic or other factors that limit the child's neural resources for speech sensorimotor learning. These brain differences delay the onset of and impair the learning processes by which children decode speech sounds and movements that they hear and see and encode these into movements of their articulators to make the sound patterns of their language (sounds and how sounds combine into syllables, words and phrases and the rate and rhythm aspects of speech). We know that children with CAS do demonstrate neuroplasticity for speech learning but that it takes them much longer and the level of speech skill they achieve is often less than for other children. It might be expected that children with deficits in neural resources for speech learning require considerably more repetition of trial and error experiences to establish neural circuitry for skilled motor behavior than children without these deficits (see Hadders-Algra, 2000).

What we need to know more about is how to capitalize on these children's capacity for neuroplasticity, from a very young age, to increase the rate and quality of their speech learning. Lebeer and Rijke (2003) studied the life histories of 20 children with severe developmental disturbances of neurogenic origin and determined that early brain imaging and functional testing did not appear highly predictive of later outcome. Rather, these children's outcomes appeared to result from complex interactions between the child and the child's "human ecology". The authors defined "human ecology" as the way the child and

significant people in environment (e.g., parents, other caregivers, therapists, physicians) perceive problems and possible solutions and the quality and quantity of the child's activities and "mediated" (i.e., facilitated in a skilled manner by a knowledgeable person) learning experiences. Both outer (stimulating environment, with lots of opportunities to engage in "learning" activities) as well as inner factors (will and interactive processes) constitute a child's rehabilitative "ecology".

Recent studies of persons with brain injury provide behavioral evidence of experience-dependent, training-induced improvement that corresponded with changes in synaptic connectivity in relevant areas of the brain cortex (Mateer & Kerns, 2000; Ogden, 2000). Suggestions from these studies about how to best capitalize on mechanisms of brain plasticity include:

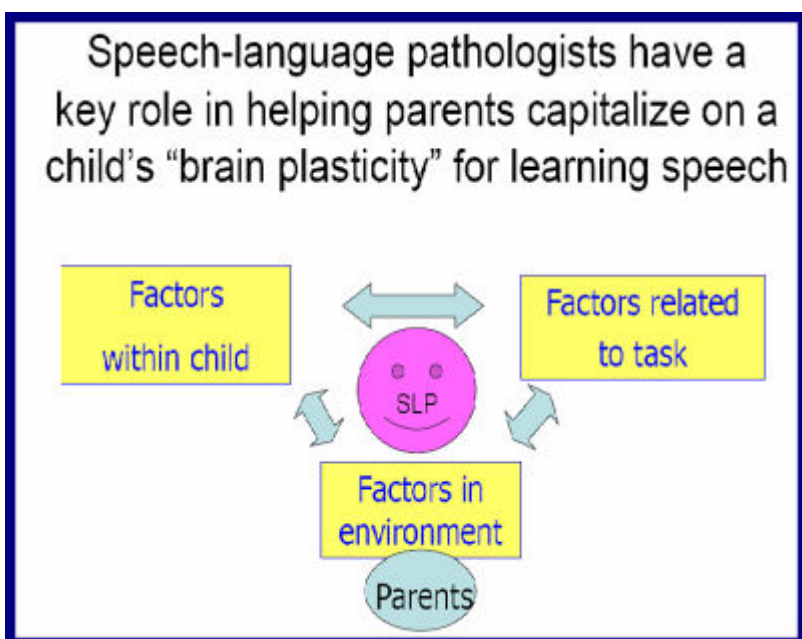
1. **The importance of active attention to sensory input from the environment .** Research results highlight the critical role that attention plays in modulating change in other cognitive and perceptual systems and suggest that the reorganization of brain circuitry is facilitated by active attention to the relevant task or stimulus. An implication of this is that from a very young age we need to find ways to obtain and increase these children's attention to the speech "input" in their environment. We need to actively help them to learn to "watch" our faces and "listen" to our voices whenever we (parents, grandparents, siblings, other caregivers, therapists) are "talking" to them.
2. **The importance of many opportunities for active learning activities that provide specific input back to areas of the brain where change is desired .** Research results suggest that to increase plasticity in a certain area of the brain, the person must engage in organized activities that use that area of the brain. An implication of this is that if you want to increase plasticity in the area of the brain involved in speech learning, the child must have multiple opportunities to be actively engaged in focused "speaking" or "speech like" activities.
3. **The importance of mediated opportunities for learning to occur in "lifelike" contexts and enriched environments .** Research suggests that the use of repetitive exercises that are removed from the context where the target behaviours occur naturally (e.g., repetitive memory exercises to facilitate memory recovery) have had disappointing results. An implication of this is that to promote the brain plasticity of young children with suspected CAS for learning speech, we need to exploit environmental influences in activities that provide "intensive" practice opportunities that are akin to "real-life" situations and that occur in contexts of their daily social routines (see McDonald & Carroll, 1992).

While this research is based on brain injury that occurred later in life, it is believed that the underlying mechanisms are similar for developmental plasticity, the plasticity that occurs in learning and memory and in recovery (Mateer & Kerns, 2000). For now, it can provide an initial basis to think about ways to exploit the potential of developmental plasticity of young children with suspected CAS. Experienced parents and clinicians know that extra, focused stimulation and many, many more opportunities for active practice are needed to help these children to develop their skills and underlying brain circuitry to change speech sound input they receive into actions of their speech muscles to produce the sound, syllable and word shapes of their language. A common report from parents is that their child with suspected CAS was a "quiet" baby who vocalized infrequently and that these vocalizations contained few consonants and vowels and combinations of these sounds. These parents are faced with the situation where they have a baby who needs a lot more "practice" to learn to make the sound patterns of the language than other children, but who in fact is "practicing" much less than other children! We also know from studies of early child-caregiver interactions that the extent to which children vocalize, communicate and explore their environment has a direct influence on quantity and quality of adults' language input (see Girolametto & colleagues, 2002; 2003). Therefore children who are more active and communicative

typically receive many more opportunities to practice and acquire language. Children who are less communicative typically receive far fewer learning opportunities to "practice" communicating when in fact, they need many more than other children do.

If we are going to exploit the power of neuroplasticity, it follows that from an early age we need to alter these babies' environments and multiply their opportunities to engage in experiences that promote speech learning. As the key component of these children's environments, parents need to provide abundant social interactions within the child's daily routines, and within each, create multiple "mediated" opportunities ("multiple doses") to obtain the child's attention and "tempt" the child to produce "speech like" vocalizations, in fun and playful learning activities. Caregivers need to invest significantly more time, thought and effort than they would typically to continually create and follow through with these kinds of activities within a day, and day after day. While the idea appears simple, it is not easy. It requires commitment, persistence and patience to incorporate these enriched learning opportunities into each day's routine but parents can be very successful in learning how to adjust and adapt their behaviour (reflecting reorganization of their underlying neural circuitry!) to accomplish this with their child.

It follows that a key role for speech-language pathologists is to guide and support parents in developing the necessary techniques, skills and confidence to foster the child's communication development and to maximize the child "speech learning" ecology through education, and active modeling and coaching. As shown in the accompanying diagram, this includes helping parents to select appropriate "speech" behaviors to focus on, as well as how to set up and carry out specific opportunities to stimulate the child to attempt these.



This is a particular challenge for young children with very limited vocalizations and few spoken words. Following from the preceding information, a very important early goal for these children is to increase the number of times that they attempt speech or "speech like" behaviors in a day, before trying to focus on increasing the accuracy of these or adding new ones. I have had the best success in these situations when: 1) I involve the parents in selecting a speech behaviour to target, 2) demonstrate a specific learning activity to provide practice opportunities for this speech behaviour, 3) discuss with them why I selected this

activity, based on the criteria summarized at the end of this article), 4) provide the materials for them to practice this activity at home, and 5) get feedback from them on how things went. Especially at the beginning, when they have the least experience, I find that parents benefit most when they clearly understand their role as active "agents" of their child's learning and are provided with materials and clear models for how to engage the child in appropriate learning activities, as well as lots of support and encouragement when trying these out. Once they experience some success and gain confidence in their abilities, the need for this level of support decreases. A sample narrative of how I have done this appears as an Appendix to this article. My experience has been that as these young children greatly increase the frequency of speech output, new sounds and words often emerge without specific instruction. Then these emerging behaviors can be reinforced with lots and lots of practice using the kinds of activities described previously so that the child actually "learns" these new words.

In summary, through well-designed speech-language therapy and home practice activities, we are trying to exploit these children's inherent brain plasticity by providing them with appropriate and frequent experiences to practice and learn speech skills that facilitate, shape, and guide development of their spoken language. Understanding how to do this better is a key research priority.

Criteria for Selecting a "Speech" Learning Activity

Will it engage the child:

- in explicit, systematic, focused, **frequent** practice opportunities
- that encourage "talking" in general and that provide context and feedback on specific target speech behaviors
- that are at an appropriate level for the child's **phonetic abilities and speech motor developmental level**
- in "enabling" (aka fun, enjoyable, motivating) learning contexts
- where the child practices "speaking" to **code meaning**, while engaging in **communicative acts** (e.g., social routines, behavior regulation, joint attention)?

NB: While at the beginning, provision of clear auditory and visual models to imitate is often essential for the child to attempt new speech behaviours, to "learn" the speech behaviour, the child also needs many opportunities to practice **retrieving** the speech target (sound, word, word combo) from memory, **planning** the sounds and **making** them.

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Appendix

Sample SLP Therapy Narrative for Parents of a Young Child with CAS and Very Limited Speech

After reviewing the checklist of the kinds of learning opportunities that should facilitate their child's speech development with the parents of a two year-old with less than 10 "words" and severe motor planning difficulties, I did the following:

1. I looked at the "words" they reported ["go" (boh), "more" (moh), "up" (uh), "look" (oh), "yep" (yuh), "no", "ball" (baw)] and identified "ball" and "O" as candidate target speech behaviors, based on the child's word and sound repertoire.
2. In preparation for the first session where they observed me with the child, I collected an assortment of 10 "soft" balls that varied in size and colour and put these in a colorful cloth bag. I also made 10 big blue letter O's out of craft foam and added interest by gluing on googly eyes and pipe cleaners for arms and legs. I put these in a colorful box with a lid. I found an upright holder for paper towel and was ready for a "ring" toss game using the "O"s. (I find it good to have at least two viable ideas because what I think will be of interest to the child, is often not.)
3. When the child and parents entered the treatment room for the session, I showed the

bag containing the balls to the child and said, "Let's go play ball". The child let me take his hand and we headed out to a short hall. I knelt down beside him and then facing him and looking in his eyes, I said, "Watch me". Then I opened the bag, took out a ball, held it by my face and waited expectantly. He did not say "ball" so I said, "Look! A ball!" while he was watching my face. Then I through it down the hall. I pulled out another ball and held it by my face and waited expectantly again. This time, he said "bah" and, making sure I had eye contact with him, I immediately responded, "Yes" it's a ball! Do you want it?" emphasizing "ball" and smiling at him. He took it from me and threw it (with great gusto). Then I opened the bag and took out another ball, showed it to him and modeled "ball", again making sure I had eye contact with him and then I threw it with great gusto. Then I looked at him and waited. He said "bah"! Looking right at him I held one up, said "ball" and gave it to him. We repeated this routine this for the rest of the balls. Then we took turns picking up the balls, and I said "ball" each time I put one in the bag and he did a few times too. In about 3 minutes he had "spoken" the target at least 12 times. After the balls were all in the bag, we returned to the treatment room, put the balls away. Then I took out the "O" ring toss materials and set the "pole" about two feet away. I showed him the first big blue "O" and then making sure I had eye contact with him I said "This is "O". "Watch!" I tossed it on the pole. I took the next "O" out of the box, held it by my face and looked at him, waiting expectantly. He didn't say anything but it was obvious that he wanted to take it and toss it. I said "O"? Do you want "O"?" After about 5 seconds (which seems like a very long time but is often worth the wait) he softly said "O"! Making sure I had eye contact with him, I said "O" in a confirming kind of way and then gave him the "O", which he threw and missed. This routine continued with me taking about 3 turns (and missing the pole at least once) and him taking about 7 turns and getting a ringer 3 times, to his great glee. To up the ante, I then tried an activity where I put two of the Os on the floor, beside each other, to see if I could get him to say it twice in a row (i.e., produce a two syllable sequence, something he had never done before). I modeled stepping on one O with one foot and said "O" and then stepping on the other O with the other foot, saying "O" a second time, about a second apart. After about 5 of my models, much to my and his parents' surprise, he tried it too!!

4. I gave the parents and child the bag of balls and the box of Os (they had their own paper towel holder for the cause) and a "log" page that had the dates for the three days before I would see them again, with three "spaces" on each day to record their experiences with three practice sessions (to last no more than 5 minutes each). The child could choose either the "ball" or "ring toss" game for each practice session.
5. When the parents returned, they had log entries for 8 "sessions" over the three days. The number of target words produced by the child in each session ranged from 4 to 15! The parents also reported that he was vocalizing more in his other daily routines. I was very impressed and let them know with lots of positive comments. Then they told me that they had introduced variants into the activities (like throwing the balls into the bathtub) that had been great fun and successful!

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