Developmental Neural Plasticity: Applying an understanding of a complex concept to a practical treatment.

Dr. Rochelle Manor and Dr. Michael Wolff

The idea of developmental neural plasticity is a complex combination of words. By individually separating the words before combining them into a meaningful string, the understanding in not too complicated.

Developmental: the process of growing, learning, or making changes.
Neural: a word indicating that the brain and/or spinal cord, in combination with each other, called the Central Nervous system (CNS) is involved.
Plasticity: indicates that something can be changed or is malleable and can respond to internal (i.e. changes in blood pressure, oxygen level) or external (i.e. physical pressure like falling on the ice and striking your head on the ground) pressures on the body or an object.

Therefore combining the words together, developmental neural plasticity in the process of the central nervous system making changes over time depending upon the types of pressures the individual might confront. A more scientific definition is: "Neural plasticity is the ability of the CNS to change and adapt in response to environmental cues, experience, behavior, injury, or disease. Neural plasticity can result from a change in function within a particular neural substrate in the CNS through alternations in synaptic strength, neuronal excitability (increasing the neurons [cells in the brains] response pattern), neurogensis (new cell development), or cell death" (Brosh & Barkai, 2004).

This "scientific definition" introduces some new ideas. Essentially, the concept indicates our brains can continue to change over time when presented with opportunities for advancement, or can worsen with negative experiences. So, the more positive stimulation, comfort, and interactive learning experiences can be, the better chance an individual has for positive developmental neural plasticity.

Yet, it is not quite that simple. There need to be some delineation between developmental and general plasticity for the Central Nervous System. When injury occurs (i.e. a stroke, head injury, concussion, low oxygen levels, birth trauma, drug/alcohol exposure) there can be direct injury to the neurons in the brain. The brain is made up of a possible 100 billion of these little microscopic neurons with maybe 100 trillion connections between them, making this pretty complex. Even a minor injury anywhere along these neurons can result in changes to any number, hundreds or thousands, of other neurons trying to communicate along the brain pathways. An analogy might be related to the Michigan potholes on our roads. We navigate the complex roads to reach our desired location(s) any given day, whether this be to drop a child off at daycare or to arrive at work. Everything can be moving along smoothly, but hitting one pothole can change your heart rate, mood, and possibly cause serious damage, even though "it was just a pothole." This is similar to an injury in the brain, sometimes even minor changes can result in significant

impairment, but sometimes major issues are not as severe. This would be similar to listening to the radio for the traffic report; if you are aware there is an accident backing things up, you have the option to choose a new path. In the meantime and without your awareness, others are working to manage the accident, so that it can hopefully be corrected by the time you need to return home. This is very similar to how the brain functions when it confronts an injury; this process is neural plasticity. With direct injury, the brain needs to find a way to develop new cells or to find a way to use a different pathway that might not have previously been utilized. This can be very challenging for the central nervous and can result in permanent changes that might never fully correct/adapt. This would be true using the previous road analogy, as well. If there was an accident on the interstate and the emergency workers decided to indefinitely leave the mangled cars in the middle of the road, commuters would have to find a new route. But, there are only so many options to choose. So if everyone is forced to use the side roads, they soon become blocked and you can not make it to your destination as fast. Translating this to the brain, injury can result in information not be processed as quickly and can result in permanent changes or "road blocks" that are too insurmountable to overcome.

Unfortunately, the adult central nervous system, to our understanding so far, only provides limited neuronal regeneration. Developmental neural plasticity is different than the changes resulting from injury. The developing central nervous system is still "making the roads," so we can process information. These roads/pathways tell us how to perform functions like learning to talk or walk, feeling comfortable with different noises, or walking on uneven surfaces. These unique differences in developmental neurons can result in many different concerns, like sensory integration problems, auditory processing differences, cerebral palsy, autism, or many other neurodevelopmental disorders. When developmental pathways become too strained, seizures can develop as well [note: seizures can also develop secondary to injury as well]. But in contrast, after injury to the developing nervous system, surviving neurons can develop alternative axonal projections to correct targets that might reduce functional deficits (Willison, Bower, & Sherrard, 2007).

This should not be intended to imply that the developing brain has an easier time and can adjust more quickly than the adult brain. This notion has been coined the Kennard principle, which has been disproven. Rather, the developing nervous system, pre- or postnatally, will be more challenged if the initial neural integration (connecting the 100-billion neurons together for the possible 100-trillion connections) is interrupted. Further, if injury occurs during the initial course of developing these connections (during pregnancy or early years of development), it is easy to recognize the challenge confronting the central nervous system. And yet, there is a multitude of research occurring to support optimism that the central nervous system can regenerate (make new neurons) or adapt/compensate. These adaptations may not always occur spontaneously, yet there are ways that development can be optimized. For example, Willson, Bower, and Sherrad (2007) have recently published an animal study demonstrating the development of reinnervation (neurons making new connections with each other after injury) in the olivocerebellar region that can help with regaining visuo-spatial abilities. Ludlow, Hoit, Kent, et. al. (2008) are demonstrating the ability to regain speech and motor control in the rehabilitation process. Other research is

connecting the effectiveness of classrooms that understand the sensory and developmental needs of children in the classroom (Willis, 2008). And most exciting for many who have children who were born premature, there is evidence that ongoing brain connectivity in premature children changes as late as age 12 (Pediatrics, 2008). But, it is anticipated that this will extend beyond this age cluster as the sensitivity of scanning tools progress. Regarding compensation, one needs look no further than www.pbs.org/kcet/wiredscience/story/97-mixed_feelings.html to watch how sensory systems can compensate for each other. Medications have been clearly linked to neuronal regeneration, with evidence stemming back to 1995 and current research. Dr. Oliver Sacks has also recently recognized the importance of music and the profound influences on the brain (Sacks, 2008). Taken all together, there is great optimism with the new research, medications, and interventions. Unfortunately, how all of these areas directly influence functional change is not yet understood. Dr. Willis (2008) clearly notes that, even though neuroscience has not yet provided a direct connection between classroom interventions and brain function or structure, this does not mean it is irrelevant. She goes on to make clear that a "one size fits all" model does not work in education, medical intervention or other outpatient work. There will be generalities that will work for most, but there also needs to be recognition of the unique needs/attributes of the individual. It must be kept in mind that all child development needs to be nurtured and positively stimulated. Children whose brains have suffered assault, injury, illness, etc. require even more direct and focal stimulation to foster adaptation and compensation. Just because a child "matures spontaneously" does not mean that the brain should be left to struggle following injury. We cannot wait for a child to fail or to be 2-years behind before providing assistance and intervention.

Knowing about neural plasticity, what can be done to apply this theory toward children who have suffered injury, assault, or illness to the CNS during the course of development?

First, families need to be wary, but also trust new treatment ideas that may help enhance the positive neuronal plasticity effects. There are certainly "snake oil" cures that purport to cure everything, but this is rarely the case and families spend exorbitant funds on these cures in hopes for improvement. To ascertain whether something might be a "snake oil" intervention or may provide real benefit, converse with professionals, take time to engage in research, and see if the idea even makes sense. For example, does it really make sense that four or five secretin shots could cure Autism? No, if this were the case, there would be an immediate national movement for this cure. However, there are interventions that are gaining research prominence and really might work. We might not fully understand why, but there is already strong anecdotal evidence and growing scientific or empirical evidence. These might include:

Sensory integration interventions: The first thing the newborn brain must do is learn to monitor, interpret, and use sensory input coming in from touch, sight, sound, taste, movement, and smell. When the brain misinterprets these sensory signals, children can become "out of synch" with their world (*The Out-Of-Sync Child* is an excellent book providing description of sensory integration difficulties). These children often misinterpret intensity of touch, pain, or placement in space.

Avoiding sensory input or seeking intense sensory input can prevent the child from interacting appropriately with their world and hinder learning. Sensory integration interventions provide the brain with appropriate sensory input that helps the brain to organize itself more effectively, interact with the world more appropriately, and build a better connection with the stimulation it needs to learn. Sensory integration strategies can be implemented through individualized physical or occupational therapy, development of a sensory diet, use of movement-based interventions (Brain Gym or similar models) and using sensory input strategically during specific activities or times of day.

Neurofeedback: Focusing on the electrical brainwave patterns in the brain, neurofeedback therapy provides the brain with the necessary "information" it needs to restabilize brainwave patterns. This process of "exercising the brain" allows for more efficient sending of signals from one neuron to the next. Improved attention, processing speed, and stabilization of emotions can often be impacted by neurofeedback. Neurofeedback therapy must be conducted in the therapist's office using specialized technology. Typically, the treatment must occur regularly (twice weekly) for a period of time (30-40 sessions) for maximal benefit. Research suggests, however, that for some symptoms, reduction in symptoms and maintenance of stable brainwave patterns can endure long after treatment ends.

Auditory Processing or Therapeutic Listening: For readers who received the last issue of the BRAINS Express, auditory processing disorders are often misunderstood and misdiagnosed. When "the brain can't hear" the information accurately, the child misses important details of language and communication. Auditory processing therapies utilize prescribed listening activities to "sound burst" part of the brain that has been missing or misinterpreting these cues. Through repeated exposure and practice, the brain learns to better interpret auditory information.

Behavioral Health: Assists the individual and family by reducing stress levels and providing emotional stability that decrease electrical and chemical activity that is unhealthy for the body and mind. With poor interpersonal and emotional health, there are clear physical and mental consequences. With intervention, these can be minimized to all for the process of CNS recovery and balance.

Massage: The nerve endings in the skin and experience of pressure against the muscles send direct signals to the brain. Various types of massage can send a range of signals to the brain to invigorate or calm.

Some form of vitamin supplements or special diets: Maximizing the health of the body is critical to maximizing the effectiveness of the brain. Well-balanced diets, certain vitamins and minerals, omega-3 fatty acids, etc are shown to improve the healing and functioning of the brain. For children with certain food allergies or sensitivities, a controlled diet may assist in minimizing the allergic reactions and help the child function better. As Dr. Steven Pastyrnak recently pointed out, everything needs to be considered in balance with the possibility for positive outcomes, cost, and

opportunities for change. Sometimes, a risk is worth taking, sometimes not. To make a good decision, talking between multiple professionals and creating a team to support the family system, parents and children will likely result in the best outcomes.

Where the Rubber Meets the Road: costs of intervention

We know that children can benefit from intervention, maximizing the potential of neuroplasticity. But how to cover the costs of those interventions is difficult within our current medical insurance and educational systems? Families need to make active decisions to live within functional means. Children enjoy video gaming systems, fancy clothes, trips, cell phones, etc. But the money saved from buying the "latest and greatest" can easily translate to many hours of direct intervention for their children. Furthermore, they can also learn from the therapist how to use these interventions in the home or other environment. Insurance cannot be expected to cover all the services a child might need, so families need to prioritize a child's therapy needs in the midst of other family budgets. Also, every aspect of the system needs to find a voice to mutually advocate and understand each other's limitations. It is impossible for insurances to cover every type of intervention, particularly if there is not scientific evidence to prove efficacy, as of yet. Similarly, the schools cannot meet all of the unique needs of children and families either. Therefore, there needs to be balance and communication. Presently, this is not occurring effectively and the families and children are paying the toll, often feeling the interventions that would be beneficial are not accessible. Without appropriate intervention, the child/family struggles. This can result in the whole system being in chaos, children fall behind or experience depression, anxiety, social isolation, drug/alcohol abuse; families fight, divorce can occur, children can be hospitalized and so on. There is not an easy solution for anyone. Parents need to prioritize, advocate, and try to find a balance for possible options. Governmental, educational, and therapeutic organizations need to help protect against possible discrimination of child and family services. And insurance carriers need to converse to develop a viable system, so that children/families can have options for treatment. Organizations like BRAINS, Helen DeVos Children's Hospital, Mary Free Bed, and a few other organizations in West Michigan are providing opportunities for insurance-covered and self-pay lines of service to help families receive multidisciplinary service in one location. The Grand Rapids community is also developing collaborative networks to create a more mutually shared voice for services. By trying to avoid competition and working together, there are good chances for collaborative care. But governmental agencies, educational systems, organizations, insurance panels, and families need to work together, which is not often occurring presently.

It is our mission to encourage the dialogue, collaboration, and efforts of all aspects of the community together. We believe that better understanding of the child's functional abilities can lead to more effective intervention planning and that, by simultaneously accessing the best of what can be offered in both educational settings and clinical domains is necessary to maximize the brain's ability to improve its functioning.

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