Brain Development and Neuroplasticity

September 30, 2013

Recent advances in neuroscience have effectively put an end to the “nature or nurture” debate. Instead, the focus of discussion has switched to mechanisms and brain-based interventions — in what ways are neural circuits changed by experience? When is the brain most receptive to education and learning? And what effects does high versus low socioeconomic status (SES) have on the development of neurocognition?

Perhaps no one is more intrigued or committed to answering these questions than 2013 APS William James Fellow Helen Neville, director of the Brain Development Lab at the University of Oregon. In her Award Address at the 25th APS Annual Convention in Washington, DC, Neville discussed how experience and genetics interact to influence neurocognitive development.

A vehement supporter of evidence-based policy, she began by stressing the importance of basic research in understanding how environmental influences can shape neural circuitry.

“Neuroplasticity is a double-edged sword,” Neville observed, referring to how experience-dependent changes in the structure and function of the brain can confer benefits but may also leave systems vulnerable.

Presenting studies of people born blind or deaf, she explained the brain’s ability to rewire circuits and alter cognition. By default, people who are born blind don’t receive visual signals to the occipital cortex, the region of the brain normally responsible for organizing information from the eye. By combining the temporal resolution of event-related potentials (ERPs) with the spatial resolution of functional magnetic resonance imaging (fMRI), Neville and her colleagues revealed that the occipital lobes in a blind individual’s brain are functionally “recycled” to organize auditory and tactile inputs. These changes help explain why blind individuals demonstrate more acute hearing to ambiguous sounds in the peripheral auditory field and more acute touch.

And Neville found analogous results in congenitally deaf individuals. For these people, visual and tactile nerves rewire to innervate the primary auditory cortex, conferring an increased ability to detect small changes in the peripheral visual field and also peripheral tactile inputs. Overall, results from these studies suggest that neuroplastic changes in response to experience can produce beneficial effects on cognition. For those who are unable to see, the brain becomes more adept at focusing attention to auditory and tactile stimuli. For those who cannot hear, on the other hand, the brain shifts resources and attention to detecting tactile and visual information.

Neville also studied attention in adults and children of high SES. These individuals are able to selectively focus attention and suppress distractions during a laboratory experiment involving competing auditory stimuli. Essentially, they can hear a particular stimulus more clearly by centering their

cognitive resources on that specific target.

But as Neville pointed out, brain plasticity doesn't always bestow advantages. Just as attention is enhanceable in deaf and blind individuals and in high SES communities, it is also vulnerable in low SES environments. This important finding was a direct result of Neville's desire to obtain veridical and representative results — only possible by gathering larger and more diverse population samples.

"We stepped beyond the university community," Neville explained. "We studied neurologically normal, psychologically normal, right-handed, monolingual people — *normal* children living below the poverty line."

The findings were as Neville predicted: These children don't exhibit the same ability to use attention to enhance auditory stimuli. Because the necessary experiences aren't present throughout early development, many of these children are not able to suppress distractions as effectively, a phenomenon that appears to have great bearing on literacy, numeracy, and intelligence later on in life.

After attempting to use this evidence to revamp early childhood education, Neville was disappointed with the reaction from policymakers. As she described, many dismissed the differences drawn along socioeconomic status as fixed, forever tethered in the genes. For Neville, this tepid response was a major motivation to gather genetic data for subsequent studies. In doing so, she and her colleagues effectively ruled out the "nature" argument — genetic differences between high and low SES groups did not account for the differences in attention abilities.

Instead, she argues that disparities in the home environment, which is typically more stressful and less stimulating, and also in education — specifically with respect to attention — account for the significant disparities in language, literacy, and intelligence between high and low SES children. But, according to Neville, these disparities are not indissoluble. Given that the brain is able to restructure itself through experience, Neville has shown — and has the data to support it — that relatively simple and inexpensive training is effective at reducing discrepancies between high and low SES children (Neville et al 2013).

In conjunction with Head Start, a federally funded program that provides education, health, nutrition, and parent involvement services to low-income children and their families, Neville and her colleagues developed their own training program — one that is focused on teaching the importance of attention skills. Designed for three- to five-year-olds and their parents, this program entails eight, 40-minute training sessions where children play games designed to hone attentional skills. Meanwhile, parents are taught about parenting, the importance of attention, and how to play these games with their children.

After comparing this training with regular Head Start and another hybrid program, the results were clear. Not only did Neville's program garner the largest improvements in children's language ability, nonverbal IQ, social skills, and problematic behavior — it also restructured their brains. The initial auditory task measured with ERPs provided further evidence that the intervention program was a success.

"They have a beautiful attention effect, which is indistinguishable in microvolts from the effect that we see in higher SES kids," Neville explained.

And the kids weren't the only ones who benefited from this training. Parents demonstrated an increased ability to have productive conversations with their children, and also showed a significant reduction in stress levels after the eight-week program.

According to Neville, the evidence for action is clear: At a nominal price — it would increase Head Start's budget by only 10 percent — she predicts that this training would improve cognitive skills, self-esteem, graduation rates, employment, and potential for economic gains in the future. But in the face of such convincing evidence, Neville is disappointed with how resources are being allocated. Preschool education is vastly underfunded when compared with secondary or college education, even though a solid early education predicts numerous beneficial outcomes throughout life.

"For the sake of the economy and the sake of the children, let's take this evidence-based approach to reducing inequality," Neville said. "Our biggest job will be to convince the public and policymakers to demand evidence and to evaluate evidence."

For their part, Neville and her colleagues have produced a film for non-scientists called *Changing Brains*, highlighting the importance of early education and offering practical, empirically verified advice for parents and educators seeking to understand the developing brain. Neville closed her address with a tip of the hat to her team of researchers and the creators of *Changing Brains* (changingbrains.org).

"They're all very proud of what they do. Young people want to feel like they're making a difference, and they are. They're changing the world one family at a time."

Reference

Neville, H. J., Stevens, C., Pakulak, E., Bell, T. A., Fanning, J., Klein, S., & Isbella, E. (2013). Family-based training program improves brain function, cognition, and behavior in lower socioeconomic status preschoolers. *Proceedings of the National Academy of Sciences of the United States of America, 110*, 12138–12143.