Neurofeedback Training Elicits Behavioral Improvements in Individuals with ASD

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Scientists have recently proposed that problems in the brain's "mirror neuron system" during early development could be responsible for many of the impairments seen in autism spectrum disorder (ASD). Mirror neurons are cells that activate both when we observe a purposeful action and when we ourselves perform the same action, so researchers believe that mirror neurons may underlie our ability to imitate, as well as cognitive processes such as theory of mind and empathy, all of which are deficient in ASD.

Several studies have found that mirror neuron activity in individuals with ASD differs from typically developing (TD) individuals. In particular, one index of this activity known as mu brainwave suppression, is absent in individuals with ASD. Mu suppression can be measured simply using electrodes placed on particular points of the scalp that are above the brain regions that contain mirror neurons. Thus, mu suppression provides a relatively low-cost and non-invasive technique to monitor mirror neuron activity.

Using a grant from Autism Speaks, Jaime A. Pineda, Ph.D., and his colleagues at the University of California San Diego tested the hypotheses that if mirror neuron activity is deficient in individuals with ASD 1) a type of intervention known as neurofeedback training (NFT) can be used to normalize mu suppression and hence, mirror neuron activity, and 2) such normalization will lead to improvements in behavior, especially in imitation. NFT is a technique that trains an individual to control his own brain frequencies with the help of visual feedback. Essentially, an individual's brainwaves are detected using scalp electrodes (electroencephalogram, EEG) and then individual frequencies presented in real time as changes in computer graphics on a video screen. The participant can see his brainwave patterns and then make adjustments, focusing or unfocusing his thoughts, and the resulting changes in brain frequencies are detected instantaneously as movement of objects or characters in a video game. In a way, the technique is a visual "thinking about thinking" which allows training of specific brain frequencies in a relatively subconscious way. NFT has been used in autistic children with some reported positive outcomes. However, the few research studies in this area did not contain all the necessary controls nor link mu rhythm suppression or mirror neuron activity to the results.

Dr. Pineda's group compared high functioning ASD children and TD children before and after they were given either NFT focused on mu brainwaves or a sham NFT (a control that mimics the general training session without focusing on mu brainwaves). The children were tested on several evaluations both before and after 10 weeks of NFT, including EEG when viewing social videos (to assess mu rhythm suppression as an index of mirror neuron activity), the Test of Variables of Attention (TOVA, to assess sustained attention), the Apraxia Imitation Scale (AIS, to assess imitation ability) and the Autism Treatment Evaluation Checklist (ATEC, a questionnaire for parents, physicians and researchers to evaluate treatments for autism, with subscale scores for speech/language communication, sociability, sensory/cognitive awareness and health/physical behavior).

Results showed that after NFT, mu rhythm suppression in children with ASD progressed towards normal. In addition, mu rhythm neurofeedback-trained children with ASD showed improvements in sustained attention and ATEC scores, correlating well with the observed normalization of mu rhythm suppression. However, although mu rhythm was positively affected and some general indices of behavior showed improvement, surprisingly no improvement in imitation could be demonstrated after NFT. One interpretation of the results is that because of early deficiencies in mirror neurons, children with ASD have had to adopt alternative brain networks for imitation behavior. If this is indeed the case, learning to engage mirror neurons by using NFT on mu rhythm would not target imitation behavior as originally hypothesized. Consistent with this idea, other recent studies using fMRI techniques have shown that high functioning children with ASD are actually able to imitate even though they show defects in the activity of their mirror neurons, again suggesting that their brains may have developed alternative brain circuitry in order to be able to carry out imitation.

The results of this pilot study have just been published in Research in Autism Spectrum Disorders. With these initial results Dr. Pineda is now examining how long after NFT behavioral improvements are sustained and, in the future, will examine whether there are anatomical changes (for example, new brain connectivity) brought about by NFT.