Neuroscientists working to test brain training claims

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The draw is huge: Play video games and get smarter. For the past decade, various groups have claimed that their cognitive training programs do everything from staving off neurodegenerative disease to enhancing education and improving daily functioning. Absent from many of these claims has been neuroscientific evidence. Cognitive neuroscientists are now rigorously testing the potential benefits of such "brain training" tools.

New work, being showcased today at the Cognitive Neuroscience Society's (CNS) annual conference in New York, on working memory tasks in children and on pairing noninvasive brain stimulation with cognitive training in adults is showing promising results. Researchers are identifying who may benefit from cognitive training and the new methods most likely to result in long-lasting, positive effects on cognition.

"We hope that by better understanding how and why cognitive abilities are altered by training, we can better harness its wider benefits," says Duncan Astle of the Medical Research Council in the UK, who is chairing the symposium on brain training. While more testing is required to apply these techniques to real-world training interventions, the studies are providing a baseline of neuroscientific evidence for developing tools that yield wider benefits.

Tasks for the developing brain

Working memory sits at the heart of many of the brain training studies. The ability to hold information in mind for brief periods of time is central to our daily lives. And, Astle says, "we know that differences in working memory during childhood are incredibly strong predictors of educational progress." As a cognitive neuroscientist long interested in how the brain develops working memory capabilities in childhood, Astle has set out with colleagues to test if it is possible to train a child's memory.

In work recently published in the *Journal of Neuroscience* and also new, yet-unpublished work that Astle will present at the CNS conference, his team investigated tasks in 8- to 11-year-olds to boost working memory. They found that the training tasks yielded improvements in working memory capacity that were also reflected in measurements taken from magnetoencephalography (MEG, which uses magnetic fields to image the brain), showing increased strength of neural connectivity when the brain was at rest.

The children performed 20 training sessions, each around 30 minutes and with 8 games, from their home computers. The games required children to remember spatial or verbal information for brief periods of time and to use this information in an ongoing task. For example, one game involved remembering the locations and order of asteroids that flashed up in sequence as they swirled across the screen. At the end of each trial, children had to click on the asteroids in order. In the experimental group, the games became more difficult as the children got better; "the children were always being worked at the limits of their current capabilities," Astle says. In the control group, the difficulty of the games remained the same.

The MEG data showed significant changes to connectivity between frontoparietal networks and the lateral occipital complex and inferior temporal cortex in those in the experimental group. "We think that the training enhances an attentional process that children are able to use strategically on similarly structured but untrained tasks," Astle says. "But it is important to note that we have not demonstrated the wider benefits of this training."

The 8 to 11 age range is "very good because the children are able to handle pretty complex tasks, and yet are still far from adult levels of performance - i.e. there is still plenty of development left to happen," Astle says. "We think that this is a really important age range in which to understand working memory and training effects. However, there is a great need to understand these processes better across the lifespan, so we are always exploring the literature more widely to see how our findings fit in with other groups that study other age ranges."

Stimulation for working memory

Among the tools scientists are using for trying to boost cognition is tDCS (transcranial direct-current stimulation) - a non-invasive brain stimulation technique that involves passing a very weak direct current through the brain. "While it is not immediately clear how the current affects neural activity, the prevailing opinion is that it makes neurons either more susceptible to firing, or less susceptible, depending on which electrode is placed where," says John Jonides of the University of Michigan.

In new work Jonides in presenting at the CNS conference, he and colleagues have found that tDCS has a robust effect on working memory, with enhancements lasting over a course of months. "Previous research has been equivocal about whether tDCS enhances training, and there have been no long-term investigations of how long that training effect lasts," Jonides says.

In the new study, 62 participants randomly received tDCS stimulation to either the right or left prefrontal cortex or received sham stimulation while performing a visuospatial working memory task. After 7 training sessions, those who received the tDCS stimulation had increased working memory capabilities, even several months after completing their training. They also found that those who receive stimulation on the right prefrontal cortex had selective ability to transfer the working memory to non-trained tasks.

"The long-lasting effect of the training was completely unexpected," Jonides says. "We investigated this largely on a lark, not expecting to find much, but the fact that the training effect lasts as long as months is both surprising and very provocative because it opens up the use of tDCS for long-term learning enhancement."

Jonides says that his study is just one data point in understanding these techniques, noting that it is still the early days of studying brain stimulation. Replication and generalization to other training and transfer tasks are necessary to continue testing the long-term impacts and best targets for stimulation.

"We need high-level, rigorous validation that focuses on understanding the mechanism of action, transfer of benefits, and sustainability of the effects in diverse populations," says Adam Gazzaley of the University of California, San Francisco, who will be presenting work to develop and validate "closed-loop" video games as cognitive enhancement tools. The closed loop approach enables scientists to intervene, record the impact of the intervention, and then reuse that data to iterate and optimize the process cyclically.

His team is using tDCS and tACS (with alternative current) to boost plasticity in the underlying brain cortex. "The goal is to accelerate the learning process that occurs during game play, especially for those individuals with damage," Gazzaley says.

"There is great promise and reason for excitement in this approach, but we are still in our infancy and have much to learn both on the development and validation side," Gazzaley says.

"Behind strong claims we need strong scientific evidence," Astle says. "Sadly the hype surrounding the field has lost touch with its scientific foundations. As a result, it is tempting to ditch the whole endeavor. On the contrary, I think that this needs to spur scientists to invest in high-quality training studies."

More information: Astle, Jonides, and Gazzaley are presenting in the symposium, "Taking stock of cognitive training: theory, neural mechanisms and application," at the CNS annual meeting in New York City. More than 1,500 scientists are attending the meeting in New York from April 2-5, 2016.

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