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Commentary

Comment on "Can transcranial electrical stimulation improve learning difficulties in atypical brain development? A future possibility for cognitive training" by Krause and Cohen Kadosh

The aphorism "A mind is a terrible thing to waste" appears to be the impetus behind a proposal (Krause and Cohen Kadosh, 2013) to extend the techniques of transcranial electrical stimulation (TES) to children. This suite of techniques have attracted a great deal of interest amongst those interested in using them to modify adult brain function, but as the authors point out, pediatric use of TES has been essentially non-existent. One reason may be that researchers in the field of developmental cognitive neuroscience are unaware of the possibilities that TES affords; the paper by Krause and Cohen Kadosh is sure to remedy any such deficiency.

The technique admits a remarkable combination of the universal and the bespoke: generality derives from the ability to apply electrical current to the brain via surface electrodes which can be positioned nearly anywhere, while specificity derives from the constraint that underlying neural activity must to be temporally and spatially coincident with the electrical stimulation to be affected. The result is that only those cognitive events that transpire within the penumbra of electrical stimulation are affected. The hypothesis that drives confidence in the field is that TES does not drive plasticity, but only alters the statistical likelihood that it will materialize.

These features of TES have brought forth an explosion of studies that have demonstrated the ability of the technique to alter cognitive function with both therapeutic and enhancement goals in mind. The results have been more impressive than many might have anticipated. The minimal side effects seen with TES to date, coupled with its surprising effectiveness support Krause and Cohen Kadosh's call for considering using TES in pediatric populations. The hope is that by combining well-crafted cognitive tasks with TES one will be able to improve cognitive functions that have a developmental trajectory that has either been delayed or derailed. Laudable as this goal may be, the associated issues are hardly trivial.

The obvious worry is safety. A minor concern is that the smaller size of the pediatric brain makes it more vulnerable to physical damage from electrical current. Issues such as these will likely be dealt with by careful experimental design, for example by lowering current density. The more vexing issue is the challenge posed in targeting a brain whose anatomy and physiology is continually changing, for nothing characterizes development more than fluidity. If this were not enough of a problem, multiple sensitive periods weave through the entirety of the developmental process (Knudsen, 2004). These critical junctures represent moments in which experience has outsized effects upon the brain. Clearly, using electrical fields to modify the developing brain should be approached carefully.

These caveats notwithstanding, *the* under appreciated peril of TES is that it may alter cognitive function in unintended ways (Fitz and Reiner, 2014). Indeed, recent experiments demonstrate that at least one version of this concern is discernable (Iuculano and Cohen Kadosh, 2013). Proponents of TES often justifiably extol that its effects primarily affect those cognitive functions that are being actively engaged. Unfortunately, it is difficult if not impossible to prevent other cognitive functions from transpiring at the same time, and the effects of TES upon them, particularly when the experimenter is not attending to them, are largely unknown. This is already a challenge in the adult brain in which anatomy is relatively stable; the fluidity of the developing brain adds gravity to the situation; the possibility of inadvertently affecting sensitive periods suggests that the enterprise might be a bit harrowing; the likelihood that the brains of children with learning disabilities exhibit altered developmental profiles transforms a challenge into a serious concern.

These issues are more a call for prudence than despair. Krause and Cohen Kadosh suggest a step-wise strategy in which the first wave of experiments are carried out on small groups of normal children; only when the effects are shown

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to be well-tolerated might they be expanded to children with learning disabilities. This is a sensible proposal, but as experimental and clinical use of TES in pediatric populations moves forward, additional safeguards may be worthy of consideration.

One approach is to invite experts to develop consensus guidelines. Perhaps the closest analogy to the situation being considered here is the use of pharmacological cognitive enhancements. The Ethics, Law and Humanities Committee of the American Association of Neurologists has developed guidelines for neurologists to follow when adult patients request such drugs (Larriviere et al., 2009), and more recently have reviewed the ethical, legal, social and neurodevelopmental issues associated with pediatric neuroenhancement (Graf et al., 2013). Although the recommendations are not binding, they do provide thoughtful commentary on topics of direct relevance to the use of TES in pediatric populations. Future deliberations should consider not just drugs but also devices for cognitive enhancement.

Perhaps the most direct way to address the issue to develop sound regulatory policy. TES for *enhancement* purposes is currently not covered by regulatory statutes in either the United States or the European Union, nor are any devices expressly approved for clinical indications at the present time (Fitz and Reiner, 2013). In response to the looming prospect of do-it-yourself TES, we have suggested that regulatory strategies would be most effective if they were not traditional top-down proclamations of experts, but also include input from members of the public to maximize compliance and reduce the likelihood of the development of black markets (Fitz and Reiner, 2013). With the prospect of pediatric applications of TES added to the mix, there exists a pressing need for developing broad and inclusive consensus on regulation of this new suite of technologies.

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