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Functional Magnetic Resonance Imaging (fMRI) in the Classroom

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Effective applications of fMRI to human problems should be valid and helpful. For valid use of fMRI, there should be evidence from multiple sources that there is a relationship between a brain system and a specific behavior. To be helpful, fMRI must show a clear benefit that would not otherwise be provided by other more cost-effective measures such as behavioral testing or interview.

Fenton and colleagues (2009) focus on two applications of pediatric fMRI that are outside the bounds of standard clinical practice. The first application Fenton and colleagues describe, a tool to guide development of educational interventions in children, has potential benefits if applied in a careful and valid manner. The second application to children in forensic settings is likely doomed to failure.

Briefly, valid application of fMRI in forensic settings is presently impossible since individuals are often noncompliant and thus the cognitive operations they perform are unknown. Furthermore, there are no real benefits to the child and instead there are risks of unfair sentencing or pressure to diagnose with disorders to exonerate a child. For this reason, we will focus on the effective use of fMRI in academic skills using clinical fMRI as examples of valid and helpful applications.

The brain-behavior relationships and risk/benefits in application to educational interventions are much like those of Alzheimer's disease (AD). Specifically, there is a need for sensitive and early characterization of brain integrity and treatment to mitigate later negative outcomes. In AD, the valid brain-behavior association between memory decline and medial temporal lobe (MTL) degeneration underlying the disorder comes from multiple sources including lesions (e.g., Rempel-Clower et al. 1996) and postmortem brain tissue (Braak and Braak 1997). Furthermore, imaging conveys a special advantage since the brain degeneration likely occurs before the behavioral manifestation and well before patients are grossly disabled; thus, neuroimaging may lead to early detection and delayed disease progression before patients are grossly disabled. Imaging changes in the functional integrity of the MTL have thus been proposed as a surrogate measure for another outcome that takes much longer to occur, such as institutionalization or death, so that clinical treatment trials will progress more rapidly (Mueller et al. 2005). Many factors other than AD cause subtle memory dysfunction so that it is standard to retest in 6 months to verify that cognition declines. MTL degeneration may provide

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convergent validation of the AD diagnosis so that delays in treatment are not a part of the diagnostic process.

If fMRI were used to validate a training program focused on an academic skill, there should be an established relationship between the cognitive process being shaped and a localizable neural system that supports it. The problem with the Mozart intervention that Fenton and colleagues (2009) described is that the task is complex and it is unclear what underlying process is related to brain functioning or academic performance. A better example of how fMRI could effectively be used comes from studies of individual differences in academic skills. Dyslexia provides evidence of a well-studied brain-behavior relationship between an academic skill, a critical process underlying that skill (phonological awareness and letter to sound mapping), and the left angular gyrus/temporoparietal junction. Evidence to support this relationship between brain and reading comes from multiple sources including postmortem data (Galaburda et al. 1985), structural imaging of neuronal white matter tracts (Klingberg et al. 2000), and functional imaging in a variety of modalities (Horwitz et al. 1998; Hoeft et al. 2007). Initial pilot work supportive of the validity of the intervention can not depend exclusively on fMRI results, as may have been the case in the Mozart effect, but needs to target the specific core skill (i.e., phonological awareness/letter to sound mapping) and ultimately would need to show, in a randomized clinical trial with appropriate controls, improvement on the target behavior, reading performance. Ultimately there needs to be a demonstrated association between behavioral improvement and fMRI data. It also needs to be demonstrated that the same brain behavior relationships and training benefits occur in children among the normal range of performance in reading development.

What added value could fMRI contribute if training studies already demonstrate behavioral improvement? fMRI again can provide convergent validity that the training is acting on the processing system initially hypothesized. In addition, it can elucidate the brain mechanisms by which behavioral improvement occurs. For example a core question in rehabilitation is whether it is best to target a dys-functional neural system or to facilitate recruitment of other brain systems and brain imaging research of reading, for example supports recruitment of additional brain regions in compensation (Horwitz et al. 1998; Hoeft et al. 2007). fMRI can also provide a convergent set of data to describe brain patterns of optimal functioning as a potential target for intervention, particularly if this pattern occurs before later training benefit. Within the context of reading, it may be that dyslexic children have less activation in the angular gyrus/temporoparietal junction than normal children but those that compensate well for their reading deficit activate the left frontal lobe more than those who do not. To the extent that fMRI can be predict valid outcomes, such as high school graduation or improved verbal SAT scores, then future interventions can be validated more quickly, before the outcome occurs and thus it can serve as a surrogate measure. Also fMRI may demonstrate that different interventions change activation in the same neural structures and thus provide a unifying explanation of why different interventions are beneficial. For example, rapid auditory processing has been related to amelioration of reading deficits behaviorally, fMRI changes (Gaab et al. 2007) and could be studied to determine if it also underlies the music-academic skills relationship.

There are some caveats to the use of fMRI in academic settings, some of which Fenton and colleagues (2009) and Hinton (2002) alluded to. Some students claim an academic skills disorder in order to obtain an exemption from time limits on standardized tests. There is thus secondary gain and the potential for feigned deficits, again raising the question of whether one can truly know what cognitive operation is being performed. There are additional risks if fMRI is used to select appropriate interventions for individual students. In choosing individual students for particular interventions, the certainty of greater benefit in those students must outweigh the risk of depriving other students of what could be helpful to them as well or worse yet, mislabeling children as lacking potential. If this selection were already occurring, then

fMRI would need to provide added value as a predictor of meaningful outcome measures beyond what is already available. Given that academic skills training typically exists in the context of many other interventions, the impact of being denied access or being provided with ineffective treatment is on the order of listening to Mozart instead of an added math class. If fMRI were used to predict potentially serious negative vulnerabilities (e. g., sociopathy, schizophrenia), labeling and self-fulfilling prophesies are of particular concern; however, it is important to consider that early intervention may improve outcomes such that special additional supports may protect children from a vulnerability and thus prevent or minimize the disability they might face. ■

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