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HOT TOPICS

Real-time fMRI neurofeedback: the promising potential of brain-training technology to advance clinical neuroscience

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Although functional magnetic resonance imaging (fMRI) has advanced our understanding of the organization of the brain with the discovery of large-scale networks, the impact of this knowledge on the diagnosis and treatment of psychiatric conditions has yet to be fully realized. The development of real-time fMRI neurofeedback (rtfMRI-NF) provides a promising avenue by which fMRI might enter the clinic. First described two decades ago, the field has matured substantially, with specialized conferences, randomized clinical trials, and multisite consortia. A recent consensus statement outlines methodological approaches and important challenges [1]. A substantial evidence base describes applications in psychiatric [2] and substance use disorders [3]. The first meta-analysis of rtfMRI-NF for psychiatric disorders [2] in 17 studies meeting criteria for inclusion in the analysis recently reported a strong effect size for 'transfer,' which is to say—the demonstration that NF-trained subjects can maintain the ability to regulate neural signal in the absence of feedback—in comparison to subjects trained with sham/control feedback, (Hedges $g = 0.84$, $p = 0.005$). This analysis demonstrates the feasibility of rtfMRI-NF training for psychiatric patients, 52.9% of whom were taking medications. However, the effect on behavioral outcomes in this heterogeneous group was modest (overall symptoms: $g = 0.37$, $p = 0.002$; cognition: $g = 0.23$, $p = 0.288$). It should be noted that the studies conducted training for an average of only 2.3 sessions (range = 1–4), and this line of investigation opens some promising avenues where the techniques could be refined and improved to generate more robust clinical outcomes.

In addition to its clinical applications, rtfMRI-NF is a dynamic, powerful tool to study basic neural processes revealed by fMRI. It provides a methodology to test hypotheses about large-scale network function, strengthening associations in brain-behavior relationships, including relationships relevant for psychiatric conditions. Demonstrations of clinical effects in only two sessions opens the door to fast-fail experimental designs that could iteratively test different targets based on principles of network functioning, leading to personalized interventions designed with NF. Emerging work is moving from targeting increases (or decreases) in single regions to targeting connected networks and leveraging the power of machine learning. For example, decoded neurofeedback uses implicit training, where a subject does not have explicit instructions about entering a specific brain state, coupled with multi-variate connectivity patterns of target states [4]. Although not immune to reliability issues common in fMRI, reliable BOLD signal can be obtained through individualized localizer runs before training or by leveraging whole-brain multivariate pattern analysis. rtfMRI-NF aligns nicely with brain machine interface work and the development of closed-loop brain stimulation, wherein the participant would be consciously trained to augment the neurostimulation feedback [5]. Pairing rtfMRI-NF with other technologies to record and stimulate the brain, both invasive and non-invasive, may be the key to developing breakthrough neuroengineering in psychiatric disorders. More scalable technologies, such as electroencephalography, can be paired with fMRI, serving as a proxy measure which combines the spatial and temporal power of each [6] and bringing personalized and neurocircuit-grounded therapies to the clinic.

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AUTHOR CONTRIBUTIONS

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COMPETING INTERESTS

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served as principal investigator for a contracted clinical trial for Boehringer Ingelheim. MEM has no potential competing interests.

ADDITIONAL INFORMATION

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