BUILDING SUSTAINED ATTENTION WITH NEUROFEEDBACK

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THE STUDY ACADEMY

Issues Explored

- Reframing sustained attention as a teachable ability
- Dovetailing behavioral frameworks of attention with current understandings of Electroencephalography (EEG)
  - Methodological considerations for in-situ neurofeedback testing

Keywords

- Beta/theta, electroencephalography, neurofeedback, sustained attention, translational research

Background

21st-century learning describes a self-regulated skill acquisition process that is constructive, contextual, and collaborative.[11] This education requires the active involvement of students and brings to the forefront a variety of cognitive abilities previously believed extraneous to explicit teaching models. Paramount among these abilities are components of self-regulation including attention.

Sustained attention is a nebulous concept with parameters that vary depending on the lens of the observer (Figure 1). It is at once both critical in importance and fleeting (Figure 2). Existing literature has identified two neurological networks associated with sustained attention.[12, 17] The top-down network—involving neurons in the DLPFC—plays a significant role in goal-oriented attention, using prior knowledge of the attentional set to bias information processing in responding to predefined stimuli.[10] The bottom-up network—involving neurons of the ACC—initiates stimuli detection.[19]

The two networks work together reciprocally to detect stimuli both expected and unexpected[24] and in persistence form the basis of sustained attention.[7] This form of attention is influenced by intrinsic and extrinsic factors including reinforcement schedule, task novelty, and the nature and temporal contiguity of outcomes or rewards.[5]

Inattention occurs with an imbalance between the two networks and is associated with dysfunction of the ACC.[25] Further, attentional research has shown decreased β:θ ratios in the PFC in ADHD diagnosed participants.[1] This particular metric has been responsive to NT when targeted in clinical trials.[14]

Although NT's specificity in treating inattentive type ADHD may not directly translate to a capacity-building view of attention, preliminary findings have been encouraging. Steiner's research group from Tufts, in a groundbreaking study, found in-situ NT using β:θ protocols to be efficacious in a school setting with treatment effects lasting 6-months post-training.[26]

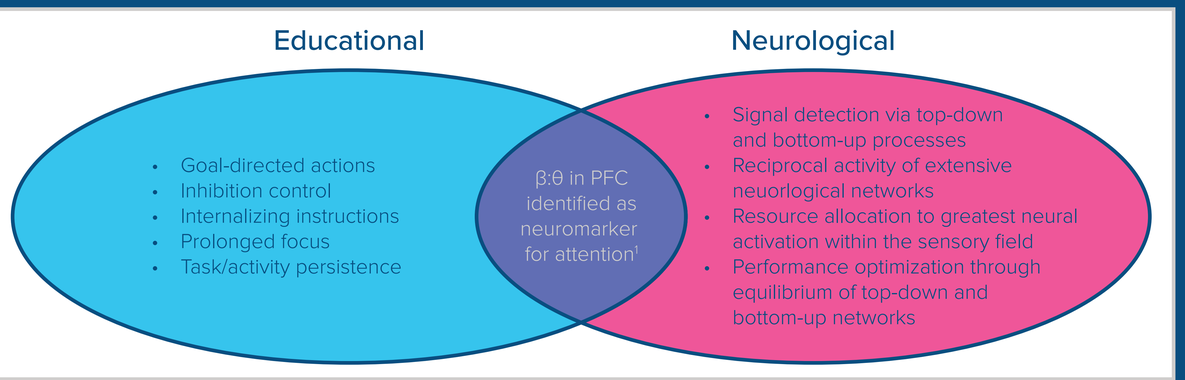

Figure 1: Varying perspectives on sustained attention including the empirically founded neuromarker that unites the observations.

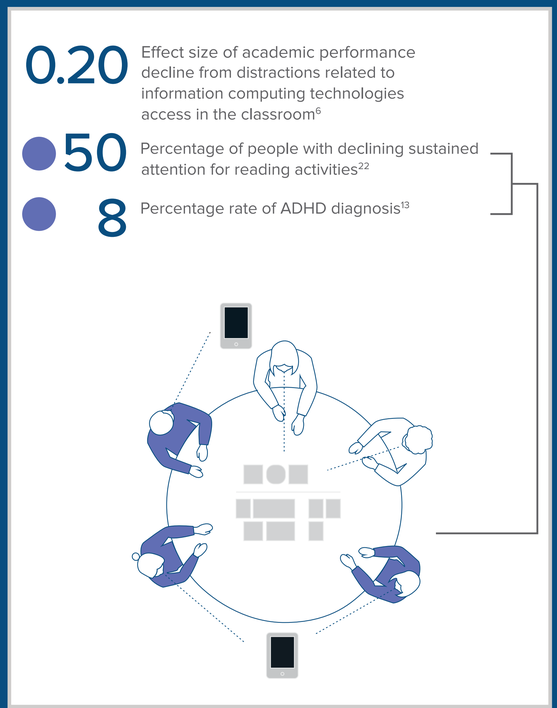

Figure 2: Learning activities of all forms including collaboration require sustained attention despite an ever-growing attentional set and number of distractions.

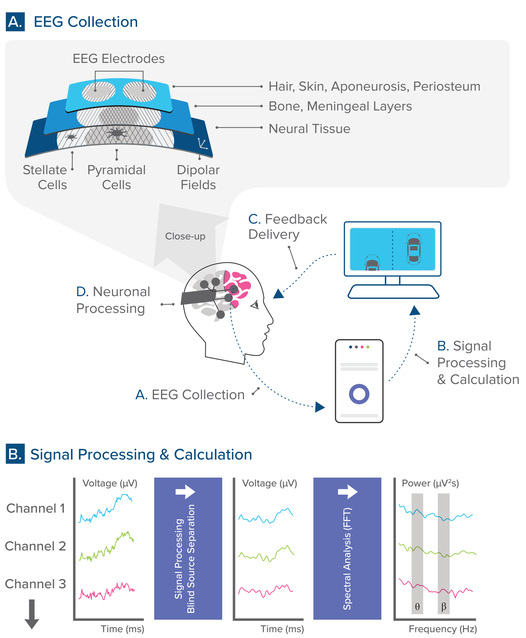

Figure 3: A closed neurofeedback loop used in training attention. Close-up A represents the collection volume for two selected electrodes. Hatched volumes depict sections of the brain with uniquely collected neuronal activity and the cross-hatched volume represents linearly-weighted neuronal activity collected in duplicate. Vector dipolar fields are used to model post-synaptic charges and allow for post-measurement decorrelation of redundant signals across EEG channels.[9] Drill-down B illustrates the stages of signal processing used to transform raw EEG data into frequency domain power spectra such as θ and β to be used as a metric of sustained attention.

Neurofeedback

Research has demonstrated that using a closed-loop feedback system (Figure 3) with real-time information, repetition, and sufficient reward, participants can volitionally alter their neural activity and that these variations may result in neuroplastic changes in the brain. This form of adaptation has been observed with network reorganization at the level of neuron clusters[16] and with increases in white matter pathways (myelination, fiber alignment, and axonal integrity) and grey matter volume at the microstructural level; changes that occur in conjunction with improvements in sustained attention from NT.[15]

It has been well documented that NT is effective in treating symptoms of ADHD, such that participants have shown superior outcomes to control groups.[3, 14] The translational focus of MBE leads to the question of whether gains in attention during training generalize to the classroom. The first peer-reviewed in-situ study supports that students participating in NT experienced a reduction of ADHD symptoms and maintained gains six months post-training.[26]

Since neurofeedback has shown robust results as a treatment modality for deficits of attention, initial research has motivated interest in its use as a training tool for building attention in the classroom. In particular, β/θ training protocols have been validated and successfully implemented in a variety of methodological designs.[23] Corroboration of initial in-situ results is required as well as further testing of the size and sustainability of effect, while more basic research is needed to build an understanding of the neural mechanisms and neuroplastic changes that underlie sustained attentional growth via NT (Figure 4).

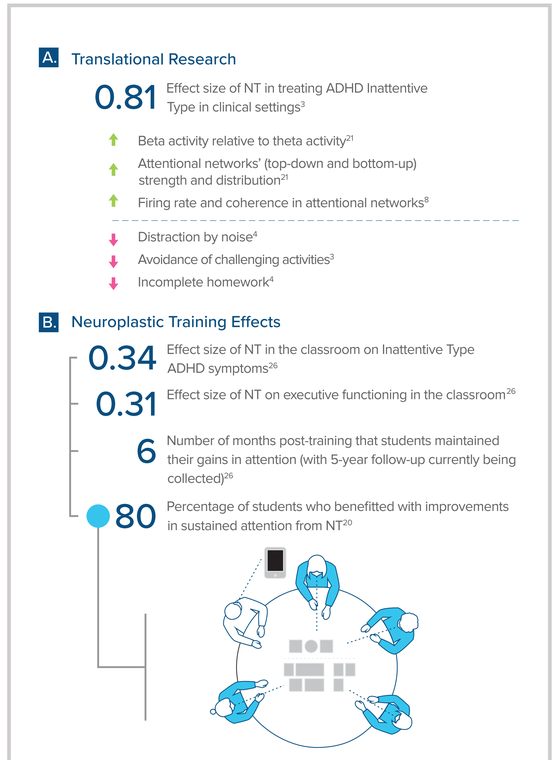

Figure 4: NT protocols provide empirical support for the efficacy of building sustained attention[18] and specificity of treating ADHD.[27] Block A summarizes essential outcomes in treating ADHD and block B provides key metrics from emerging research illustrating the potential of NT as a disruptive innovation.

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