Chapter 100

Concurrent fNIRS and TMS for Neurocognitive Enhancement on a Speed-of-Processing Task

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Learning through practice is expected to result in the development of strategies that are more efficient at cognitive resource management.[1] Speed of processing represents a fundamental limiting step in performance of routine tasks. This measure is typically quantified using tests that require an elementary amount of cognitive effort, delineating them from purely sensorimotor activities. Because processing speed is so sensitive to cognitive changes associated with age, brain injury, or disease, it has frequently been studied as a benchmark for diagnosis, cognitive remediation, and enhancement.[2] Among tasks attempting to measure cognitive processing speed, the Symbol Digit Substitution Test (SDST), derived from the Wechsler intelligence scales, has been widely employed due to its ease of use and sensitivity. Despite the apparent simplicity and brevity of the task, the SDST can be taken as a general index of an individual's cognition due to the intersection of perception, encoding, working memory, and response selection.[3]

In this study, we sought to illuminate the dynamics of neural efficiency during adaptation to a common speed of processing task (i.e., SDST), and explore how metrics of neural efficiency might change with different types of transcranial magnetic stimulation (TMS) methods. Sixteen healthy volunteers were enrolled in this study and were compensated for their participation. Subjects participated in four sessions across 2 days separated by a minimum of 1 h. In each session, subjects performed four repetitions of a 90-s digitized SDST task interleaved with a 30 s baseline period. In between trials 2 and 3, the subject received 10 pulse trains of TMS at F3 (according to the International 10-20 System) separated by 40 s, according to a randomized paradigm (Sham, Single Pulse–110% Resting Motor Threshold (RMT), High Frequency 2s 15 Hz–110% RMT, and Theta Burst 2s–90% RMT) with a different stimulation type performed each session. Cortical activity in the dorsolateral prefrontal cortex (dlPFC) was measured continuously using functional Near-Infrared Spectroscopy (fNIRS).

Our preliminary results suggest that neurocognitive metrics of efficiency are sensitive to learning produced by repeated task performance over several sessions. We observed strong prefrontal involvement in SDST task performance that increased in efficiency with training. Additionally, we noted that intersession TMS paradigms influenced efficiency metrics despite subtherapeutic dosing (Fig. 100.1).

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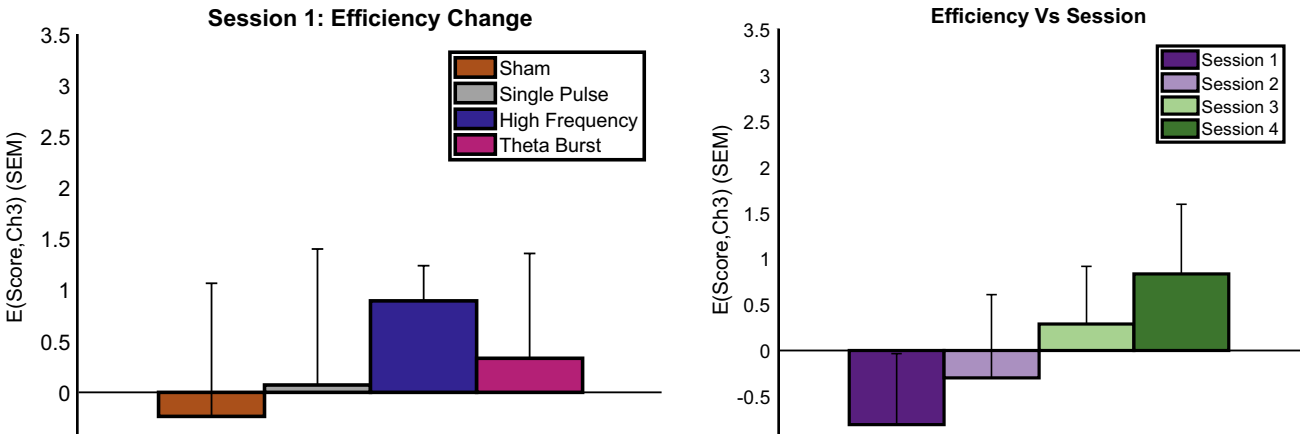

FIGURE 100.1 Efficiency change for Sham and three different TMS stimulation (Single Pulse, High Frequency, and Theta Burst) indicate High Frequency has highest impact for enhancement comparing before and after stimulation (left). Efficiency (performance normalized by neuroimaging-based mental effort) changes over four sessions (right).

REFERENCES

1. Neubauer AC, Fink A. Intelligence and neural efficiency. *Neuroscience and Biobehavioral Reviews* 2009;**33**(7):1004–23.
2. Rypma B, Berger JS, Prabhakaran V, Martin Bly B, Kimberg DY, Biswal BB, D'Esposito M. Neural correlates of cognitive efficiency. *Neuroimage* 2006;**33**(3):969–79.
3. Dickinson D, Ramsey ME, Gold JM. Overlooking the obvious: a meta-analytic comparison of digit symbol coding tasks and other cognitive measures in schizophrenia. *Archives of General Psychiatry* May 2007;**64**(5):532–42.