

Thesis Project Portfolio

Neural Decoder for Targeted Real-Time Transcranial Magnetic Stimulation

(Technical Report)

Overcoming Barriers to TMS Adoption in Military Mental Health Care: Addressing Stigma, Leadership, and Infrastructure Challenges

(STS Research Paper)

An Undergraduate Thesis

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Sociotechnical Synthesis

My technical and STS research are closely connected by a shared objective: to enhance the clinical effectiveness and institutional acceptance of transcranial magnetic stimulation (TMS), particularly for mental health applications in the military. For the technical portion of my Capstone, I developed a MATLAB-based neural decoding platform that integrates functional near-infrared spectroscopy (fNIRS), electroencephalography (EEG), and TMS to enable real-time, closed-loop brain recording and stimulation. For my STS research, I investigated the cultural stigma and institutional barriers within the U.S. military that prevent the widespread adoption of TMS, despite its potential as a non-invasive treatment for post-traumatic stress disorder (PTSD) and major depressive disorder (MDD).

The technical component of my work focused on building a system capable of identifying task-evoked hemodynamic changes in brain activity and automatically triggering TMS at optimized moments. To achieve this, I designed a MATLAB graphical user interface (GUI) that calculates individualized thresholds based on oxygenated hemoglobin (HbO) signals from real-time fNIRS data. These thresholds are used to initiate single-pulse or repetitive TMS protocols during tasks like motor activation. The platform displays real-time neuroimaging data and integrates inputs from multiple systems, including EEG for electrical activity tracking and fNIRS for changes in blood-oxygen levels. The system demonstrates high potential for precision neuromodulation and closed-loop control, essential for tailoring TMS protocols to individual neurophysiology.

The broader significance of this project lies in its potential to address persistent challenges in clinical neuromodulation. TMS is widely used for treating neuropsychiatric conditions such as MDD, but traditional protocols often lack personalization, resulting in

variable patient outcomes. By integrating real-time neural feedback from multiple data modalities, the platform enables more individualized and adaptive TMS protocols.

My STS research examined why such a promising technology remains underutilized in military mental health care. Drawing from the Social Construction of Technology (SCOT) framework, I argued that adoption of TMS is not simply limited by access to equipment or infrastructure, but also by the meanings attached to the technology by various social groups, particularly service members, military leaders, and mental health professionals. I analyzed over 30 veteran interviews, Department of Defense reports, and existing literature to understand the roots of stigma and cultural resistance. Despite FDA approval and a growing clinical evidence supporting TMS for treatment-resistant PTSD and depression, many service members remain unaware of its existence. Stigma around mental health, fear of career repercussions, lack of provider training, and limited leadership advocacy all contribute to the marginalization of TMS in military treatment settings.

Working on these projects concurrently enabled a comprehensive view of neuromodulation that spans both engineering feasibility and sociocultural relevance. Through my Capstone, I gained firsthand experience with the technical challenges of data integration, signal processing, and real-time neurostimulation, as well as the human-centered barriers that limit real-world implementation. Ultimately, the success of TMS as a military mental health treatment isn't just about building the right technology, it's about pairing that innovation with real advocacy, making sure the infrastructure is there and educating both providers and service members. My work highlights the need for a dual approach: one that advances the tools to deliver personalized stimulation, and one that reshapes the institutions and narratives that determine whether these tools are ever used.