

Prospectus

A Research Paper submitted to the Department of Engineering and Society

Presented to the Faculty of the School of Engineering and Applied Science

University of Virginia • Charlottesville, Virginia

In Partial Fulfillment of the Requirements for the Degree

Bachelor of Science, School of Engineering

Ella Gray Settle

Fall 2024

**On my honor as a University Student, I have neither given nor received unauthorized aid
on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments**

Advisor

Karina Rider , Department of Engineering and Society

Introduction

The military is facing a critical mental health crisis, with rates of suicide, post-traumatic stress disorder (PTSD), and major depressive disorder (MDD) being alarmingly higher than those in civilian populations. According to the calendar year 2022 Annual Report on Suicide in the Military, the suicide rate among active-duty personnel stands at 25.1 per 100,000, far exceeding the civilian rate (Department of Defense, 2022). Additionally, 13.8% of deployed service members meet criteria for PTSD, while 13.7% experience MDD, compared to only 3.5% and 6.7% in civilians (Hoge et al., 2022). These statistics highlight an urgent public health issue that affects not just the well-being of service members but also military readiness and national security. When those who defend our country are unable to access effective mental health care, it hinders their ability to perform and undermines the overall strength of our armed forces. One area of promise is transcranial magnetic stimulation (TMS), a non-invasive brain stimulation treatment shown to effectively alleviate symptoms of PTSD and depression, which has great potential to address this crisis. However, it remains underutilized within military settings due to concerns surrounding confidentiality, stigma, and limited awareness of its benefits.

In the military, traditional mental health interventions are often seen as an admission of weakness, and medications may carry both undesirable side effects and the stigma of needing treatment. TMS offers a promising alternative: it is non-invasive, has fewer side effects than pharmaceuticals, and can provide rapid symptom relief, making it an appealing option for treating depression and PTSD. However, one of the primary barriers to its adoption is the stigma surrounding mental health within military culture. Seeking help is often perceived as a sign of weakness or as a risk to one's career progression, which discourages many service members from pursuing mental health care, including newer treatments like TMS. Additionally, limited

awareness and understanding of TMS among military personnel and providers result in a preference for traditional therapies that are more widely recognized and accessible, further complicating efforts to integrate TMS into military healthcare.

This prospectus proposes a dual approach to addressing this issue. First, it outlines plans for developing a neural decoding platform designed to advance TMS applications through real-time multimodal brain imaging integration, including function near-infrared spectroscopy (fNIRS), electroencephalography (EEG), and neuronavigation. This MATLAB-based platform is intended to facilitate closed-loop brain recording and stimulation, with the potential to enhance TMS's precision and efficacy. Second, it proposes to examine the role of mental health stigma within the U.S. military and its influence on the adoption and efficacy of TMS as a treatment for PTSD, depression, and suicide prevention. By bridging the fields of technology and social perception, this research aims to lay the groundwork for developing a more effective mental health intervention framework tailored to military needs.

Technical Project

Transcranial magnetic stimulation is a neuromodulation technique that uses magnetic fields to activate nerve cells in specific areas of the brain. This stimulation produces electromagnetic pulses that generate electric currents, which modulate neural activity in targeted brain regions (Siebner et al., 2009). TMS has shown considerable promise in treating MDD, particularly in cases where conventional therapies are ineffective. The FDA approved repetitive TMS (rTMS) for MDD in 2008, and studies indicate that daily rTMS sessions targeting the dorsolateral prefrontal cortex (DLPFC) can lead to significant mood improvements and functional gains for patients (Ziemann et al., 2014). Despite its therapeutic potential,

understanding the brain's response to TMS in real time and personalizing stimulation parameters remains challenging.

This project aims to address these challenges by creating a real-time neural decoding platform that integrates TMS with other brain monitoring tools, including EEG and fNIRS. This MATLAB-based platform will provide researchers with a graphical user interface (GUI) that provides dynamic and individualized TMS. By merging data from these modalities, the platform will display real-time brain activity, allowing users to analyze both electrical and hemodynamic responses. The integration of multiple data streams will enable a comprehensive view of brain dynamics, allowing more precise targeting for TMS and potentially enhancing its clinical efficacy in treating neurological and psychiatric conditions (Faller et al., 2022).

To achieve these objectives, we will incorporate machine learning algorithms within the platform to identify and classify brain activity patterns associated with specific cognitive or behavioral responses. EEG and fNIRS data will be analyzed using support vector machine (SVM) classifiers, which will detect task-specific neural activations that may influence therapeutic outcomes. SVM was chosen based on its ability to handle high-dimensional data and ability to perform real-time neural decoding. By decoding brain activity patterns in response to TMS, the platform aims to allow clinicians to modulate TMS parameters dynamically, making TMS treatments more adaptable and individualized.

A potential drawback to this approach is the increased complexity of treatment decisions. The integration of multiple data sources and machine learning algorithms introduces additional layers of interpretation, which could make treatment processes less transparent for both patients

and clinicians. Furthermore, real-time neural data processing raises ethical concerns related to data privacy and security, as it involves sensitive brain information.

This project builds on recent advancements in EEG-TMS platforms, expanding their capabilities by incorporating fNIRS to create a multi-modal neural decoding system. By visualizing and modulating brain activity in real time, the platform aims to enhance the precision and effectiveness of TMS, offering new insights into brain network dynamics and potentially providing more responsive and individualized mental health treatments. Ultimately, this approach has the potential to improve outcomes for service members and others experiencing conditions like MDD and PTSD, supporting a more targeted approach to neurostimulation therapies.

STS Project

Despite the demonstrated effectiveness of TMS in treating depression and PTSD, its use within the U.S. military has been limited. This prospectus proposes to examine how societal stigmatization of mental health impacts the adoption and efficacy of TMS for service members, with a focus on how military culture, leadership influence, and logistical barriers collectively shape access to and perception of TMS. By addressing these layers, this proposed research seeks to contribute to understanding the complex factors that prevent the integration of innovative mental health treatments in military settings.

Mental health stigma in the military presents challenges that discourage service members from seeking treatment. In military culture, mental health struggles are often perceived as a sign of weakness or a risk to career advancement, creating an environment where people may fear judgment or consequences for seeking help. Nearly half of active-duty military members were

hesitant to pursue mental health support due to fears of stigmatization and potential career setbacks (Acosta et al. 2014). This is particularly relevant in cases of newer treatments like TMS, which may still be unfamiliar and therefore lead to more hesitation within the military community. Stigma against mental health interventions is often tied to concerns about confidentiality, service members often worry about mental health records affecting their career prospects (Sharp et al. 2015). This perception is not only prevalent but is also compounded by military leadership's reluctance to prioritize mental health openly. Because TMS is a relatively new therapeutic approach, stigma around mental health could further limit its acceptance. Understanding this stigma and how it shapes access to TMS helps clarify the barriers to effective treatment adoption in the military.

TMS could be instrumental in addressing mental health challenges unique to the military. TMS showed significant promise in alleviating symptoms of PTSD among veterans, indicating that it could provide critical support to military personnel (Philip et al. 2016). Despite TMS's potential, its adoption in military settings remains limited. While TMS is available in some VA hospitals, access to this treatment is inconsistent (Philip et al. 2016). The barriers to broader implementation may lie in both the stigma surrounding mental health treatment in the military and the logistical challenges of providing specialized equipment in diverse locations. This analysis aims to clarify these barriers to facilitate the integration of effective treatments for service members.

Military leaders play a crucial role in influencing the attitudes of service members toward mental health care. Leaders who prioritize mental health and openly support treatment-seeking behaviors can significantly reduce stigma within their ranks. When military leaders demonstrated support for mental health initiatives, there was a marked increase in treatment-seeking behavior

among their personnel (Trachik et al. 2021). These findings highlight the potential impact that leadership initiatives could have on normalizing TMS as a viable treatment option within the military.

Leadership-driven efforts have the potential to address stigma directly by reframing mental health treatment as an essential component of overall resilience and readiness. Peer-led programs, endorsements from high-ranking officers, and open discussions about mental health could make treatments like TMS more acceptable. However, while there is evidence that leadership can influence attitudes toward mental health care generally, it remains unclear how these initiatives could specifically impact the acceptance of new treatments like TMS within a military context. This project aims to assess how leadership-driven stigma reduction strategies could shape attitudes toward TMS adoption.

While existing research provides valuable insights into the effectiveness of TMS and the prevalence of mental health stigma in the military, there remain significant gaps in understanding how these factors intersect. One key area of ambiguity is whether stigma impacts the adoption of TMS differently than it does more established mental health treatments. Additionally, logistical considerations within the military, such as availability of equipment and trained personnel, further complicate TMS implementation. The success of technology integration in any setting is contingent on available resources, support structures, and proper training (Buabeng-Andoh 2012). In the case of TMS, these challenges are amplified by the military's decentralized and often geographically dispersed infrastructure.

This STS project seeks to answer the central question: How does societal stigmatization of mental health within the U.S. military impact the adoption and effectiveness of TMS aimed at

reducing suicide rates and treating PTSD and depression among service members? To address this question, a mixed-method approach will be adopted, utilizing data and reports from the Department of Defense (DoD) over the past 10 years. By focusing exclusively on the U.S. military and data within this time frame, the research will capture relevant trends in mental health treatment and the influence of stigma on emerging therapies.

This study combines qualitative analysis of secondary interviews, quantitative data analysis, and meta-reviews of existing research. The qualitative component will include an analysis of secondary interviews to assess service members' and veterans' perceptions of mental health stigma and the services provided by the military. Additionally, responses from mental health professionals working within military institutions will be examined to gain insight into logistical, operational, and cultural barriers to TMS adoption. These perspectives will help reveal how stigma shapes both the individual experiences of military personnel and broader institutional attitudes toward mental health treatments.

Interviews from service members, veterans, and mental health professionals will be examined for recurring themes regarding mental health stigma, confidentiality concerns, career impact fears, and overall comfort with seeking mental health support. The data will include responses that reflect the broader military culture's views on mental health care. The analysis will identify key factors in service members' willingness or reluctance to pursue mental health treatments, particularly newer and less familiar options like TMS. The goal of this analysis is to clarify how stigma and fear of career repercussions contribute to or hinder the adoption of TMS in the U.S. military.

Quantitative data, primarily derived from recent DoD reports and surveys, will be analyzed to measure trends in mental health treatment use, rates of diagnosed PTSD and depression, and suicide rates among service members. This component will provide a quantitative basis for examining the extent to which stigma has influenced mental health care engagement in the military over the past decade. Additionally, data on TMS usage within VA and military hospitals will be analyzed to assess adoption trends, availability of TMS services, and usage rates.

To supplement interview and survey data, this study will include a meta-review of DoD reports from the past 10 years. This review will focus on policy changes, stigma reduction programs, and the military's stance on innovative mental health treatments. Key documents will include mental health reports, policy analyses, and evaluations of the DoD's suicide prevention and mental health programs. These documents will help provide a broader institutional context, revealing the DoD's approach to TMS and other treatments in response to rising mental health needs.

Conclusion

By analyzing the impact of stigma on TMS adoption in the military, this research aims to identify strategies for normalizing mental health treatments and reducing barriers to TMS access. Understanding and addressing these barriers could not only improve mental health outcomes but also promote resilience and well-being within military ranks. Through an integrated approach, this project contributes to the broader effort of destigmatizing mental health care in the military, fostering a more inclusive and effective approach to treating service members with PTSD, depression, and other mental health conditions.

References

- Acosta J, Huang W, Edelen M, Cerully J, Soliman S, Chandra A. *Measuring Barriers to Mental Health Care in the Military: The RAND Barriers and Facilitators to Care Item Banks*. RAND Corporation; 2018. doi:[10.7249/RR1762](https://doi.org/10.7249/RR1762)
- Buabeng-Andoh, C. (2012). Factors influencing teachers' adoption and integration of information and communication technology into teaching: A review of the literature. *International Journal of Education and Development using Information and Communication Technology*, 8(1), 136-155.
- Department of Defense. (2022). *Annual report on suicide in the military: Calendar year 2022*. Office of the Under Secretary of Defense for Personnel and Readiness. https://www.dspo.mil/Portals/113/Documents/ARSM_CY22.pdf?ver=StAk_q6lJgNRUsOlptzVVA%3d%3d
- Faller J, Doose J, Sun X, et al. Daily prefrontal closed-loop repetitive transcranial magnetic stimulation (rTMS) produces progressive EEG quasi-alpha phase entrainment in depressed adults. *Brain Stimulation*. 2022;15(2):458-471. doi:[10.1016/j.brs.2022.02.008](https://doi.org/10.1016/j.brs.2022.02.008)
- Hoge CW, Auchterlonie JL, Milliken CS. Mental Health Problems, Use of Mental Health Services, and Attrition From Military Service After Returning From Deployment to Iraq or Afghanistan. *JAMA*. 2006;295(9):1023. doi:[10.1001/jama.295.9.1023](https://doi.org/10.1001/jama.295.9.1023)
- Philip NS, Ridout SJ, Albright SE, Sanchez G, Carpenter LL. 5-Hz Transcranial Magnetic Stimulation for Comorbid Posttraumatic Stress Disorder and Major Depression. *Journal of Traumatic Stress*. 2016;29(1):93-96. doi:[10.1002/jts.22065](https://doi.org/10.1002/jts.22065)
- Sharp ML, Fear NT, Rona RJ, et al. Stigma as a Barrier to Seeking Health Care Among Military Personnel With Mental Health Problems. *Epidemiologic Reviews*. 2015;37(1):144-162. doi:[10.1093/epirev/mxu012](https://doi.org/10.1093/epirev/mxu012)

Siebner HR, Hartwigsen G, Kassuba T, Rothwell JC. How does transcranial magnetic stimulation modify neuronal activity in the brain? Implications for studies of cognition. *Cortex*. 2009;45(9):1035-1042. doi:[10.1016/j.cortex.2009.02.007](https://doi.org/10.1016/j.cortex.2009.02.007)

Trachik B, Oakey-Frost N, Ganulin ML, et al. Military suicide prevention: The importance of leadership behaviors as an upstream suicide prevention target. *Suicide & Life Threat Behav*. 2021;51(2):316-324. doi:[10.1111/sltb.12707](https://doi.org/10.1111/sltb.12707)

Ziemann U, Reis J, Schwenkreis P, et al. TMS and drugs revisited 2014. *Clinical Neurophysiology*. 2015;126(10):1847-1868. doi:[10.1016/j.clinph.2014.08.028](https://doi.org/10.1016/j.clinph.2014.08.028)