­NSF Project Pitch

*Proposed Title:* A new system to augment learning and memory through neurofeedback and subconscious priming during sleep

Information: <https://seedfund.nsf.gov/apply/project-pitch/>

Instructions

The required Project Pitch allows startups to learn if their proposed project is a good fit for funding from America’s Seed Fund powered by NSF. See four key questions you'll be asked to answer.

1. The Technology Innovation. (Up to 500 words)

Describe the technical innovation that would be the focus of a Phase I project, including a brief discussion of the origins of the innovation as well as explanation as to why it meets the program’s mandate to focus on supporting research and development (R&D) of unproven, high-impact innovations.

We are living in the age of distraction, with 11% of 4-17 year old’s receiving an ADHD diagnoses, parent-reported ADHD increasing by 42% from 2003-2011,1 and it impacting 4.4% of adults.2 Sleep disturbances are a predecessor for ADHD, where improving sleep can alleviate symptoms and sleep restriction worsens them.3 Another societal problem characterized by difficulty controlling one’s thoughts and disturbances in sleep is Post Traumatic Stress Disorder (PTSD).4 While these disorders may seem disparate, technology that empowers individuals to regain control of their thoughts in regards to goals that they want to achieve may be a common link for addressing these issues. Almost everyone would benefit from better focus on the things that they are most passionate about.

A recent meta-analysis showed that neurofeedback to treat ADHD was more effective than medication use, and could further benefit from personalization-based interventions (i.e. sleep hygiene).5 Additionally, scientists have recently discovered an innovative method to enhance memory consolidation and reinforce cognition called Targeted Memory Reactivation (TMR). TMR is a methodology where declarative memory and skill acquisition can be improved by playing specific stimuli, like sounds or odors, during non-rapid-eye-movement (NREM) sleep that are systematically associated with tasks that are performed during waking life (see meta-analysis).6 TMR was also used to treat nightmare disorder by targeting REM sleep when the stimuli was strengthened during imagery rehearsal therapy (IRT), which involves asking patients to change the negative story line of their nightmare to a positive one.7 However, neurofeedback has never been combined with TMR to further augment memory and focus.

Combining neurofeedback with TMR is novel and has various applications. The technology could more precisely associate focus on stimuli during waking life for the purpose of replaying and reintegrating that information during sleep. After meeting at the Quake Venture Capitalist Accelerator program, Proactive Life Inc (SleepSpace), who has developed an IP portfolio and technology for administering audio-stimulation based on sleep stage (patents #8468115B2, #10524661B2; #DM/218400; submitted #16/504,285, #16/950,987), teamed up with Neurosity, a company that has developed an innovative headset for administering neurofeedback, in order to develop such a technology. We are currently collaborating on a small, completely remote study to evaluate if the Neurosity Headset can improve cognitive performance compared to brown noise, another effective treatment for ADHD.8 However, combining the technologies involves developing a new system for inserting sound played during neurofeedback, at specific periods in cognitive performance, and replaying them at the right moment, intensity, and sleep stage.

The technical focus of this Phase 1 project is to combine Neurosity’s real-time neurofeedback methodology with SleepSpace’s real-time TMR technique using audio stimulation in order to enhance focus and memory. We will then conduct an experiment on healthy adults to collect data that are necessary to develop this new system for delivering customized consciousness enhancing sounds during sleep and waking life. The novel technology will be integrated into both SleepSpace and Neurosity for improving workplace performance and productivity. It has potential future applications for addressing various cognitive-based disorders, including ADHD and PTSD.

References:

 1. Visser, S.N., Danielson, M.L., Bitsko, R.H., Holbrook, J.R., Kogan, M.D., Ghandour, R.M., Perou, R., and Blumberg, S.J. (2014). Trends in the Parent-Report of Health Care Provider-Diagnosed and Medicated Attention-Deficit/Hyperactivity Disorder: United States, 2003–2011. J. Am. Acad. Child Adolesc. Psychiatry *53*, 34-46.e2. 10.1016/j.jaac.2013.09.001.

2. Kessler, R.C., Adler, L., Barkley, R., Biederman, J., Conners, C.K., Demler, O., Faraone, S.V., Greenhill, L.L., Howes, M.J., Secnik, K., et al. (2006). The Prevalence and Correlates of Adult ADHD in the United States: Results From the National Comorbidity Survey Replication. Am. J. Psychiatry *163*, 716–723. 10.1176/ajp.2006.163.4.716.

3. Gruber, R. (2012). Sleep patterns and the risk for ADHD: a review. Nat. Sci. Sleep, 73. 10.2147/NSS.S31269.

4. Lancel, M., van Marle, H.J.F., Van Veen, M.M., and van Schagen, A.M. (2021). Disturbed Sleep in PTSD: Thinking Beyond Nightmares. Front. Psychiatry *12*, 767760. 10.3389/fpsyt.2021.767760.

5. Garcia Pimenta, M., Brown, T., Arns, M., and Enriquez-Geppert, S. (2021). Treatment Efficacy and Clinical Effectiveness of EEG Neurofeedback as a Personalized and Multimodal Treatment in ADHD: A Critical Review. Neuropsychiatr. Dis. Treat. *Volume 17*, 637–648. 10.2147/NDT.S251547.

6. Hu, X., Cheng, L.Y., Chiu, M.H., and Paller, K.A. (2020). Promoting memory consolidation during sleep: A meta-analysis of targeted memory reactivation. Psychol. Bull. *146*, 218–244. 10.1037/bul0000223.

7. Schwartz, S., Clerget, A., and Perogamvros, L. (2022). Enhancing imagery rehearsal therapy for nightmares with targeted memory reactivation. Curr. Biol. *32*, 4808–4816.

8. Söderlund, G., Sikström, S., and Smart, A. (2007). Listen to the noise: noise is beneficial for cognitive performance in ADHD. J. Child Psychol. Psychiatry *48*, 840–847. 10.1111/j.1469-7610.2007.01749.x.

9. Cerino, E.S., Katz, M.J., Wang, C., Qin, J., Gao, Q., Hyun, J., Hakun, J.G., Roque, N.A., Derby, C.A., Lipton, R.B., et al. (2021). Variability in Cognitive Performance on Mobile Devices Is Sensitive to Mild Cognitive Impairment: Results From the Einstein Aging Study. Front. Digit. Health *3*, 758031. 10.3389/fdgth.2021.758031.

10. Sliwinski, M.J., Mogle, J.A., Hyun, J., Munoz, E., Smyth, J.M., and Lipton, R.B. (2016). Reliability and Validity of Ambulatory Cognitive Assessments. Assessment. 10.1177/1073191116643164.

11. Roberts, D.M., Schade, M.M., Mathew, G.M., Gartenberg, D., and Buxton, O.M. (2020). Detecting sleep using heart rate and motion data from multisensor consumer-grade wearables, relative to wrist actigraphy and polysomnography. Sleep *43*, zsaa045. 10.1093/sleep/zsaa045.