Quest International Journal of Medical and Health Sciences – [Online]

SHORT COMMUNICATION

Enhancement of slow wave sleep and declarative memory consolidation with pink noise acoustic stimulation during sleep: A ray of hope

Chan Jia Ping

Chan Jia Ping, BMS student, faculty of Medicine, Quest International University (QIU), No. 227, Plaza Teh Teng Seng (Level 2), Jalan Raja Permaisuri Bainun, 30250 Ipoh, Perak Darul Ridzuan, Malaysia

Email: jiaping820@gmail.com [ORCID]

Information about the article:

Received: Oct. 5, 2022
Accepted: Dec. 2, 2022
Published online: Dec 31, 2022

Publisher

Quest International University (QIU), No.227, Plaza Teh Teng Seng (Level 2), Jalan Raja Permaisuri Bainun, 30250 Ipoh, Perak Darul Ridzuan, Malaysia

e-ISSN: 2636-9478

ABSTRACT

Introduction:
The prevalence of insomnia in Malaysia increased in the past decade. 9 out of 10 Malaysians have insomnia and have one or more sleep problems. Various treatments, such as acoustic stimulation and transcranial infraslow pink-noise stimulation (HD-tIPNS), have been introduced to overcome insomnia.

Conclusion:
Pink noise auditory stimulation shows a significant beneficial impact on sleep quality and sleep efficiency as well as on declarative memory consolidation by enhancing low oscillation, fast spindle activity, and delta power.

Keywords
Delta power, memory, pink noise, slow oscillation, slow wave sleep

Introduction

Insomnia is the most common sleep disorder, influencing around 35% of the total population in Malaysia, and 12.2% of the population has been diagnosed with chronic insomnia. [1] It is inextricably associated with cognitive performance, and insomniac patients are more susceptible to declarative memory disturbances, executive dysfunction, and lower alertness and concentration. [2]

Pink (1/f) noise is a mixture of sound or electrical signals whose intensity decreases in proportion to frequency to produce relatively equal energy per octave. [3] It is capable of masking ambient noise that may disrupt or disturb sleep. [4] Pink noise auditory stimulation is a feasible non-invasive method that amplifies slow oscillation, fast spindle activity, and delta power. Evidence suggests that slow oscillations (SO) seem particularly pertinent for declarative memory consolidation via targeted memory reactivation during sleep. Slow oscillations can be increased by transcranial direct current stimulation (tDCS), transcranial magnetic stimulation (TMS), intracranial electrical stimulation, and acoustic stimulation. Rhythmic acoustic stimulation enables simultaneous fine-grained analysis of electroencephalogram (EEG) and, has low technical requirements compared to other methods, is mainly preferred. [5] The amplitude of slow oscillations and fast and slow spindle power is elevated by closed-loop pink noise acoustic stimulation during non-rapid eye movement (NREM) sleep. All of these are linked with enhanced declarative memory. The performance of declarative memory tasks (word pair association task) is improved as fast sleep spindle power increases. In addition, the pink noise acoustic stimulation timing is also important. Neither slow-wave activity (SWA) nor memory is enhanced if the pink noise is delivered during the negative peak of the SO. Also, while there is no SO power elevation during randomly timed stimulation, fast spindle power is increased. [6]

The active system consolidation hypothesis was proposed to describe the mechanism of sleep-dependent memory consolidation. Memory representations are continuously and spontaneously reactivated in the hippocampal network during slow wave sleep (SWS) or stage 3 (N3) sleep, resulting in sharp ripple activity. The slow-oscillation upstates regulate the synchronization between hippocampal ripples and thalamocortical spindles. Moreover, the temporal coordination of NREM sleep oscillations coordinates the crosstalk between the hippocampus and neocortex. It leads to the transfer of memories from hippocampus short-term storage to neocortex long-term storage. Another alternative model called the synaptic homeostasis hypothesis (SHY) was introduced to explain the benefits of sleep for memory. The SHY states that slow wave activity during sleep enhances synaptic network downscaling. Its goal is to desaturate synapses and support new subsequent learning. [7] Sleep-dependent synaptic desaturation raises the signal-to-noise ratio and renews the ability to encode new information through associative plasticity. [8] Both the SHY and active system consolidation models are mutually compatible and complementary to each other. They describe how memories are replayed during sleep for long-term storage, normalization of synaptic strength by synaptic downscaling, clearing the memory traces in the hippocampus, and getting ready for more learning. [6]

Furthermore, pink noise auditory stimulation during sleep enhances the delta-frequency activity and slow oscillation as well as the proportion of time spent in slow wave sleep or stage 3 sleep (N3). The momentary delta power is significantly increased when the auditory stimulation is played beneath the acoustic arousal threshold. [9] Delta binaural beats allow people to fall asleep fast, wake up less often during sleep, and get a good night's sleep. Improved sleep quality has a positive impact on daily mood. Reduce anxiety, irritability, and other negative emotions. [10] It provides a non-pharmacologically beneficial translational application of acoustic stimulation to improve sleep. The auditory stimulation of pink noise improves the quantity of N3 sleep, and the depth of sleep and assists people with poor sleep quality, especially the elderly or those with medical and psychiatric diseases. [9]

Conclusion

Pink noise improves sleep quality, sleep efficacy, and declarative memory consolidation. The proportion of Slow-wave sleep or N3 increase promotes body restoration, boosts the immune system, enhances work performance, growth, and cell regeneration. Further research is needed on safety, long-term effects, optimal parameters, and therapeutic use of pink noise auditory stimulation.

Abbreviations

Electroencephalogram (EEG), High-definition transcranial infraslow pink-noise stimulation (HD-tIPNS), Non-rapid eye movement (NREM), Slow oscillations (SO), Slow wave sleep (SWS), Slow-wave activity (SWA), Stage 3 sleep (N3), Synaptic homeostasis hypothesis (SHY), Transcranial direct current stimulation (tDCS), Transcranial magnetic stimulation (TMS)

Acknowledgments

Author is grateful to Amanpreet Kaur Gurdarshan Singh of Quest International University for her contributions to the manuscript's language and grammar editing.

Funding

No funding was received.

Availability of data and materials

All data are available as part of the article, and no additional source data are required.

Competing interests

We declare no competing interests.

Publisher's Note

QIU remains neutral with regard to jurisdictional claims in published maps and institutional affiliations. The publisher shall not be legally responsible for any types of loss, actions, claims, proceedings, demand, or costs or damages whatsoever caused arising directly or indirectly in connection with or arising out of the use of this material.

References

1. Mustapha, K. Sleep on it. New Straits Times [Online] 2018, [cited 2018, May 8]. Accessed from https://www.nst.com.my/lifestyle/heal/2018/05/367079/sleep-it
2. Brownlow JA, Miller KE, Gehrman PR. Insomnia and Cognitive Performance. Sleep Med Clin. 2020 Mar;15(1):71-76. https://doi.org/10.1016/j.jsmc.2019.10.002
3. "Pink noise." Merriam-Webster.com Dictionary, Merriam-Webster, Accessed from https://www.merriam-webster.com/dictionary/pink%20noise
4. Kara Mayer Robinson, White Noise, Pink Noise, and Brown Noise: What's the Difference? WebMD. 2022, July 12. Retrieved from https://www.webmd.com/sleep-disorders/pink-noise-sleep#091e9c5e81fe9bc1-1-3
5. Ong JL, Lo JC, Chee NI, Santostasi G, Paller KA, Zee PC, Chee MW. Effects of phase-locked acoustic stimulation during a nap on EEG spectra and declarative memory consolidation. Sleep Med. 2016 Apr;20:88-97. https://doi.org/10.1016/j.sleep.2015.10.016
6. Malkani RG, Zee PC. Brain Stimulation for Improving Sleep and Memory. Sleep Med Clin. 2020;15(1):101-115. https://doi.org/10.1016/j.jsmc.2019.11.002
7. Salfi F, D'Atri A, Tempesta D, De Gennaro L, Ferrara M. Boosting Slow Oscillations during Sleep to Improve Memory Function in Elderly People: A Review of the Literature. Brain Sci. 2020 May 15;10(5):300. https://doi.org/10.3390/brainsci10050300
8. Kuhn M, Wolf E, Maier JG, Mainberger F, Feige B, Schmid H, et al. Sleep recalibrates homeostatic and associative synaptic plasticity in the human cortex. Nat Commun. 2016;7:12455. https://doi.org/10.1038/ncomms12455
9. Schade MM, Mathew GM, Roberts DM, Gartenberg D, Buxton OM. Enhancing Slow Oscillations and Increasing N3 Sleep Proportion with Supervised, Non-Phase-Locked Pink Noise and Other Non-Standard Auditory Stimulation During NREM Sleep. Nat Sci Sleep. 2020;12:411-429. https://doi.org/10.2147/NSS.S243204
10. Dabiri R, Monazzam Esmaielpour MR, Salmani Nodoushan M, Khaneshenas F, Zakerian SA. The effect of auditory stimulation using delta binaural beat for a better sleep and post-sleep mood: A pilot study. Digit Health. 2022;8:20552076221102243. https://doi.org/10.1177/20552076221102243