

# Portable Device for At-Home Auditory Stimulation of Slow Wave Sleep

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# PORTABLE DEVICE FOR AT-HOME AUDITORY STIMULATION OF SLOW WAVE SLEEP

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## Introduction

Sleep is a complex process that plays a fundamental role in restorative brain and body functions [Banks, 2007]. Specifically, the brain activity patterns during non-rapid eye movement (NREM) sleep, such as slow waves (SW) might be the carriers of these restorative effects. Thus, the search of non-invasive and non-pharmacological techniques to improve SW has received attention in the past years. Tononi et al. [Tononi, 2010] compared different non-invasive peripheral stimuli and their effect on SW during NREM sleep, demonstrating that acoustic stimulation (AS) was particularly effective on enhancing SW. Thereafter, several in-lab studies showed that feedback-controlled systems are needed to precisely time the tones with the SW's up-phase to enhance them [Leminen, 2017]. Due to in-lab limitations, single-night studies were performed and therefore AS long-term effects on sleep and health remains unknown. Thus, we have developed a mobile system that enables automated and precise AS of SW sleep.

## Methods

The mobile system combines a comfortable and adjustable headband (Figure 1a) with a 5-channels portable device (Figure 1b). The device integrates a low-power and high quality biosignal recorder, a real-time signal processor, an audio system, a SD card, and a wireless streaming unit (Figure 2), along with safety mechanisms to prevent accidental and intentional misuse.


*Figure 1 (a) Frontal biosignal recording with fixation headband and integrated headphones. (b) Mobile acoustic stimulation device.*

To validate the mobile system functionality and the algorithms' performance, we focus our interest on elderly population (five healthy participants, age range 64-73 years) since ageing is characterized by reduced SW. Subjects underwent one test night without AS, at home, and without supervision.

Biosignal data was acquired using auto-adhesive electrodes (Neuroline 720, Ambu A/S, Ballerup, Denmark). Processing was performed over Fz-A2 electrode, while the remaining four electrodes were recorded for offline analysis (sample frequency: 250Hz). Tones' trigger flags are delivered when NREM sleep and SW conditions are met, and the SW phase detector reaches the 45 degrees phase. Tone presence and volume are controlled by an arousal detection algorithm. Finally, the recorded raw data as well as the online processing outputs are saved on the SD card for offline analysis.

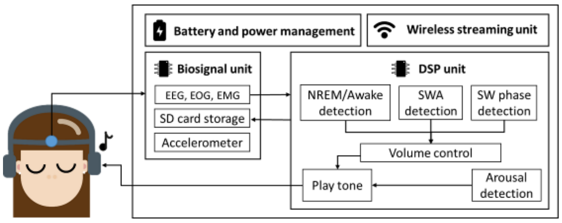


*Figure 2: Mechanism of action of the mobile acoustic stimulation system.*

## Results

Our device considerably decreased the set-up time compared to in-lab methodologies. The obtained biosignal quality and resolution was comparable to lab-based systems with a constant processing delay of 4ms. When evaluated the subjects' recording, real-time SW stimulation during NREM sleep was detected with a 97.98±1% precision, while the online SW phase detection was 50±58 degrees.

## Discussion

The presented mobile device enables high-quality, large-scale SW sleep stimulation with a good ability for online SW activity detection during NREM sleep when compared with visual scoring. The real-time SW phase detection is accurate but precision should be improved. We believe that future automatic adaptation of algorithms' parameters to specific sleep patterns among subject and across nights will improve the overall system performance.

## References

[1] Banks et al, *J. Clin. Sleep Med.*, 519–28, 2007.
[2] Tononi et al, *Medicamundi*, 82–88, 2010.
[3] Leminen et al, SLEEP, Vol. 40, No. 3, 2017.