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REVIEW

Introduction to the Special Issue on 'Effects of Non-Invasive Vagus Nerve Stimulation on Brain and Cognition'

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1 | Introduction

The vagus nerve is well-known for its peripheral, parasympathetic modulation of organs, including the heart and lungs, and for being part of the cholinergic anti-inflammatory system (Yuan and Silberstein 2016). Eighty percent of its fibers are afferent, carrying information from the body to the brain (Yuan and Silberstein 2016). Given its involvement in brain–body communication, stimulating the vagus nerve has the potential to influence the peripheral (autonomic) nervous system, but also alter the activity of the central nervous system and, in turn, behavior (e.g., Burger et al. 2020; Vonck et al. 2014; Yuan and Silberstein 2016). A non-invasive form of vagus nerve stimulation is transcutaneous auricular vagus nerve stimulation (taVNS), which consists of electrically stimulating areas of the ear thought to be innervated by afferent vagal fibers (Peuker and Filler 2002). Advantages of this technique are that it is safe, well-tolerated, and relatively easy to use (Redgrave et al. 2018).

Given its non-invasive nature, taVNS has sparked great interest in both the scientific community and industry. On the one hand, it has been tested as a potential treatment for various psychological and neurological disorders, including depression, pain, and dementia (Austelle et al. 2022; Costa et al. 2024; Naparstek et al. 2023). On the other hand, taVNS has been used for fundamental research as a neuromodulation tool to alter behavior and cognition and investigate the brain–body interaction (Burger et al. 2020; Farmer et al. 2020; Müller et al. 2022; Vonck et al. 2014). This special issue highlights empirical advancements in this fast-growing field, focusing on the effects of taVNS on three domains: cognition, physiology, and the brain.

Despite the growing interest, the mixed evidence in the field has raised doubts about the viability of taVNS as a clinical and research tool (Burger et al. 2020; Farmer et al. 2020). To accelerate its development, the taVNS community has recognized the urgent need to test its working mechanism, select an optimal control condition, identify a reliable biomarker, and the most effective settings of taVNS (e.g., stimulation parameters, ear location, duration, and timing of stimulation) (Badran et al. 2018; Burger et al. 2020; D'Agostini et al. 2023; Farmer et al. 2020; Ludwig et al. 2021). The field has also acknowledged the importance of rigorous scientific research, statistically well-powered studies, and reproducibility (Burger et al. 2020; Farmer et al. 2020). The present special issue contributes to this discussion, presenting empirical studies in both human and animal research that use a rich range of behavioral, physiological, and neuroimaging techniques.

2 | Overview of Special Issue Articles

2.1 | Cognition

Several of the special issue contributions analyze the efficacy of taVNS in enhancing cognitive functions and its potential to mitigate cognitive impairments. Kicking off this special issue, Vabba et al. (2025) report that taVNS reduces individuals' susceptibility to the well-known rubber-hand illusion. Their findings raise the intriguing possibility that vagus nerve stimulation can affect the experience of body ownership, making individuals more sensitive to their real bodily signals and less susceptible to perceptual illusions.

Another excellent contribution is that of Çakır et al. (2025). In a well-designed study, they investigate whether taVNS improves probabilistic reinforcement learning using a simple reward-based probabilistic learning task and computational modeling. They show that taVNS enhances reinforcement learning and that this learning persists in a later extinction phase in which the stimulation was administered but rewards and feedback were absent. This work offers new perspectives for the development of interventions for new habit formation.

The special issue also includes several highly powered and well-designed studies reporting null effects of taVNS on cognitive functions. Luna et al. (2025) report they find no evidence that taVNS mitigates the behavioral vigilance decrements that typically occur with time on task. This finding seems inconsistent with a role for the locus coeruleus-noradrenergic system in modulating sustained attention over long periods of time. Furthermore, D'Agostini et al. (2025) present frequentist and Bayesian analyses indicating that taVNS does not accelerate fear extinction learning, a core mechanism underlying exposure therapy for anxiety disorders. Their findings in humans sharply contrast with evidence in rats that invasive VNS (iVNS) accelerates fear extinction learning and question whether taVNS modulates the vagus nerve and the fear extinction network as iVNS does in animals.

2.2 | Physiology

Four studies included in the special issue test the effects of taVNS on physiological outcomes, along with tackling methodological questions on taVNS. Ludwig et al. (2025) investigate whether short bursts of taVNS improve (emotional) memory and modulate pupil dilation during encoding. While the large majority of studies in the field have compared taVNS with an active sham condition, a merit of this study is that it includes a third, no-stimulation condition, which allows for elucidating whether sham stimulation can lead to similar effects as active taVNS. Importantly, they find that active stimulation, whether real or sham, enhances pupil dilation and memory, providing a new framework to understand the published mixed results.

The scarce knowledge of the most effective taVNS parameters urges a systematic investigation of their effects. To this end, Phillips et al. (2025) conduct a thorough investigation of taVNS intensity and its impact on pupil dilation in a statistically well-powered study. The authors employ an innovative statistical approach, generalized additive mixed modeling, which enables the testing of non-linear effects of taVNS intensity. This work contradicts existing expectations that higher taVNS intensities lead to stronger effects, demonstrating that taVNS modulates pupil size in individuals who select intermediate intensities but not in those selecting high intensities.

Another point of debate in the taVNS research community has been the side of the stimulated ear (left or right). taVNS has traditionally been administered on the left side for safety reasons, given the greater vagal innervation of the right side of the heart (Kreuzer et al. 2012). In a 4-day study, Kaduk et al. (2025) challenge this assumption, assessing the impact of the stimulation side (left vs. right ear) in interaction with the metabolic state on cardiovascular indices derived from the electrocardiogram. Encouragingly, they find that taVNS on both sides decreases heart rate variability independently of the metabolic state and without inducing side effects and affecting heart rate.

Building on knowledge about the important role of the vagus nerve in conveying signals from internal organs to the brain, Salaris and Azevedo (2025) examine whether taVNS affects gastric interoceptive sensations. Although they do not find evidence for an effect of vagus nerve stimulation on gastric interoceptive accuracy, their results reveal that taVNS modulates the subjective appraisal of food, highlighting the potential of taVNS to modulate stomach-brain interactions. This finding opens exciting avenues for future work on treatments for eating disorders or disorders of gut–brain interaction.

2.3 | Brain

Two of the special issue articles examine the effect of taVNS on event-related potentials, addressing the timing of taVNS effects on information processing. Jelinčić et al. (2025) find no effect of taVNS on early evoked potentials (P50 and N1) but do find increased amplitudes of the P2 elicited by auditory and somatosensory stimuli. Ventura-Bort et al. (2025) report that taVNS increases the late positive potential and the old/new effect, electrophysiological correlates of emotional encoding and subsequent memory retrieval, respectively. Together, these studies suggest that taVNS exerts an influence on central information processing, independent of the specific sensory modality.

The nucleus of the solitary tract is the first central relay of vagal afferents, and then sends signals to the cortex via the thalamus. Therefore, stimulating afferent fibers of the vagus nerve with taVNS has the potential to modulate cortical activity. Two of the contributions elucidate the effect of vagal stimulation on the frontal cortex. Sönmez et al. (2025) find that taVNS significantly increases task-related neural activity in the anterior cingulate cortex, a key region involved in conflict monitoring and cognitive control. Combining taVNS with transcranial magnetic stimulation and electromyography, Gerges et al. (2025) show that taVNS modifies the excitability of the primary motor cortex in healthy middle-aged and older adults. Interestingly, this effect depends on the stimulation duration, with effects observed after 60 min of taVNS but not after 30 min. Such duration-specific effects may be important for identifying optimal stimulation parameters and enhancing the therapeutic efficacy of taVNS.

The final contribution takes a translational neuroscience angle. Using PET imaging in healthy rats, Binda et al. (2025) show that acute taVNS induces changes in presynaptic density in subcortical and cortical areas as well as in cerebral glucose metabolism. This study may help pave the way for future clinical applications of taVNS, particularly in central nervous system disorders such as Parkinson's disease in which modulation of presynaptic density and glucose metabolism might have therapeutic benefits.

3 | Conclusions

Taken together, in this special issue, we have explored the effects of taVNS on cognition, physiology, and the brain through well-designed empirical human and animal studies that use a wide range of experimental techniques. The included studies tackle pressing research questions on the working mechanism, biomarkers, and optimal settings of taVNS, but also showcase the investigation of taVNS as a therapeutic intervention in a preclinical development stage. We hope that the examples in this issue demonstrate the tremendous potential of taVNS across fundamental, translational, and clinical research and encourage continued and rigorous research on taVNS.

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Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

Data sharing not applicable to this article as no datasets were generated or analysed during the current study.

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