# Develop your Hawkeye: Enhancing visual abilities with vagus nerve stimulation

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## Introduction

In sports like baseball, object perception and trajectory are paramount for successful task completion. The iris sphincter and dilatory pupil muscles are under the control of the parasympathetic and sympathetic nervous system (DiCriscio et al., 2018), however whether improvements to athlete visual abilities can be produced by autonomic nervous system (ANS) stimulation is still unclear. We used the critical flicker fusion frequency (CFFF) as a measurement of visual perception and transcutaneous auricular vagus nerve stimulation (TaVNS) for the manipulation of the ANS. CFFF has been used frequently for the assessment of cognitive performance (Muth et al., 2023; Rota-Bartelink, 1999) and is an uncomplicated, non-invasive and objective tool to quantify visual cognitive ability. **The aim of this study was therefore to enhance visual perception by influencing vagal activity.**

## Hypotheses

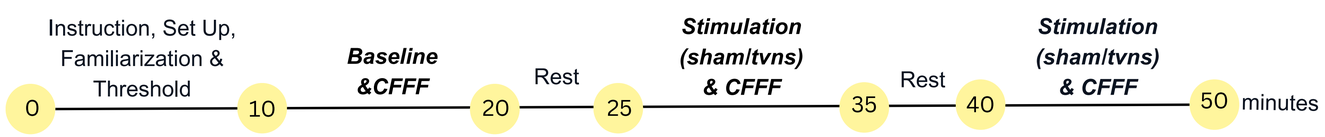
We hypothesised
(I) that taVNS would **increase** HRV and
(II) that cognitive performance on the CFFF task would **increase**.

## Materials and methods

A manually operated flicker device (Scaleo, Esslingen, DE; one LED: 8,000 K) was used in three conditions for 22 healthy participants (age 24.3 ± 2.8, 14 female). Frequencies were steadily increased from 20Hz until the participants perceived the flickering stimulus as constant. Each condition consisted of three flicker trials with short breaks between the trials. The order of the trials was randomised (Baseline, TaVNS, sham). For TaVNS we used a NEMOS device attached to the right ear of the participants and Bittium Faros 2-lead ECGs to record heart-rate variability (HRV).

***Figure 1***

Testing Protocol with Timeline




CFFF Testing Protocol

| | | | | | |
|---|---|---|---|---|---|
| 0s-300s (Min 0-5) | 300s-360s (Min 5-6) CFFF. | 360s-420s (Min 6-7) | 420s-480s (Min 7-8) CFFF | 480s-540s (Min 8-9) | 540s-600s (Min 9-10) CFFF |

## Video and pictures of the experiment

## Results

Analysis with paired samples t-tests revealed no significant differences in CFFF between taVNS and sham conditions (p=.208, d=.177; taVNS: 35.2 Hz, sham: 34.9 Hz), and taVNS showed no clear effect on HRV (p=.420, d=.044; taVNS: 63.5ms, sham: 63.1ms).

***Figure 2***

Mean values for HRV and CFFF across conditions

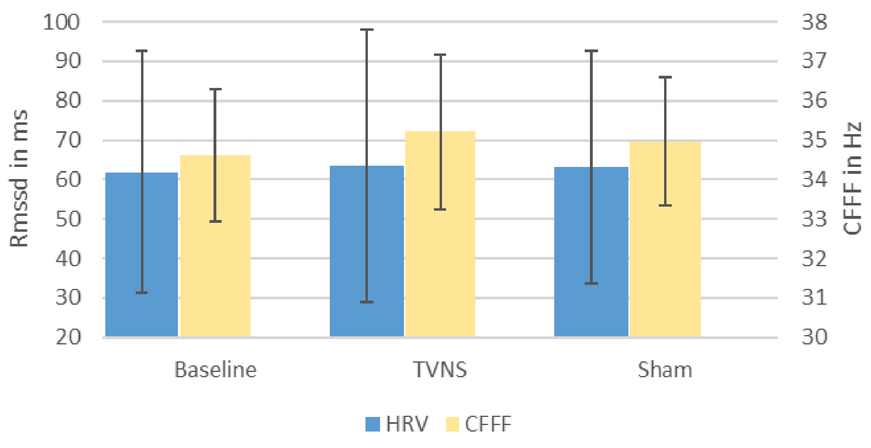
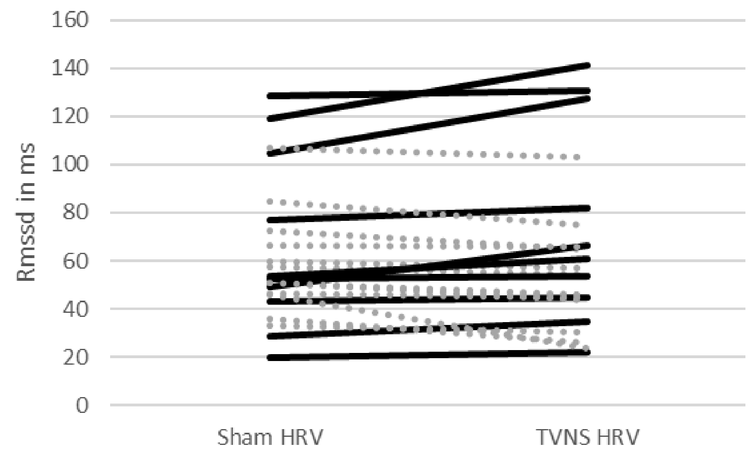



***Figure 3***

HRV Comparison in different conditions




## Discussion

Contrary to our hypothesis the stimulation of the vagus nerve did not result in enhanced performance in CFFF. We therefore opted to analyse the data in three categories: **TaVNS vs. HRV, CFFF vs. HRV, and CFFF perception.** Most studies have used the left ear to stimulate the vagus nerve. The right side used here was suggested to exhibit stronger cardiac effects (Farmer, 2021) but those effects were not found in our sample, as can be seen in Figures 2 & 3. However, carry-over effects between the conditions cannot be ruled out completely. Since CFFF is used as a diagnostic for cognitive functions, and numerous studies have shown a relation between HRV and cognition (Arakaki, 2023; Nicolini, 2024), we assumed a positive correlation between CFFF and HRV (RMSSD). This correlation could not be established with our data set. Whereas previous studies indicated a potential stability of the CFFF measurement against confounding variables (Mewborn, 2015; Muth, 2023; Rocco, 2019; Schipke, 2023), this may not be suited to test our hypothesis. Though the CFFF measurement tool has shown stability against another confounder (vagal stimulation), we propose that enhancing perception is (I) not an entirely cognitive endeavour, and (II) cannot be quantified with the CFFF diagnostic.

## Conclusions

Contrary to our hypotheses, neither did TaVNS increase HRV, nor did it result in improved Flicker task performance. Whereas the stability of the CFFF measurement would allow the tool to be applied in a variety of sport settings, manipulating the vagus nerve ahead of sporting events to enhance visual perception currently does not look to be a likely success story. Whether or not other cognitive abilities can be challenged by TaVNS or whether perception can be enhanced via a different path needs to be investigated in the future.

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