

# Motion sickness mitigation in autonomous vehicles by calming effect through vibration

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**ABSTRACT** – Non-driving related tasks inside an autonomous vehicle is expected to induce motion sickness symptoms. This study explored the vibration from a wearable forearm haptic device to mitigate the symptoms. A total of 20 participants took part in this within-subjects study. They were driven around a pre-determined route in an instrumented car while watching a video. Motion sickness level was evaluated by questionnaires including the participant's heart rate. Results suggested that there was indeed a calming effect through the vibration that helps reducing motion sickness symptoms.

## 1. INTRODUCTION

The advent of autonomous vehicles is proving to be an eventuality rather than a possibility in the current context [1]. Autonomous vehicles' occupants are expected to be more productive while travelling by doing non-driving tasks such as working on a laptop, watching a video, socializing with other occupants, or just doing nothing by observing the road scenery [2]. However, as mentioned by Diels [3], the occupants are likely to suffer from motion sickness symptoms.

Motion sickness is the uncomfortable feeling that anyone can experience which could lead to symptoms such as dizziness, sweating, headaches, drowsiness, and vomiting due to disturbance of their sense of balance by constant motion [4]. Motion sickness is known to be correlated with pulse rate variability (PRV) [5]. PRV represents the activity of two subsystems of our autonomic nervous system; the sympathetic and parasympathetic nervous systems. The sympathetic nervous system is linked with the fight-or-flight response that occurs in response to a stressful condition (i.e. motion sickness), while the parasympathetic nervous system is linked with the rest-and-digest response that occurs in response to help in calming the body down [6].

Patting is a commonly used form of touch used to convey feelings to loved ones or to calm a child down. This leads to the idea of using vibrations to simulate affective touch similar to someone patting the forearm. It can be used to achieve a calming effect on occupants by invoking the parasympathetic nervous system while riding in an autonomous vehicle. Hence, the purpose of this study is to investigate the calming effect on

occupants inside an autonomous vehicle while doing a non-driving related task (watching a video).

## 2. METHODOLOGY

Wizard of Oz autonomous car simulation method that was inspired by Baltodano et al. [7] was used. Based on Karjanto et al. [8] method, the defensive autonomous car driving style was simulated. The experiment was conducted using an instrumented car called Mobility Lab [9] as shown in Figure 1.



Figure 1 Mobility lab.

All participants were subjected to two experimental conditions, with (test-condition) and without (control-condition) the wearable forearm haptic device (see Figure 2). The only task for the participants inside the instrumented car was watching a video. A minimum gap of three days (between the two conditions) was adapted for each participant to reduce motion sickness effects that might have arose from the first condition of the experiment. A fully-counterbalanced order (2! = 2 orders) was applied to balance potential order or learning effects. In order to ensure experimental consistency, all sessions were conducted on the exact same route on the Eindhoven University of Technology terrain. The independent variable was the presence or absence of the device, and the dependent variables were assessments on motion sickness level of the participants using the Motion Sickness Assessment Questionnaire (MSAQ) [10], a multidimensional method of assessing level of motion sickness across four constructs (gastrointestinal, central, peripheral, and sopite), and using PRV analysis.

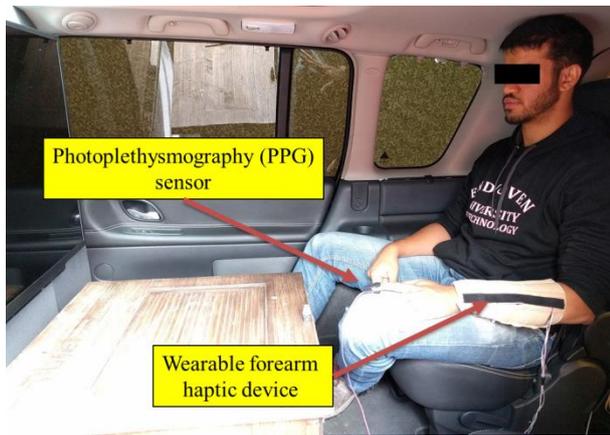


Figure 2 Experiment setup inside mobility lab.

### 3. RESULTS AND DISCUSSION

Figure 3 depicts the average of MSAQ results as a subjective measurement. It could be seen that most participants rated the implementation of the wearable forearm haptic device was indeed worsening the motion sickness level by 1% to 6%. This could be that the way they answered the questionnaire subjectively depended on the individual.

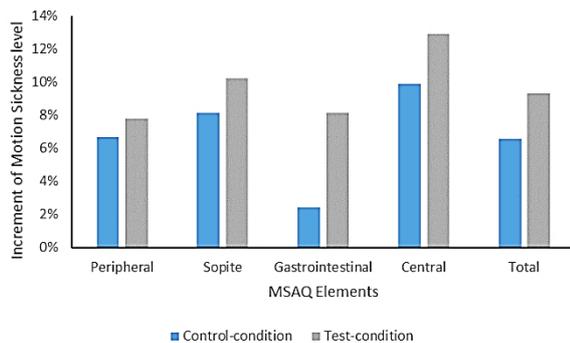


Figure 3 MSAQ results.

On the other hand, the continuous measurement using a PPG sensor shows a reduction in motion sickness level. This result was based on the root-mean-square of successive differences (RMSSD) in the PRV analysis (see Figure 4). An increment in the RMSSD was found to be correlated with the increment in the parasympathetic nervous system [11], indicating a decrease in motion sickness.

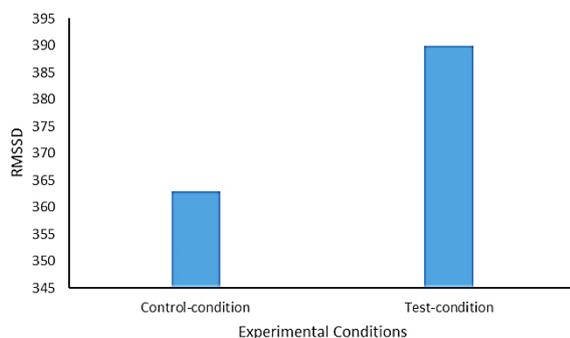


Figure 4 PRV results based on RMSSD.

### 4. CONCLUSION

Overall the results suggest that there was indeed an effect of vibrations on the autonomic nervous system during a simulated autonomous vehicle journey, although the subjective measurement reported otherwise. These results provide an interesting design direction that can be taken by car manufacturers as the autonomous future beckons.

### ACKNOWLEDGEMENT

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