Motion Sickness Inhibition Technology for In-Car Displays and Smart Phones

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Abstract
This experiment evaluates the effectiveness of a lab-developed anti-motion sickness app for smartphones and tablets. Thirty-two participants underwent tests with controlled vehicle dynamics and varied conditions. The app employs a U-shaped reference image and an adaptive video player to reduce discomfort. Data collected using MISC and SSQ demonstrated that the app significantly reduced motion sickness symptoms, especially with smartphones.

Author Keywords
In-car display, smart phone, tablet, motion sickness

1. Introduction
The development of autonomous driving technology has led to the rise of intelligent cockpit systems, significantly increasing the demand and application for displays that provide relevant information and entertainment. As in-car occupants spend more time interacting with these displays, the comfort of viewing this information has become an important research topic. Therefore, effectively reducing motion sickness and visual discomfort has become a crucial issue for developers.

Motion sickness is generally believed to be related to 'sensory conflict,' which arises from the inconsistency or conflict among the information from the inner ear vestibular system, vision, and proprioceptive senses. This conflict leads to symptoms such as dizziness, blurred vision, sweating, stomach discomfort, and vomiting.

Previous research has confirmed that vertical oscillations of linear motion are not the main cause of motion sickness (Cheung & Nakashima, 2006). Instead, low-frequency lateral horizontal linear oscillations and longitudinal and lateral accelerations during driving are related to motion sickness symptoms (Griffin & Newman, 2004; Turner & Griffin, 1999a). Maculewicz et al. (2021) investigated whether auditory displays providing expected road conditions could reduce motion sickness in autonomous vehicle passengers.

In this experiment, we induced motion sickness in test subjects through various vehicle dynamics such as acceleration, deceleration, and steering, as shown in Figure 1. We conducted tests, collected data, and analyzed motion sickness to evaluate the effectiveness of motion sickness inhibition display technology in reducing motion sickness.

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Figure 1. Setup of In-Car Equipment for Motion Sickness Evaluation

2. Experiments and Results

The entire experiment meticulously controls the vehicle's trajectory and speed changes to ensure consistent test scenarios and conditions. The planned path is marked within the test field or used as a control signal. A driving robot manages the vehicle's steering wheel, throttle, and brakes, while high-precision positioning equipment combining GNSS and INS (Inertial Navigation System) provides parameters such as position and speed. The distribution of acceleration in the planned test path and process is illustrated in the diagram. Apart from starting and stopping, the overall test vehicle speed ranges approximately from 16 to 46 km/h. The longitudinal acceleration varies from 3.2 to -5.8 m/s², and the lateral acceleration ranges from 2.6 to -3.3 m/s². Each test includes acceleration events, braking events, and left and right turns, encompassing 90-degree turns, 180-degree U-turns, and lane changes, as shown in Figure 2.

In this experiment, smartphones and tablets were equipped with an anti-motion sickness app developed by our lab. This app uses two anti-motion sickness technologies: a U-shaped reference image that changes with the vehicle's acceleration and a video player that adjusts the main window's position according to the vehicle's movements. Test subjects watched designated videos during the testing process, allowing us to observe the app's effectiveness in suppressing motion sickness and reducing discomfort from viewing displays in the vehicle.

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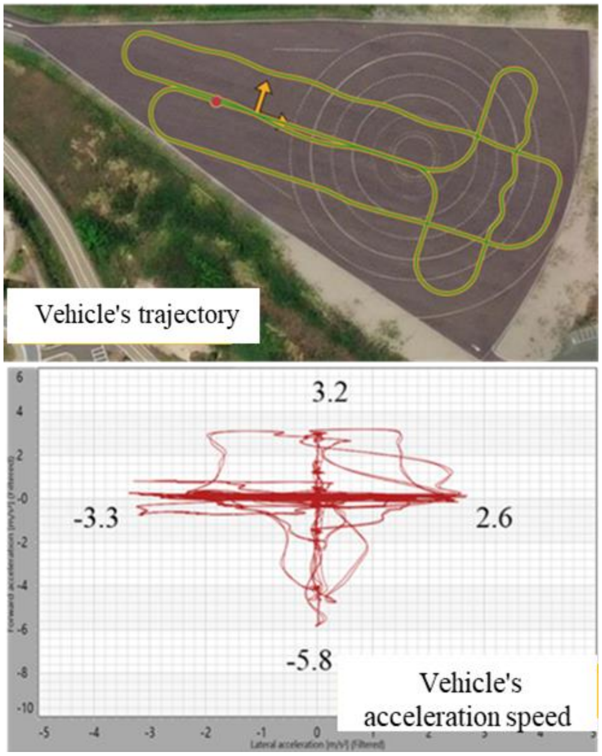

Figure 2. The planned path and acceleration in the test

We collected questionnaire scores from 32 participants, with MSSQ scores for motion sickness susceptibility ranging from approximately 5.1 to 38.3, covering the 20th to 90th percentiles of motion sickness susceptibility. During the test, subjects kept their eyes on the display. Participants underwent three types of tests: Baseline (Baseline_0), Control Test without motion sickness inhibition (Control Test_1), and Target Test with motion sickness inhibition (Target Test_2). There were two testing targets: tablet and smartphone. Therefore, each participant performed the Baseline Test (Test_0_0), Tablet Control Test (Test_1_0), Tablet Target Test (Test_1_1), Smartphone Control Test (Test_2_0), and Smartphone Target Test (Test_2_1).

The vehicle followed specific conditions such as speed trajectory, with the Misery Scale (MISC) questionnaire administered once every minute. After each test, participants completed the Simulator Sickness Questionnaire (SSQ). After sufficient rest, the next trial was conducted. Tests were performed in a randomized order. Finally, an Analysis of Variance (ANOVA) was conducted on the overall sample data. By analyzing the variance among the sample data, it was inferred whether there were significant differences among the groups. If the statistics were significantly different, then $p < 0.05$ (indicating the probability of difference in the sample data mean, which is the probability of false detection during the test).

The average scores and standard deviations of the SSQ for 32 participants under 5 different driving test conditions are shown in Table 1, and the distribution charts of the SSQ scores under the 5 driving test conditions are shown in Figure 3. The experimental results show that using motion sickness inhibition function on both smartphones and tablets results in lower motion sickness scores compared to not using the function, indicating that the function has an inhibitory effect on motion sickness.

SSQ	Nausea	Oculomotor	Disorientation	Total
00	14.90(17.46)	10.43(10.50)	10.87(15.71)	13.90(14.47)
10	26.53(24.44)	26.77(19.73)	30.87(39.17)	31.91(27.77)
11	21.47(18.94)	22.99(16.95)	22.18(27.12)	25.72(20.62)
20	40.24(37.14)	38.14(30.83)	43.93(54.33)	46.40(41.87)
21	31.61(33.97)	31.28(29.44)	35.67(48.87)	37.40(39.01)

Table 1. "Mean and Standard Deviation of SSQ Total Score and Subscale Scores (n=32)

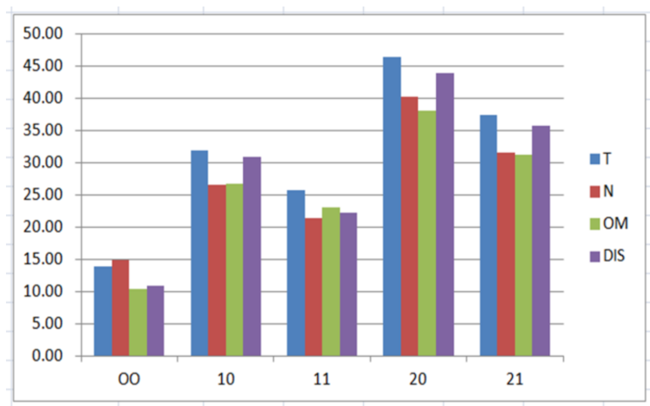

Figure 3. Distribution of SSQ Scores Under 5 Different Driving Test Conditions

The results of the 2 x 2 factorial repeated measures ANOVA on the change scores of total SSQ and subscale scores (Nausea, Oculomotor, Disorientation) are detailed in Table 2. In the four analyses, the interaction effect between the two factors was not significant. This result indicates that the effect of the device on the gSSQ scores was not influenced by the inhibition effect, and the effect of the inhibition was not affected by the use of different devices. Therefore, the main effects of the device and inhibition should be observed directly to determine whether they significantly influence gSSQ. The main effect of the device showed significant differences in the four analyses of gSSQT, gSSQN, gSSQOM, and gSSQDIS. This result indicates that the test condition using smartphones caused more noticeable motion sickness compared to tablets. Additionally, the benefit of the motion-sickness-inhibition function showed significant differences in all four analyses, demonstrating that this anti-motion sickness technology tends to reduce the severity of motion sickness when using a smartphone or tablet in the car.

		F	df	df(error)	p
gSSQT	interaction	0.341	1	31	0.564
	device	11.262	1	31	0.002*
	inhibition	14.313	1	31	0.001*
gSSQN	interaction	0.672	1	31	0.419
	device	11.654	1	31	0.002*
	inhibition	2.794	1	31	0.007*
gSSQOM	interaction	0.640	1	31	0.43
	device	11.394	1	31	0.002*
	inhibition	9.010	1	31	0.005*
gSSQDIS	interaction	0.005	1	31	0.945
	device	6.691	1	31	0.015*
	inhibition	11.559	1	31	0.002*

Table 2. "Two-Factor Repeated Measures ANOVA Table for gSSQT, gSSQN, gSSQOM, gSSQDIS

Statistical analysis of available MISC scores was used to understand the real-time differences in the severity of motion sickness among various test conditions during driving. The analysis methods included a two-factor repeated measures ANOVA (5 × 12), a single-factor repeated measures ANOVA for Factor 1 (driving test conditions) with conditions 0_0 (control no reading), 1_0 (tablet), 1_1 (tablet inhibition), 2_0 (smartphone), and 2_1 (smartphone inhibition), and a single-factor repeated measures ANOVA for Factor 2 (driving time) with 12 driving intervals from the 1st minute to the 12th minute. Descriptive statistical analysis revealed the mean MISC scores over 12 minutes of driving for 20 participants under 5 different driving test conditions, as shown in the line chart in Figure 4.

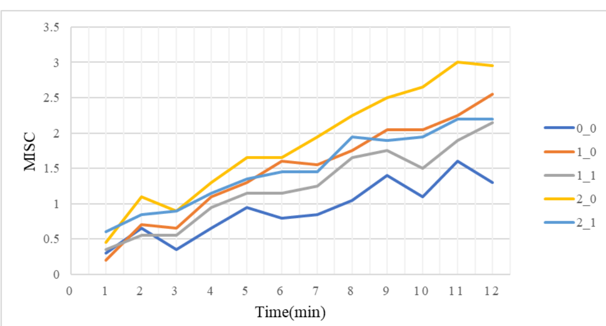

Figure 4. Line Chart of MISC Scores Over 12 Minutes of Driving Under Five Different Test Conditions

Analyzing the interaction between Factor 1 and Factor 2 [F(44, 836) = 2.331, p = 0.000*] shows that the influence of driving test conditions on MISC varies across different driving periods. Therefore, it is necessary to conduct analyses of simple main effects for individual factors, as shown in Table 3.

Under all test conditions, Factor 2 (driving time) has a significant effect, with the highest scores appearing in the 11th or 12th minute, significantly higher than the MISC scores in the first 10 minutes. In the first 8 minutes, for Factor 1 (driving test conditions), the highest MISC scores were observed in 2_0, followed by 2_1, then 1_0, and 1_1, all significantly higher than 0_0. This result indicates that using a tablet or smartphone, regardless of the motion-sickness-inhibition function, led to a more pronounced degree of motion sickness compared to not using a tablet or smartphone. However, within the first 8 minutes, the motion-sickness-inhibition function did not statistically significantly reduce motion sickness (p>0.05).

Notably, starting at the 9th minute, the MISC score for the smartphone condition with the motion-sickness-inhibition function enabled (2_1) was significantly lower (p=0.004) than the smartphone condition without the motion-sickness-inhibition function (2_0). This result clearly demonstrates the benefit of the motion-sickness-inhibition function in reducing motion sickness when using a smartphone. From the 10th minute onwards, the MISC score for the smartphone condition with the motion-sickness-inhibition function enabled (2_1) was significantly lower (p=0.007) than the smartphone condition without the motion-sickness-inhibition function (2_0). Similarly, the MISC score for the tablet condition with the motion-sickness-inhibition function enabled (1_1) was significantly lower (p=0.017) than the tablet condition without the motion-sickness-inhibition function (1_0). This demonstrates the benefit of the motion-sickness-inhibition function in reducing motion sickness for both smartphones and tablets.

This result shows that enabling the motion-sickness-inhibition function when using a smartphone or tablet during driving can significantly reduce the severity of motion sickness per minute in the later stages of driving, following a marked increase in motion sickness severity in the early stages. It is speculated that smartphones are more likely to cause motion sickness compared to tablets, thus the significant inhibition effect can be observed more quickly.

8^{th}minute	0_0	1_0	1_1	2_0
1_0	0.003*	-		
1_1	0.024*	0.606	-	
2_0	0.000*	0.106	0.083	-
2_1	0.000*	0.447	0.230	0.209

9^{th}minute	0_0	1_0	1_1	2_0
1_0	0.033*	-		
1_1	0.330	0.330	-	
2_0	0.004*	0.131	0.021*	-
2_1	0.144	0.591	0.603	0.004*

10^{th}minute	0_0	1_0	1_1	2_0
1_0	0.000*	-		
1_1	0.104	0.017*	-	
2_0	0.000*	0.069	0.005*	-
2_1	0.007*	0.733	0.186	0.007*

Table 3. MISC Scores Among Five Different Driving Test Conditions(the 8^{th}, 9^{th}, 10^{th} minutes)

3. Conclusion

The study assessed the anti-motion sickness app's effectiveness, utilizing a U-shaped reference image and an adaptive video player. Thirty-two participants experienced controlled vehicle dynamics under multiple conditions, providing data via MISC and SSQ. Results indicated that smartphones induced more pronounced motion sickness symptoms compared to tablets. However, the app significantly reduced symptoms for both devices, as shown by ANOVA analysis. The two-factor repeated measures ANOVA showed no significant interaction effect between device type and motion-sickness-inhibition function, indicating that the app's effectiveness was consistent across different devices. Notably, the app's motion-sickness-inhibition function was particularly effective from the 9th minute for smartphones and the 10th minute for tablets. The significant reduction in MISC scores demonstrates the app's ability to mitigate motion sickness severity during vehicular use, especially in the later stages of driving. This study concludes that the app enhances passenger comfort by effectively reducing motion sickness symptoms while using mobile devices in a vehicle.

4. References

[1] Cheung, B., & Nakashima, A. (2006). A review on the effects of frequency of oscillation on motion sickness. 29.
[2] Griffin, M. J., & Newman, M. M. (2004). An experimental study of low-frequency motion in cars. Proceedings of the Institution of Mechanical Engineers, Part D: Journal of Automobile Engineering, 218(11), 1231-1238..
[3] Golding, J. F., Bles, W., Bos, J. E., Haynes, T., & Gresty, M. A. (2003). Motion sickness and tilts of the inertial force environment: Active suspension systems vs. Active passengers. Aviat Space Environ Med, 74(3), 220-227.
[4] Turner, M., & Griffin, M. J. (1999a). Motion sickness in public road transport: Passenger behavior and susceptibility. Ergonomics, 42(3), 444-461.
[5] Turner, M., & Griffin, M. J. (1999b). Motion sickness in public road transport: The effect of driver, route and vehicle. Ergonomics, 42(12), 1646-1664
[6] Maculewicz, J., Larsson, P., & Fagerlönn, J. (2021). Intuitive and subtle motion-anticipatory auditory cues reduce motion sickness in self-driving cars. International journal of human factors and ergonomics, 8(4), 370-392.