DESIGN AND DEVELOPMENT OF A WEARABLE ANTI-MOTION SICKNESS DEVICE FOR AUTONOMOUS VEHICLE RIDING EXPERIENCE

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DECLARATION

I declare that this project report entitled "Design and Development of a Wearable Anti-Motion Sickness Device for Autonomous Vehicle Riding Experience" is the result of my own work except as cited in the references.

Signature	:	....
Name	:	....
Date	:	....

APPROVAL

I hereby declare that I have read this project report and in my opinion this report is sufficient in terms of scope and quality for the award of the degree of Bachelor of Mechanical Engineering (Design).

Signature : ....

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ABSTRACT

Motion sickness is inevitable and affects human in many situations mainly during travelling on a moving vehicle such as car, plane, boat, and train. In an autonomous vehicle, there is certainly going to have a high probability of motion sickness to occur due to the passengers might want to do non-driving related tasks such as reading and watching videos, which is among of the many reasons why motion sickness happens. Therefore, it is getting important to quickly identify the best treatment approach because the most effective treatment currently is by taking medication, which is not good because it gives side effects such as felling sleepy and tired. The purpose of this study is to develop a wearable anti-motion sickness device that can alleviate the symptoms of motion sickness such as nausea and dizziness. Substantial statistical analysis was performed after the fabrication process and on-road user testing. Evaluation was based on the Motion Sickness Assessment Questionnaire (MSAQ) scoring from four participants with two conditions tested, which is wearing and not wearing the wearable device while reading in a moving car. The responses obtained from the MSAQ scores were analyzed using the Wilcoxon Signed Ranked Tests. It was found that the results proven that there is an insignificant difference between pre-test and post-test with a condition of wearing the anti-motion sickness device when comparing the median and p-values. Meanwhile, in condition of not wearing the anti-motion sickness device, the data shows a significant difference between pre-test and post-test. This means that the participants experience little or no motion sickness when wearing the device as opposed to not wearing the device.

ABSTRAK

'Motion sickness' tidak dapat dielakkan dan mempengaruhi manusia dalam banyak keadaan terutamanya semasa melancong dengan kenderaan seperti kereta, kapal terbang, kapal, dan kereta api. Di dalam kenderaan 'autonomous', kebarangkalian 'motion sickness' berlaku adalah besar kerana penumpang ingin melakukan aktiviti-aktiviti seperti membaca dan menonton video, yang merupakan antara sebab mengapa 'motion sickness' berlaku. Oleh itu, adalah penting untuk mengenal pasti pendekatan rawatan terbaik dengan cepat kerana rawatan yang paling berkesan ketika ini adalah dengan mengambil ubat, yang mana tidak elok kerana memberikan kesan sampingan seperti mengantuk dan letih. Tujuan kajian ini adalah untuk membuat alat anti 'motion sickness' yang boleh dipakai dan mampu meringankan gejala 'motion sickness' seperti mual dan pening. Analisis statistik yang ketara telah dilakukan setelah proses fabrikasi dan ujian pengguna di jalan raya. Penilaian dibuat berdasarkan skor Motion Sickness Assessment Questionnaire (MSAQ) diperolehi dari empat peserta dengan dua keadaan diuji, iaitu memakai dan tidak memakai alat anti 'motion sickness' ketika membaca di dalam kereta yang bergerak. Tindak balas yang diperoleh dari skor MSAQ dianalisis menggunakan Wilcoxon Signed Rank Test. Hasil kajian membuktikan bahawa terdapat perbezaan yang tidak ketara antara sebelum dan selepas ujian dalam keadaan memakai alat tersebut jika membandingkan nilai median dan nilai p. Sementara itu, dalam keadaan tidak memakai alat tersebut pula, data menunjukkan perbezaan yang ketara antara ujian pra dan ujian pasca. Ini bermaksud bahawa para peserta mengalami sedikit atau tiada 'motion sickness' ketika memakai alat tersebut berbanding dengan tidak memakai alat tersebut.

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3D	-	Three dimensional
ABS	-	Acrylonitrile Butadiene Styrene
ADAS	-	Advanced Driver Assistance System
CAD	-	Computer Aided Design
FDM	-	Fused Deposition Modelling
HOQ	-	House of Quality
MSAQ	-	Motion Sickness Assessment Questionnaire
MSSQ	-	Motion Sickness Susceptibility Questionnaire
NDRT	-	Non-driving related tasks
PDS	-	Product Design Specification
PSM I	-	Projek Sarjana Muda I
PSM II	-	Projek Sarjana Muda II
QFD	-	Quality Function Deployment
SPSS	-	Statistical Package for the Social Sciences
STL	-	Standard Triangle Language
TPU	-	Thermoplastic Polyurethane

CHAPTER 1

INTRODUCTION

1.1 Background

Motion sickness is a sense of unwellness produced by movement, particularly during voyaging and augmented reality immersion (Zhang et al., 2016). The symptoms of motion sickness include autonomic reactions and sopite syndromes such as nausea, vomiting, pallor, sweating, hypersalivation, stomach awareness, drowsiness, lethargy, and persistent fatigue (Lackner, 2014). Motion sickness is anticipated to be an obstacle in the work of autonomous vehicles on the road. Therefore, this investigation means to build up a wearable gadget to relieve motion sickness from building as a result of tri-axial accelerations during autonomous driving.

Although the reason for why motion sickness happens is still inconclusive, one theory is the most widely accepted, which is the sensory conflict theory by Reason and Brand (1975). Reason and Brand (1975) expressed that motion sickness is a self-delivered maladaptation phenomenon that happens because of conflict between vestibular system (centre of balance), visual input (what the eyes perceive), and proprioceptive sensors (sense of self-movement and body position). For example, during a voyage in a boat, the eyes indicate to the brain that there is no self-motion. Still, the vestibular system does indicate the person is moving, which then causes motion sickness due to the conflict. However, another theory by Gary and Thomas (1991) argued the sensory conflict theory and proposed a theory that claims the prolonged postural instability as the cause of motion sickness.

There are various treatments for reducing motion sickness, which includes changing posture, medication, wearables like a magnet attached to wrists (e.g., a bracelet), ingestion of food such as ginger root, and among the latest of all is the motion sickness glasses (Wright and Picot, 2016). The design and development of this project will focus on the wearable glasses and its effectiveness to reduce motion sickness. Furthermore, recently a widely known automaker company Citroën presented the first glasses to eliminate motion sickness, which is called Seetroën (Jeannin, 2020). Seetroën is formed by the glass and four colourised levels of fluid fused on the rings. During use, the fluid in the rings moves as indicated by movement. Within the peripheral view, the eyes will get similar data as the inner ear thus preventing motion sickness as there are no different perceptions of balance and sight (Jeannin et al., 2016).

This research is keen on finding treatment approaches to ensure future travelling users, inside a completely autonomous vehicle, to perform their favoured non-driving related tasks joyfully. Such tasks are visual amusement through reading news, viewing a film, or planning for or mirroring the business day (Pfleging and Schmidt, 2015). Simultaneously, users will be better-informed concerning the vehicle's route to decrease the event of a sensory conflict that adds to the improvement of motion sickness.

1.2 Problem Statement

An autonomous car is a vehicle programmed to detect the surroundings while moving and operating without human interaction. There are six (6) levels of automation according to the standard released by the Society of Automotive Engineers (SAE) (Shuttleworth, 2019). As the levels increase, the degree of the vehicle's autonomy concerning activity control also increases. At SAE Level 0, the vehicle does not influence its activity, and the human driver does the driving. At SAE Level 1, 2, and 3, the vehicle's advanced driver assistance system (ADAS) can assist the driver with either steering or accelerate and braking with minor involvement of the human driver. At SAE Level 4, the vehicle's ADAS can play out every single driving errand freely in specific conditions in which human attention is not required. Finally, SAE Level 5 is the highest and portrays an entirely autonomous vehicle. The contrast between SAE Level 5 and Level 4 is that for the prior, the vehicles can navigate and handle various kind of driving modes, distinctive driving conditions and roads autonomously without the requirement for human driver communication (TWI Ltd, 2020).

By having an utterly autonomous vehicle, a human driver/user just chooses the last goal, and the robotised vehicle will deal with all the driving assignments and choices. Hence, human drivers have the opportunity to do their desired activities and become travellers or inhabitants. Initially, autonomous vehicles started to be developed to expand the driver's comfort and efficiency during transportation (Diels, 2014). However, taking part in a non-driving related task will cause the passengers of the autonomous vehicle to experience lower awareness in terms of the intentions of the vehicle concerning the route. Therefore, they will be incapable of foreseeing forthcoming occasions. In relation to that, those non-driving related tasks increase the chance of the passenger to get motion sickness.

An autonomous vehicle must allow its users to perform non-driving related tasks without experiencing motion sickness. This is because of the most crucial factor in maximising the comfort of the passengers besides maintaining the value of the autonomous vehicle (Litman, 2019). Currently, the treatments for reducing motion sickness is not entirely clear. For example, medication helps the users in some cases, but it also gives side effects such as sleepy and feeling drowsy (Wright and Picot, 2016). Besides that, previous research by Murdin et al. (2011) states that habituation can prevent motion sickness, but this method takes a long time to be effective. Lately, Citroën commercialised their motion sickness glasses, which they claim can remove motion sickness altogether. Thus, this research will investigate whether motion sickness glasses works or not and shed understanding using an engineering design approach. On the other hand, this research will prove whether the first theory, as stated in the background which is the sensory conflict or the second theory, postural instability, or maybe both are the cause of the motion sickness.

1.3 Objectives

The objectives of this project are as follows:

1. To select the best prototype using an engineering design approach to prevent motion sickness in autonomous driving when engaging in a selected non-driving related task (i.e., reading a book, watching a video, or writing using a handheld device).
2. To fabricate a working prototype of a wearable device to prevent motion sickness using 3D printing or other suitable processes.
3. To determine the effectiveness of the proposed motion sickness wearable device by analysing the level of motion sickness using subjective measurement done on an on-road test.

1.4 Scope of Project

The scopes of this project are:

1. Only the average and most susceptible person to the motion sickness were asked to test the selected prototype. Motion sickness Susceptibility Questionnaire (MSSQ) referred from Golding (2006) were handed out before planning for the test to know the level of motion sickness of the human participants.

2. Design and fabrication were focused only on motion sickness glasses. However, other forms of the wearable device were also considered in the literature review.

1.5 General Methodology

The actions that need to be carried out to achieve the objectives in this project are:

1. Literature review

Journals, patents, conferences, books, websites, or any materials regarding the project will be reviewed.

2. Engineering design

The engineering design approach will be conducted, such as engineering sketches, morphological charts, house of quality, and other related methods.

3. Fabrication

Based on the design, the fabrication process will be made to develop the product by using 3D printing or any suitable process.

4. User test

After the prototype has been developed, there is a test to ensure the effectiveness of the glasses, whether it can eliminate motion sickness or not. The volunteers will sit at the back seat of a vehicle while performing and not performing non-driving related tasks. At the same time, the time and speed of each test will remain constant if possible to ensure that the level of motion sickness input to the user will be identical.

5. Analysis

Statistical analysis will be presented on the effectiveness of the motion sickness glasses device.

6. Report writing

A report on this study will be written at the end of the project.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Many theories have been proposed to explain what causes motion sickness in an autonomous vehicle. Although the literature covers a wide variety of such theories, this review will focus on themes which repeatedly emerge throughout the literature review. These themes are: how autonomous vehicle will work, theories of how motion sickness occurs, and possible treatments of motion sickness. Although the literature presents these themes in a variety of contexts, this particular work will primarily focus on the development of a wearable device to cure motion sickness.

2.2 Autonomous Vehicle

An autonomous vehicle, or also known as a self-driving vehicle, is a vehicle that equipped for detecting its condition and working without human intervention. A human occupant is not required to take action for the movement of the vehicle, nor is a human occupant required to be available in the vehicle by any means (Synopsys, 2020). However, there are different levels of automation, and in this review, the taxonomy and standard referred to are by the Society of Automotive Engineers (SAE) (Shuttleworth, 2019).

2.2.1 Level of automation

The Society of Automotive Engineers (SAE) at present characterizes six (6) levels of driving automation starting from Level 0 (completely manual) to Level 5 (completely selfsufficient). These levels have been embraced by the U.S. Division of Transportation (Synopsys, 2020). Shuttleworth (2019) provides the SAE J3016 autonomous-driving taxonomy, where various levels of autonomous or self-driving technology were defined as follows:

- Level 0 (No Automation). Manual control. The human driver operates every single driving tasks (steering, acceleration, braking, etc.).
- Level 1 (Driver Assistance). The vehicle includes an autonomous system. For instance, the vehicle monitors its speed through the cruise control system.
- Level 2 (Partial Automation). The vehicle can perform steering and speeding up tasks. The human driver still monitors all tasks and can take control whenever.
- Level 3 (Conditional Automation). Environmental detection capabilities. The vehicle can perform most of the driving tasks; however, human override is still required in certain situations.
- Level 4 (High Automation). The vehicle performs all driving tasks under specific circumstances. Geofencing is required. Human override is still an alternative.
- Level 5 (Full Automation). The vehicle performs all driving tasks under all conditions. Zero human attention or interaction is required.

Based on the SAE taxonomy, from Level 0 to 2, the human driver needs to monitor the road. While from SAE Level 3 to 5, the autonomous driving system monitors the road. Corresponding to the different levels of driving automation, especially SAE Level 3 and above, there might be changes such as seating posture or participating in non-driving tasks by the passenger (Wada, 2017). Non-driving related task is defined as performing activities other than driving-related tasks (Pfleging and Schmidt, 2015). Since human drivers are no longer required to drive or monitor the road, they are free to indulge in their preferred activities inside the vehicle while travelling.

2.2.2 Activities inside an autonomous vehicle

Autonomous vehicles can drastically change how we utilize and interact with our vehicles. Logically, it is assumed that drivers will take part in non-driving activities in autonomous driving and, correspondingly, future vehicle design may look drastically changed (Diels, 2014). Furthermore, Karjanto et al. (2018) state that around 50-60% of the respondents in their research envisioned themselves doing non-driving tasks, for example, viewing a film, communicating with other travellers, working, reading, and sleeping to occupy in their journey. However, the question is what people would do as opposed to driving in a completely self-driving vehicle. According to the opinion surveyed by Schoettle and Sivak (2014), the results are shown in Table 2.1 based on the responses from six (6) different countries.

Table 2.1: Percentages (%) of responses to the question "If you were to ride in a completely self-driving vehicle, what do you think you would use the extra time doing instead of driving?" (Source: Schoettle and Sivak (2014))

Response	The U.S.	China	India	Japan	The U.K.	Australia
Watch the road even though I would not be driving	46.1	37.2	33.3	49.5	57.1	55.0
Read	14.0	10.8	11.1	8.4	9.9	8.3
Text or talk with friends/family	12.7	21.5	16.3	11.0	7.1	10.1
Sleep	8.8	11.2	5.1	18.9	9.4	9.0
Watch movies/TV	7.8	11.7	13.4	9.2	5.4	7.3
Work	6.2	5.6	17.7	1.0	6.4	6.5
Play games	2.6	1.4	2.3	1.8	2.5	2.5
Other	1.8	0.7	0.8	0.3	2.2	1.3

However, in this era of continuous change, there are a lot of advancements in science and technology specifically to autonomous technology. Therefore, people's mindset has changed, and the perspective of what they think they would do in an autonomous vehicle is different. According to the research done by Ali (2020) with 179 respondents, the non-driving related tasks envisioned to happen in a completely mechanized vehicle were general phone use, music or radio, texting, eat or drink, and reading as shown in Figure 2.1.

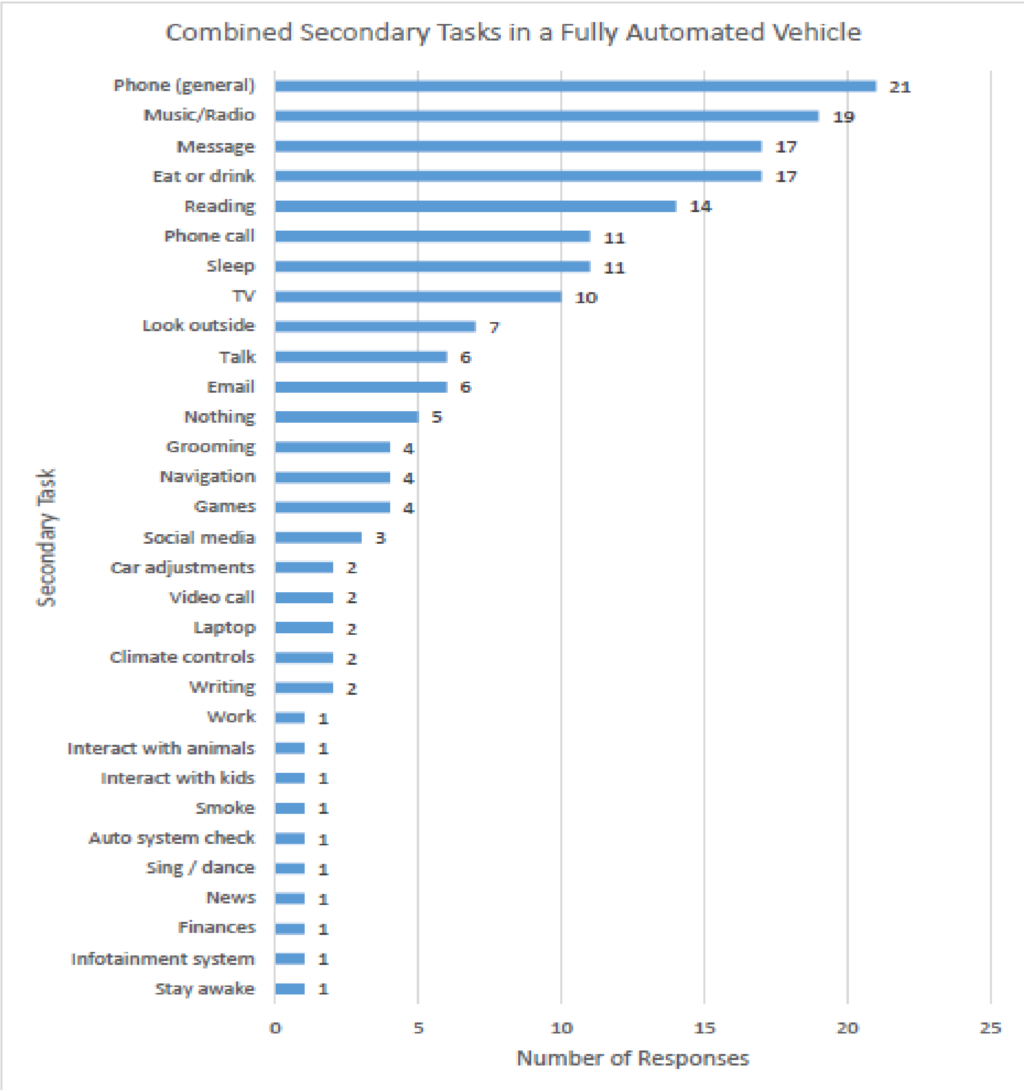

Figure 2.1: Number of responses regarding the non-driving related tasks participants imagined to do in a conditionally autonomous vehicle. (Source: Ali (2020))

2.2.3 Synopsis

By referring to Figure 2.1, Ali (2020) states that his research demonstrated calculated results where there is no impact on motion sickness on either viewing the street or chatting on the telephone. Another assumption by Ali (2020) was that reading and watching video shows the highest and lowest impact respectively on the motion sickness of all other activities that have adverse effects on motion sickness such as messaging, working, and playing games. Despite having the benefits of doing non-driving related tasks in an autonomous vehicle, it is imagined that some of the activities are additionally known to intensify the occurrence and seriousness of motion sickness (Diels, 2014).

Besides that, to relate motion sickness with an autonomous vehicle, motion sickness vigorously relies upon how the vehicle is driven (Diels, 2014). By having an autonomous vehicle, the driving manner can be negligible and assumed that road safety would increase as human factors are the common cause of an accident. However, motion sickness is a potential concern in light of the fact that the driver is no longer in charge, they may not look ahead, and they may take part in non-driving related tasks, where motion sickness could increase, thus resulting as the disadvantage of self-driving vehicles (Paul, 2016).

2.3 Motion Sickness

Motion sickness is a feeling of unwellness resulted by movement, particularly during voyaging and augmented reality immersion (Zhang et al., 2016). Motion sickness can happen during exposure to physical movement, visual movement, and virtual movement, and just those without a working vestibular system are completely insusceptible for example, people who have Meniere’s syndrome (Lackner, 2014). Meniere’s syndrome is a disorder of the internal ear portrayed by both cochlear and vestibular dysfunction, characterized by the symptom complex of fluctuating sensorineural hearing loss, vertigo, tinnitus, and aural