Tactile Feedback Within Virtual Reality Training: an immersive study for motorcycle training

By

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A thesis submitted to the Faculty of Graduate and Postdoctoral Affairs in partial fulfillment of the requirements for the degree of

Master of Design

in the

School of Industrial Design

Carleton University
Ottawa, Ontario

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ABSTRACT
Over 750 million motorcycles are estimated to be on roads, of which 380,000 annual deaths are of motorcyclists. Motorcyclists are affiliated with higher fatality rates than drivers as motorcycles are more physically demanding due to their innate design. Unlike most cars today, motorcycles are manual and require its rider to manage its controls intuitively. This is where training can be seen as vital to the safety of the rider. Although motorcycle training programs (MTPs) exist, these programs are seen to be short and do not allow their trainees enough time to practice. As virtual reality (VR) is being used to train professionals in numerous industries, it may be a potential training tool for novice trainees. The research investigates VR as a possible supplementary tool for learning the operations of operating a motorcycle. Specific levels of tactile feedback have been seen to increase performance of specific skill in VR, although research on the effects of tactile feedback within the domain of motorcycle training and VR have not yet been investigated. To investigate the addition of tactile feedback on operator performance in VR, three groups of participants were trained on three different VR simulators with each differing in levels of tactile feedback. The results show that low levels of tactile feedback contribute to better performance in motorcycle training, while higher levels of tactile feedback increase immersiveness, encouraging participants to treat the virtual reality simulation more as a training tool and less as a game.

Keywords: virtual reality, tactile feedback, cognitive load, motorcycle training
ACKNOWLEDGEMENTS

Thank you to both my parents who always encouraged me to strive for the best and to believe in myself. Since the beginning, you have both provided me with everything I need to succeed but most importantly with your love and care. Your efforts will always be cherished with me. Thank you.

A special thank you to my supervisors Stephen Field and Robert Teather for providing me with guidance and support throughout this project. Rob thank you for all your support with the technical aspects of the study involving VR. Steve, I know how busy you were this year, yet you still took on the task of being my supervisor. You really care about your students, thank you. As much as we may not agree with each other, we always find a way to make amends and to help each other grow. Thank you for being my supervisor, my friend and for seeing potential in me.

Daren, thank you for all your support as a research assistant and as a friend throughout this journey. I know how busy you were with your own thesis, work and yet you still found time to help me with mine.

Thank you to Farzu for always being there for me, believing in me, supporting my every step and for helping edit my work. Thank you to Harv for taking the time to assist me with many parts of this journey and for all the moral support. Farzu and Harv you both always give me the confidence and the strength I need to pull through any obstacles I face, thank you.
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PREFACE

In 2020 the Asia Pacific market for motorcycles reached 110 billion US dollars (Fortune Business Insights, 2020). Though this region is growing the largest, the use of motorcycles globally increases; in the United States alone, the annual growth rate of 7.93%, resulting in a projected market volume of 159,792,000 dollars by 2026 (Statista, 2021). In 2016 Canadian motorcycle annual sales were 59,951, by 2020 sales have reached over 66,000 units (Canadian Annual Motorcycle, Scooter and OHV Industry Statistics Report Summary 2020). Motorcycle use is increasing globally and with e-bikes being introduced to the existing market, the adoption of two-wheeler transportation can be enticing to many global regions due to is cost effective power solution.

In 2018 I had the opportunity to visit my home country, India, where I got a chance to see firsthand the need of two-wheel transportation. In many areas India is highly congested, the motorcycle is the number one mode of transportation due to their inherit ability to be maneuvered through traffic. The use of motorcycles goes beyond transportation, farmers in India use motorcycles to plow and till their crops as it is seen as a cost-effective solution when compared to tractors. Because the motorcycle’s components are exposed, the ingenuity of Indians have transformed its power source to run their small local businesses. From milling wheat and extracting sugar cane juice to pumping water and powering construction site supply elevators, the motorcycle provides a solution to many of India’s economic needs.

The knowledge I gained in the time I spent in India and being an industrial designer made me want to contribute to this industry even more, although I did not know how. I knew that to begin my exploration in this field, I had to start by riding a
motorcycle. It occurred in a fraction of a second. A blur followed by an unequivocal fear, the fear of ever riding again. In 2018, without adequate training, I rode my cousin’s Vespa and crashed while braking on a turn. In that moment, the scooter stopped but I did not. I landed on my hands and knees and, tumbled several meters forward. I thought it would be like riding a bicycle, squeeze the brake and you will come to a controlled stop. Little did I know that two wheeled-motored vehicles have a more sensitive braking force than bicycles. Despite wanting to own a motorcycle for years, this experience led me to fear riding them.

Fast-forward one year, after joining the Master of Design program at Carleton University, I decided to focus my thesis inquiry on motorcycle training while also overcoming the fear of the previous incident. I had to understand how one is trained through current motorcycle training programs; I had to learn to ride a motorcycle. After completing my M1 written exam, I joined a motorcycle training course to acquire my M2 license. The training program was spectacular; it taught those without any experience to ride confidently on a bike. The training process consisted of a virtual synchronous class of about 3 hours followed by two days of physical training using a motorcycle with the guidance of an instructor. On the second day, all participants had to undergo practical test to acquire an M2 license. Surprisingly, in two days many participants passed the test, however some did not. The test is timed and trainees must complete specific courses within an allocated time period without stalling or dropping the bike. Although I did not stall or drop the bike, I didn’t complete the courses in the timed parameters. My hesitance to ride at required speed may have been due to the rain that day or because of lack of
practice within the two days of in-person training. Regardless, I was able to come back the following week to complete the test, after which I successfully earned my M2 license.

The test was a timed test and while it can be argued that this form of testing may or may not be the ideal way to test one’s learning, it is required at the provincial level, to earn the M2 license. After completing the course, I felt comfortable enough to ride a bike, however I am also aware that I could use more time to refine my skills. While I do have the option to register for another course or buy myself a motorcycle and insurance in order to practice, these approaches to extending my training are expensive. They also don’t eliminate the risks associated with novice riders like myself. I saw this as an area I could contribute to.

Through the Bachelor of Industrial Design program at Carleton University, I had the opportunity to work within the space of virtual reality. The experience brought me to consider the technology as a means for effective training within the domain of motorcycle education. Virtual reality not only provides an immersive experience to its user, it also eliminates the consequences faced in the real world. While this may seem like an intrinsic form of supplementary training, it also required an in-depth analysis of its true potential; riding a motorcycle requires finely tuned motor skills, as I evidently learned in 2018 through my personal experience. In order to explore the technology and its application, I decided to investigate the two as the primary focus of this thesis.
GLOSSARY OF TERMS

**Cognitive Load - CL:** The amount of mental effort required for a task due to the number influencing factors.

**Extraneous Load - EL:** Non-relevant information processing contributes to the working memory of the user.

**Fine Motor Skill:** A physical skill which involves minuet and controlled movements of the body, such as writing or pressing a button.

**Germaine Load - GL:** Information directly relevant to the task at hand that contributes to the long-term memory of the user.

**Gross Motor Skill:** A physical skill incorporates large movements of the body, such as bending, walking or waving.

**Head Up Display - HUD:** Display data without requiring the user to look away from viewpoints which would exist outside the simulation. It provides a more immersive experience.

**Immersiveness:** In this study it is what a user may experience in a computer-generated world as if it were real.
**Implicit Learning:** A type of learning which involves learning complex information in an incidental manner. This type of learning happens subconsciously and without awareness.

**Intrinsic Load - IL:** A form of cognitive load which refers to the user’s existing knowledge and the task complexity.

**Motor Skills:** A function which require particular movements of the body to perform a specific task.

**Motorcycle Training Program - MTP:** The motorcycle training program described in this thesis refers to the OSC (Ottawa Safety Council) motorcycle training program.

**Tactile Feedback:** A system allowing the user to obtain realistic control of a system.

**Virtual Reality - VR:** An artificial simulation which can be observed or manipulated based on user input controls. While modern virtual reality systems use HUD, virtual reality simulations have also been used on 2 dimensional screens.
CHAPTER 1: INTRODUCTION

Over 750 million motorcycles are estimated to be on roads, of which 380,000 annual deaths are of motorcyclists (Ospina-Mateus et al., 2019). Motorcycle riders are affiliated with high fatality and injury risks (Rifaat et al., 2012). Although motorcycles can be easily maneuvered in congested traffic due to their inherit agility (Ospina-Mateus and Jiménez 2019), they are at greater risk than cars because of the level of exposure to their surrounding environment (Walker et al. 2006). Motorcyclists undergo formal testing prior to receiving their license, yet their fatalities have increased worldwide by 22% (Ospina-Mateus & Quintana Jiménez, 2019). While training has seemed to be useful in the past, many motorcycle training programs’ (MTPs) instructors have been found they need to spend more time with their trainees (Daniello et al., 2009).

Virtual reality (VR) is a computer-generated simulation of a three-dimensional environment that can be interacted with in a seemingly real or physical way (Lexico, n.d.) The goal of VR systems is to let the user experience the computer-generated world as if it were real; this notion is known as immersion. Immersion produces a sense of presence in the user’s mind. To increase the immersion of a user in VR, synthetic stimuli, such as tactile feedback can be used (Bowman & McMahan, 2007). Tactile feedback systems allow the user to obtain realistic control of a system (Bergamasco, 1995). The amount of tactile feedback in a VR simulator can affect the user’s mental effort to absorb the information that is required of them to learn (Frederiksen et al., 2020). The amount of mental effort used by the user to perform a task is known as cognitive load (Hochreiter et
al., 2018). When designing a VR simulation to foster learning in novices the amount of tactile feedback required to learn should be determined to avoid cognitive overload.

Virtual reality devices can be used as supplementary tools for learning because it provides flexibility as to when and where the trainee can practice (Valentino et al., 2017). For example, surgeons in training, use virtual reality simulations to practice surgical procedures without the need for instructors to be present. This is possible because virtual reality systems allow one to practice without facing the consequences of the real world. Although virtual reality systems are used as a training tool, there are research gaps on the amount of tactile feedback that needs to be applied to train novice motorcycle riders.

The scope of this research is to investigate how the addition of tactile feedback in a virtual reality system can assist with developing the skills of operating a motorcycle’s controls in novice riders. 12 participants were recruited for this study. Participants were separated into three groups, each group was exposed to a simulator designed with varying tactile feedback, to learn basic motorcycle operating controls, which included using the clutch, break and throttle. Through assigning each group a VR simulator varying in tactile feedback, the affects of tactile feedback on their performance and behaviour could be observed by the researcher. The research determines the relationship between tactile feedback and cognitive load in learning to ride a motorcycle in a VR environment.
1.1 Rationale & Purpose of the Study

Virtual reality is a technology used to immerse the user in an artificial environment, in which they can observe and interact with. VR training is now used to train professionals in numerous industries as it has been proven to effectively improve students’ knowledge retention and motivation. VR courses have been shown to train people four times faster than other forms of training such as eLearning or learning in a classroom (PwC VR Soft Skills Training Efficacy Study, 2020). In addition to training efficacy, VR can be used at anytime and anywhere by trainees to further practice their skills (Valentino et al., 2017), potentially providing a solution to training programs which require instructors to be present. The need for an instructor is required as real-world training have risks which cannot be otherwise mitigated; VR allows students to practice in a virtual environments without having to face the consequences of the real-world (Madhavan, 2004).

While there is evidence that tactile feedback may increase the immersiveness of learning in VR, there is still a need for research to be conducted on how different degrees of tactile feedback may affect the development of motorcycle operations in VR. The purpose of this study is to investigate if tactile feedback is needed in VR motorcycle training. It also explores the amount of immersiveness required to facilitate a form of remote training, enabling a supplementary tool for training in motorcycle training programs.
1.2 Research Question

Traditional motorcycle training encourages trainees to improve their fine motor skills and hand eye coordination but in a short period of time (Daniello et al., 2009). Virtual reality is becoming an essential technology used in modern education and its benefits include improving fine motor skills, hand-eye coordination and overcoming challenges which may be faced in the real world (Roy et al., 2017). The research aims to identify how different degrees of tactile feedback in a VR motorcycle simulation can affect the learning of motorcycle operations in VR. In order to determine this, a VR motorcycle training lab is designed to conduct tests on participants’ performance in VR. The data from these simulation tests are accompanied by questionnaires completed by the participants on their experience.

The principal research question of this thesis asks:

*How does the addition of tactile feedback in a virtual reality motorcycle riding simulation affect the development of the skills for motorcycle operation in novice riders?*

To explore this question, the study examines supplementary research questions:

- *How do novice riders respond to increased immersion provided by tactile feedback in a VR motorcycle simulator?*
- *What degree of tactile feedback affects the performance of VR motorcycle operations in novice riders?*
- *How do different degrees of tactile feedback in a VR motorcycle simulator affect novice riders’ behaviour?*
1.3 Research Approach

To facilitate the exploration of the principal research question, the research has been divided into three phases:

**Phase 1** aims to determine methods of knowledge transfer used in the existing motorcycle training program, which required the researcher to undergo motorcycle training by the Ottawa Safety Council’s Motorcycle Training Program.

**Phase 2** is initiated using a literature review which examines current literature of how tactile feedback may hinder knowledge transfer in VR.

**Phase 3** determines whether the addition of tactile feedback affects the development of the skills for motorcycle operations.

A VR motorcycle training lab was used to teach and test participants in motorcycle controls. First participants were asked to complete a pretest questionnaire inquiring about their prior experience with motorcycle riding and VR. After the pretest questionnaire three practice sessions (20 minutes per session) in VR were observed by the researcher to determine how the participants were improving over time. This was followed by a test which was evaluated by the researcher. On the third day, after the last session of training each participant was required to complete a post test questionnaire to evaluate their experience. The data collected through the questionnaires, the observations and the testing, were compared to determine the affects of tactile feedback on the development of the skills for operating a motorcycle in VR.
1.4 Contribution to the Field

The research contributes to the development and design of virtual reality training systems, to further understand the affects of tactile feedback on the development of the skills required to operate a motorcycle in VR. The research bridges the gap between the virtual reality technology and motorcycle training. While virtual reality embeds itself into safety training through numerous industries, it has the potential to create new forms of training, such as remote training, where instructors are not required to be present in order to teach. In 2020 and 2021, the world faced a catastrophic pandemic which affected in person training in several industries. The intention of this research is to help virtual reality developers and trainers of different sectors better understand the effects of tactile feedback on users of virtual training simulators.
As companies begin to see the potential virtual reality has on employee training, they may begin to incorporate it into their existing training modules and onboarding practices. It is also important to note that this thesis focuses on complex motor skills associated with motorcycle riding; while niche, as the need to learn more complex motor skill related tasks increase, the need to understand the affects of tactile feedback in VR. I hope the findings will help advance virtual reality by incorporating technology which better understands one’s learning ability, as a result creating a learning environment tailored to an individuals’ needs rather than using current inflexible technology that teaches everyone in the exact same way. This can indirectly lead towards fewer motorcycle related accidents on the road would truly be rewarding.
CHAPTER 2: LITERATURE REVIEW

Motorcycle Training Programs are currently unable to provide the time required to fully train novice riders (P.Wells, 1983). The literature review examines how virtual reality VR technologies accompanied by tactile feedback have the potential to provide a supplementary tool for learning how to operate a motorcycle (Valentino et al., 2017). Prior to the examination of VR technologies, the literature further investigates how the knowledge of this caliber is transferred from expert to novice.

The literature review is comprised of four subchapters. Subchapter 2.1 discusses the risk associated with riding motorcycles and the limitations of the current motorcycle training available. It is important to discuss these limitations as they provide direction for the application of VR. This subchapter also addresses the type of knowledge relating to the operation and motor skills involved in riding a motorcycle. It will examine implicit learning, which is involved in riding, and how VR can facilitate implicit learning of a motorcycle’s controls in a remote setting. Subchapter 2.2 identifies what tactile feedback is and its relevance to the learning in VR. This subchapter then describes an impediment to one’s learning, known as cognitive load and the relationship is shares with tactile feedback. By understanding that cognitive load and tactile feedback affect users’ ability to learn, designers can be better equipped with a unique perspective when designing future training systems using VR. In the last subchapter of the literature review, subchapter 2.4, VR technologies and their uses for training are assessed to further validate its efficacy for a solution to the limitations faced by current MTPs.
The aim of the literature review is to expose the inefficiencies in MTPs and to explore how VR systems accompanied by tactile feedback can be a solution to mitigate these inefficiencies.

FIGURE 2   Literature Review Map

2.1 Motorcycle Training & Risks

A motorcycle may seem to be an ostentatious way to commute, but riders put themselves in far greater danger than automobile drivers, as they are exposed to traffic condition and are more sensitive to a wider variety of risks (Keall, M. D & Newstead, S, 2012). These risks may be avoided through rigorous practice and the guidance of experienced riders, though it is noteworthy that regardless of training, motorcyclists are 25 times more likely to be killed and five times more likely to face injury in a collision than automobile drivers (Dewar et al., 2013). In Ontario, there are several motorcycle/two-wheeler training programs that provide a ‘rider safety training’ for novice riders. These programs provide training for novice riders to pass their M2 exit test,
though they do have differences in training curricula (Daniello et al., 2009). While these MTPs are beneficial to training novice riders and discuss the risks associated with motorcycles, they are brief and are often found by trainees to be a waste of time during certain parts of the training (P.Wells, 1983). Dewar et al., 2013 recommend that MTPs space their training over a number of days and provide more time for the training program in order to assure the novice rider’s skills are engrained.

The United States as well as other countries, have an increased number of traffic accidents, due in part to the increase in popularity of motorcycles (Stutts et al., 2004). Though young riders, ages 18-24, account for only small percent of the traffic their fatality rate in motorcycle accidents are 3 times higher than older riders (Halbersberg & Lerner, 2019). There is a strong correlation of older riders having a lower risk of moderate to fatal accidents (Mullin et al., 2000).

‘Rider training, reasons for riding, and the social context of riding among young on-road motorcyclists in New Zealand’ published in the Australian and New Zealand Journal of Public Health describes how little was known about the subjective insights of young riders, their views and behaviors which may be putting them at risk and leading to serious injury. Hence, the authors pursued to acquire more insight regarding the topic on young motorcyclists. It was found that at the early age of 18, through a comprehensive questionnaire, that formal training was rare, and the primary source of riding instruction was provided by a male friend or father which occurred in a remote and unrealistic setting (Reeder et al., 1996). Though this only accounts for New Zealand, in the United States, formal training is only mandatory for riders between the ages of 18-21 in 16 states (Daniello et al., 2009). It seems that younger riders are more susceptible to considering
knowledge from unreliable sources. Furthermore, in the study ‘Improving Motorcycle Training Programs: Suggestions & Recommendations’ it was found that young riders, in particular were less likely advance their skill by undergoing formal training (Dewar et al., 2013). The literature on this topic suggests that there must be a focus on training for young riders.

Information which cannot be articulated to fully preserve the nature and meaning of something is considered to be tacit knowledge (Spinnuzi, 2005). For example, riding a bike; it is difficult to express to someone how one should first learn to ride a bike. One cannot simply read a book on how to ride a bike nor directly vocalize instructions that will immediately transfer the knowledge required to perform the task (Collins, 2010). Somatic tacit knowledge is directly related to our body’s motor skills. This knowledge tends to better transfer over practice and experience. It is important to note that somatic tacit is acquired progressively, over a period of time, and must be put into practice in a conscious state (Holford & Hadaya, 2017). By acquiring somatic tacit knowledge progressively, it allows the learner to digest complex motor skills in small doses.

FIGURE 3 Somatic Knowledge of “kick flip” Photo by Mong Mong from Pexels
Implicit learning involves learning complex information in an incidental manner (Sun, 2008). This type of learning happens subconsciously and without awareness. Implicit learning involves little to no guidance from an instructor while allowing the trainee to utilize their own somatic tacit knowledge. It was found that individuals performed worse when having to describe what they thought they understood from the training, rather than allowing the trainee to learn from their own experience (Leonard & Sensiper, 1998). Implicit learning may be a catalyst to facilitate learning in VR.

While the outcome of the MTPs method of implicit learning and knowledge transfer pass trainees their M2 test with ninety percent success rate, it puts novice riders in situations that they would not have experienced in the training program (Savolainen, P., & Mannering, F., 2007). Although studies from the mid-80s suggest that riders who went through a training program tend to wear more protective gear than those who did not (Mortimer, 1984), there is recent evidence which suggests MTPs to be attracting young novice riders who end up leaving the program with a greater likelihood of getting into an accident as the programs can’t transfer their instructors’ tacit knowledge effectively (Savolainen & Mannering, 2007). This may be due to the fact that implicit learning occurs over a long period of time and with continuous practice, something MTPs cannot do during their short training course (P.Wells, 1983).

While implicit learning may act as a catalyst for explicit-tacit knowledge transfer, it is associated with external factors that may alter the transfer rate of said knowledge, such as social and cognitive skills (Janacsek, K., Fiser, J., & Nemeth, D., 2012).
2.2 Tactile Feedback

Tactile feedback systems allow the user to obtain realistic control of a system (Bergamasco, 1995). Tactile information is transferred from the device providing the tactile feedback (Richter et al., n.d.). A function which requires movements of the body to perform a specific task is referred to as a motor skill (Janalta, 2020). A fine motor skill is one which involve minuet and controlled movements of the body, such as writing or pressing a button; a gross motor skill incorporates large movements of the body, such as bending, walking or waving (Janalta, 2020). To learn a new motor skill, one may rely on auditory feedback from an instructor (Spelmezan et al., 2009). Similarly tactile feedback can be effective in providing the feedback required for one to easily interpret the instructions on adjusting their posture, while also informing them on how to perform the correct motor skill (Guo et al., 2009). Tactile feedback can be applied to VR applications, to enable the user to feel an object they touch with their hand or body, which can improve the immersion and interactivity as it increases the range of sensations experienced by the user (Pamungkas & Ward, 2016).

When compared to other forms of feedback, like visual or auditory feedback, which are provided by an instructor being present, tactile feedback is the most effective aid in acquiring a motor skill (Guo et al., 2009). As an instructor may not always be present, alternate forms of teaching can be used to maintain the motor skills of a trainee outside a traditional learning environment. While tactile feedback can be considered an effective aid in teaching, large amounts of tactile feedback exposed to the trainee can be cumbersome and have a negative effect on their ability to perform the task required by them (Pamungkas & Ward, 2016). Since tactile feedback is associated with motor skills,
understanding how the addition different tactile feedback conditions could be used to further improve the immersion of interactions relating to motorcycle operation in VR. Different variations in tactile feedback conditions and how they affect the self-reported rating of participants have been demonstrated in other studies (Koiliias et al., 2020), however, there has been little or no research that examines the effects of tactile feedback on human movement behaviour of participants operating a VR motorcycle.

2.2.1 Cognitive Load Theory

Cognitive load (CL) is the load a particular task imposes on the learner’s cognitive system (Paas et al., 2008). In the study, ‘Cognitive Load Measurement as a Means to Advance Cognitive Load Theory’, Cognitive Load Theory (CLT) is concerned with “the design of instructional methods that efficiently use people's limited cognitive processing capacity to apply acquired knowledge and skills to new situations (i.e., transfer)” (Paas et al., 2003). CLT, coined in 1988 by John Sweller, consists of three types of load, intrinsic load, extraneous load or ineffective load and germane load or effective load. User’s existing knowledge and task complexity determine the intrinsic load, non-relevant information processing contributes to the extraneous load and any information directly relating to the task is considered germane load (Leppink et al., 2013). Figure 4 illustrates the different types of cognitive load which contribute to the user’s overall learning process. Cognitive load can be thought of like a glass, what fills the glass is what contributes to one’s cognitive load. The intrinsic load is the prior knowledge and
experience of the person, and it defines complexity of the task or information the person is trying to learn. For example, an experienced motorcycle rider would find a new maneuver to be less difficult to execute than a novice rider. In this same example, an extraneous load could be the traffic that the maneuver needs to be performed in. A lot of traffic can result in high extraneous load. Germane load in this example would be the maneuver itself, it is the knowledge which is required to be acquired by the rider to perform the maneuver. Ideally, the metaphorical glass of one’s cognitive load should be initially as empty as possible to be able to accommodate the germane load. Instructional designers are in control over both extraneous and germane load (Paas et al., 2003).

![Cognitive Load Components](image)

**FIGURE 4  Cognitive Load Components**

### 2.2.2 Tactile Feedback & Cognitive Load

Tactile feedback may contribute to the extraneous load when trying to perform a task in virtual reality. One’s prior experience or intrinsic load may contribute to the spare cognitive load capacity when completing a task; those with more experience of a given task may benefit more from tactile feedback as it contributes less to their extraneous load (Zhou et al., 2007).
The study at the University of Florida titled ‘Cognitive and Touch Performance Effects of Mismatched 3D Physical and Visual Perceptions’ explored the effects of physical tactile and visual fidelity of an augmented reality AR task on users’ cognitive load and performance (Hochreiter et al., 2018). Physical tactile fidelity was distinguished using the matching and nonmatching shapes while visual fidelity differed using a head mounted display augmented reality (HMD-AR) device and a projector, with the latter being the higher fidelity condition. Under four conditions, the participants were required to touch visual targets of the shape, the shape was of a human head. The researchers evaluated performance of the users in terms of touch accuracy, response time and a cognitive load task requiring target size estimations. After each condition participants were given a questionnaire inquiring about mental and physical demands, stress, frustrations and usability. Results showed that higher performance, lower cognitive load and increased usability were associated when participants touched the higher tactile fidelity shape (matching head shaped surface) and when using a higher fidelity display system, the projector.

FIGURE 5  Tactile vs Non-Tactile Experiment by (Hochreiter et al., 2018)
By using higher fidelity tactile feedback, cognitive load can decrease in users resulting in increased performance. It should be noted that the condition involving tactile feedback involved fidelity of the feedback, not the amount of feedback. This should be taken into consideration as the condition of fidelity may not have been perceived as cumbersome to the participants. It should also be noted that the task required involved only the participants fine motor skills, neglecting the effects the condition of higher fidelity may have on the gross motor skills which may be required of them in other tasks not conducted in the tests of this study.

In the study ‘Effects of Visual and Cognitive Load in Real and Simulated Motorway Driving’ two simulator, one dynamic and the other static are compared to identify the effects they have on participants’ cognitive load (Engström et al., 2005). The dynamic simulator provided feedback of road conditions to the participant driving by using a hydraulic system, while the static simulator did not provide feedback of road conditions as the simulator was stationary. The study also examined the effects of using a touch screen built into the simulator while driving. It was found that when cognitive load is increased there is a higher level of gaze concentration and increased ‘lane keeping’ performance in the participants.

*FIGURE 6* Dynamic simulator (left) touch screen (middle) static simulator (right) (Engström et al., 2005)
This study demonstrates that an increased cognitive load may increase performance of the user, yet it contradicts the finding from the previous study, where a decrease in cognitive load increases performance. It should be noted that the increased cognitive load provided by the use of the touch screen was not part of the driving task. Although, there may have been an increase of ‘lane keeping’ performance due to heightened levels of cognitive load, this load was not directly contributing to the tactile feedback involved in driving a car. To further examine the effects of cognitive load a final study on the effects of cognitive load in virtual reality is reviewed.

In the study ‘Cognitive Load And Performance In Immersive Virtual Reality Versus Conventional Virtual Reality Simulation Training Of Laparoscopic Surgery: A Randomized Trial’ two virtual reality training systems are analyzed to determine its effects on performance of laparoscopic surgery with medical students (Frederiksen et al., 2020). Figure 7 illustrates the control system used a conventional screen display while the test system used a head mounted display HMD for the participants to visualize the surgical procedure they would undergo. The researchers used a secondary task reaction time as the measurement tool for cognitive load as prior studies have demonstrated its reliability in measuring cognitive load during surgical skill training. This method was justified in the study by suggesting that subjective methods such as questionnaires are limited to measuring cognitive load during the training process, rather than it being used at the end of the procedure.

Completion time, amount of damage to surrounding tissue and efficiency of instrument movements were used to determine performance. This real-time approach
provided objective data to the researchers. The cognitive load was 8% higher in immersed virtual reality. The researchers mention that this was a result of high extraneous load in the immersive VR system. The immersive system did not provide view of the participants hands or physical instruments making it difficult for participants to locate their control inputs in the virtual environment. It is clear from this research study that a major part of the immersion aspect is being able to clearly visualize the hands/instruments of the VR user. These are the components involved in the execution of the task and must be, at the minimum visualized, if not felt by the participant.

![Image of immersive vs screen VR system for laparoscopic surgery training](image.jpg)

**FIGURE 7** Immersive vs Screen VR System For Laparoscopic Surgery Training (Frederiksen et al., 2020)

The three research studies examine the effects of tactile feedback when performing tasks in VR. Although the tasks, test methods and results involved in each study may vary, there are specific insights which may benefit the research of this study. First, fine and gross motor skills are involved in riding a motorcycle. Fine motor skills of operating the controls and gross motor skills of posture and lean of the participant. When evaluating tactile feedback’s affects on novice rider behaviour in VR, tactile feedback must be evaluated by isolating the fine and gross motor skills associated with riding.
Second, the increased variations of tactile feedback in the VR simulators should be directly related to the operations of a motorcycle when evaluating riding performance in VR. Third, the participants hands, and instruments to operate on a motorcycle should be visualized in VR on all variations of the simulators to avoid one simulator from having more immersed visuals than the other. These three insights from the three studies explored above, guide the development of the design for the simulators in this research study.

2.3 Virtual Reality

VR developers convert tacit to explicit knowledge with the focus on their ability to provide implicit learning through immersive virtual environments for tacit knowledge transfer (Sogand et al. 2017). This form of knowledge creation is considered to be highly contextual (Roux, D., et al. 2006).

Based on statistics provided by Greenlight and Touchstone Research’s 2015 virtual reality consumer report, consisting of 2000 participants from the age of 10 through 65+, virtual reality interest primarily lie among generation Z at 79%, followed by millennials (Greenlight & Touchstone, 2015). Among the 79% of generation Z, 70% will ask their parents for a virtual reality device. 50% of millennials intend to use a VR device with a game system rather than connected to PC or smartphone. Commonsense Media’s report ‘Virtual reality 101’ found that 62% of overall parents believe that VR will provide educational experiences, while 84% of parents who have used VR believe the same (Jennifer Stevens Aubrey et al., 2018). The report also found that 58% of parents agree that virtual reality allow children to do things they otherwise could not do.
2.3.1 Virtual Reality Technologies

360 Virtual Reality

This form of VR training involves recording a training environment and then re-playing the recording over for the trainee to visualize the environment (Kittel et al., 2020). 360 VR has been shown to show significant merit in the application of surgical training as an independent training tool as well as a supplementary tool (Yoganathan et al., 2018). Based on a SWOT analysis conducted by researchers from Victoria University in Australia, a threat or limitation this form of VR has been its inability to incorporate haptic and movement information (Kittel et al., 2020). One of the unique benefits the analysis expressed was its ability to be incorporated in many organizations due to its low cost.

Computer Generated Imagery (CGI)

The virtual environments in computer graphic imagery (CGI) VR systems are built with real world restraints. The trainee can manipulate this environment using controllers or a simulator which are programmed into the environment. This form of virtual reality makes it more powerful tool compared to non-interactive forms of 3D visualization (Huang & Lin, 2002).

Brain Computer Interface

In the article ‘Levity: A Virtual Reality System that Responds to Cognitive Load’ the training environment automatically adjusts its difficulty, in real-time, based on the trainee’s cognitive load, which is measured through alpha wave signals (Gerry et al., 2018). This form of VR system uses a 16 – channel EEG device to measure the alpha
waves of the user and according signal the VR system’s software to adjust the difficulty of the shape search game in real time.

### 2.3.2 Virtual Reality Training Procedures & Peripherals

Due to simulated training environments requiring large spaces and equipment to train with, depending on the training context, virtual reality devices can be used to act as conventional simulators (Valentino et al., 2017). Today, virtual reality can be seen as a supplementary tool for surgical training (Gurusamy KS & Davidson, 2009) and for training pilots (Socha et al., 2016).

### Medical

In the 1980s neurosurgery was beginning to develop with the advancements of computer graphics rendering (Paul J. Schmitt, Nitin Agarwal, Charles J, 2012). Although computer graphics rendering was beginning to advance, they remained in two-dimensions and as a result were not reliable to practice neurosurgical procedures. After the development of three-dimensional environments and its realistic rendering outcomes, virtual reality seemed to be a more reliable tool for practicing medical procedures (Schmitt et al, 2012).

A study on virtual reality bronchoscopy simulation illustrates the steps required when training surgical student in a bronchoscopy procedure with VR (Henri G. Colt, Stephen W. Crawford, Oliver Galbraith, 2001).

1. 1 hour group session during which trainees observed an on-line video about FFB provided with a bronchoscopy simulator.
2. 1 hour instructor-led overview of tracheobronchial anatomy and inspection FFB techniques. A critical commentary of the on-line video and a demonstration of alternate techniques were also provided.

3. 2 hour session of supervised group instruction during which each individual practiced FFB using the simulator

4 hour of individual, unsupervised practice using the simulator. (Implicit Learning)

Note: The simulator automatically recorded the time and duration of each log-on practice session. The bronchoscopy simulator components in this study consisted of the following. A proxy flexible bronchoscope, modeled after a conventional flexible fiberoptic bronchoscope, providing realistic images as the user navigates through the virtual anatomy. A robotic interface device which tracks the motions of the proxy flexible bronchoscope and reproduces all forces felt during an actual bronchoscope examination. A monitor which generated images of the airway derived from CT data sets. The simulation software in addition to being anatomically correct, the virtual airway is also physiologically realistic. The virtual patient breathes, coughs, bleeds, and exhibits change in vital signs.
Pilot Training

The following are the steps used in the flight simulator training procedure of the study ‘Training of Pilots Using Flight Simulator and its Impact on Piloting Precision’ (Socha et.al, 2016).

1. 2 hours theory-based class which included basic flight skills, introduction to parts of the aircraft (cockpit and flight deck) and their use during a flight.
2. Mental fitness and theoretical knowledge on flight basics were examined with a quiz and then a test.
3. 11 hours on a simulator. Hours 2, 6 and 11 consisted of measured simulation flights.
4. 1 hour, 12th hour, was performed in a real plane and was measured.
5. 3 hours of simulator flying proceeded step 4.
6. 2 hours of real flight time was given post step 5. With the final hour being a measured flight by the instructor.

A total of 17 hours of combined training was given to 35 students without a pilot’s license on an aircraft.
A flight simulator consists of the following components (Rosenkopf, Lori & Tushman, Michael, 1998). Software & mathematical models are considered to be the core of the flight simulation system as it integrates critical data from aircraft manufacturers. They are based on the data pack, also known as the black box from specific aircrafts. This allows for the simulation to appropriately train pilots on specific aircrafts. A computer defines the digital computing capabilities of the simulation system. Complex software and modelling, which provide realism to the simulation, require computers capable of processing and powering the systems information. Flight instruments help replicate the position the aircraft is in the simulated airspace. Finally, motion systems are used in simulators which are designed to provide 3 or 6 degrees of freedom based on the pilots inputs. The benefit of incorporating virtual reality devices into flight training is because it can be used anywhere and at any time by the trainee (Valentino et al., 2017).

The main take away from the literature above is that in order to train novices of a particular field using VR, the novices must undergo a number of days of training and be evaluated on performance after those days of training. In addition, the VR system but provide somewhat realistic controls to the task they would perform in real life.
2.4 Literature Review Summary

By investigating how virtual reality systems are used for numerous types of training, the literature demonstrates that virtual reality can fill the gap which motorcycle training programs are currently unable to because of time constraints (Valentino et al., 2017).

Three research studies are investigated, and it is determined that tactile feedback affects one’s cognitive load (Frederiksen et al., 2020) (Engström et al., 2005) (Hochreiter et al., 2018). Three different studies examined tactile feedback on various tasks, resulting in varied performance outcomes in non-motorcycle related training/tasks. Although these studies investigated the effects of tactile feedback differently, three insights were taken away to help guide the design of the test simulators for this study.

1. When evaluating tactile feedback’s effects on novice rider behaviour in VR, tactile feedback must be evaluated by isolating the fine and gross motor skills associated with riding.

2. Increased variations of tactile feedback in the VR simulators should be directly related to the operations of a motorcycle when evaluating riding performance in VR. The participants hands, and instruments to operate on a motorcycle should be visualized in VR on all variations of the simulators to avoid one simulator from displaying more immersed features than the other.

Virtual reality training procedures were also reviewed to help guide how training of the participants in this study should be conducted. Training in VR must occur over a number of days in order to evaluate participants’s riding performance accurately.
CHAPTER 3: METHODOLOGY

3.1 Overview

The research question asks, how does the addition of tactile feedback in a virtual reality motorcycle riding simulation affect the development of the skills for motorcycle operation in novice riders? To acquire data to answer this question, participants in this research study are required to fill out a pre-test questionnaire, undergo three days of VR motorcycle testing, followed by a post test questionnaire. Figure 8 describes the methods used in further detail.

The pre-test questionnaire was completed by each participant prior to the VR motorcycle testing; it inquired about the participants’ prior experience with VR, riding a motorcycle and driving a car. The VR motorcycle testing required each participant to practice operating a VR motorcycle for 20 minutes, followed by a test to evaluate what they had learned during the practice time. Participants had to partake in three of these sessions; a total of 60 minutes of practice and three tests were conduct during the VR motorcycle testing phase of this research. To evaluate how the addition of tactile feedback in VR motorcycle riding affects the development of the skills for motorcycle operation, three different VR test rigs were used, each varying in the amount of tactile feedback and immersion. Because there were three test rigs, three separate groups of participants were used in this study. After the third day of testing, each participant was required to complete a post-test questionnaire.

Prior to recruiting participants for this study, the research study was approved by Carleton University’s CUREB-B ethics board. The document submitted for the ethics application is in Appendix A.
Research Methods Rationale

The methods used have been selected to compare the participants experience in this study. Questionnaires provide a flexible means of gathering data and can be used to help triangulate other forms of data in a research study (Martin & Hanington, 2012). Questionnaires can also be used at various phases of the research study to help the researcher evaluate changes in participants subjective response (Martin & Hanington, 2012). VR motorcycle testing allowed the researcher to evaluate each participants learning and performance during the tests. The observations noted through the VR motorcycle testing phase of each group helped the researcher examine affects tactile feedback on developing the skills for motorcycle operation. By using questionnaires before and after the VR motorcycle testing, the researcher can induce a comparative analysis of the data collected from the observations noted during the VR motorcycle testing. This comparison allows for a more holistic understanding of the participants’ overall learning experience during the study.
3.2 Participants

A total of 12 participants were recruited from Carleton University to partake in this research study. The participants were recruited using posters and through which were placed throughout the campus. Participants who were interested scanned a QR code on the poster which was automated by the researcher to send a message to the researcher’s university email. The researcher would then schedule three time slots with each participant for testing. The researcher also requested the School of Industrial Design to send an invitation email to students in the bachelor and master programs. The study’s aim, procedure, requirements and compensation were all mentioned in this email. Participants were compensated with a Tim Hortons gift card.

Participant were required to be between the ages of 18-30 in order to partake in the study. This restriction was required for two reasons. First, based on the literature review, those who had a higher fatality rate when riding a motorcycle fit within this age group. Second, as mentioned in chapter 2.3, the majority VR users fit within this age criteria.

3.3 Material & Design

3.3.1 Pre-test Questionnaire Design

Qualtrics is an online software which was used to build the questionnaires in the study. Qualtrics records all participants’ responses and organizes them for the researcher to analyze. Qualtrics also allows the researcher to make a QR code which can be scanned by participants on their phone to access the questionnaire. The purpose of the pretest questionnaire was to determine the prior experience each participant had with virtual reality headsets, driving and riding motorcycles. Each participant filled out the skill level
assessment questionnaire on the first day of their testing after signing and agreeing to the consent form. The same questionnaire was used across all three test groups. By evaluating the prior knowledge/experience each participant had before proceeding to the study, the researcher was able to determine the level of each participant’s intrinsic load; considering the intrinsic load factor can help determine how the participant’s overall cognitive load was affected during the test. This information is crucial to determining if any external factors may be affecting a participant’s performance other than the tactile feedback of the rigs.

Three simulator rigs, varying in tactile feedback, were required to test the effects of adding tactile feedback to a VR motorcycle riding simulator. An Oculus Quest VR headset and controllers were used in all three rigs. Figure 9 illustrates the design of each test rig and how they vary in tactile feedback and immersiveness. The participant group using the test rig with the least amount of tactile feedback is referred to as the control group. The participant group using the rig set up on the desk, is referred to as the desktop group. The desktop rig is designed to mount the Oculus Quest controllers in a position which mimics the tactile feedback which would be received by the handlebars of a real motorcycle. Finally, the group with the highest amount of tactile feedback is referred to as the immersed group. The immersed group used a rig which was built to put the participant in the position of riding a motorcycle and while also providing the tactile feedback of the handlebar used in the desktop group. Because 12 participants were recruited, four participants were in each group.
3.3.2 Virtual Reality Training Lab Design

Figure 10 illustrates the virtual reality training lab made for the purpose of this study. Camera 1 was used by the research assistant to take pictures of the participant’s posture, every 5 minutes of their time in VR; the images were used to evaluate the degradation of the participants posture over time. Camera 2 was used to record the audio and video of the participants during each session for the researcher to use for observations.
Three groups were used in the study. The first group, the control group, did not use the simulator Figure 11. They were only to use the Oculus Quest and a chair for their training. This setup provided the least tactile feedback to the user. This setup consisted only of a chair for the participant to sit on, the Oculus headset and controllers.

![Control Group Setup](image)

**FIGURE 11 Control Group Setup**

The second group (Figure 12), the desktop group, used a simulator which could be mounted on a table to provide tactile feedback associated with steering a motorcycle. The primary function of the desktop rig was to help the rider learn to operate the controls of the motorcycle using the VR controller with their hand separated at the distance of an actual motorcycle’s handlebars. This design targets the fine motor skills of the participant more than the immersed rig. This rig is designed to be compact enough to allow for the novice rider to practice in a remote setting without the need of a full-sized rig.
The third group, the immersed group, used the immersed rig to conform them into the position of a motorcycle, providing the most tactile feedback. The simulator was made and designed by the researcher; all its angles and lengths mimic the shape of a 2003
Honda CB500, a commonly used beginner bike. The information of the motorcycle was acquired from cycle-ergo.com, a motorcycle ergonomic simulator. The specific dimensions of the immersed rig was based on the angle of the rider back relative to the seat of an actual motorcycle, the height of the seat to the foot rests and the overall length of the motorcycle. Figure 14 illustrates this in further detail. The Oculus Quest controllers were mounted to the same handle bar design as the desktop rig. The third simulator was built to provide the most realistic tactile feedback of riding a motorcycle. Based on this model of motorcycle, the third simulator was designed using Fusion 360.

![Figure 14: Immersed rig design based on Honda motorcycle](image1)

![Figure 15: Immersed rig handlebar design based on Honda motorcycle](image2)
Each participant was required to experience the MotoVR simulator for 20 minutes during each of their three test days, totaling 60 minutes of virtual practice riding a motorcycle. At the end of each 20-minute practice, each participant was required to complete a test. On the first two days each participant was asked to blend through gears 1-3, as smoothly as possible, while correctly administering the clutch, throttle and gear change. The researcher would evaluate them by observing their control inputs through a laptop which displayed their control inputs. Each participant was given a grade out of nine, three for their use of the clutch, three for gearing up and three for using the throttle appropriately. Pulling the clutch in, switching gears, accelerating and slowly releasing the clutch need to be done consecutively in order to get a 9/9. If the participant did not perform these movement correctly or in order points were deducted for the related criteria. For example, if the clutch was not engaged prior to switching gears, one mark was deducted from their overall clutch score. The purpose of testing this twice was to observe if their performance increased from the previous training session.
The test on the third day involved the participant to get up to third gear, similar to the previous test, and then come to a controlled stop in the neutral gear. This test was evaluated out of 18. Six points were allocated for their gear change (three gears up and three gears down), six points were allocated for their clutch use (three times to engage to third gear and three times to come to a complete stop in neutral), three points to their use of the throttle to get up to third gear and finally, three points for their use of the brake to come to a controlled stop from third gear. Their overall score for all three tests was 36.

3.3.3 Post-test Questionnaire Design

The post-test questionnaire was completed by each participant on the third day, after their training and test in their corresponding VR simulator. This questionnaire’s questions were primarily based on the honeycomb framework’s 7 criteria. For example, the findability criterion of the framework was permuted into the question, ‘How difficult was it to find the controls when using the simulator?’, participants would rate their answer using a 9-point Likert scale. After each rating, the participant was asked why they provided the rating that they did in order to acquire more qualitative data. The researcher chose a 9-point scale to lower scales, such as a 7-point or 5-point scale, to increase the sensitivity of each participant’s answer with respect to the other participants’ scores. The questionnaire ends with the question ‘Do you feel like you have learned how to use a motorcycle’s controls?’ to evaluate their perceived understanding of the control inputs; the primary form of somatic knowledge attempting to be transferred in the VR simulator. The purpose of this questionnaire was to determine how each participant’s cognitive load was affected during their training and what may have contributed to their extraneous load.
In section 2.2.2, the literature review exemplifies how the level of tactile feedback plays a role in one’s performance in certain tasks due to its relationship with cognitive load. In each of the studies the post-test questionnaire aimed at determining the effects of the tactile feedback variance from each simulator. As the tactile feedback was introduced using the handlebars in the desktop simulator and the seat accompanied by the handlebars in the immersed rig, questions 4 and 6 specifically inquired about the two features. By acquiring this data from the three groups, the researcher was able to determine if different levels of tactility had an effect of their perceived (Likert scale results) and/or true performance (the participant’s test results).

**Honeycomb Framework**

In attempt to determine the levels of cognitive load affecting participant groups, the post-test questionnaire adopts the Honeycomb framework. The honeycomb framework has seven criteria used to evaluate the user experience of a product. They are, usable, useful, desirable, valuable, findable, creditable and accessible. These seven
criteria consider the affordances and limitations of a product; as a result, they align with research on cognitive load (Crompton et al., 2020). Within the seven criteria mentioned above, the useful criterion directly examines one’s learning experience with respect to their cognitive load. The useful criterion of the honeycomb framework takes into account human cognitive limitations and such as the human cognitive load on working memory (Troop et al., 2020). To determine what components of the test rigs affected the participants cognitive load, the questions were aligned with the honeycomb framework. The post-test questionnaire utilizes the 7 criteria in a Likert scale format to quantify the subjective ratings of the participants. The questionnaire also inquires why the participant chose the rating they did for each criterion. The inherit nature of the Honeycomb framework accommodates for two modes of comparison between participant groups, the quantifiable mode, through the use of Likert scales, and a qualitative mode, through inquiry of the participants choice. This provides the analysis phase with two subjective forms of data to compare to the usability testing outcome, the objective results from the Motorcycle VR test data.

![Honeycomb Diagram](image)

FIGURE 18  Morville's User Experience Honeycomb
3.4 Procedure

After the research was approved by the CUREB-B ethics board, the researcher pinned recruitment posters in Carleton University’s campus. The recruitment poster had a description of the study, what was required of the participants and a QR code which could be scanned to send an automatic email of interest to the researcher. Once the researcher received and email from a participant, three days were scheduled to meet on Carleton University’s campus to proceed with the research. Participants were randomly assigned to one of the test rigs.

3.4.1 Mock Test Trial

Prior to conducting tests with participants, the researcher and research assistant conducted a mock trial. The purpose of the mock trial was to determine any unforeseen setbacks which may occur in the testing process. This also provided an opportunity for the researcher to demonstrate the testing procedure to the research assistant for feedback. The time estimated by the researcher would be 40 minutes per participant, though the mock trial proved to take approximately 50 minutes with minor unanticipated impediments such as:

a. the researcher’s laptop crashing due to its graphics card overheating

b. the virtual reality headset needing to be rerouted in various spaces depending on the simulator being used

c. helping guide the participant’s (in this case the research assistant’s) hands to the simulator where the controllers were mounted

d. answering questions regarding the questionnaires
e. the VR headset overheating
f. parts of the simulator breaking

The drawbacks provided critical information to the researcher about the process; after making appropriate changes to the testing procedure the researcher was able to get a better understanding of how the testing should be conducted. The test times for each participant were increased to one hour in order to accommodate for any hardware or software malfunctions and the questionnaires were changed to online questionnaires (with question logic) rather than written. With each participant needing approximately one hour per session and requiring three sessions in VR, to see how their performance progressed, the researcher determined that 12 participants would suffice the research. 12 participants with three hours of training results in 27 hours of observational data for the researcher to gather. Though 12 participants may not seem to be many, this was the greatest number of participants the researcher could test with given his circumstances. The researcher lived in Toronto and as a result could only be present in Ottawa to conduct the testing for one week. Due to the global pandemic, the number students in the university were fewer producing less interest in the study. If circumstances permitted the researcher to conduct more tests with a larger sample size the variance in data would be more conclusive and persuasive.
3.4.2 Procedure During Test Days

On the first day of testing, participants would be introduced to the researcher and would be given a short description of the research study. The participants would then fill out a consent form and would scan a QR code to access the pretest survey. Once complete, the participant was measured using a measuring board; as seen in Figure 19.

![Measurement Board](image)

**FIGURE 19 Measurement Board**

The researcher would then note down the participants height and arm length. After which, the participant would be given a demonstration of how the VR test rig they would be using works and how to operate the motorcycle controls using the Oculus headset and controllers. If the participant was in the desktop or immersed group they would be shown how to mount the Oculus Quest controllers into the handlebars of the rigs. Each participant would practice for 20 minutes, during this time the researcher took notes of what he observed during the practice. After the 20-minute practice the participant would be asked to perform a short test in the VR rig. The participants ability to operate the controls of the motorcycle were being evaluated. A point was deducted every time the participant did not engage the appropriate control during the test. The researcher would
note down the test score of each participant. Once completed the participant would leave and come back the next day for another session. On the final day, the third session, upon completing the test, each participant was required to fill out a post-test questionnaire inquiring about their experience. After completing the post-test questionnaire each participant was given a gift card for participating in the study.

3.5 Methods Analysis

The analysis of the pretest questionnaire, the results from the VR motorcycle testing and the post-test questionnaire had separate methods of analysis but the outcome of the analysis of each was used to compare the effects the addition tactile feedback had on each group.

3.5.1 Pre-test Questionnaire Analysis

The purpose of the pretest questionnaire was to determine the prior experience each participant had with virtual reality headsets, driving and riding motorcycles. This questionnaire’s data was not to be analyzed on its own, rather it was to be compared to the performance data of the participants during the VR motorcycle testing phase.

3.5.2 VR Motorcycle Testing Analysis

The 1-Way ANOVA analysis is used when one independent variable is being examined. The variable being analyzed is the level of tactile feedback of the three simulators; the independent variable is being analyzed against the participants’ results in the simulator. Columns C1(x), C2(x) and C3(x) of Table 1 are the performance results of the participants within their respective groups. C1(x) is the control group, C2(x) is the
desktop group and C3(x) is the immersed group. $\sum T$ is the sum of all the score and $\sum x^2$ equals the sum of the squared individual scores.

<table>
<thead>
<tr>
<th></th>
<th>C1 (x)</th>
<th>(x²)</th>
<th>C2 (x)</th>
<th>(x²)</th>
<th>C3 (x)</th>
<th>(x²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>P1</td>
<td>P5</td>
<td></td>
<td></td>
<td></td>
<td>P9</td>
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<tr>
<td>P2</td>
<td>P6</td>
<td></td>
<td></td>
<td></td>
<td>P10</td>
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<tr>
<td>P3</td>
<td>P7</td>
<td></td>
<td></td>
<td></td>
<td>P11</td>
<td></td>
</tr>
<tr>
<td>P4</td>
<td>P8</td>
<td></td>
<td></td>
<td></td>
<td>P12</td>
<td></td>
</tr>
</tbody>
</table>

$\sum T_{c1} = \quad \sum T_{c2} = \quad \sum T_{c3} = \quad (\sum x) = \quad \sum x^2 =$

**TABLE 1 Participant Data Table**

The results from Table 1 are used to determine the variables in Table 2. The following formulae are required to complete Table 2:

1. $SS_{between} = \frac{\sum T_{c}^2}{n} - \frac{(\sum x)^2}{N}$

   where; $\sum T_{c}^2 = sum \ of \ squared \ totals \ for \ each \ condition$

   $n = number \ of \ subjects \ in \ each \ condition = 4$

   $N = Total \ number \ of \ participants = 12$

   $(\sum x)^2 = Grand \ Total \ Squared = 270^2 = 72900$

2. $SS_{total} = \sum x^2 - \frac{(\sum x)^2}{N}$

   where; $\sum x^2 = sum \ of \ squared \ individual \ scores = 6328$

3. $SS_{within} = SS_{total} - SS_{between}$

4. $df_{between} = no. \ of \ conditions - 1$

5. $df_{total} = N - 1$
6. \( df_{within} = df_{total} - df_{between} \)

7. \( MS_{Between} = \text{Means Squares Between} = \frac{SS_{between}}{df_{between}} \)

8. \( MS_{Within} = \text{Means Squares Within} = \frac{SS_{within}}{df_{within}} \)

9. \( F_{ratio} = \frac{MS_{between}}{MS_{within}} \)

In order to determine if there is a difference between each group, the calculated \( F_{ratio} \) and the \( F \) critical at degrees of freedom 2,9 at a \( p \) level of 0.05 must be compared. To determine where the difference lies between the groups, a Tukey-Kramer test is used. Each group is compared from one to the other. For example, as seen in table 3, the control group is compared to the desktop group. In order to compare, the mean difference between the groups is calculated. The mean values are in table 2. After which the \( Q_{critical} \) value must be calculated in order to determine which groups have statistical significance. To calculate the \( Q_{critical} \) value, the following formula is used. If the mean difference between the groups is larger than the \( Q \) value, there is statistical significance between the groups.

\[
Q_{critical} = Q\left(\sqrt{\frac{S_{pooled}^2}{n}}\right)
\]

where, \( Q = \text{Value from the studentized range } Q \text{ table} \)

\( S_{pooled}^2 = \text{Pooled variance across all groups or the average variance} \)

\( n = \text{participants per group} \)
### 3.5.3 Post-test Questionnaire Design Analysis

A Kruskal Wallis test is used for a between subjects’ experiment when there are three or more levels of the independent variable. For each question, all the scores are ranked across each condition. The statistic acquired from this test is called $H_{\text{observed}}$, and if there is a difference between the three conditions then $H_{\text{observed}}$ will be equal or greater than the $H_{\text{critical}}$ value which is acquired from a Kruskal Wallis statistics table. If the number of participants in a group exceed five, then the $H_{\text{critical}}$ value will be taken from the Chi-Square test table instead. In this case the number of participants per group is four, therefore the Kruskal Wallis table will be used for the critical value. Due to the low sample size the Kruskal Wallis test results will not be the primary means of determining significance between the group’s responses. Instead, the responses have been visualized in a 100 percent chart to better examine the differences between the groups. If the sample size were larger, the following formula would be used to determine the $H_{\text{observed}}$ value.

$$H_{\text{observed}} = \left[ \frac{12}{N(N+1)} \sum \frac{T^2}{n_c} \right] - 3(N+1)$$

where $N =$ number of participants  
$n_c =$ number of participants in each group  
$\sum \frac{T^2}{n_c} =$ sum of squared rank totals for each condition divided by the number of participants.

After determining the H value, the degrees of freedom are required to find the critical value using the Kruskal Wallis table. The degrees of freedom are equal to the difference of number of conditions and one. In this test, the number of conditions is three, therefore the degrees of freedom is two.
CHAPTER 4: DATA COLLECTION & RESULTS

The results are categorized in three sections. First the pretest questionnaire’s results are presented in section 4.1. It is an overview of the participants data and acts as a data reservoir which pool the groups prior experiences and knowledge. Section 4.2 displays the test results of the participants and groups. Finally, the post-test questionnaires’ results are presented.

4.1 Pre-test Questionnaire

A total of 12 individuals, from ages 18 – 27, participated in the study. Of which, the four were female and eight were male. Each group consisted of one female participant except group three, the immersed group which had two female participants.

VR experience of participants varied. Three participants had never used virtual reality prior to the study, nine participants have used VR before, of which, five participants used it for gaming, two participants used it to watch videos and two participants used it of other purposes such as flight simulation. The types of headsets used differed from the nine participants. Four participants did not know what headset they used previously, two used the Oculus Rift, 1 used the Oculus Quest 2, one used the PlayStation VR headset and two participants used a Google Cardboard VR box which allowed them to use their phones as the VR screen. Out of these participants with prior experience, four had experiences interacting with the VR headset they used due to the nature of the device; the Oculus Quest 2, the Oculus Rift and the PlayStation VR all use control inputs to manipulate their virtual environments.
Two participants had experience riding a motorcycle and four had the experience riding as a passenger. Of the two with riding experience, one had a complete motorcycle license with professional training course, while the other did not have a license but had ridden dirt bikes in trails without a license.

All 12 participants were able to drive a car and had some sort of driver license. Participants knowledge on driving manual compared to automatic in a car was also noted. Four participants were able to drive manual. This information was acquired as it
contributed to their existing tacit knowledge of engaging, disengaging the clutch and shifting gears.

This knowledge may affect the intrinsic load of the participant during the test. It should also be noted that the immersed group had the greatest number of participants with gaming in VR but did not attempt to race during the practice session Figure 22. It can be said that prior gaming experience does not affect the participants’ behaviour during practice.

FIGURE 22  Pre-test Questionnaire Results
4.2 VR Motorcycle Testing

On the first and second day participants were graded out of nine for their performance of the test, which required the participants to start the bike and switch up to the third gear seamlessly. On the third day they were graded out of 18 as the test required them to get into third gear after which they had to come to a complete and controlled stop in the neutral gear. The results of these tests were grouped together to total score out of 36 for the three days of training. When blatantly viewing Figure 23, it can be said that the control group outperformed the groups with higher tactile feedback, concluding that lowering tactile feedback increases performance metrics. Although, this is not a pragmatic means of analyzing the data as it does not consider the user prior experiences/knowledge, in this case their intrinsic load.

FIGURE 23  Overall Test Results/Group

4.2.1 1-Way ANOVA Analysis & Tukey-Kramer Test

Initially, prior to the pandemic, the researcher’s intention was to have a larger sample size. This would allow the researcher to conduct a 1-way ANOVA analysis to
determine variance in the results between each group. The sample size of 12 does not show significant variance in the data using a 1-way ANOVA analysis even though from the Figure 23, it is obvious that the control group outperformed the desktop and immersed groups. Regardless of the sample size the researcher conducted the 1-way ANOVA analysis in attempt to replicate the steps that would’ve been used to analyze a larger sample size.

The 1-Way ANOVA analysis is used when one independent variable is being examined. The variable being analyzed is the level of tactile feedback of the 3 simulators; the independent variable is being analyzed against the participants’ results in the simulator. Columns C1(x), C2(x) and C3(x) of table 1 are the performance results of the participants within their respective groups. C1(x) is the control group, C2(x) is the desktop group and C3(x) is the immersed group. $\sum T$ is the sum of all the score and $\sum x^2$ equals the sum of the squared individual scores.

<table>
<thead>
<tr>
<th></th>
<th>C1 (x)</th>
<th>(x²)</th>
<th>C2 (x)</th>
<th>(x²)</th>
<th>C3 (x)</th>
<th>(x²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>P1</td>
<td>27</td>
<td>729</td>
<td>P5</td>
<td>15</td>
<td>225</td>
<td>P9</td>
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<td>P2</td>
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<td>900</td>
<td>P6</td>
<td>23</td>
<td>529</td>
<td>P10</td>
</tr>
<tr>
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<td>27</td>
<td>729</td>
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<td>26</td>
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<td>24</td>
<td>576</td>
<td>P8</td>
<td>15</td>
<td>225</td>
<td>P12</td>
</tr>
</tbody>
</table>

$\sum T_{c1} = 108, \quad \sum T_{c2} = 79, \quad \sum T_{c3} = 83, \quad (\sum x) = 270, \quad \sum x^2 = 6328$

\[
\begin{array}{|c|c|c|c|c|}
\hline
\text{Groups} & \text{Count} & \text{Sum} & \text{Mean} & \text{Variance} \\
\hline
\text{Control} & 4 & 108 & 27 & 6 \\
\text{Desktop} & 4 & 79 & 19.75 & 31.58 \\
\hline
\end{array}
\]

\[\text{Average Variance} = 14.38\]
TABLE 3  1 Way ANOVA Variable Chart

In order to determine if there is a difference between each group, the calculated F ratio and the F critical at degrees of freedom 2,9 at a p level of 0.05 must be compared. The F critical value at 2,9 is 4.26. Since the calculated F ratio is larger than the F critical value, $F_{\text{ratio}} = 4.29 > F_{\text{crit}} = 4.26$ it can be said that there is a difference in the data.

However, from this information alone, where the difference lies among the groups cannot be determined (i.e. between which conditions).

To determine where the difference lies between the groups, a Tukey-Kramer test is used. Each group is compared from one to the other. For example, as seen in table 3, the control group is compared to the desktop group. In order to compare, the mean difference between the groups is calculated. The mean values are in table 2. Between the control and desktop group, the mean difference is, $27 - 19.75 = 7.25$. After which the $Q_{\text{critical}}$ value must be calculated in order to determine which groups have statistical significance. The $Q_{\text{critical}}$ value is 6.28. If the mean difference between the groups is larger than the $Q$ value, there is statistical significance between the groups. From table 3, it can be said that the control and desktop groups significantly differed in performance, though, the immersed and control group also come very close to proving that there is statistical significance as the $Q_{\text{critical}}$ value and the mean difference are 0.03 apart from one another.
Although the 1-way ANOVA analysis and Tukey-Kramer tests require larger sample sizes to be considered viable, they quantitatively describe the visual variable in the overall test result graph, Figure 24.

It is important to note that the 1-way ANOVA analysis only examines one independent variable, assuming all other variables remain constant. For example, when viewing the performance results with the individual participants Figure 24, prior knowledge in driving manual, it can be said that the significance lies not only in the level of tactile feedback but also in the prior knowledge that contribute to the participant’s intrinsic load, lowering the complexity of the task, resulting in the participant being able to perform better at the required task, the germane load. The ability to drive manual enables the participant to transfer their existing somatic tacit knowledge, of driving manual, and apply it to new knowledge domain. Though when examining each group, the highest score in performance is always of the individual who drives automatic. The conclusion pertaining to prior knowledge affecting one’s performance is weak due to a small sample size, but from a far, it can be said that it does play a role in training performance.

<table>
<thead>
<tr>
<th>Comparison</th>
<th>Mean Difference</th>
<th>Q Value</th>
<th>Significance?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control vs Desktop</td>
<td>7.25</td>
<td>6.28</td>
<td>Yes</td>
</tr>
<tr>
<td>Desktop vs Immersed</td>
<td>1</td>
<td>6.28</td>
<td>No</td>
</tr>
<tr>
<td>Immersed vs Control</td>
<td>6.25</td>
<td>6.28</td>
<td>No</td>
</tr>
</tbody>
</table>

*TABLE 4  Tukey Kramer Test Results*
4.2.2 Observations

The researcher used a camera to video and audio record each session with each participant to review after the real-time observations. In real-time, the researcher took notes on the participants progress, comments and feelings. These observations were structured in 5-minute intervals to keep track of when the observations were made. For example, if a participant commented that they were experiencing back pain on the 12th minute, this would be noted in the 10-15 minute interval. This allowed the researcher to review when specific discrepancies occurred and with which group. As there were 12 participants, who trained three times for 20 minutes each, the total number of time frames observed and noted by the researcher was 144. Of the 144 observed time frames, only relevant and consistent observations are explored in this section. Weighted matrices are used to visualize the most consistent issues faced by the participants. From a far these matrices show that the majority of issues faced on the first day either did not exist or
impacted the participants far less on the last day. There are some outlying issues which
did not improve or increased; they will also be discussed.

![Day 1 Observations Weighted Matrix](image)

**FIGURE 25  Day 1 Observations Weighted Matrix**

**Lane Control**

Initially, it was deemed by only some of the participants that the handlebars made
the experience feel realistic. Although, the desktop group faced the most lane control
issues from all 3 groups. As there was no traffic and only a track was used, an issue with
lane control was noted by the researcher when the participant would steer off the track’s
course. This occurred mainly at high speeds as steering the bike would require the
participant to steer at smaller increments than when at lower speeds. Each day all three
groups improved in lane control with the control improving the most. This progression
can be seen in Figures 25, 26 and 27.
Controller Size/Layout

Controller size/layout refers to either the size of the Oculus Quest’s controllers with respect to the participants hand size or the configuration of button inputs. Figure 25 illustrates how participants 1, 5, 7, 8 and 9 had a great deal of difficulty reaching for the controller inputs or remembering the controller layout. It was mentioned by many of the participants that the proximity of the control inputs affected their ability to remember them initially. For example, to grip the handlebars in VR, the left grip trigger button had to be pressed, but to engage the clutch the left trigger also had to be pressed. This proximity of buttons confused the participants. Figure 16 shows the Oculus Quest’s buttons with respect to their function in MotoVR. It should also be noted that some of the participants found that certain controls did not afford their function. One in particular, the left and simulator joystick buttons were programmed to be pressed to switch gears up and
down. Joysticks afford gyroscopic functions while the function of switching gears is linear. Although this issue was consistently noted by many of the participants, the majority of participants were able to overcome it.

**FIGURE 27  Day 3 Observations Weighted Matrix**

**Attempting To Race**

Although this category was mainly found only in the control group, it was noted as it began to deter the participants from the primary focus of this test, which was to learn. The MotoVR game was designed to show the participants lap time with respect to other players around the world. At first this was not obvious to the participants but when they discovered, the participants in the control group constantly attempted to beat the previous lap time. Although the research participant requested to focus on practicing blending through the gears smoothly, they continued to try and beat the previous lap time. Only at the end of each session did the participants, who were racing, try to focus on
smoothly blending through the gears. They attempted to use all the time they could
during the 20-minute practice session to race, rather than train. Among the control group
participants, the lap time became an obsession, after the first day, they were only
interested in completing the lap faster than the previous participant’s score. This
obsession increased to a point where some of the participants messaged the researcher
after their training session to inquire whether someone was able to complete a lap faster
than theirs since they completed their training session that day. This may have been
affecting only the control group because resetting the game was not as difficult for them.
To reset the game required the controllers to be pulled out of the handlebars which was
taxing to the desktop and immersed group as they would need assistance with placing the
controller back into the handlebars after each lap. This continuous replacement of the
controllers was so frustrating to the desktop and immersed group, that they avoided
resetting the game altogether by turning the motorcycle around just before completing the
lap to continue practicing. Figure 28 shows the lap time results displayed after
completing each lap.

![Lap Time Results Displayed in VR](image-url)
Balance, Dizziness & Nausea

To lean the motorcycle in MotoVR the system was programmed to sense the user’s head tilt. If the user tilts their head left the motorcycle would lean to the left, similarly if they tilted their head to the right. During the first two days this caused the participants to feel dizzy and/or nauseous. To the point where some of the participants had to take a break. This may have been a result of the participant visualizing their body lean but not physically experience the lean on their entire body. The centrifugal forces visualized while riding the motorcycle in VR were not felt by the user. This dissociation may have caused the motion sickness initially felt by many of the participants. This will be further explored in the discussion section.

Back, Shoulder & Wrist Pain

Throughout the testing, many participants experienced pain in their upper/lower back, shoulders and wrist. The wrist in particular felt pain as the MotoVR game was programmed to flex the participants wrist forward when not using the throttle. This over flex of the wrist over time cause pain in some of the participants. Back pain was found to be primarily in the immersed group as it forced the participant to take on the posture of riding an actual motorcycle. The desktop and control group were able to adjust themselves into a comfortable position. Although, it should be noted that because of the freedom to adjust themselves, these two groups lacked realistic posture that they would normally experience on a motorcycle. Participant 9 was significantly shorter than the rest
of the participants in her group, this resulted in her bending her back to reach the controllers as seen in Figure 29.

![Posture of Each Participant](image)

**FIGURE 29  Posture of Each Participant**

**Length of Break**

Breaks were requested by many of the participants to either stretch, relax their shoulder/back or because they were experiencing some form of motion sickness. The number of breaks and the time required for each of these breaks decreased over the period of the three days. Break times ranged from 1 minute to 12 minutes. Longer intervals were needed for those experiencing either dizziness or nausea. Breaks tend to occur during the last 10 minutes of the training session as that seems to be when fatigue sets in.
4.3 Post-Test Questionnaire

The post-test questionnaire used the honeycomb framework to phrase its questions. Each participant answered each question using a 9-point Likert scale, some of these questions are accompanied by inquiring why the participant chose the rating they did. The honeycomb framework evaluates 7 dimensions of the user’s experience and can indicate the level of cognitive load affecting the user. This section examines the questions using the results of the participants’ responses, which are visualized using a 100 percent chart. The following charts are the results of the questionnaires completed by the participants on the third day, after their last 20-minute training session. The responses of each participant’s choice can be found in appendix B.6.
After experiencing VR through this study, do you find that it was a useful tool for learning to ride a motorcycle?

<table>
<thead>
<tr>
<th></th>
<th>Useful</th>
<th>Somewhat Useful</th>
<th>Neutral</th>
<th>Somewhat Unuseful</th>
<th>Unuseful</th>
</tr>
</thead>
<tbody>
<tr>
<td>Immersed</td>
<td>50%</td>
<td>25%</td>
<td>25%</td>
<td>25%</td>
<td></td>
</tr>
<tr>
<td>Desktop</td>
<td>50%</td>
<td>25%</td>
<td>25%</td>
<td>25%</td>
<td></td>
</tr>
<tr>
<td>Control</td>
<td></td>
<td></td>
<td>100%</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

This question addresses the *useful* dimension of the honeycomb framework. It inquires about the VR training system on the whole.

How useful did you find the handlebars/controllers when trying to steer the motorcycle?

<table>
<thead>
<tr>
<th></th>
<th>Useful</th>
<th>Somewhat Useful</th>
<th>Neutral</th>
<th>Somewhat Unuseful</th>
<th>Unuseful</th>
</tr>
</thead>
<tbody>
<tr>
<td>Immersed</td>
<td>25%</td>
<td>25%</td>
<td>25%</td>
<td>25%</td>
<td></td>
</tr>
<tr>
<td>Desktop</td>
<td>25%</td>
<td></td>
<td>50%</td>
<td>25%</td>
<td></td>
</tr>
<tr>
<td>Control</td>
<td></td>
<td></td>
<td>75%</td>
<td>25%</td>
<td></td>
</tr>
</tbody>
</table>
This question addresses the *useful* dimension of the honeycomb framework. It inquires specifically about the handlebars. The control did not use handlebars; therefore, this question was phrased using *controllers* instead of handlebars.

**How useful did you find the seat of the simulator when trying to learn to ride a motorcycle?**

- **Immersed**
  - Useful: 25%
  - Somewhat Useful: 50%
  - Neutral: 25%
  - Somewhat Unuseful: 25%
  - Not Useful: 25%

- **Desktop**
  - Useful: 25%
  - Somewhat Useful: 25%
  - Neutral: 25%
  - Somewhat Unuseful: 25%
  - Not Useful: 25%

- **Control**
  - Useful: 25%
  - Somewhat Useful: 25%
  - Neutral: 50%
  - Somewhat Unuseful: 25%
  - Not Useful: 25%

This question addresses the *usable* dimension of the honeycomb framework. It inquires specifically about the seat.

**How easy was it to use the simulator?**

- **Immersed**
  - Easy: 75%
  - Somewhat Easy: 25%

- **Desktop**
  - Easy: 25%
  - Somewhat Easy: 50%
  - Neutral: 25%

- **Control**
  - Easy: 25%
  - Somewhat Easy: 75%

This question addresses the *usable* dimension of the honeycomb framework.
Did you have fun riding the simulator?

<table>
<thead>
<tr>
<th></th>
<th>Fun</th>
<th>Somewhat Fun</th>
<th>Neutral</th>
<th>Somewhat Not Fun</th>
<th>Not Fun</th>
</tr>
</thead>
<tbody>
<tr>
<td>Immersed</td>
<td>75%</td>
<td></td>
<td></td>
<td>25%</td>
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</tr>
<tr>
<td>Desktop</td>
<td>75%</td>
<td></td>
<td></td>
<td>25%</td>
<td></td>
</tr>
<tr>
<td>Control</td>
<td>100%</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

This question addresses the *desirable* dimension of the honeycomb framework.

How difficult was it to find the controls when using the simulator?

<table>
<thead>
<tr>
<th></th>
<th>Easy</th>
<th>Somewhat Easy</th>
<th>Neutral</th>
<th>Somewhat Difficult</th>
<th>Very Difficult</th>
</tr>
</thead>
<tbody>
<tr>
<td>Immersed</td>
<td>50%</td>
<td>25%</td>
<td>25%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Desktop</td>
<td>25%</td>
<td>50%</td>
<td>25%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control</td>
<td>75%</td>
<td>25%</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

This question addresses the *findable* dimension of the honeycomb framework. The question specifically addresses the controls as the test at the end of each 20 minute
session evaluated the participants’ ability to use the VR system’s controls to learn how to seamlessly blend through gears on a motorcycle.

**How confident do you feel to ride a bike after your experience with this simulator?**

<table>
<thead>
<tr>
<th></th>
<th>Confident</th>
<th>Somewhat Confident</th>
<th>Neutral</th>
<th>Somewhat Unconfident</th>
<th>Unconfident</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Immersed</strong></td>
<td>25%</td>
<td>25%</td>
<td>25%</td>
<td>25%</td>
<td></td>
</tr>
<tr>
<td><strong>Desktop</strong></td>
<td></td>
<td>50%</td>
<td>25%</td>
<td>25%</td>
<td></td>
</tr>
<tr>
<td><strong>Control</strong></td>
<td></td>
<td>50%</td>
<td></td>
<td>50%</td>
<td></td>
</tr>
</tbody>
</table>

This question addresses the *credible* dimension of the honeycomb framework.

**How easily can you get access to a VR system?**

<table>
<thead>
<tr>
<th></th>
<th>Easy</th>
<th>Somewhat Easy</th>
<th>Neutral</th>
<th>Somewhat Difficult</th>
<th>Very Difficult</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Immersed</strong></td>
<td>25%</td>
<td>25%</td>
<td>50%</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Desktop</strong></td>
<td>25%</td>
<td>50%</td>
<td></td>
<td>25%</td>
<td></td>
</tr>
<tr>
<td><strong>Control</strong></td>
<td></td>
<td>75%</td>
<td></td>
<td>25%</td>
<td></td>
</tr>
</tbody>
</table>
This question addresses the *accessibility* dimension of the honeycomb framework. The following pie chart visualizes the results of the entire sample size without considering the group conditions.

**How easily can you get access to a VR system?**

![Pie chart showing the distribution of responses to how easily access to a VR system can be obtained.]

- Easy: 33%
- Somewhat Easy: 25%
- Neutral: 16%
- Somewhat Difficult: 25%
- Very Difficult: 16%

**Do you find what you have learned through the simulator to be valuable?**

<table>
<thead>
<tr>
<th>Condition</th>
<th>Very Valuable</th>
<th>Valuable</th>
<th>Neutral</th>
<th>Somewhat Valuable</th>
<th>Not Valuable</th>
</tr>
</thead>
<tbody>
<tr>
<td>Immersed</td>
<td>25%</td>
<td>25%</td>
<td>25%</td>
<td>25%</td>
<td></td>
</tr>
<tr>
<td>Desktop</td>
<td>25%</td>
<td>50%</td>
<td></td>
<td>25%</td>
<td></td>
</tr>
<tr>
<td>Control</td>
<td>50%</td>
<td>25%</td>
<td></td>
<td>25%</td>
<td></td>
</tr>
</tbody>
</table>

This question addresses the *valuable* dimension of the honeycomb framework.
Do you feel like you have learned how to use a motorcycle's controls?

<table>
<thead>
<tr>
<th></th>
<th>25%</th>
<th>50%</th>
<th>75%</th>
<th>25%</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Immersed</strong></td>
<td></td>
<td></td>
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<tr>
<td><strong>Desktop</strong></td>
<td></td>
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</tr>
<tr>
<td><strong>Control</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

This question is not part of the honeycomb framework. It is used to compare the participants’ subjective view of their own learning and the test results/observations.
CHAPTER 5: DISCUSSION

The principal research question asks, how does the addition of tactile feedback in a virtual reality motorcycle riding simulation affect the development of the skills for motorcycle operation in novice riders? The methods used gather data in real-time to examine how tactile feedback of the three rigs affect skills of operating a motorcycle in VR. The data gathering methods used were VR motorcycle testing and questionnaires. As the methodological approach was primarily user focused and though not formally related, the data gathered was subjective in nature. The participants’ ability to operate the VR motorcycle was measured using a performance test between groups during the VR motorcycle testing phase. The data from the test revealed that the control group outperformed the desktop and immersed groups, although, from the researchers’ observations, all three groups were able to understand and demonstrate the fine motor skills required to operate a motorcycle, although, participants of the desktop and immersed group had lower performance score. This suggests that one factor affecting cognitive load is the higher level of tactile.

5.1 Tactile Feedback & Cognitive Load

To suggest that tactile feedback alone caused lower performance results in participants would be misleading. The tactile feedback provided in this test was intended to increase the immersion of riding a motorcycle. By increasing the immersion many factors contributed to the participants’ cognitive load. Participants on the immersed rig had their posture affected dramatically as it replicated an actual motorcycle. This led to participants experiencing pain in their back and shoulders. This contributed to their cognitive load differently when compared to other sources of increased the extraneous
load such as motion sickness. The change in posture experienced by the immersed group affected their gross motor skills as it worked muscles beyond those required to just operate the controllers. Motion sickness was experienced closer to the end of the 20-minute practices while back and shoulder pain affected the participants earlier in the training.

Participants with smaller hands found it difficult to reach certain buttons on controllers. With the handlebars, their fingers reach was further strained resulting in them finding it more tedious to select the buttons they were supposed to. Although, it should be noted that these issues were only temporary and were overcome after a few minutes in the simulator. This is a unique insight as it suggests that fine motor skills may take a short time to get accustomed to if the stimuli is hindering the riders’ finger reach, but stimuli affecting the gross motor skills take longer to adjust too. It is clear that the tactile feedback affecting cognitive load comes more from the stimuli associated with riders gross motor skills.

When weighing the negative aspects of tactile feedback to the positive, it can be said that the benefits outweigh the costs associated when adding tactile feedback as almost all the participants in the immersed group mentioned that *it really does feel like they are riding a motorcycle*. Though they did not perform as well as the control group during the test, they gained experience of learning the controls in the posture required from them on an actual motorcycle. By loading their cognition with more information, by placing them in a riding position, their performance results during the test may have been affected but they gained a more realistic learning experience.
The increased realism of the desktop and immersed group also played a role in how each group used their time during the 20-minute practice session. MotoVR uses a racing track, when the participant completes one round of the track their timestamp is displayed in their view Figure 28. Although the researcher asked all three groups to practice switching gears as smoothly as possible, the control group insisted on outperforming the previous time stamp. The researcher observed that this became an obsession with three of the four participants in the control group, to the point where one participant emailed the researcher inquiring as to whether his lap time had been surpassed by other participants. The increased immersion brought by the increased amounts of tactile feedback affected how seriously the group took the practice time in the simulation. With no peripherals the Oculus Quest seems to be just a game, but when tactile feedback is introduced and the participants cognitive load increases, how they use their practice time differs. Because the control group constantly attempted to race and outperform the previous score, they were able to blend more smoothly through the gears during their test after the 20-minute mark. This explains their performance score. As their posture lacked the realism of an actual motorcycle it would be difficult to conclude that they would be able to acquire the same results on an actual motorcycle.

5.2 Motion Sickness

Motion sickness was a common symptom in many of the participants regardless of the group they were in. All the participants who faced some form of motion sickness during the first day, either did not experience it on the following days or the motion sickness was reduced significantly. Some participants found that their motion sickness
was affected due to the response rate of the Oculus Quest. For example, when these participants would lean, their field of view would not lean at the same time. The dissociation between what the user feels and what they see is what causes motion sickness, especially when associated with tilting their head. In the real world, a motorcyclist would feel the centrifugal forces act on them when banking in a turn, but when in VR, their brain is expecting to feel the forces because of what is being viewed but their body is not. This is only because the participants have always experienced the forces they are viewing in the real world, but over time in VR their brain is able to get accustomed to the disassociation between real world forces and visually perceived forces.

Another factor affecting motion sickness was the resolution capabilities of the Oculus Quest headset. Some participants mentioned that they were feeling dizzy because they found it difficult to differentiate between the texture of the road and the sky. Colour was the only means of differentiating between the two.

5.3 Comparing Results to Existing Research

In chapter 2.2.2, three research studies about the relationship between tactile feedback and cognitive load were reviewed. These studies guided the design of the rigs for this study but also provided a reference point of what was missing in the existing research. As mentioned above, the results from the testing suggest that the fine motor skills associated with hand and finger reach can adapt over a short time, unlike the gross motor skills associated with arm and back posture. Though, the rigs in this study were designed to prompt fine and gross motor skills separately, they were only designed to be focused on two areas of the body, the back and arms (gross motor skills) and the
hands/fingers (fine motor skills). Different types of motorcycles place users in different positions, positions which have not been examined in this study. It should also be noted that the tactile feedback been administered through the rigs were only relevant to the operations of the motorcycle. Some motorcycles provide different types of tactile feedback which are not directly related to operating a motorcycle. For example, some cruiser motorcycles have leg rests close to the front of the motorcycle, making the rider lean to the rear. This may impact the results differently if introduced to a similar study. Areas of a riders body should be mapped out and compared to alternate forms of tactile feedback to further explore the effects of tactile feedback on learning in VR.

5.4 Limitations

Recruitment

The researcher had to leave Ottawa and go back to his home in Toronto due to the COVID-19 pandemic. As the in-person research for this study was planned to be conducted on Carleton University’s campus, the researcher was required to drive to Ottawa limiting the time he had to spare for the research study. Recruitment posters were also limited to particular areas of the campus as there were not many locations with students who would fit the age criteria. The pandemic also affected the number of participants the researcher could recruit, as the participants were recruited from Carleton’s campus and the number of students on campus were few. If the sample size was larger, the researcher would have to drive multiple times to Ottawa in order to complete the testing. Participants with motorcycle riding experience was also limited as students tend to acquire their driver’s license first. If more participants in this research
study had their motorcycle license the relationship of prior motorcycle experience and need for tactile feedback could be more valid.

**Building The Simulators**

The majority of the test simulators were designed and built in Toronto as the researcher was required to relocate from Ottawa due to the pandemic. This limited the tools and equipment the researcher had access to build the rigs with. To work around this discrepancy, the research designed the motorcycle simulator to be primarily 3D printed and assembled with epoxy and fasteners. This made the parts weak and resulted in minor fractures in the handlebars during the tests. As some of the parts of the simulators required equipment which the researcher did not have access to, the researcher was required to drive to Ottawa to build these parts in Carleton University’s wood and metal shops.

The simulator used the Oculus Quest to immerse the participants in this study. The Oculus Quest, although effective in immersing its user, lacks a number of features which may have limited effectiveness of the testing. First, the Oculus Quest has a low resolution compared to newer headset which was noted by a number of the participants in this study. Higher resolution headset would be more effective at immersing users. The Oculus Quest headset also had a low response time compared to the Oculus Quest 2. The HTC Vive headset has eye tracking which would have added insight to the researcher’s observations as it would provide more information on how tactile feedback affects user gaze behaviour in VR. Finally, the researcher’s laptop was not capable of recording the
participants performance in the MotoVR software while projecting the simulation into the Oculus Quest headset.

Software

One of the limitations was the software required for the testing. Though the researcher was inexperienced in game development he attempted to design and build a software specifically for this study. Due to his lack of experience in C# coding the researcher was unable to develop the virtual simulation, because of the complexity of the coding and the game mathematics involved. In order to conduct this study, the researcher used MotoVR, provided by SteamVR. Though this software was built as a game, it provided the necessary controller inputs. MotoVR did not have the ability to output to console of evaluating the participants inputs. The researcher intended for the software to measure braking force, steering, clutch control and other motorcycle related inputs. As this was not possible with MotoVR the researcher had to observe the control inputs of each participant and record his observations. MotoVR is compatible with only the Oculus Quest system. This did not allow for the research to be conducted using more realistic hardware such as an actual motorcycle handlebar, throttle and clutch/brake levers. The software also lacked the rear brake input which is a key component in operating a motorcycle.

MotoVR was only able to provide a track for the participants to ride the virtual motorcycle on. It would be ideal to have the rider immersed on city roads with traffic to provide a more realistic experience. Although, the purpose of the study was to only foster learning of motorcycle operations in VR; traffic may be too distracting to the participants
who are just beginning to learn the controls. Realistic traffic conditions could be used after participants’ have learned to operate the virtual motorcycle on an empty track.
CHAPTER 6: CONCLUSION

Motorcycle riders are affiliated with high fatality and injury risks (Rifaat et al., 2012). Motorcyclists undergo formal testing prior to receiving their license, yet their fatalities have increased worldwide by 22% (Ospina-Mateus & Quintana Jiménez, 2019). While training has seemed to be useful in the past, many training programs’ instructors have been found they need to spend more time with their trainees (Daniello et al., 2009). Virtual reality devices are used as supplementary tools for training because it provides flexibility of when and where the trainee can practice (Valentino et al., 2017). The purpose of this study is to investigate the effectiveness of VR within the domain of motorcycle training.

The research study’s aim was to evaluate, how does the addition of tactile feedback in a virtual reality motorcycle riding simulation affect the development of the skills for motorcycle operation in novice riders? The research methods were deliberately chosen to elicit a comparative analysis between the data collected. 12 participants volunteered to partake in this study. The first method was a pretest questionnaire, which aimed to understand the participants’ prior exposure to motorcycle riding and virtual reality systems. A VR motorcycle test, followed by the post-test questionnaire were used to determine the effects of tactile feedback on the skills of motorcycle operation in VR. The VR motorcycle test consisted of three groups of four participants undergoing three 20-minute practice sessions in a VR simulator. Each group was assigned different VR rig varying in tactile feedback. These rigs were designed and built by the researcher for this study. After the participants completed three days of training in their assigned VR rig, a
post test questionnaire was used to understand the participants’ experience during the test.

The literature review demonstrates through numerous studies that tactile feedback may improve or hinder one’s learning in VR by increasing or decreasing the cognitive load of the user, which results in a lower or higher performance outcome. In this study, it was observed that an increase in cognitive load, due to high levels of tactile feedback, only affected the performance outcomes of the participants during the tests. Because of increased levels of tactile feedback provided in the immersed test rig, the participants gained knowledge on how to execute motorcycle control inputs while developing the gross motor skills linked to the posture of operating a real motorcycle. Based on the results provided through this research study, it can be said that motorcycle training programs, using VR, can integrate a remote means of training for riders interested in learning how to operate a motorcycle’s controls. Low levels of tactile feedback in a VR simulator can lower the initial cognitive load experienced by riders, after which higher levels of tactile feedback may benefit the novice rider through exposure to a realistic operation position.
CHAPTER 7: FUTURE RESEARCH

Future research within this domain should consider additional technologies of measuring and acquiring data on participants’ cognitive load in virtual reality. By diversifying the technologies used to gather data will encourage a more interdisciplinary structure to future research. This new structure may result in a unique understanding of the impediments in implicit learning of motorcycle riding in VR, which are currently unidentified because of the lack of perspective from fewer disciplinary lenses.

Technologies for Future Research

Some technologies to consider being used in conjunction with VR are electroencephalograms EEG, electrocardiograms ECG and eye tracking. EEGs are devices used to record electrical activity on the surface layer of the brain. The electrical activity is converted into distinct wave lengths which can be observed by the research. Alpha and beta waves in particular can identify when the addition of tactile feedback in VR is affecting the participant’s cognitive load. An ECG can record the heart rate of an individual in real time. This can provide the researcher with an additional metric on how one’s stress fluctuates depending on the tactile feedback the person is in contact with. It can also help researchers understand when a participant begins to feel more comfortable with a given amount of tactile feedback, suggesting they can be introduced to more tactile stimuli. Eye tracking can be used to identify where the participant’s gaze is being focused on when additional tactile feedback is introduced in a VR rig. This can provide the researcher with insight as to whether the tactile feedback is distracting or benefiting the participants learning in VR.
Expert Assistance with Measurements

These technologies can be very complex to use, researchers who decide to use such devices should be trained in how to read their metrics. It should also be noted that some of these devices can be intrusive to the participants they are being used on. ECG sensors must be placed under clothing near the participants chest. EEG sensors have to be placed on the participant’s scalp. Some EEGs may require short hair or may require head wear to be removed when testing. These devices also provide tactile feedback of their own which may interfere with the results of future studies evaluating the effects of tactile feedback on motorcycle operations in VR. If these devices can be integrated into riding gear, then they might be able to provide realistic and more immersive forms of tactile feedback without compensating the effects of applying these devices to the participant. For example, EEG sensors can be placed inside a motorcycle helmet and ECG sensors can be placed inside a motorcycle jacket to replicate realistic riding gear.

Avoiding Unanticipated Consequences

As the future of virtual reality technology evolves, the technology’s ability to foster realistic experiences will escalate. Part of these realistic experiences will be the introduction of tactile feedback systems, which will improve the immersiveness of one’s experience in VR. With this added benefit, research in this field of study must be able to determine how one’s training progresses based on the effects of VR when compared to real live training. Though the outcome of this research increases the immersiveness, it must not train the user to undermine the consequences of the real world. There is a fine line between immersivity and reality. The purpose of researching VR technology should
be to improve and explore how people can train without experiencing the consequences of the real world, however it should not reach a point where people undermine the consequences of the real world and are unprepared for them. By increasing immersiveness through the use of tactile feedback and by removing the consequences of the real world, we thin the line which separates immersivity from reality.
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APPENDICES

Appendix A Participant Recruitment Material

Appendix A.1 Ethics Clearance Form

CERTIFICATION OF INSTITUTIONAL ETHICS CLEARANCE

The Carleton University Research Ethics Board-B (CUREB-B) has granted ethics clearance for the changes to protocol to research project described below and research may now proceed. CUREB-B is constituted and operates in compliance with the Tri-Council Policy Statement: Ethical Conduct for Research Involving Humans (TCPS2).

Ethics Clearance ID: Project # 116140

Principal Investigator: Mr. Ruzbeh Irani

Co-Investigator(s) (if applicable): Mr. Ruzbeh Irani (Primary Investigator)
Stephen Field (Research Supervisor)
Dr. Robert Teasner (Research Supervisor)
Daren Durnhor (Research Assistant)

Project Title: Transmitting Tacit Knowledge In Virtual Reality Using Tactile feedback: Improving Implicit Learning Through Motorcycle Simulators

Funding Source:


This certification is subject to the following conditions:

1. Clearance is granted only for the research and purposes described in the application.
2. Any modification to the approved research must be submitted to CUREB-B via a Change to Protocol Form. All changes must be cleared prior to the continuance of the research.
3. An Annual Status Report for the renewal or closure of ethics clearance must be submitted and cleared by the renewal date listed above. Failure to submit the Annual Status Report will result in the closure of the file. If funding is associated, funds will be frozen.
4. During the course of the study, if you encounter an adverse event, material incidental finding, protocol deviation or other unanticipated problem, you must complete and submit a Report of Adverse Events and Unanticipated Problems Form.
5. It is the responsibility of the student to notify their supervisor of any adverse events, changes to their application, or requests to renew/close the protocol.
6. Failure to conduct the research in accordance with the principles of the Tri-Council Policy Statement: Ethical Conduct for Research Involving Humans 2nd edition and the Carleton University Policies and Procedures for the Ethical Conduct of Research may result in the suspension or termination of the research project.
Special requirements for COVID-19:

If this study involves in-person research interactions with human participants, whether on- or off-campus, the following rules apply:

1. Upon receiving clearance from CUREB, please seek the approval of the relevant Dean for your research. Provide a copy of your CUREB clearance to the Dean for their records. See Principles and Procedures for On-campus Research at Carleton University and note that this document applies both to on- and off-campus research that involves human participants. Please contact your Dean’s Office for more information about obtaining their approval.

2. Provide a copy of the Dean’s approval to the Office of Research Ethics prior to starting any in-person research activities.

3. If the Dean’s approval requires any significant change(s) to any element of the study, you must notify the Office of Research Ethics of such change(s).

Upon reasonable request, it is the policy of CUREB, for cleared protocols, to release the name of the PI, the title of the project, and the date of clearance and any renewal(s).

Please email the Research Compliance Coordinators at ethics@carleton.ca if you have any questions.

CLEARED BY: Date: November 10, 2021

Bernadette Campbell, PhD, Chair, CUREB-B

Kathryne Dupre, PhD, Co-Chair, CUREB-B
Appendix A.2 Recruitment Poster

Recruitment Poster

Participate in a study on
Transferring Tacit Knowledge In Virtual Reality
Using Tactile Feedback: Improving Implicit
Learning Through Motorcycle Simulators

The aim of this project is to determine whether the tactile feedback from a simulator rig will affect learning outcomes in a virtual reality training simulator.

To participate in this study, you must be:

- **Comfortable using a virtual reality headset**
- **At least 18 years old**
- **Non-epileptic**

This is a 40-minute study. You will be asked to use a virtual reality simulator to ride a virtual motorcycle in a city.

Please note: This study will take place in person on Carleton University’s campus. The study will be recorded; that is, through audio & video recordings. Video, photo, audio recording, height and arm measurements are mandatory to participate. Video and audio recordings will be used for observational analysis by the researcher only (they will not be published anywhere or will be shown to anyone except the researcher). Photos will be used for posture analysis of the participants in each simulator. Photos of participants’ faces will be blurred if used in the published paper.

Participants will be compensated with a $5 Tim Horton’s gift card after completing the study.

This study has been cleared by the Carleton University Research Ethics Board B Clearance #116140

Please contact the researcher, Ruzbeh Irani, for more details on this study at ruzbehiran@gmail.ca
Appendix A.3 Consent Form

Consent Form

**Title:** Transferring Tacit Knowledge In Virtual Reality Using Tactile Feedback: Improving Implicit Learning Through Motorcycle Simulators

**Date of ethics clearance:** September 29, 2021

**Ethics Clearance for the Collection of Data Expires:** September 30, 2022

This research has been cleared by Carleton University Research Ethics Board-B (Clearance #116140).

I ___________________________, choose to participate in a study in evaluating one’s learning through a virtual reality training system. The aim of this study is to evaluate 3 types of simulators, each with different levels of tactile feedback. I understand that this study requires each participant to wear a virtual reality headset in a seated position while interacting with a virtual motorcycle training environment. I understand that I will be required to always wear a face mask and disposable plastic gloves during this study. Face masks and gloves will be disposed of after every session by each participant. All equipment used will be thoroughly sanitized between each session. Note: This study does not involve participants to ride an actual motorcycle at any time. Only a virtual reality simulator will be used where no risk will be brought to any participants.

**Purpose:**

This study aims to contribute to the development of virtual reality training simulators. In order to do this, 3 simulators are being tested to determine its affects on complex motor skill tasks, in this case, riding a motorcycle in a virtual environment. Virtual reality simulators have been used to improve learning involving skill sets like, flying a plane and surgery. Though the use of tactile feedback has been deemed
beneficial to these existing training simulators (plane/surgery), the motor skills required are not as complex as riding a motorcycle in virtual reality. Hence, the affects of tactile feedback are being evaluated in a virtual reality motorcycle simulation.

**Research Personnel:**

The primary researcher, Ruzbeh Irani, in this study is a Carleton Graduate Student working under the supervision of Professor Stephen Field from Carleton University’s School of Industrial Design, and co-supervisor Professor Robert Teather from Carleton University’s School of Information Technology, both in the Faculty of Engineering and Design.

**Task Requirements:**

This study will take place in person on Carleton University’s campus. The study involves each participant to fill out a short skill level assessment questionnaire on Qualtrics using their phone, the participant will scan a QR code to access the questionnaire (or an iPad will be provided if the participant does not have access to their phone) to determine how experienced they are with riding a motorcycle. Following which, the participant will view a short demonstration by the researcher on how each simulator must be used. The participant will then begin using the first training simulator. The participant will be asked to sit in the simulator and wear the virtual reality headset and position their hands on the controllers. All participants will be video and audio recorded. Video and audio recordings will be used for observational analysis by the researcher only (they will not be published anywhere or will be shown to anyone except the researcher). Photos will be used for posture analysis of the participants in each simulator. Photos of participants’ faces will be blurred if used in the published paper. When they are ready, they may begin the training procedure. Instructions will be provided in the virtual environment. Once completed, the participant will use the second simulator followed by the third. Once the participant has completed the training, they will be required to fill out a questionnaire on their experience on Qualtrics using their phone,
the participant will scan a QR code to access the questionnaire (or an iPad will be provided if the participant does not have access to their phone).

**Time Required:**
The entire individual session will take approximately 40 minutes, to complete. The breakdown of each session with a participant is as follows:
- 5 minutes – Introduction
- 5 minutes – Skill level assessment questionnaire
- 10 minutes – Debriefing
- 20 Minutes – Experience Simulator
- 5 minutes – Questionnaire

**Withdraw/Compensation:**
You have the right to end your participation in the study at any time, for any reason, up until February 28th, 2022. You can withdraw from the study at any time by directly verbally requesting to withdrawal, phoning or emailing the research supervisor. If you withdraw from the study, all information you have provided will be immediately destroyed. As a token of appreciation, I will be providing you with a $5 Tim Hortons gift card after completing the study. The compensation is yours to keep, even if you choose to withdraw.

**Potential Risk/Discomfort:**
No physical risk will be brought to any of the participants, though, participants may experience nausea when using the virtual reality system. If the participant may find the virtual reality headset to be uncomfortable or that it makes them feel nauseous, they may remove it and stop the research session at any time. Each participant will be in contact with the following equipment. An Oculus Quest virtual reality headset, controllers (left and right), chair, pen (to take notes) and forms. The Oculus Quest is the virtual reality headset (and controllers) which will be used during the study. Due to COVID-19 all equipment will be thoroughly sanitized prior to each research session using 90% ethyl alcohol. Both participants and the researcher will be wearing gloves and mask during each session. There is a small risk that videos/photos/audio could be identifiable.
Anonymity/Confidentiality:

It is mandatory that all participants consent to have height and arm measurements, photos and videos taken of them. Only photos of the participants posture while using the simulator, will be used in publications and these photos will blur the participants faces and not mention names in order to keep their privacy. Publications will also consist of participant physiological data but will be coded in the publication to sustain participant privacy. Video and audio recordings will not be used in any publication nor will be shared with anyone but the researcher. Video and audio recordings will be stored in the researcher’s password protected computer folder.

Data Storage:

After each participant completes their test session, all their data files will be immediately transferred to an password protected folder on the researcher’s password protected laptop until May 1, 2022. At the end of May 1, 2022, all data will be destroyed. This includes data from the Master List where matched participant names and participant numbers (to identify participants) which will also be stored in the password protected folder on the researcher’s password protected laptop. This list will also be destroyed on May 1, 2022. Data from the Qualtrics questionnaires will be stored in the Qualtrics server when the participant completes their questionnaire after which the data will be transferred to the researcher’s password protected folder on their computer. Once transferred from the server to the password protected folder, the server data will be deleted. Qualtrics will not store IP addresses, this function has been disabled.

Your data will be stored and protected by Qualtrics in Ireland, but may be disclosed via a court order or data breach.

The ethics protocol for this study was reviewed and cleared by the Carleton University Research Ethics Board. Should you have any ethical concerns with the study, please contact the REB Chair, Carleton University Research Ethics Board-B (by email: ethics@carleton.ca). During Covid, the Research Ethics Staff are working from home without access to their Carleton phone extensions. Accordingly, until staff return

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Carleton University
Email: stephen.field@carleton.ca
to campus, please contact them by email. For all other questions about the study, please contact the researcher.

For all other questions about the study, please contact the researcher
Do you agree to observation of you in the testing environment? ___Yes ___No
Do you agree to photos of you being taken? ___Yes ___No
Do you agree to videos of you being recorded with audio? ___Yes ___No
Do you agree to having your height and arm length measured? ___Yes ___No

Co-supervisor contact information:
Name: Robert Teather
Department: School of Information Technology
Carleton University
Email: rob.teather@carleton.ca

Signature of participant ___________________________ Date ______________
Signature of researcher ___________________________ Date ______________
Appendix A.4 Letter of Invitation

Letter of Invitation

Title: Transferring Tacit Knowledge In Virtual Reality Using Tactile Feedback: Improving Implicit Learning Through Motorcycle Simulators

2021-05-23

Hello,

My name is Ruzbeh Irani and I am a Master’s student in the School of Industrial Design at Carleton University. I am working on a research project under the supervision of professors Stephen Field and Robert J. Teather.

To participate in this study, you must be:
- Comfortable using a virtual reality headset
- At least 18 years old
- Non-epileptic

I am writing to you today to invite you to participate in a study entitled “Transferring Tacit Knowledge In Virtual Reality Using Tactile Feedback: Improving Implicit Learning Through Motorcycle Simulators”. This study aims to to determine whether different levels of tactile feedback from three different simulators will affect learning outcomes.

This study will take place in person on Carleton University’s campus. The study will be conducted for approximately 40 minutes. Introductions will take 5 minutes. The study involves a short skill assessment questionnaire (5 minutes) on Qualtrics using their phone,
the participant will scan a QR code to access the questionnaire (or an iPad will be provided if the participant does not have access to their phone), followed by a 5-minute debriefing on how to use the virtual reality simulator; once complete you will be asked to experience the virtual reality training simulators (20 minutes). After which, you will be asked to fill out a short questionnaire (5 minutes) on Qualtrics using their phone the participant will scan a QR code to access the questionnaire (or an iPad will be provided if the participant does not have access to their phone). The study will take place in a controlled room, only the researcher and you will be in this room, maintain a 6-foot distance at all times. All the virtual reality equipment will be sanitized prior and after each participant. With your consent, your experience during the virtual reality training system will be video & audio recorded.

Video, photo, audio recording, height and arm measurements are mandatory to participate in this study. Video and audio recordings will be used for observational analysis by the researcher only (they will not be published anywhere or will be shown to anyone except the researcher). Photos will be used for posture analysis of the participants in each simulator. Photos of participants’ faces will be blurred if used in the published paper.

Care will be taken to protect your identity. This will be done by keeping all participant personal information coded.

You will have the right to skip the questions that you do not want to answer and end your participation in the study at any time, for any reason, up until February 28th, 2022. If you choose to withdraw, all the information you have provided will be destroyed.

As a token of appreciation, I will be providing you with a $5 Tim Hortons gift card after completing the study. The compensation is yours to keep, even if you choose to withdraw.

All research data, including video recordings and any notes will be password protected on the researcher’s personal computer. Any hard copies of data including will be kept in a locked cabinet in the
researcher’s home. Data from the Qualtrics questionnaires will be stored in the Qualtrics server when the participant completes their questionnaire after which the data will be transferred to the researcher’s password protected folder on their computer. Once transferred from the server to the password protected folder, the server data will be deleted. Research data will only be accessible by the researcher and research supervisors. Qualtrics will not store IP addresses, this function has been disabled.

This research has been cleared by Carleton University Research Ethics Board B Clearance # 116140

If you would like to participate in this research project, or have any questions about the research, please contact me at ruzehirani@cemial.carleton.ca

Sincerely,

Ruzbeh Irani
Appendix B Questionnaire Material & Data

Appendix B.1 Pre-Test Skill Assessment Questionnaire

Start of Block: Skill Assessment Questionnaire

Q0 What is your participant number? (Ask researcher if you are unsure)

__________________________________________________________

Q1 What is your age?

__________________________________________________________

Q2 What is your biological sex at birth?

○ Male (1)

○ Female (2)

○ Prefer not to say (3)
Q3 Have you ever used a virtual reality headset before?

- Yes (1)
- No (2)

Skip To: Q9 If Have you ever used a virtual reality headset before? = No

Q5 What did you use the virtual reality headset for? Select all that apply.

- Gaming (1)
- Designing (2)
- Watching Videos (3)
- Other (4) ___________________________________
Q6 How often do you use a virtual reality headset?

- Everyday (7)
- Weekly (8)
- Monthly (9)
- I've only used it once (10)

Q7 Which of the following VR systems have you used? Select all that apply.

- Oculus Quest (1)
- Oculus Quest 2 (2)
- Oculus Rift (3)
- HTC Vive (4)
- Samsung Odessa (5)
- Other (6) ____________________________________________
Q8 Do you find virtual reality headsets to be useful? Why?

- Yes (4) _________________________________
- No (5) _________________________________

Q9 Have you ever driven a car?

- No (1)
- Yes (2)
- I race competitively (3)

Skip To: Q12 If Have you ever driven a car? = No

Q10 Do you have a driver's license?

- No (1)
- Yes (2)
Q11 What kind of driver's license do you have?

- G (1)
- G2 (2)
- G1 (3)
- Other (4) ________________________________

Q11.5 Did you go to driving school?

- No (1)
- Yes (2)
Q11.6 Looking back, do you think you should have taken driving lessons? Why?

☐ Yes (1) ________________________________________________

☐ No (2) ________________________________________________

Q11.7 Did you find the driving lessons to be useful? Why?

☐ Yes (1) ________________________________________________

☐ No (2) ________________________________________________

Q12 Have you ever ridden a motorcycle?

☐ No (1)

☐ Yes, as a passenger (2)

☐ Yes, as a rider (3)

☐ Yes, I race competitively (4)
Q13 Do you have a motorcycle license?

- Yes (1)
- No (2)

Q14 What motorcycle license do you have?

- M (1)
- M2 (2)
- M1 (3)
- Other (4) _________________________________ 
Q15 Have you taken professional lessons for motorcycle training?

○ No (1)
○ Yes (2)

Q15.5 Looking back, do you think you should have taken motorcycle lessons?

○ Yes (1) ________________________________________________
○ No (2) ________________________________________________

Q15.6 Did you find the motorcycle lessons to be useful? Why?

○ Yes (1) ________________________________________________
○ No (2) ________________________________________________
Q16 How many days of training did you receive?

- 1 Day (1)
- 2-3 Days (2)
- 4-5 Days (3)
- Other (4) ______________________________________________

Q18 How many hours was each day of training?

- 1-2 Hours (1)
- 2-4 Hours (2)
- 5-6 Hours (3)
- Other (4) ________________________________________________

End of Block: Skill Assessment Questionnaire
Appendix B.2 Post-Test Questionnaire Control Group

Start of Block: Post Test Questionnaire Control

P# What is your participant number? (Ask researcher if you are unsure)

________________________________________________________________

Q1 What was your overall learning experience like when using this simulator?

________________________________________________________________

________________________________________________________________

Q2 After experiencing VR through this study, do you find that it was a useful tool for learning to ride a motorcycle?

1 2 3 4 5 6 7 8 9

1 Not Useful - 9 Very Useful ()
Q3 What is the reason for your choice?

________________________________________________________________
________________________________________________________________
________________________________________________________________
________________________________________________________________

Q4 How useful did you find the controllers when trying to steer the motorcycle?

1 2 3 4 5 6 7 8 9

1 Not Useful - 9 Very Useful ()

Q5 Why were the controllers useful / not useful when trying to steer the motorcycle?

________________________________________________________________
________________________________________________________________
________________________________________________________________
________________________________________________________________
________________________________________________________________
________________________________________________________________
Q6 How useful did you find the seat of the simulator when trying to learn to ride a motorcycle?

1 2 3 4 5 6 7 8 9

1 Not Useful - 9 Very Useful ()

Q7 Why did you find the seat useful / not useful when trying to learn to ride a motorcycle?

________________________________________________________________
________________________________________________________________
________________________________________________________________
________________________________________________________________
________________________________________________________________
________________________________________________________________
Q8 How easy was it to use the simulator?

1 2 3 4 5 6 7 8 9

1 Not Easy - 9 Very Easy ()

Q9 What made it easy? / What made it hard to use?

________________________________________________________________
________________________________________________________________
________________________________________________________________
________________________________________________________________
________________________________________________________________
________________________________________________________________

Page Break
Q10 Did you have fun riding in the simulator?

1 Not Fun - 9 A lot of Fun

Q11 How difficult was it to find the controls when using the simulator?

1 Difficult - 9 Easy

Q12 What about the controls made it difficult/easy to use?
Q13 How easily can you get access to a VR system?

1 Not Accessible - 9 Very Accessible

---

Q14 How would you get access to one?

- Borrow a friend's (1)
- Purchase one of your own (2)
- Rent one online (3)
- Borrow from a local/school library (4)
- Other (5)
- I can't get access to one because... (6)
- I own a VR system (7)
Q15 How confident do you feel to ride a bike after your experience with this simulator?

1 Not Confident - 9 Very Confident

Q16 Do you find what you learned through the simulator to be valuable?

1 Not Valuable - 9 Very Valuable

Q17 Is there anything else you would like to mention about your experience?
Appendix B.3 Post-Test Questionnaire Desktop Group

Start of Block: Post Test Questionnaire Desktop

P# What is your participant number? (Ask researcher if you are unsure)

________________________________________________________________________

________________________________________________________________________

Q1 What was your overall learning experience like when using this simulator?

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________
Q2 After experiencing VR through this study, do you find that it was a useful tool for learning to ride a motorcycle?

1  2  3  4  5  6  7  8  9

1 Not Useful - 9 Very Useful

Q3 What is the reason for your choice?

________________________________________________________________
________________________________________________________________
________________________________________________________________
________________________________________________________________
________________________________________________________________
________________________________________________________________

Page Break
Q4 How useful did you find the handlebars when trying to steer the motorcycle?

<table>
<thead>
<tr>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
</tr>
</thead>
</table>

1 Not Useful - 9 Very Useful

Q5 Why were the handlebars useful / not useful when trying to steer the motorcycle?

________________________________________________________________
________________________________________________________________
________________________________________________________________
________________________________________________________________
________________________________________________________________
Q6 How useful did you find the seat of the simulator when trying to learn to ride a motorcycle?

1  2  3  4  5  6  7  8  9

1 Not Useful - 9 Very Useful ()

Q7 Why did you find the seat useful / not useful when trying to learn to ride a motorcycle?

________________________________________________________________
________________________________________________________________
________________________________________________________________
_______________________________________________________________
________________________________________________________________
________________________________________________________________
________________________________________________________________
________________________________________________________________
Q8 How easy was it to use the simulator?

<p>| | | | | | | | | |</p>
<table>
<thead>
<tr>
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<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
<td>8</td>
<td>9</td>
</tr>
<tr>
<td>1 Not Easy - 9 Very Easy ()</td>
<td>[graphic showing a score]</td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
</tbody>
</table>

________________________________________________________________
________________________________________________________________
________________________________________________________________
________________________________________________________________
________________________________________________________________
________________________________________________________________
________________________________________________________________
________________________________________________________________

Q9 What made it easy? / What made it hard to use?

________________________________________________________________
________________________________________________________________
________________________________________________________________
________________________________________________________________
________________________________________________________________

Page Break
Q10 Did you have fun riding in the simulator?

<table>
<thead>
<tr>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Not Fun - 9 A lot of Fun ()</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Q11 How difficult was it to find the controls when using the simulator?

<table>
<thead>
<tr>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Difficult - 9 Easy ()</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Q12 What about the controls made it difficult/easy to use?

__________________________________________________________________
__________________________________________________________________
__________________________________________________________________
__________________________________________________________________
__________________________________________________________________
__________________________________________________________________
Q13 How easily can you get access to a VR system?

1  2  3  4  5  5  6  7  8  9

1 Not Accessible - 9 Very Accessible ()

Q14 How would you get access to one?

○ Borrow a friend's (1)

○ Purchase one of your own (2)

○ Rent one online (3)

○ Borrow from a local/school library (4)

○ Other (5) ____________________________________________

○ I can't get access to one because... (6)

______________________________________________________

○ I own a VR System (7)
Q15 How confident do you feel to ride a bike after your experience with this simulator?

1 2 3 4 5 6 7 8 9

1 Not Confident - 9 Very Confident ()

Q16 Do you find what you learned through the simulator to be valuable?

1 2 3 4 5 6 7 8 9

1 Not Valuable – 9 Very Valuable ()

Q17 Is there anything else you would like to mention about your experience?

________________________________________________________________
________________________________________________________________

End of Block: Post Test Questionnaire Desktop
Appendix B.4 Post-Test Questionnaire Seated Simulator Group

Start of Block: Post Test Questionnaire Seated Simulator

P# What is your participant number? (Ask researcher if you are unsure)

________________________________________________________________________________________________________

Q1 What was your overall learning experience like when using this simulator?

________________________________________________________________________________________________________
________________________________________________________________________________________________________
________________________________________________________________________________________________________
________________________________________________________________________________________________________
________________________________________________________________________________________________________

Page Break

Q2 After experiencing VR through this study, do you find that it was a useful tool for learning to ride a motorcycle?

1 2 3 4 5 6 7 8 9
Q3 What is the reason for your choice?

________________________________________________________________
________________________________________________________________
________________________________________________________________
________________________________________________________________
________________________________________________________________
________________________________________________________________
________________________________________________________________

Page Break
Q4 How useful did you find the handle bars when trying to learn to ride a motorcycle?

1  2  3  4  5  6  7  8  9

1 Not Useful - 9 Very Useful ()

Q5 Why were the handlebars useful / not useful when trying to learn to ride a motorcycle?

________________________________________________________________
________________________________________________________________
________________________________________________________________
________________________________________________________________
________________________________________________________________
________________________________________________________________

Page Break
Q6 How useful did you find the seat of the simulator when trying to learn to ride a motorcycle?

1 2 3 4 5 6 7 8 9

1 Not Useful - 9 Very Useful

Q7 Why did you find the seat useful / not useful when trying to learn to ride a motorcycle?

________________________________________________________________
________________________________________________________________
________________________________________________________________
________________________________________________________________
________________________________________________________________

Page Break
Q8 How easy was it to use the simulator?

1 2 3 4 5 6 7 8 9

1 Not Easy - 9 Very Easy ()

Q9 What made it easy? / What made it hard to use?

________________________________________________________________
________________________________________________________________
________________________________________________________________
________________________________________________________________
________________________________________________________________
________________________________________________________________

Page Break
Q10 Did you have fun riding in the simulator?

1  2  3  4  5  6  7  8  9

1 Not Fun - 9 A lot of Fun ()

Q11 How difficult was it to find the controls when using the simulator?

1  2  3  4  5  6  7  8  9

1 Difficult - 9 Easy ()

Q12 What about the controls made it difficult/easy to use?

__________________________________________________________________
Q13 How easily can you get access to a VR system?

1 2 3 4 5 6 7 8 9

1 Not Accessible - 9 Very Accessible ()

Q14 How would you get access to one?

- Borrow a friend's (1)
- Purchase one of your own (2)
- Rent one online (3)
- Borrow from a local/school library (4)
- Other (5) ____________________________________________
- I can't get access to one because... (6) ____________________________________________
- I own a VR system (7)
Q15 How confident do you feel to ride a bike after your experience with this simulator?

1 Not Confident - 9 Very Confident

Q16 Do you find what you learned through the simulator to be valuable?

1 Not Valuable - 9 Very Valuable

Q17 Is there anything else you would like to mention about your experience?

End of Block: Post Test Questionnaire Seated Simulator
Appendix B.5 Pre-Test Questionnaire Results Excel Spreadsheet

Pre-test questionnaire of control group

<table>
<thead>
<tr>
<th>Participant #</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Height (CM)</td>
<td>153</td>
<td>176.5</td>
<td>180</td>
<td>177</td>
</tr>
<tr>
<td>Arm Length (CM)</td>
<td>65.5</td>
<td>70</td>
<td>81</td>
<td>76</td>
</tr>
<tr>
<td>Age</td>
<td>24</td>
<td>19</td>
<td>22</td>
<td>24</td>
</tr>
<tr>
<td>Sex</td>
<td>F</td>
<td>M</td>
<td>M</td>
<td>M</td>
</tr>
<tr>
<td>VR Exp (Y/N)</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>VR Use</td>
<td>Videos</td>
<td>Gaming</td>
<td>Other</td>
<td>Gaming</td>
</tr>
<tr>
<td>VR Exp (Time)</td>
<td>Once</td>
<td>Once</td>
<td>Once</td>
<td>Once</td>
</tr>
<tr>
<td>VR System</td>
<td>Can't Remember</td>
<td>Oculus Quest 2</td>
<td>Other</td>
<td>Other</td>
</tr>
<tr>
<td>VR Usefulness (Y/N)</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Why?</td>
<td>N/A</td>
<td>Great way to be immersed in a setting without having to go there, great for training.</td>
<td>More freedom/ different opportunities/ allow for better exploration of environments / puts you in that environment</td>
<td>Enhances the gaming experience</td>
</tr>
<tr>
<td>Driven Car (Y/N/R)</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Drivers License (Y/N)</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>License Type</td>
<td>G2</td>
<td>G2</td>
<td>G</td>
<td>G</td>
</tr>
<tr>
<td>Driving School</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>If No, Should have? (Y/N)</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Why?</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>If Yes, Useful? (Y/N)</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Why?</td>
<td>The test involves elements that are not as strictly followed in everyday driving so it was good to take it to know what the tester is looking for</td>
<td>Helpful to have someone teach me the basics, as well as things that I use daily when driving</td>
<td>Taught the proper way to drive/rules of the road early on</td>
<td>Taught me rules of the road and developed good habits early on</td>
</tr>
<tr>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>Ridden Bike? (N/P/Y/R)</td>
<td>Rider</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>License Type</td>
<td>M</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Bike Training? (Y/N)</td>
<td>Yes</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>If No, Should have? (Y/N)</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Why?</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>If Yes, Useful? (Y/N)</td>
<td>No</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Why?</td>
<td>The first was good because it taught me how to ride and also exposed me to different types of motorcycles. The second time I took it to get my M licence was to refresh any skills I may have let slide.</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Days of Training</td>
<td>2-3 Days</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Hours/Day</td>
<td>5-6 Hours</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
</tbody>
</table>

## Pre-test questionnaire of desktop group

<table>
<thead>
<tr>
<th>Participant #</th>
<th>5</th>
<th>6</th>
<th>7</th>
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</thead>
<tbody>
<tr>
<td>Height (CM)</td>
<td>172</td>
<td>185</td>
<td>173</td>
<td>176</td>
</tr>
<tr>
<td>Arm Length (CM)</td>
<td>74</td>
<td>78</td>
<td>80</td>
<td>81</td>
</tr>
<tr>
<td>Age</td>
<td>24</td>
<td>25</td>
<td>18</td>
<td>24</td>
</tr>
<tr>
<td>Sex</td>
<td>F</td>
<td>M</td>
<td>M</td>
<td>M</td>
</tr>
<tr>
<td>VR Exp (Y/N)</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>VR Use</td>
<td>N/A</td>
<td>Videos</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>VR Exp (Time)</td>
<td>N/A</td>
<td>Once</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>VR System</td>
<td>N/A</td>
<td>Other (phone headset)</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>VR Usefulness (Y/N)</td>
<td>N/A</td>
<td>Yes</td>
<td>N/A</td>
<td>N/A</td>
</tr>
</tbody>
</table>

- **Why?**
  - N/A
  - The potential is unlimited. Useful for design, therapy, videos, etc
  - N/A
  - N/A

<table>
<thead>
<tr>
<th>Driven Car (Y/N/R)</th>
<th>Yes</th>
<th>Yes</th>
<th>Yes</th>
<th>Yes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manual/Automatic/I DK</td>
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<td>Manual</td>
<td>Auto</td>
<td>Auto</td>
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<tr>
<td>Drivers License (Y/N)</td>
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<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>License Type</td>
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<td>G</td>
<td>N</td>
<td>G</td>
</tr>
<tr>
<td>Driving School</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>If No, Should have? (Y/N)</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
</tbody>
</table>

- **Why?**
  - N/A
  - N/A
  - N/A
  - N/A

<table>
<thead>
<tr>
<th>If Yes, Useful? (Y/N)</th>
<th>Yes</th>
<th>Yes</th>
<th>Yes</th>
<th>Yes</th>
</tr>
</thead>
</table>

- **Why?**
  - I was really scared when I started driving and we were in a remote area
  - Coming from a different country rules are different
  - Better preparation for on road events
  - N/A
<table>
<thead>
<tr>
<th></th>
<th>Passenger</th>
<th>No</th>
<th>Passenger</th>
<th>No</th>
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<tbody>
<tr>
<td><strong>Ridden Bike?</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(N/P/Y/R)</td>
<td>No</td>
<td>N/A</td>
<td>No</td>
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<tr>
<td><strong>License Type</strong></td>
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<td></td>
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<tr>
<td></td>
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<td><strong>Bike Training? (Y/N)</strong></td>
<td>N/A</td>
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<td>N/A</td>
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<td><strong>If No, Should have?</strong></td>
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<td></td>
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<td>(Y/N)</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
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<tr>
<td><strong>Why?</strong></td>
<td></td>
<td></td>
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<td>N/A</td>
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<td><strong>If Yes, Useful? (Y/N)</strong></td>
<td></td>
<td></td>
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<td></td>
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<tr>
<td></td>
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<tr>
<td><strong>Days of Training</strong></td>
<td></td>
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<tr>
<td></td>
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<td>N/A</td>
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<td><strong>Hours/Day</strong></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td></td>
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<td>N/A</td>
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</table>
# Pre-test questionnaire of seated group

<table>
<thead>
<tr>
<th>Participant #</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Height (CM)</strong></td>
<td>173</td>
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<td>163</td>
<td>163</td>
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<tr>
<td><strong>Arm Length (CM)</strong></td>
<td>86</td>
<td>84</td>
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<tr>
<td><strong>Age</strong></td>
<td>20</td>
<td>27</td>
<td>24</td>
<td>19</td>
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<tr>
<td><strong>Sex</strong></td>
<td>F</td>
<td>M</td>
<td>M</td>
<td>F</td>
</tr>
<tr>
<td><strong>VR Exp (Y/N)</strong></td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td><strong>VR Use</strong></td>
<td>Other (Flight Sim)</td>
<td>Gaming</td>
<td>Gaming</td>
<td>Gaming</td>
</tr>
<tr>
<td><strong>VR Exp (Time)</strong></td>
<td>Once</td>
<td>Once</td>
<td>Once</td>
<td>Once</td>
</tr>
<tr>
<td><strong>VR System</strong></td>
<td>Not Sure</td>
<td>Oculus Rift</td>
<td>Oculus Rift</td>
<td>Not Sure</td>
</tr>
<tr>
<td><strong>VR Usefulness (Y/N)</strong></td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td><strong>Why?</strong></td>
<td>They have many uses in various fields for study and for entertainment</td>
<td>Give a perspective without the risks associated</td>
<td>It gives you somewhat of a real life experience so if you were to cross a bridge in VR, it may condition you to get used to heights</td>
<td>You can accurately simulate reality in a safe setting</td>
</tr>
<tr>
<td><strong>Driven Car (Y/N/R)</strong></td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td><strong>Manual/Auto matic/IDK</strong></td>
<td>Auto</td>
<td>Auto</td>
<td>Auto</td>
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<tr>
<td><strong>Drivers License (Y/N)</strong></td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
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<tr>
<td><strong>License Type</strong></td>
<td>G1</td>
<td>G</td>
<td>G</td>
<td>G1</td>
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<tr>
<td><strong>Driving School</strong></td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td><strong>If No, Should have? (Y/N)</strong></td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>Yes</td>
</tr>
<tr>
<td><strong>Why?</strong></td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>Yes, I’m planning on taking lessons</td>
</tr>
<tr>
<td><strong>If Yes, Useful? (Y/N)</strong></td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>N/A</td>
</tr>
<tr>
<td>Why?</td>
<td>The instructor was not very good, but the classroom sessions were good in terms of knowledge</td>
<td>informative information regarding safe driving behaviours and actions</td>
<td>useful to know your rights and drive safely</td>
<td>N/A</td>
</tr>
<tr>
<td>---------------------------------------------------------------------</td>
<td>-----------------------------------------------------------------------------------------------</td>
<td>-----------------------------------------------------------------------</td>
<td>---------------------------------------------------------------------------------------------</td>
<td>-----</td>
</tr>
<tr>
<td>Ridden Bike? (N/P/Y/R)</td>
<td>No</td>
<td>Rider</td>
<td>Passenger</td>
<td>N/A</td>
</tr>
<tr>
<td>License Type</td>
<td>N/A</td>
<td>No</td>
<td>No</td>
<td>N/A</td>
</tr>
<tr>
<td>Bike Training? (Y/N)</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>If No, Should have? (Y/N)</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Why?</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
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<tr>
<td>If Yes, Useful? (Y/N)</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
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<tr>
<td>Days of Training</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Hours/Day</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
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</tbody>
</table>
## Appendix B.6 Post-Test Questionnaire Results Excel Spreadsheet

Control group post-test questionnaire

<table>
<thead>
<tr>
<th>Participant #</th>
<th>Q1 Overall Experience</th>
<th>Q2 Useful Tool (1-9)</th>
<th>Q3 Why?</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Very enjoyable once I got used to where the buttons were and could feel more immersed in the experience. The first day I was a bit unused to the VR and experienced slight feelings of nausea. The second and third day I was able to play around with the throttle control and try to figure out how to steer.</td>
<td>7</td>
<td>I think it is a great tool to learning where the controls are and what they do. Most beginner riders start out in parking lots learning how to move the bike. If you are familiar with the controls this process is easier as you have less new information to remember. Furthermore the engine sounds responded realistically to the throttle input which I think is an important part of learning to ride. Knowing how much throttle to give when starting so you don’t dump your bike or stall and also changing gears at the simulator time requires you to recognize the sound rather than staring at the tach. I don’t think this bike stalls though</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>I definitely learned more about how a clutch works and when to shift based on the rpms and sound of the bike but the graphics can make you realize that it is a simulation as your body is not moving with the bike. Had there been a bike that could simulate the movement then it may have been better for learning.</td>
<td>6</td>
<td>It was somewhat useful but I still think having a bike in person would be the way to go. There was also the fact that it felt much more like a game and if I crashed I was fine whereas in the real world there would be serious injuries</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Very fun, it gave me a good idea of how changing gears could work, and while it wouldn’t be enough to learnt to drive an actual bike I can see how it would help.</td>
<td>7</td>
<td>I would consider it necessary but it would be a great benefit, especially for those with apprehensions. I’d recommend an actual bike simulator though, just vr wouldn’t get fa</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>The simulation did a great job of familiarizing me with the physical mechanics of riding a motorcycle (clutch, changing gear, acceleration, braking)</td>
<td></td>
<td>I think it is a very useful tool, it familiarizes the user with the mechanics of riding a motorcycle (clutch braking, acceleration, turning) and helps ease the transition to a real motorcycle. I gave it a 6/9 because I think there are some aspects of riding a real motorcycle that cannot be fully replicated on the VR setup. For example, the operation and feeling of a real clutch and the physical forces that make you lean side to side.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
</tbody>
</table>

136
<table>
<thead>
<tr>
<th>Q4 Controller Useful Steering (1-9)</th>
<th>5</th>
<th>8</th>
<th>6</th>
<th>9</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Q5 Why?</strong></td>
<td>I found steering the most difficult. Often times I thought I was straight but my bike would just turn into the wall. To achieve the direction I wanted in the simulator I would sometimes not move the same way I would if I was riding a motorcycle on the road. Button wise the controllers were good and the placement was intuitive in regards to where I would actually press in the simulator.</td>
<td>They were pretty useful as they reacted well with the game but after trying the simulator that would make steering much hard than being able to move the controllers around freely.</td>
<td>The controllers worked great position tracking wise, my irl movement matched the in game, but the grip themselves would be more useful if they were shaped and controlled like a bike.</td>
<td>The controllers themselves were very useful, they were quite responsive and I never felt like they limited my ability to learn the mechanics of the motorcycle.</td>
</tr>
<tr>
<td>Q6 Seat Useful (1-9)</td>
<td>2</td>
<td>5</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td><strong>Q7 Why?</strong></td>
<td>It was better than standing but the position is quite different when riding a motorcycle in real life. Had the seat moved it would have been better but I was in the no simulator group.</td>
<td>It was better than standing up but the position of my body didn’t match the position I would be in on the bike.</td>
<td>I feel like any other seat could have been used so I didn’t find the seat particularly use for or not useful.</td>
<td></td>
</tr>
<tr>
<td>Q8 Easiness (1-9)</td>
<td>9</td>
<td>9</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Q 9 What made it easy/hard?</td>
<td>The headset fit very well and I didn’t feel detached from the simulator due to gaps. On the first day I didn’t know where the buttons were but by the second and third day I was able to use the commands I wanted and restart easily. The controllers are in free space but in the simulator are attached to the handlebars while you are pressing the button. While riding I felt like I sometimes lost track of where my hands were in relation to my body as they did not move when in the simulator.</td>
<td>The game was pretty simple and easy to navigate. It took some getting used to, and I’m not quite sure how the physics worked exactly. It wasn’t very realistic when it came to how a bike would handle (engine rpm, when to change gear etc) as I didn’t need to brake at all and could just put it in 6th and floor it.</td>
<td>The controller and button setup was easy to get the hang off the start and it felt quite intuitive to me from my past experience with racing games. The lack of physical/haptic feedback made it difficult to feel what the bike was doing. It would have been nice to have feedback from the clutch or vibration when the tire slips etc.</td>
<td></td>
</tr>
<tr>
<td>Q10 Fun (1-9)</td>
<td>9</td>
<td>9</td>
<td>9</td>
<td>9</td>
</tr>
<tr>
<td>Q11 Difficulty Finding Controls (1-9)</td>
<td>9</td>
<td>9</td>
<td>5</td>
<td>9</td>
</tr>
<tr>
<td>Q12 What made it difficult?</td>
<td>I have had my motorcycle for about four years so I was already familiar with how to operate the with shifting gears and the role of the clutch and throttle. Pretty simple buttons and the clutch and shift gear button were close together which helped. It took some getting used to, again I’d recommend using motorbike handles as it would match what my eyes are seeing and real life. They were all intuitively placed and after a couple of try’s I didn’t have to think about what/where I was clicking.</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Q13 Accessing VR?</td>
<td>9</td>
<td>8</td>
<td>8</td>
<td>2</td>
</tr>
<tr>
<td>Q14 How’d you get access to one?</td>
<td>Other: If I didn’t want to commit to buying a VR system I could borrow a system from work.</td>
<td>Purchase</td>
<td>Purchase</td>
<td>Purchase</td>
</tr>
<tr>
<td>Q15 Confidence (1-9)</td>
<td>9</td>
<td>5</td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td>Q16 Valuable? (1-9)</td>
<td>6</td>
<td>6</td>
<td>2</td>
<td>9</td>
</tr>
<tr>
<td>Q 16.5</td>
<td>Learned Controls? (1-9)</td>
<td>9</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>--------</td>
<td>-------------------------</td>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>Q17 Comments</td>
<td>I feel confident about riding a motorcycle because I already do so. If I didn't have this experience I would only feel comfortable trying a motorcycle at low speeds in an empty parking lot. The throttle response was the most valuable part of this experience for me and most akin to real life response. The steering and feeling of moving at high speeds was not as well conveyed in the simulator. For next time it would be nice to have the set up be a wider space with cones to practice throttle control and braking.</td>
<td>N/A</td>
<td>My shoulders hurt, I gotta work on my back I guess</td>
<td>I think VR simulators like this could be VERY useful in teaching people how to ride a motorcycle and I think they should be employed / encouraged more often</td>
</tr>
</tbody>
</table>
## Desktop group post-test questionnaire

<table>
<thead>
<tr>
<th>Participant #</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Q1 Overall Experience</strong></td>
<td>It was fun to go in loops once I got the hang of it. It was hard to both learn control of the bike simulator and the VR system. I was never really able to tell when I was supposed to change gears (except neutral) it would have been nice to have a more set learning plan/drills</td>
<td>I learned the basics of riding a manual gearshift motorcycle. It was an interesting and fun experience and method of learning. I learned to shift gears and I can only assume that the simulation is identical to the real experience thanks to the sound effects and the realistic gear shifting</td>
<td>I felt that the simulator provided me a much better understanding of how using a clutch and gears would work on a motorcycle. The physical interaction pieces were a bit rough around the edges and removed some of the submersion but the gist was there</td>
<td>It was a positive learning experience, I found it difficult at times to maintain the strength in my neck and shoulders. I found the simulator immersive however doesn’t account for careless actions</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Q2 Useful Tool (1-9)</strong></th>
<th>3</th>
<th>9</th>
<th>7</th>
<th>8</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Q3 Why?</strong></td>
<td>I feel like I learned to play a game, not ride a bike. I’m not sure how transferable the gestures would be</td>
<td>Learning how to ride a motorcycle without spending money on one. It doesn’t get safer than this as a method of learning</td>
<td>I believe VR could provide motorcyclists with more confidence to deal with on road scenarios without being put in harms way. It will also lead to safer driving practices due to being able to physically learn without consequences.</td>
<td>I believe it was a useful learning tool as it gave me a good idea of the multi-tasking that is required to learn to drive a motorcycle while eliminating the fear of consequences. However you do lack the feeling of riding a bike with the setup</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Q4 Handlebar Useful Steering (1-9)</strong></th>
<th>1</th>
<th>5</th>
<th>5</th>
<th>7</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q5 Why?</td>
<td>I didn't know I was supposed to steer with them. I was more leaning my body. It's useful to get an idea of what a person's ergonomics/posture would feel like in real life. Otherwise I learned more from the idea of gear shifting and using other components of the bike. The handlebars held back the overall learning due to their positioning and overall build. With some refining here, they would provide a fantastic extra piece of realism to the VR experience. They were useful for keeping your hands separated and maintaining a straight line throughout it. However at times it was also more of a hinderance as certain corners were difficult to manoeuvre with the width.</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>---</td>
<td>---</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Q6 Seat Useful (1-5)</td>
<td>4</td>
<td>8</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>Q7 Why?</td>
<td>I'm neutral. It was a stool. The height was fine. I could move it easily when I needed to. It's good to make a simulation realistic even further by having a person sit when they're supposed to be sitting in the simulation. I simply used the stool but I feel a seat could have been beneficial to be put in proper riding position. Using a stool I found it was hard to maintain a quality posture throughout the study as well believe it was leading to strained muscles in certain areas.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Q8 Easiness (1-9)</td>
<td>3</td>
<td>6</td>
<td>7</td>
<td>8</td>
</tr>
<tr>
<td>Q 9What made it easy/hard?</td>
<td>Once I got a hang of its controls it wasn't so bad. But it was very quirky. The menus appeared at weird times and I had trouble seeing what gear I was in (not enough contrast). Resetting was very annoying and I had to relatively frequently. Challenging at first but after the second day it seemed natural. (On the third day) The simulator was quite easy to get into and use, but slightly rough around the edges. A couple small tweaks such as a quick restart would be super useful and make operating the sim a lot more user friendly. Quite user friendly using the simulator. Occasional adjustments needed to align bike with steering wheel in real life. Other than that quite seamles</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Q10 Fun (1-9)</td>
<td>6</td>
<td>9</td>
<td>9</td>
<td>9</td>
</tr>
<tr>
<td>Q11 Difficulty Finding Controls (1-9)</td>
<td>1</td>
<td>6</td>
<td>9</td>
<td>6</td>
</tr>
<tr>
<td>Q12 What made it difficult?</td>
<td>Very hard. The mapping of functions from buttons to motorcycle handlebar to controller was mediocre. The controllers had too many buttons. The position the controllers were in to ride and to controller the simulator was different and transitioning them was hard</td>
<td>Difficult to get used to at first. After some time I got used to where all the buttons and controls were. I did how to make a few mistakes pressing on the YX butting instead of the joystick</td>
<td>Having a played a lot of video games and with no prior vr experience it took me all of 3 minutes to be comfortable with the controls. It's very simple and super easy to pick up and get into</td>
<td>It has its challenges with the controls especially when set up in the handlebar simulator. I found often I was accidentally taking my hands off the handles in game due to the handle bar setup with the controls</td>
</tr>
<tr>
<td>Q13 Accessing VR?</td>
<td>4</td>
<td>5</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>Q14 How'd you get access to one?</td>
<td>Borrow From Library</td>
<td>Purchase</td>
<td>Can't Get Access b/c expensive and no room for one</td>
<td>Borrow Library</td>
</tr>
<tr>
<td>Q15 Confidence (1-9)</td>
<td>1</td>
<td>7</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>Q16 Valuable? (1-9)</td>
<td>5</td>
<td>8</td>
<td>6</td>
<td>7</td>
</tr>
<tr>
<td>Q17 Learned Controls? (1-9)</td>
<td>1</td>
<td>9</td>
<td>5</td>
<td>8</td>
</tr>
<tr>
<td>Comments</td>
<td>It could have been an ok videogame like Mario Cart or something</td>
<td>If at all feasible. Enhancing the sense even more by adding vibrations and maybe wind or air simulation would be great. - a handle bar that is more realistic to the type of bike on the simulation would be great. I felt like I was riding a Harley Davidson when I was riding a sports bik</td>
<td>I think the sim lays a fantastic framework for someone understanding the basic controls of a motorcycle. Obviously the more in depth the sim the better prepared they will be, but I have gained knowledge that would've been extremely difficult to just have explained to me through using the sim and experiencing how the bike would work.</td>
<td>Overall fun and valuable experience, had its pitfalls with certain handles and the controls of the VR. Found soreness after 5 min.</td>
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Seated group post-test questionnaire

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<tr>
<td>Q1 Overall Experience</td>
<td>The learning process was a bit rough at first especially as I had little to no prior knowledge. Learning to use the controls was a bit confusing at first since the buttons were very close together. Watching the simulator being demo-ed more slowly may have helped since I could not focus on both what the simulator looked like on the screen and the buttons that the researcher was pressing at the same time. The level of difficulty decreased drastically with each session since it became easier to remember how to maneuver.</td>
<td>It was great. It was a different experience at first as I have not used a VR headset in a view years, but the experience was completely relatable to riding a motorcycle.</td>
<td>Initially when I was approached by Ruzbeh to participate in his user testing research, I did not have any prior knowledge on riding a motorcycle. The last time I used a VR headset was couple years ago, so long enough to forget about my VR excitement, but not long enough not to have any expectations. On the first day, Ruzbeh instructed me on the control layout. He explained some basics of driving manual, including how to use and coordinate the clutch and switch gears, although He did not elaborate on WHEN to switch gears. The instructions we’re helpful, but not enough to learn how to ride a bike lol. Which is a good thing, because as I will explain later, most of my learning came from the simulator. Upon getting on the simulator, I was thrown off by how virtually “realistic” it was. At first I may have felt dizzy, and unbalanced. Once I got past that, my main struggle was my lack of control and my body coordination. That session I focused on learning the very basics like changing</td>
<td>My overall experience was good, I feel like I learned the basics of riding a motorcycle. I would feel more trained if the training tool had more extensive features than simply a racetrack, maybe practicing on a busy road or highway and practicing more than gearing up and down. I liked that the VR motorcycle had its own simulator to feel more immersed, but found it uncomfortable and so were the handles and VR goggles. The simulator could be more adjustable. If the VR googles are the actual weight of the helmet that works for the participant to feel more immersed but if not its weight made me dizzy when I moved my head. The way to start the simulation should be simpler to navigate, and so should the way to restart/reset the game. Visually, I liked the bright colours and clouds, and that all the buttons were in either hand. If there were a way to be able to see where to attach them to the simulator that would be even better. Overall though, a VR motorcycle training tool is a great product idea and I thoroughly</td>
</tr>
</tbody>
</table>
gears and making smooth turns while staying in the lane. Ruzbeh guided me throughout by giving me pointers, but for the most part I would learn from my mistakes (which you can afford to make in VR). At the end of the day I got the hang of switching gears and picking up some speed while staying on the track. On the second day, I was actually feeling confident and excited to get on the simulator. Even with few mistakes, I felt like I was able to pick back up where I had left off. I practiced the basics again and this time I was able to switch gears faster. I realized my self-improvements, wanted to do more, and got addicted to getting better. As someone who loves video games and staying physically active, not only does the VR feel like a video game, but the simulator/jig makes you put some physical movement into it which makes it more engaging and entertaining. I enjoyed the second day as I was getting better and also hit a high score of 37s which really didn’t mean much to Ruzbeh’s testing but sure brought out my competitive side and made me want to learn more tips and tricks. On the third day, not that I had mastered the
basics of driving manual, but I was feeling confident and good enough to pay attention to other details such as the speedometer, BPM levels, body coordination (head tilting), and coming to full stops without crashing the bike. Ruzbeh was in to see me pay attention to other details and so was I as I started focusing less of getting a quicker time and more on how to ride a bike in real life. The overall leading experience was great! I learned the basics of riding manual and progressed quickly after 3 days of 20-30 minute sessions. The handles on the jig made the “Ride” and turning much easier and realistic. On another note, the seat was quite uncomfortable and too far from the handles which caused some back pain. I felt dizzy and uneasy after 10-15 minutes of riding in VR, so a break was needed! Some instructions like when to switch gears and how to coordinate the body appropriately, can be helpful on the first day.

| Q 2 Useful Tool (1-9) | 4 | 8 | 9 | 6 |
| Q3 Why? | It brought back familiarity with riding a motorcycle. As in remembering how to properly use a clutch, change through gears fluidly, and how to properly downshift to come to a stop. | In my opinion the VR feels quite realistic and since it’s a virtual reality, you can afford to make mistakes which is the best way to learn. | As said before, it’s a great idea and works up to a point. I feel that as someone coming from no motorcycle experience, I would need to practice many other aspects of driving a motorcycle before feeling ready to get back on the road. |

<p>| Q4 Handlebar Usefulness Steering (1-9) | 2 | 7 | 9 | 5 |</p>
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<th>Q6 Seat Useful (1-5)</th>
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<tr>
<td>Q7 Why?</td>
<td>I am a small person and I had to sit at the very edge of the seat to try to be more comfortable, and even then the position of all the elements had me strain my body unnaturally. I was not sitting on the seat as I would be if it were a real life motor cycle</td>
<td>It was useful because it was a similar distance away from the handlebars as a real life experience. However, I wish the seat was more comfortable.</td>
<td>I can see how this piece could have definitely been useful to add to the realism of the simulation. I believe it could have been useful Unfortunately this seat was very uncomfortable I couldn’t wait to stand up</td>
<td>Useful but far away from the handlebars, maybe make adjustable</td>
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<td>Q8 Easiness (1-9)</td>
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</table>
Q 9 What made it easy/hard?

- It was easy to use once you got used to using all the controls simultaneously, but in the beginning the simulator was very hard as changing the acceleration with your wrist was easy to do unintentionally. The scoreboard showing up all the time when you made a lap also made things annoying and difficult.
- The simulator made it similar to a real experience, the VR experience made it seem real. As my first initial lap I was very nervous. What made it hard was remembering how to change gears. I can imagine it would have been even more challenging for someone who has no experience riding a motorcycle.
- Just like most video games or anything in life really, it takes time and practice getting used to something. I would say the simulator was quite challenging to use as you had to focus on multiple things at once; knowing the controls, coordinating your body and head to stay balanced on the bike virtually and physically, switching gears by paying attention the sound and the bpm level.. Although the training is challenging, the simulator is well built to get used to it quick.
- Stated at the beginning, the actual simulation was easy but the other things weren’t as much.

<p>| Q10 Fun (1-9) | 6 | 8 | 9 | 8 |
| Q11 Difficulty Finding Controls (1-9) | 5 | 8 | 6 | 8 |
| Q12 What made it difficult? | Most controls were very easy, but pressing on the joystick for changing gears and then switching your thumb to the other button to bring up the menu /reset view was difficult since you can’t see what you’re doing. I often mixed up the 2. | The brake and clutch made sense, the only thing that was challenging or that was a conscious effort was to remember which button changed the gears. As I sometimes wanted to click the menu button to change up. I had to remember it was the joy-stick that changed gears. | 1. Not being able to see your controller because of the headset is already make it difficult. 2. Sometimes you forget to keep holding onto those two handlebar buttons. | Said before |
| Q13 Accessing VR? | 3 | 2 | 5 | 2 |
| Q14 How’d you get access to one? | Rent Online | Borrow a friend’s | Purchase | Borrow a friend’s |
| Q15 Confidence (1-9) | 1 | 7 | 5 | 3 |</p>
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<th>Q16</th>
<th>Valuable? (1-9)</th>
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<td>Q17</td>
<td>Comments</td>
<td>N/A</td>
<td>The whole experience was great, Ruzbeh was fantastic at delivering the information in a clear and concise manner. I believe it is a valuable tool to use for someone that wants to learn how to ride a motorcycle without the risks associated.</td>
<td>Keep it up Ruz, killer project!</td>
<td>would also like to mention that if I had more time to learn how to ride a motorcycle via VR I’d be more experienced for sure</td>
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**Appendix C Participant Test Result Data**

**Appendix C.1 Control Group Test Data Excel Spreadsheet**

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