DEVELOPMENT AND USER EXPERIENCE ASSESSMENT OF A VR RESOURCE FOR LACTATION LATCHING

BY

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The above committee determined that the thesis is acceptable in form and content and that a satisfactory knowledge of the field covered by the thesis was demonstrated by the candidate during an oral examination. A signed copy of the Certificate of Approval is available from the School of Graduate and Postdoctoral Studies.

ABSTRACT

Breastfeeding is essential for infants and mothers. However, low breastfeeding rates have become a major health problem despite the use of electronic health resources used in videos, websites, and online video calls that lack spatial interactions. Existing VR breastfeeding research focuses on gathering technological acceptance, general information, and relationship with virtual infants by providing a first-person immersive experience, although lacking user experience and educational value assessments. This thesis develops a Virtual Reality (VR) breastfeeding experience focused on latching and compares user experience and educational value using head and eye tracking interactions. The preliminary results with 10 participants, five women, and five men volunteered to participate in a within-subjects study indicate that eye tracking improved education value despite the nuances of artifacts caused by sudden eye movement and blinking. Future work will focus on a larger study, migration to a system with better support for hand and eye tracking, and increased realism.

KEYWORDS: VIRTUAL REALITY, BREASTFEEDING, LATCHING, USABILITY, EYE-TRACKING, SIMULATION

AUTHOR'S DECLARATION

I hereby declare that this thesis consists of original work of which I have authored. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners.

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The research work in this thesis was performed in compliance with the regulations of Ontario Tech Research Ethics Board/Animal Care Committee under REB #17150 certificate file number.

GABRIELLE YOLANDE NYREE HOLLAENDER

STATEMENT OF CONTRIBUTION

This thesis research and studies have contributed to the fields relating to the following: Computer Science, specifically with different interactions possible in VR, Health Science, related to education and dissemination of information on breastfeeding, and Education, using 3D simulation techniques in order to teaching skills in a variety of domains. An abstract and presentation detailing a preliminary paper examining usability gaps relating to virtual reality health education and breastfeeding was published and presented at the 5th International Conference on the Future of Women 2022.

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CONTENTS

LIST OF FIGURES

LIST OF TABLES

ACRONYMS

VR Virtual Reality

AR Augmented Reality

XR Extended Reality

MR Mixed Reality

MRC Medical Research Council

HCI Human Computer Interaction(s)

CBKS Comprehensive Breastfeeding Knowledge Scale

HMD Head Mounted Displays

3D Three-dimensional

USA United States of America

SIGGRAPH Special Interest Group on Computer Graphics and Interactive Techniques

HCP Health Care Practitioner

TAM Technology Acceptance Model

FAQ Frequently Asked Questions

LSM Lactation Simulation Model

MISSES Michigan Standard Simulation Experience Scale

1

INTRODUCTION

1.1 OVERVIEW

Breastfeeding is essential for the health of newborns to ensure proper development and survival, as milk contains nutrients and antibodies that help grow and protect against common child-related illnesses [39]. Breastfeeding benefits both the mother and the baby, reducing the risk of breast and ovarian cancer, overweight, and diabetes, respectively [39]. Although the benefits of breastfeeding are recognized globally, there are ongoing efforts to increase the rate and success of breastfeeding for the first six months to at least 50% by 2025 and 70% by 2030 [14]. In Canada, only 35% of the parents exclusively breastfeed for the first six months, 19% stopped breastfeeding because it was unappealing, 12.2% stopped breastfeeding because bottle feeding was easier, 42.5% stopped breastfeeding before the 6-month mark due to a lack of breast milk supply and 20. 8% due to difficulties [14].

The current low breastfeeding indices are a major public health concern [15]. Efforts to improve and increase the rate and success of breastfeeding have been based on programs that traditionally rely on videos, images, and in-person or online sessions as part of prenatal courses and are complemented by relying on the availability of lactation experts and breastfeeding clinics. These resources focus on helping expectant mothers, mothers, and their support network (e.g., partner, spouse, family or friends) prepare and troubleshoot when breastfeeding [17]. Furthermore, recent years have seen a spike in the use of websites and mobile applications also known as e-Health (technology to provide health remotely), which has also enabled wide access to information in an effort to bridge gaps with access to in person services [21]. However, immersion and spatial interactions are associated with the complex skill of breastfeeding. Freund-Azaria et al. sought to understand this phenomenon, investigating breastfeeding barriers that are associated with maternal motor skills, infant motor skills, temperament, and whether the mother has chosen to exclusively breastfeed or not [23]. The results of this study indicate that motor coordination was higher between mothers who exclusively breastfed and those who did not. This is likely due to understanding the psychomotor nature of breastfeeding, which requires bilateral motor and eye-hand coordination to participate in successful and effective breastfeeding. Overall, these findings propose that mothers who have greater difficulty with motor coordination are more likely to develop a negative attitude toward breastfeeding even before they have attempted breastfeeding. The perception that breastfeeding is too difficult due to a lack of psychomotor skills or failure to succeed will decrease the likelihood of continuing breastfeeding. As such, it is necessary to consider this as a skill barrier that contributes to low rates of breastfeeding and needs to be addressed.

Despite the availability of e-health resources and breastfeeding services, low breastfeeding rates remain low. For example, within Ontario, Canada, breastfeeding rates are lower on the provincial scale (25%) and national scale (26%), despite the support and funding of the Durham Region [3]. In an effort to understand and improve the effectiveness and outreach of e-Health, research has focused on understanding how these tools aid in breastfeeding [21]. The use of e-health materials caters to younger generations born in 1981 or later who find the use of technology in daily life commonplace [5]. Furthermore, younger generations are gaining more exposure to interactive media content [62]. e-Health resources have expanded access to breastfeeding materials, which are complemented by prenatal courses and support from lactation experts when available [21]. However, the COVID-19 pandemic restricted in-person support in favor of online meetings that eliminated any supervised hands-on. Furthermore, online meetings limit hands-on breastfeeding practice with props available in in-person courses. Conveying breastfeeding instruction through video requires those participating to role-play with plushies, dolls, or other elements at hand how the baby is held and manipulated to achieve proper latching. While existing e-health resources provide interactive media using images and videos enhanced with text, these lack immersion and spatial interactions relevant to breastfeeding that can be possible when using VR.

Novel e-Health solutions are seeing an upward trend in exploring virtual reality (VR) technologies that allow users to experience immersive environments are gaining momentum in educational and training settings due to their affordability as consumer-level technologies [8], particularly within medical education, healthcare, and simulated training [11]. Currently, the VR market is projected to double in size by 2025, with the current market size valued at $15.8 billion USD [19]. With the ability to create real-world representations that allow users to explore environments otherwise impossible to replicate, VR has been positioned as the go-to technology for complementary training and education [29]. While rapidly growing, consumer-level VR technology remains a one-size-fits-all where the user adapts to the technology, which presents research opportunities to study usability, cognitive load, and task performance when used for non-gaming applications [16]. While usability examines how effectively a user can use a product or system, cognitive load, and task performance examine how much effort the user would need to expend in order to complete the task that they were given. For any mental task, a certain amount of effort is required in order to take advantage of the perception and memory that humans have available. Exploring a variety of methods of tracking would allow us to determine which would be the most effective to expand upon non-gaming applications. In addition to consumer-level VR technologies, various tracking technologies employing physiological measures such as eye tracking and heart rate are gaining momentum as solutions that can help create improved interactions by enhancing the user experience. For example, eye tracking is currently found in VR headsets such as the Pico Neo, the Meta Quest Pro, and the PSVR2 headsets, as it allows one to capture where the user's attention is. Prior to the consumer-level availability of eye-tracking, the technology was exclusive to industry and research. This scenario resulted in VR developments that guided users through a combination of audiovisual salient cues and head tracking. This approach presented a major limitation as head orientation does not equal the eye's position, meaning that the head could be oriented to the right while the gaze (i.e., location being looked at) could be set to another location within the user's field of view. The discrepancy between gaze and head orientation can produce VR interactions that can result in excessive head movement. Furthermore, it did not capture where the user's attention truly lies, which could help identify distractions and guide attention to areas of interest [36] [67]. These advances in tracking technology provided natural forms of interaction that leverage hand gestures, eye movements, and physiological measures that can facilitate user interactions and improve the user experience [36]. Typical uses of physical interactions and physiological measures include the assessment of user experience during the software development process to identify and eliminate problematic interactions or processes [67]. By understanding the user's focus and prioritizing these areas of focus, the usability and effectiveness of these applications can be improved through information scaffolding[9].

Current efforts at the intersection of breastfeeding, midwifery, and VR have been made possible with the development of VR simulations. Simulations, as defined by the Oxford Dictionary, relate to imitation experiences that aim to represent a process that occurs in real life. Often simulations can be governed by mathematical models to replicate real-life phenomena accurately; however, within simulated teaching, several simulations focus on the aspects of procedural knowledge by exposing users to scenarios otherwise impossible or difficult to replicate while in a safe environment. Virtual Feed [56], Virtual Parent [51], and "Real Baby - Real Family" [31] are examples of VR research focused on breastfeeding. Virtual Feed is a simulation drafted by Tang et al. through Oculus VR HMD, incorporating the usage of a doll embedded with a controller and hand tracking. The child would then be brought to the mother's breast to latch while in the simulation. Virtual Parent was one of the four simulation prototypes done by Simeone et al. exploring different immersive enactments that could be viable in VR. Virtual Parent focused more on having to do household chores while taking care of the basic needs of a baby, but did not include any breastfeeding component. Lastly, "Real Baby - Real

Family" developed by Mochizuki et al., is a nursing simulator that incorporates a tangible user interface in the form of a baby with haptics, a custom visual face generator that would create a virtual face replica of the baby based on the photos of two participants. Rather than focusing on breastfeeding, the baby can be bottle-fed in this scenario, and the outcome was intended to improve family ties and allow others to experience the joy of raising their own child. More details on these studies will be discussed in Related Works, Chapter 2.

1.2 PROBLEM STATEMENT

Breastfeeding requires the mother to properly hold the infant in a manner that ensures successful latching, which is critical for milk suction [63]. Currently, hands-on activities for expectant mothers and their support individuals (e.g., partner, spouse, family, and/or friends) include the use of plushies, breast mockups, videos, pictures, oral descriptions, and play-pretend with toy babies [53]. After giving birth, hands-on interaction occurs with the infant, where a lactation expert helps with holding, positioning, and proper latching [52]. However, COVID-19 made evident the shortcomings of existing approaches when relying only on online and e-health resources, which is why the use of VR presents an opportunity to complement breastfeeding latch instruction in an immersive manner that brings the content closer to real practice [7]. Current projects within this field have explored acceptance and the applicability of VR resources without focusing on the user experience and educational value.

1.2.1 *Justification*

Unlike traditional 2D e-Health resources, VR introduces users to 3D virtual spaces that provide immersion, spatial interactions, and real-life-like experience. Granic [25] and Wenk et al. [65] studied problems associated with the usability of software, as it is often a barrier to acceptance of technology. This remains true with VR and motivates work that help users to succeed. Typical approaches to ease of use for VR include prominent audiovisual cues and head tracking, which adds complexity to interactions as the user familiarizes with them [33]. Along with reduced depth cues and visuospatial transformations compared to standard 2D visualization, many of these changes further reduce the usability of VR. For most, especially in the case of medical professionals [18], the simplicity of software and how well an individual can use the system have a profound impact on the acceptance of a program, which is why eye tracking offers the possibility of naturally orienting attention to facilitate the use of VR, with various examples focusing on attention and user interactions [43].

1.3 RESEARCH QUESTION

This thesis aims to answer What are the usability, cognitive load, presence, task completion, and educational value effects of using VR head and eye tracking as an interaction mechanism for breastfeeding latching?

1.3.1 *Hypotheses*

- Eye-tracking interactions will result in higher usability than head tracking interactions.
- Eye-tracking interactions will result in lower cognitive load than head tracking interactions.
- Eye-tracking interactions will result in higher educational value than head tracking interactions.

1.4 THESIS SUMMARY

This thesis consists of six chapters along with two appendix sections. The chapters will cover the following information, listed in order. Chapter 2 presents the relevant literature currently available on VR breastfeeding, trends in VR medical education, breastfeeding simulations, and e-Health resources. Chapter 3 presented the process for the development of the prototype that will be tested in the study. This chapter provides information on the use case, hardware, software, and theory behind the latching skill that is being mimicked in VR, initial brainstorming, completed prototype, development challenges, and problem-solving conducted. Chapter 4 introduces the study design including experimental design, participants, measures, procedures, and instruments. Chapter 5 discusses and analyzes the results of the study. Finally, Chapter 6 summarizes the results, limitations, and future work that can be done based on the findings.

2 RELATED WORKS

2.1 OVERVIEW

This chapter presents a review of the current literature and the trends present within breastfeeding simulation education, immersive technology for breastfeeding, and related e-health resources. This systematic review aims to understand the current state-of-the-art in the use of e-health breastfeeding resources using VR, identify the gaps in common e-health breastfeeding resources that have led to the use of VR, and determine common methods for the development and evaluation of e-health breastfeeding resources and in particular VR.

2.2 LITERATURE REVIEW METHODS

This systematic review was performed using the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) 2020 guidelines [41]. The PRISMA guidelines serve as a tool to guide authors when conducting systematic reviews of content, with the aim of a clear report on methodology, justification, and results. These guidelines review eligibility criteria, information sources, search strategy, selection process, study selection, and individual study results. Once the systematic review is completed, gaps in the literature and overall results will be discussed.

2.2.1 *Eligibility Criteria*

In order to determine whether the papers would be eligible for use or not, a set of criteria has been used. For VR, most advances have been made recently, so to stay up-to-date, papers that have been written within the past ten years

Table 1: Category Organization Chart

Category	**Related Search Terms**
Breastfeeding Simulation Education	Simulation, human factors, breastfeeding, mothers, intervention
Immersive Technology for Breastfeeding	Immersive technology, education, medical, augmented reality, virtual reality, usability, eye-tracking
E-Health Breastfeeding	Exclusive breastfeeding, website, mobile, tele-health, breastfeeding, e-health

will be included. All databases take into account the appearance of keywords mentioned in the search engine to factor in relevance. The keywords that were used can be found in Table 1 is separated into their encompassing category. Only the first hundred papers were selected on the basis of having the most citations and relevance determined by each database.

2.2.2 *Databases*

A total of nine databases available from the Ontario Tech University Library were selected to be used, including ACM Digital Library Complete, IEEE Xplore Electronic Library, Springer Link, PubMed Central, Elsevier, Oxford Academic, Wiley Online Library, Frontiers, and Gale Academic OneFile. These databases were chosen to feature manuscripts in the domain of interest at the intersection of breastfeeding and e-health resources.

2.2.3 *Search Strategy*

A variety of search terms related to each category presented in Table 1 were used within each database. Exclusion criteria included the type and date of publication to examine studies that are relevant to current trends in the development of VR and breastfeeding. During the search, the amount of resources found included Books (4,827), Chapters (15,039), Journal Articles (548,996), and Conference Proceedings (268,196). These resources appeared within the search engine and were the amount of resources available before the selection process was applied. The manuscripts selected using the PRISMA guidelines were then filtered through the search terms to determine whether they were related to the identified categories. If any of the articles were related to at least one to two of the categories mentioned in Table 1, they were added to the synthesis table for further analysis. To reduce bias, a variety of databases were considered and articles were not solely selected based on their support of the hypothesis of this study.

2.3 Data Synthesis

Once the articles were selected, they were compiled into Table 3 (included in the Appendix A). Data for each article include the theme, title of the article, authors, venue/journal, date of publication, research summary, and size of participants. To gauge the quality and contributions of each article, a synthesis table was drafted, including a detailed evaluation of the ideas and methodology for each study. The analysis of the articles focused on identifying patterns over time and shining a spotlight on the current knowledge gap.

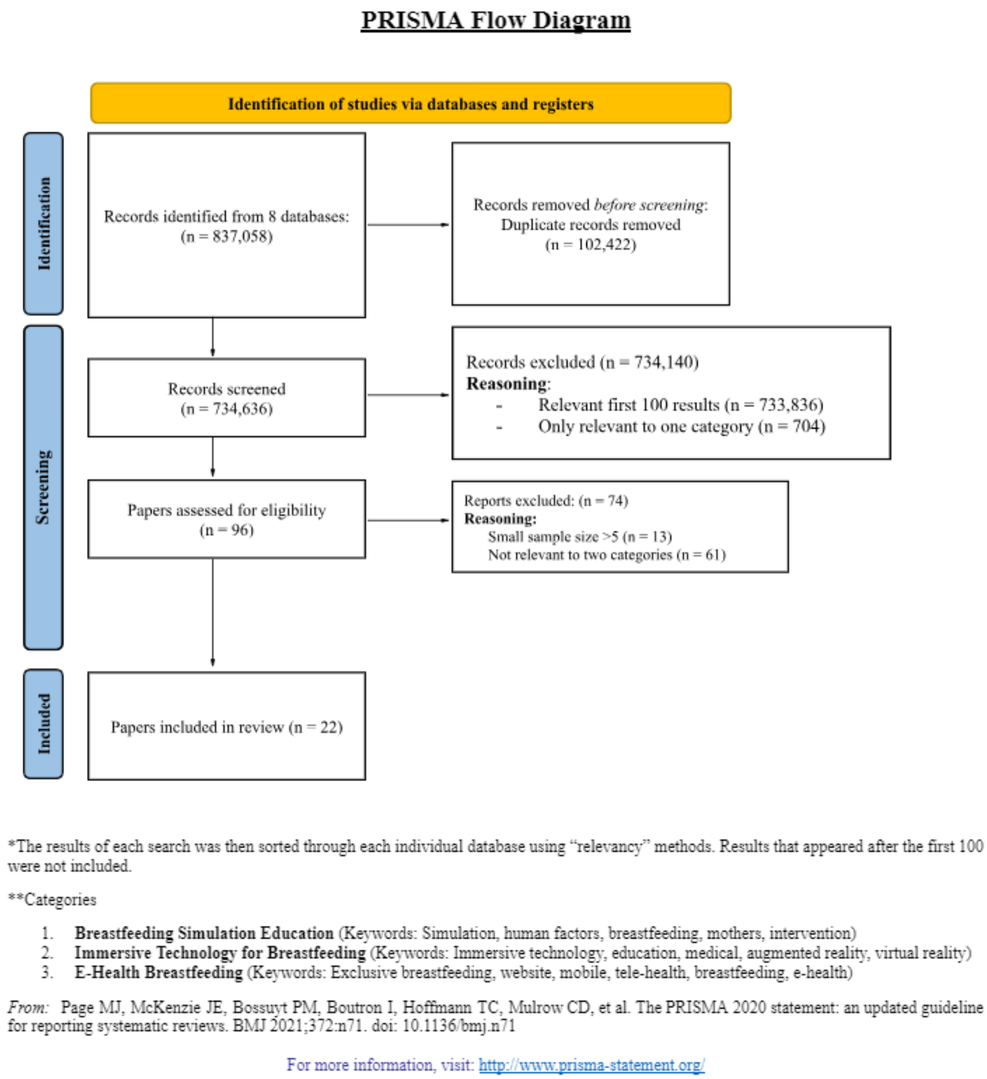


Figure 1: PRISMA Flow Chart Diagram

2.4 LITERATURE REVIEW PROCESS

The final selection of the article is summarized in Appendix A2, which presents the relevant findings of this review of the literature. The search yielded a total of 837,058 scholarly records, comprised of 432,953 from Springer Link, 231,095 from ACM Digital Library, 79,732 from Elsevier, 60,859 from IEEE Xplore, 13,337 from Oxford Academic, 17,198 from Gale Academic OneFile, 1,724 from PubMed, 113 from Frontiers and 47 from Wiley Online Library.

Once duplicates were removed, screening was performed on the remaining 734,636 records to further cull the number of papers. These articles were selected according to their relevance to the categories. 96 papers remained for another round of eligibility screening. After removing 13 papers that have a sample size or resource pool of less than 5, as well as 61 papers that are not relevant to at least two categories, a total of 23 papers remained. With this final selection of articles, the literature review was conducted to determine the study results and an overall summary of the synthesis carried out.

2.4.1 *Literature Review Results*

The 23 reviewed papers report various approaches to creating new and innovative methods to teach breastfeeding. Some of these methods included a VR feeding simulator, a high-fidelity simulator using silicone breast models, and the design of haptic baby devices for users to interact with. A common trend that is observed between all of these articles is the discussion of decreased exclusive breastfeeding rates within developed countries [14], with young mothers, specifically, being less likely to seek help compared to older ones. Another was a significant lack of discussion surrounding usability and the cognitive demand needed to use products that were designed. This showed that while these solutions could be accepted, it is not clear how easy it would be for users to use them and the frequency at which they would use them. Papers were organized to first discuss immersive technology as these papers would showcase the current state of VR technology for breastfeeding education.

2.4.2 *Human-Computer Interaction Key Terms*

Below are listed common terms that may also be discussed when analyzing selected papers. Definitions have been sourced from the Physical-Digital Affordances Group from the University of Regensburg and Science Direct.

- **Human-Computer Interaction** [66]: A human-computer interaction, in most cases, refers to the design and research of computer technology and how these devices may interact with people. Within this field, many aim to investigate new and novel ways of interacting with computers. As a field of research there are intersections between other fields such as behavioral science, media and within the case of this study, health sciences.
- **Usability** [66]: Usability refers to how effectively a system or software can be used in order to achieve the desired goals for its use and design. While a system may succeed in teaching the necessary information, if it has low usability it is very unlikely to be continuously used as the users may not be satisfied with how it feels or performs.
- **Cognitive Load** [24]: Cognitive load when within the field of computer science discusses the amount of mental effort that is needed for users to spend when using software. The level of cognitive can change depending on the tasks implemented and their means of implementation. When investigating this in research, usually developers' measure cognitive load to understand its impact on the usability and effectiveness of their software.

2.4.3 *Immersive Technology for Breastfeeding*

The first research question for this systematic review is the following: What are the current state-of-the-art breastfeeding e-health resources in VR? To understand the state of VR within breastfeeding, we must first investigate common research methods and trends in development. Ten articles were analyzed to determine prevalent trends in results, hardware, and methodologies.

2.4.3.1 *Systematic & Bibliometric Reviews*

Ryan et al. conducted a systematic review that provided more evidence on the current state of immersive technology within the health sciences. The objective of the article was to evaluate the current educational role that immersive technology has in the fields of medicine, nursing, and midwifery by analyzing 15,627 articles, evaluating the study design, study characteristics, main findings, and study learning outcomes [46]. Of the 29 articles selected for review, a total of 2,722 students were participants with no studies involving midwives. 76% of 29 authors also chose to use VR applications, with AR (17%) and MR (7%) significantly lower. This indicates a distinct gap within the midwifery field or the involvement of their students in studies, particularly in VR. It was also highlighted that the primary outcome of most studies involved reporting on attitudes, satisfaction, and opinions on the technology being used. In comparison, only 3% of these studies focus on psychometric results and evaluate the stress of participants while performing their tasks. This highlights another gap within studies lacking investigation regarding the practical skill effects these simulations may have on participants.

Pawassar et al. conducted a bibliometric review of VR in health care, compiling metrics on publication productivity, country productivity, journal productivity and impact, keywords, and dominant research clusters [42]. A bibliometric review focuses on using statistical methods to analyze different works, while a systematic review focuses more on the synthesis and assessment of these works. As breastfeeding is related to health care and midwifery, it is important to consider the current breadth of information available in this sector. What are the current trends for VR in healthcare and what are the primary specializations on which these projects are focused?

Halbig et al. investigated opportunities within immersive technology, conducting a medical expert survey on current options and challenges associated with VR development [28]. This article provided insight into the current thoughts of medical professionals about the incorporation of VR into practicing medical skills. Data were collected through an online survey involving 102 participants that focused on evaluating how well this technology could be accepted among medical professionals using the Technology Acceptance Model (TAM) [37]. The 102 healthcare professionals (HCPs) identified that VR could be useful in a variety of scenarios, mainly in therapy for those with anxiety and trauma, addressing body image disorders, teaching specific scenarios, or improving skill competency. The general results indicated that medical professionals felt that there were more opportunities for development than concerns about the incorporation of VR into medical practice. There was little mention of evaluating usability, as researchers were more focused on the adoption of the technology rather than the implementation. This study implies that VR has potential and interest within medical field professionals, especially in their daily routine.

Another systematic review was also conducted by Xu et al. investigating the current state of head-mounted displays within medical education. 17 articles published between 2017 and 2020 highlight the trend that most studies in VR, 33.9% use the Oculus Rift, 22% use the HTC Vive, 10.5% use Gear VR, and 2.4% have created a custom HMD that would suit the objective of the article [68]. In terms of AR, this was less commonly used with 31.2% of papers using some sort of AR-based HMDs. The headset most commonly used was the HoloLens at 28.2% and the now discontinued Brother AirScouter WD-200B headset at 3%. Common methods used for these studies were randomized controlled trials, cross-over studies, and pre-post-study. In general, after considering the hardware and different analysis methods for each study, the researchers Xu et al. found a trend that VR and AR have great potential to improve cognitive skills in medical education, as actions carried out in the environment correlate well with the real world. However, there are still concerns about the implementation of these tools relating to motion sickness depending on the task and the possibility of increased cognitive load that users could experience when in an overly hyper-realistic environment, as seen in the paper by Frederiksen et al. [22]. This paper discussed more on the topic on the possible mental demand that could be present within the field of medical education. Depending on the level of fidelity a simulation may have, cognitive demands may also potentially increase.

Bacca-Acosta et al. explored eye-tracking within an immersive virtual reality environment. Although not explicitly related to breastfeeding, this study incorporated eye tracking to improve English language knowledge and retention in a VR environment [9]. With a total of 41 students, all participants were taking English courses as their second language. The within-subject study compared an environment with eye tracking that prompts information depending on the focus of the user compared to a static environment with all the information already present. More specifically, the study focused on task completion, gaze focus times, and overall time spent, rather than implementing questionnaires to investigate user opinion on usability. While this was still an effective method to gauge mental demand and how the user interacts with the system, it would be more difficult to gather a general opinion on the usability of the system. However, the results indicated that scaffolding information was effective in increasing user learning performance. Bacca-Accosta et al. also provided effective suggestions for designing these environments. These suggestions included spatial contiguity, ensuring that the presented information is located closely to the information that it is related to. This spatial contiguity would also increase the amount of time students would devote to the area of focus, therefore increasing effectiveness. The natural integration of the scaffolded information should be seamless so that the information provided blends appropriately with the content. The scaffolded information should guide participants toward the most important information required to complete the task. Lastly, visual cues and other methods of representation are also necessary to increase user performance within these environments.

2.4.3.2 *VR Breastfeeding Practice & Engagement*

Virtual Feed [56], Virtual Parent [51], and 'Real Baby - Real Family [31]' are three works that best-emulated concepts related to breastfeeding and handling in VR. Tang et al. created the immersive VR experience, Virtual Feed, that presents early-stage breastfeeding with a baby [56]. The design of the application was carried out through sketches, mood boards, storyboards, and semi-structured interviews with 19 participants. Once the design was completed, the researchers added audio visual cues to reflect appropriate behavior for the baby. Their method of input for the simulation used a blend of hand tracking and using a VR controller. With the controller placed in the body of a real-life doll, the participant would manipulate the translation and rotation of the baby in VR as they did in real life following the gyroscope of the controller. Then, hand tracking was used to track and render hands in VR so that more delicate interactions could be had with the baby. Researchers also provided different scenarios including a personal living room, a meeting room, and a park to add a variety of places where participants would need to get familiar with breastfeeding. The research method for data collection for this study was primarily qualitative, as they wanted to gather the perspectives of the participants. The results suggest that there is a necessary point in providing customization for the user to simulate an individual and reflective experience for the user. Most of the participants were enthusiastic about using this experience and learned that breastfeeding could be more difficult when there was no previous experience, prompting further reflection. Uncertainty about how they were supposed to complete their task was also present. However, the researchers wanted to embrace and take advantage of this feeling of tension to provoke further discussion and allow parents to experience one of the main challenges of breastfeeding. This study provides a detailed discussion of the perspective of VR breastfeeding and suggests further development of these simulations, specifically investigating higher fidelity, family incorporation, and tailoring, as well as different breastfeeding modes (i.e., single child vs. twin holds). There was no evaluation of usability, as this document prioritized the participant perspective and acceptance of the application.

After the development of Virtual Feed, Tang et al. conducted another series of tests to determine the potential of playful technology as a method of engaging users within the Virtual Feed VR simulation [55]. Playful technology provides an opportunity for users to engage through the incorporation of clear goals, feedback, and rewards for the user. As the original Virtual Feed prototype did not have specific game elements, as they wanted to maintain fidelity to the breastfeeding task, researchers were curious how the simulation would be affected by the incorporation of these elements. After recruiting 10 participants, mainly women, the researchers were able to gather findings on the VR tool, its role in breastfeeding, and the impact that playful elements could have on the experience. Most of the participants felt that the uncertainty and challenges of breastfeeding were well replicated within the simulation and that a tool like this could make an effective companion to antenatal education. In terms of playful elements, most participants expected the simulation to have them due to the common association it has with VR systems. Due to this lack of game elements, participants struggled to understand the implicit breastfeeding process and requested that it be made more explicit. Messages or feedback that could inform them if the latch was performed successfully would be preferred. Another point that was mentioned was the inclusion of a tutorial in order to ease the player into the learning curve of the process. In general, the results indicate that the elements of the game could be useful in the context of a breastfeeding simulation to guide the user to correctly complete their task. Although this may affect the seriousness of the simulation, it could make users feel more comfortable with engaging in the task. Feedback in future iterations of the project would aim to provide these effects while ensuring that the user does not lose focus of the task. After this second research study, there was no quantitative evaluation of usability or cognitive load as the focus was the incorporation of playful technology.

Continuing from the creation of their prototype "Virtual Feed" [56] and the investigation of challenges and opportunities, Tang et al. continued their studies in 2023 by investigating the impacts of gamification being added to their original simulation. Gamification is the process of adding game-related mechanics, rules, and elements to improve user engagement and motivation. The researchers chose to use a design within-subjects to compare gamified and nongamified versions [57]. After recruiting 34 participants, information was collected using questionnaires such as the Player Experience Inventory (PXI) and the NASA Task Load Index along with semi-structured interviews. Of the three research studies published by Tang et al., this is the only paper that explored cognitive load and its potential impact on the user. Of all the articles studied, this was one of the only studies that continued to conduct further studies and investigate usability along with user experience. The technical setup of the system did not differ from the initial Virtual Feed study. However, for the gamified version, there was an added focus on providing gamification elements such as positive and negative feedback particle effects, a progression bar, and badges. After testing, the results indicated that the gamification of the system improved the player experience. Significant effects were seen in all functional areas, as they were rated higher than the nongamified version. While in the psychological domain, only immersion and enjoyment had a slight difference, the NASA Task Load Index overall score was not calculated and instead each of the six items was analyzed for statistical significance. The results show that both the temporal demand and the effort required were significantly higher for the gamified version, indicating that the time and effort needed to complete the task were higher because they were more involved in the system. Overall, the gamification of the system made the task more enjoyable for the participants and removed the sense of uncertainty users had when initiating a latch. However, this did take away from the seriousness of the simulation with the addition of these aspects and required more effort from the participant to be rewarded by the system.

Virtual Parent is another VR prototype focusing on child care done by Simeone et al. as part of a study that investigates a total of four possible immersive speculative enactments with a range of technologies available within the extended reality spectrum. More specifically, the participant will be immersed in a mundane moment of parenting, having to juggle chores and also taking care of the child. Researchers propose that within Human-Computer Interactions (HCI), immersive speculative enactments could be used as a method to "immerse users in an open-ended environment where they can interact with a rendition that could be available in the possible future" [51]. For analysis, this study focused on having both quantitative and qualitative results using the Slater-Usoh-Steed questionnaire followed by interview questions that compared their VR experience. Slater-Usoh-Steed questionnaire focuses on evaluating and determining if there is a difference between virtual and real experience [59]. While reviewing the presence, there is no investigation of the usability of the system or the cognitive load associated with any of these enactments. The results indicate that the participants had a neutral or average experience using VR enactment (M = 2.45 out of 5) and childcare experience (M = 2.75 out of 5). The presence within the simulation was acceptable; however, most of the participants felt divided due to the fact that the child was present and moving within the simulation, but they were unable to interact with it. In general, while it was somewhat effective in allowing the participant to gain insight into a possible future that would involve child care, this study primarily focused on general experience and freedom for the participants rather than teaching a specific skill in breastfeeding.

Researchers Mochizuki et al. created "Real Baby - Real Family", a project that aimed to improve family ties and love expression for those who are raising an infant [31]. This study used the HTC Vive for the VR HMD, while also incorporating a doll that would house a controller for high-precision tracking. The VR program was designed using the Unity game engine to incorporate a visual face generator along with controller haptics, which are synchronized with the voice of the participant. All of these were added to immerse the user in a believable experience to gain empathy. The face visualizer was one of the main focuses of this study, as it would change the face of the child based on the data collected from the participants. From multiple photographs, the baby's face would change to match a matching skin color of the two players used as a reference, along with a newly generated face made using a blend of the two. Age regression would also be applied to the generated face to fit the facial features of a baby. Data for this study were collected through questionnaires presented at various conferences, including the International Collegiate Virtual Reality Contest 2016, Laval Virtual 2017, Anime Expo 2017, and SIGGRAPH 2017, which recruited 591 attendees. The overall results indicate from the first conference that the preliminary 12 participants felt that the technology would require further improvement as the average scoring for the face generation system was rated at 2.27 out of 4. More testing and a varied face database would be needed to ensure that this could be applied to all races; however, most of the comments from the participants indicate that there is potential for nursing applications. For the 2017 conferences, the willingness to have a child was also evaluated to determine whether this project would impact participants. 259 participants out of 579 changed their opinion from "not wanting children" to "considering" after completing this experience. Iterative feedback was provided for the improvement of the simulation; however, usability of the system was not touched upon either. There is potential for future development with this project; however, further quantitative and qualitative tests would be needed to determine its effectiveness in the educational field.

2.4.4 *E-Health & Breastfeeding*

A total of five articles were selected to better identify the gaps in medical e-health resources or breastfeeding resources that could lead to the incorporation of VR. E-health resources refer to health-related resources available online, which could also be provided in a variety of mediums including an app, website, blog, forum, etc. Buckland et al. conducted a systematic review and meta-analysis of the current trends that have occurred when creating exclusive breastfeeding interventions for young mothers [12]. Of the initial 69 articles that passed screening, many were excluded due to the median age of the mothers, which was older than 25 years. This study was aimed primarily at young mothers, so those older than that age were excluded. Within the nine selected articles from the United States and Chile, the most popular method identified was peer counseling, used in combination with other methods such as telephone support, financial incentives and antenatal education (including online resources). As most articles included this method, it was clear that there was a significant positive effect on the promotion of breastfeeding. Since antenatal education is easier to access before the birth of the child, Buckland et al. noted that this information would likely be the most crucial for parents to have in order to make sure that they feel prepared for the birth of their child.

Reyes et al. conducted a study that looked at the effectiveness of school-based education on breastfeeding knowledge and intentions among adolescent females [45]. Within the study, 77 participants from all-female health education courses were recruited from a secondary school in the Greater Toronto area. The age range for the students was 14 to 16, most of them from grade 9. 79. 2% of the students indicated that they had not received any education on infant feeding before. Rather than exclusively breastfeeding, most indicated that within their culture, 40.3% used a combination of formula and breast milk. After an education session that included slides, videos, props, and an open discussion, participant feedback was collected to investigate the results of the intervention. 66. 7% of the students felt better informed after receiving this information, highlighting a positive change in their overall breastfeeding education. 81. 5% of the students also indicated that they felt that this content should be included in their secondary education as it is relevant for their future health. Based on these trends, it can be highlighted that single-session interventions, depending on the content, can be effective in increasing breastfeeding knowledge and behaviors. Especially with those who may be younger in age or those who may not have been exposed to this information beforehand.

Agrina et al. also conducted a small-scale study investigating the effectiveness of simulation education to improve the skill of a mother in breastfeeding focusing on rural areas of Indonesia, which lack access to many resources, including literature, online resources, and lactation consultants. Of the 26 participants, all were mothers with only high school or junior level education, while also not having a formal job outside of the home. Thirteen mothers were between 25 and 35 years old, and the others were over 35 years old. 30 8% of these mothers would also not continue to exclusively breastfeed, as they felt their baby was not satisfied with breast milk, likely due to mothers using incorrect techniques [6]. A between-subjects study employing a control group and an intervention group that would teach mothers using 3D simulation techniques. Once presented with the intervention for two weeks, or not at all, as in the control group, they would be evaluated using an observational checklist to assess the processes and skills of the mother. The results indicated that there was a significant difference of almost doubling the score (4.54 vs. 7.00) when comparing the skills of both groups, indicating that the intervention was very effective in improving breastfeeding skills. The limitations of this study include a lack of details on the exact implementation of the techniques, and a breakdown of the tools used would be useful to replicate the results of this intervention in other areas.

Tang et al. investigated the role of technology and its contribution to breastfeeding. 12 semi-formal interviews and 175 survey responses were used to better understand general attitudes toward parents, common norms, environments, and thoughts surrounding the use of technology [54]. During interviews, parents discuss how they were mainly positive or neutral on the point of breastfeeding, as it was an important source of contact with the mother and child. The participants seemed to accept that technology is being applied to address certain challenges within breastfeeding, but they had concerns about the accuracy and privacy of the facts as they involved their children. The method of feeding was mentioned as a factor that affected the self-efficacy of being able to feed their child. Parents felt that bottle feeding had a clearer routine with easier instructions, while breastfeeding caused more uncertainty and loss of control. Most of the participants stated that they also had a clear understanding of the theoretical aspects of breastfeeding but a clear lack of practical proficiency with the task. An interesting point that was also mentioned was that one partner expressed jealousy over not being able to experience the breastfeeding experience as their wife would. In general, these points indicate that many parents have sufficient knowledge of breastfeeding, but lack the practical experience needed to feel more comfortable with the skill. Due to this uncertainty, some parents lose the desire to continue breastfeeding because they are unsure how to overcome these challenges. The results of the study survey also support these findings, highlighting an average score of 5 out of 5 for the emotional toll of breastfeeding and knowledge on an average of 4 out of 5.

De Souza et al. investigated the design of HCIs for lactation professionals. As this was more focused on overall technology than VR, the researchers provided information on current challenges and potential solutions that could benefit consultants [18]. Qualitative data was collected through an interview and survey of six lactation consultants, investigating common issues and sentiments these professionals may have. The results indicate that thoughts around remote consultations vary, as they allow more frequent contact with mothers. However, a participant found that long in-person consultations would be more effective with their patients and harder to replicate in the virtual setting. Another concern stated was that traditional virtual settings, such as video conferencing, lacked physical manipulation and would dull the senses of the lactation consultant. As understanding feeding cues relies on observing movements and sounds, this may be difficult to see and hear depending on the quality of the video feed. The participants proposed to annotate videos and build a virtual library for patients to take advantage of technology, and virtual reality was not considered. This indicates that these professionals may not be aware of this technology or may feel that there is no information available to them on the subject due to the low amount of VR studies on breastfeeding.

Lastly, Wallwiener et al. investigated the characteristics of women who would be using e-health resources. This study allowed for a closer look at how well these resources are received and the demographics that are targeted for these tools. 220 women were gathered for this study, which focused mainly on qualitative results related to the use of the Internet and their smartphones [62]. The results indicated and supported other previous findings that a high number of participants are going online to seek medical information during their pregnancy. The information found online was usually of high influence for them, indicating that at least 63% of the participants would use the information found online on the websites. Maternity forums and smartphone applications were used sparingly, with less than a third of the participants referring to them. It was also observed that those who used these tools tended to be younger, likely preparing for their first pregnancy, as this was the time when they had the greatest need for this information.

2.4.5 *Breastfeeding Education & Simulations*

Simulations provide an alternate means of transferring knowledge along with practical skills. During COVID-19, it became apparent that physical or in-person tasks would be limited due to physical distancing restrictions, thus limiting access to information. Simulations that could be conducted at home or in a purely virtual setting would alleviate in-person visits and promote remote counseling. Eight articles will be investigated for their desired results, demographic target, methodology, and results [10].

Gurkan et al. conducted a between-subjects study of a simulation used for breastfeeding support during COVID-19 [26]. Participants in this study included 73 pregnant women who did not have medical complications and planned to breastfeed after birth. Participants were divided and would go through standard breastfeeding education or receive a simulation intervention, which was then supported by online counseling afterwards. Data collection tools were predominantly quantitative in nature including a demographic form, LATCH which is a breastfeeding assessment and diagnostic tool, breastfeeding self-efficacy scale, and the mother-infant bonding scale. After evaluating the experimental group, which used a breast simulation model along with a baby model, it was found that the self-efficacy and success of the mothers were higher than those of the control group, which used traditional methods with a difference of 71.2%. In general, the researchers found that these simulations would allow a decrease in hospital visits and face-to-face communications, providing a safer alternative for parents when they have to be socially distant. Usability was also not considered for these simulations, as they were aimed at gauging the effectiveness of the learning model.

Webber et al. investigated breastfeeding education and self-efficacy with 77 nursing students [64]. The study focused on the lack of opportunities practicing students have with respect to breastfeeding support and management, as students were unable to gain hands-on/practical experience other than during rotation. The study proposed the incorporation of a low- and high-fidelity lactation simulation model prior to rotation to reduce risk and harm during breastfeeding diagnoses. The study had participants placed in pairs, taking turns wearing the breast model and performing an examination using practical and communicative skills. To evaluate the differences and perceptions between these two simulations, the study primarily focused on qualitative data rather than quantitative data. Such an approach is different from most simulation studies which usually include quantitative data to support the findings. Due to this, the usability of the system was also not evaluated. Data analysis revealed a total of four themes that were presented as outcomes between responses: student comfort in applying breastfeeding techniques, student confidence in patient education and overall care, breastfeeding advocacy and the importance of having support, and positive simulation experience. An important qualitative finding presented was that regardless of fidelity (low or high), both were able to provide positive results for students. A high-fidelity simulation may be more effective with more experienced individuals or those who require practice with a more complicated technique. Limitations were also addressed in recognizing that the incorporation of quantitative data would give this study more clinical significance, as well as being able to identify which simulation fidelity level is the most effective.

Louis-Jacques et al. examined another facet of breastfeeding education, specifically examining the impacts of doula-led community interventions for 121 mothers who may be marginalized, racially diverse and of low income [35]. Doula support was presented as an alternative to improving breastfeeding rates by reducing medical costs while ensuring improved maternal and infant health. A within-subjects study investigated breastfeeding knowledge before and after an education intervention that would last one hour. Data collection points included before and after the intervention, 2 to 4 weeks after birth, and 6 to 8 weeks after birth. The measures used included a questionnaire on the breastfeeding initiative and breastfeeding knowledge. During this education intervention, expecting mothers received breastfeeding information graphics, including frequently asked questions, and materials from the breastfeeding support toolkits. Practical information was also given along with presenting needed techniques such as hand expression through the use of models of breasts and infants. After data collection was completed, the results indicated that this intervention was not fully successful in significantly improving the rates of mothers wanting and continuing to breastfeed. This meant that if the mother did not already have the intention of breastfeeding her child, this rate was not affected or would slightly decrease for those who did not. While there was an increase, these numbers could have been affected by the ability to continue to have access to these resources rather than a single intervention. However, there was an improvement in breastfeeding knowledge for participants who were exclusively breastfeeding or engaged in combination feeding (breast milk and formula). These scores would improve from the pre-and post-test at 7.80 to 10.42 respectively. For those who only fed formula, there was no significant effect while doula-led education had an impact on breastfeeding, as it provided another means of educating mothers who may not have had access to these materials prior. As most of these services use evidence-based tools and kits, there is an opportunity for growth and distribution as long as the tools remain sustainable while providing clear communication about breastfeeding.

Liu et al. designed an interactive system built on the standard baby doll that is used to train parents when first exploring neonatal nursing [34]. The focus of this study was to integrate a multi-sensor simulator that would provide real-time feedback to the parents following their actions with the child. This would be used in conjunction with an on-screen application using a mobile device such as an iPad, to guide parents through the steps required for breastfeeding and latching. The application did not provide these steps in 3D and used 2D images to provide context for each step. Using the sensors that were placed in the doll, the user would receive specific feedback from the child and application should the actions that they take be incorrect for what is needed for the baby. The doll consists of a vibration sensor, a touch sensor, an accelerometer, a shock sensor to simulate burping, and a servo motor for arm movement. The user studies were predominantly qualitative and included semi-structured interviews with 3 nursing experts, focusing on the design of the application. These experts then highlighted the main goals that this simulation should cover: providing parents with clear steps to proceed with nursing to reduce learning costs, providing physical practice and contact, which they are usually not able to do before birth, and error correction to ensure effective development of these skills. After the application was designed, it was tested in a user study with two men and two women. The results indicated that the step-by-step process could be broken down more thoroughly and that real-time feedback was very helpful in ensuring that it remained on track. Overall, the participants were willing to use Pababy to learn about newborn nursing, as it provided clear goals for parents while also allowing them to practice the necessary motor skills. As this was designed during the pandemic, researchers also created this while considering how to support home nursing or those who may not be able to access resources due to distance. Usability was not considered for this study even though the device also included an application that was used in conjunction with the device. Therefore, it was not clear if this would be usable with a more diverse audience. Limitations also need to be taken into account that the small sample size for both interviews and user studies may not have provided enough usable feedback to improve function and design.

Villegas et al. also took a quantitative approach in their study to evaluate the development of a simulation that is more tele-health-based online for nursing students [60]. 205 undergraduate students were recruited to complete two simulation scenarios, which would have more experienced nursing students acting as mothers who would need consultation. The first scenario focused on informing the mother about breastfeeding maintenance at work and its benefits. The second included a mother who was experiencing engorgement due to improper technique. Data collection tools included evaluation of telehealth simulations, knowledge of telehealth, benefits of telehealth, use of telehealth, and possible future simulation implementations. The results indicated that 47. 5% thought the simulation required no improvements, with 8.3% discussing a needed improvement on the technical setup. 38.5% believed that this type of simulation would be useful for overcoming distance problems and 30% thought that this would be useful for those who have limited or no access to healthcare. These quantitative results highlight the usefulness of using simulations and technology to overcome current obstacles within the healthcare system.

Sadovnikova et al. looked at another method to support breastfeeding education by creating a high-fidelity hybrid simulator called the Lactation Simulation Model (LSM). Compared to other studies, this simulation focuses on the manipulation and diagnosis of breasts, rather than placing a priority on the replication of an interactable infant [47]. Using a blend of silicone materials, the researchers created a female torso. For this study, participants were able to practice examinations and movement of breast tissue, specifically related to breast massaging to simulate milk production. Since placement and coordination are important factors in ensuring that an infant has a successful latch, it was important to provide an environment where participants could gain confidence in the movements they are doing. This hybrid simulation would allow trainees to gain empathy and culturally accurate responses when dealing with patients of different ethnicities and with varying complications, including nipple damage, engorgement, or a plugged duct. The user tests included a survey that would investigate the breastfeeding experience, the form and function of the breast simulator, and the clinical skills of lactation. The results indicate that most of the residents studying family medicine and gynecology at the University of Michigan (n = 17) had little or no experience practicing a breast examination and were not confident in their ability to perform the task. After completing the LSM simulations, the residents felt that the model was very realistic and made them more comfortable with their hand coordination and examination skills after practicing it. When this was tested with 15 midwifery students, the results changed slightly, as they had significantly more experience with breast examinations. The material and feel of the skin for the simulation they felt were somewhat inaccurate, while the medical conditions that were displayed were still accurate. In general, all participants believed that this simulation was useful to train healthcare professionals on the practical aspects associated with breast examination and lactation; however, more work is required to improve the realism and portrayal of certain medical conditions due to the quality of silicone.

Hackerman et al. took a different approach by looking at the paternal aspect associated with breastfeeding [27]. This is of interest as VR does not need to be limited to sex or motherhood, as there are a variety of support formats in which a child could be raised. For this study, a longitudinal approach was used to interview 2,829 couples to determine maternal and paternal education. The results indicated that most women were coupled or married to men at the same level of education as them (e.g., having a college degree). Based on these levels, researchers did find a correlation between a father's education and the likelihood that a mother breastfeeding. Therefore, the more educated the father, the more likely the mother would initiate and continue to breastfeed. Fathers with lower levels of education, such as having only a high school or technical school degree, were less likely to have partners initiate breastfeeding. Compared to education, researchers also found that there was no significance associated with the relationship between mother and father when it comes to breastfeeding. In general, these findings indicate that it is crucial to educate fathers, as they could affect the likelihood that their partner will want to breastfeed and continue to do so. Studies done by Abbass-Dick and Dennis also corroborate this point [1][2] highlighting high ratings with interventions targeting both parents and enjoying information which would aid them on working as a team and fulfilling parental goals together. As fathers do not have the opportunity to breastfeed themselves, having other interactions and opportunities to bond with their child may help increase paternal confidence and decrease feelings of envy or being left out. Co-parenting would also provide further support for the mother and reduce potential stress which could come with approaching the task alone.

2.4.6 *Chapter Summary*

The literature review presented in this chapter indicates that the current state of breastfeeding e-health resources in VR is scarce. Of the articles mentioned, the three studies including Pababy, Virtual Parent, and "Real Baby - Real Family" aimed to address this problem. However, of these three articles, only one investigated the usability and cognitive load associated with the task of identifying a large information gap. Furthermore, breastfeeding e-health resources lack immersive simulated scenarios that teach the mother the practical skills needed for breastfeeding, leading to the use of VR. Regarding the research methods, most studies focused on the acceptance and incorporation of these tools, rather than how easily the user was able to use them. The methods reported in the literature include the Technology Acceptance Model (TAM), qualitative questions that were codified, the Slater-Usoh-Steed questionnaire, and the Player Experience Inventory. The NASA Task Load Index was used for only one study, showcasing the lack of investigation into cognitive load as well.

Practical skills and learning outcomes were also rarely investigated, other than when tested in a clinical setting. This highlighted that most of the simulations and experiences for students would primarily focus on knowledge acquisition or technology acceptance rather than skill transfer. Participants would experience these simulations along with an intervention where they would conduct the activity usually one time rather than repeatedly, not being able to take advantage of the distribution of practice effects that would occur when practicing a skill repeatedly. Murphy et al. discussed this phenomenon in 1916 through the mass practice of throwing javelins with participants. It was shown that since the group practiced three times a week for 12 weeks, results 3 months later showed improvement in both learning and performance [49]. Repetition of a skill helps in the retention and acquisition of skills.

Another trend that was made apparent was that for many of the VR studies that were conducted, there was a heavy emphasis on collecting qualitative data rather than quantitative. Most sought these data to understand the perspectives of the participants and to determine whether the creation of these VR scenarios would be viable for education and have the support to continue development. This highlights a gap in quantitative results that would provide supporting statistics for the design of VR breastfeeding scenarios.

3 EXPERIMENTAL PROTOCOLS

3.1 OVERVIEW

This chapter presents the study design, the setup and development of the VR experience development, and protocols for participant testing.The study procedure was approved by Ontario Tech University's Research Ethics Board (REB #17150). The study design aimed to address the following:

- Research Question: What are the usability, cognitive load, presence, task completion, and educational value effects of using VR head and eye tracking as an interaction mechanism for breastfeeding latching?
- Hypotheses:
  - Eye tracking interactions will result in higher usability than head tracking interactions.
  - Eye tracking interactions will result in lower cognitive load than head tracking interactions.
  - Eye tracking interactions will result in higher educational value than head tracking interactions.

3.2 VR DEVELOPMENT

The virtual latching scenario was developed for compatibility with the Pico Neo VR headsets with support of eye-tracking. The Pico Neo VR headsets are standalone and desktop VR headsets all-in-one consumer-level devices that support eye tracking. The Pico Neo 2 Eye and Pico Neo 3 Pro Eye were used for development and data collection, respectively. The reason for collecting the data with the Pico

Neo 3 offered better support for hand and eye tracking that would not impact the participants. The VR breastfeeding application was developed exclusively using Unity Engine due to compatibility with Pico headsets through Pico's official software development kit[1].

In addition to the Pico Neo software development kit, the XR Interaction Toolkit Version 0.9[2] and 2.1.1[3] for Unity 2019.4.5. (LTS) were chosen to design the core VR functionality of the application. The XR Interaction Toolkit provides base interactive features including basic controls, item hovering, selecting, grabbing, haptic feedback (if present in the headset), visual feedback, 3D participant Interface (UI) interaction, VR camera rigging, and room-scale VR experiences, among others. More recent versions of the Unity game engine were avoided because of a lack of compatibility with the Pico Neo software development kit. This issue therefore limited access to two-handed grab functionality and the usage of multi-sockets (which are used to attach more than one object).The final two components of the VR scene development saw the addition of the Tobii XR SDK for Unity 3.0.0[4] to access the eye-tracking capabilities that are integrated into the headset, and the use of heart rate monitoring through using a smartwatch by integrating the hyperrate[5] unity plugin[6] for heart rate monitoring.

3.2.1 *Breastfeeding Latching Scenario Development*

Breastfeeding requires that a lactating mother holds the infant in a manner that ensures proper latching. A successful latch is indicated by a comfortable breast-

1 https://developer-global.pico-interactive.com/document/unity/
2 https://docs.unity3d.com/Packages/com.unity.xr.interaction.toolkit@0.9/manual/index.html
3 https://docs.unity3d.com/Packages/com.unity.xr.interaction.toolkit@2.1/manual/index.html
4 https://developer.tobii.com/xr/downloads/
5 https://www.hyperate.io/
6 https://assetstore.unity.com/packages/tools/input-management/heart-rate-plugin-for-hyperate-212796

feeding experience that does not cause the nipples to feel damaged or stored. For the infant, these signs include swallowing sounds, feeding in bursts, the mouth wide open, deep latch placement, and ear movement [61].Achieving proper latching requires understanding how to properly maneuver the infant based on the audiovisual when breastfeeding [5].

3.2.2 *Ideation*

Before developing the VR experience, Brainstorming, an ideation creative method was used to consider different ideas for the scenario following the method of the Stanford Design Thinking Model in which empathizing, defining the problem, ideating, and iteratively prototyping lead to creative solutions to a problem [40]. The Brainstorming was conducted with Dr. Abbass-Dick, a researcher with content expertise on breastfeeding. After reviewing findings from the literature review and works by Dr. Abbass-Dick, the needs and requirements for the VR latch scenario were defined.

The brainstorming ideas captured during the ideation phase included:

- **VR Serious Game on Latching**: The participant would be led through the latching process, and there would be game elements included, such as a timer, scoreboard, added feedback effects, and possible penalties. Eye tracking would also be added on top of this to provide hints to the player.
- **VR Latching Tour**: The participant would be led through a curated experience where they would need to do no manipulation and would only need to mimic what is occurring during the experience. While watching what is occurring with the set avatar animations, they can still look around and see added prompts from eye tracking. While they are not able to practice in the environment, they would be able to see the correct method of latching.
- **VR Latching Application**: The participant will be set in a VR environment where they will be able to interact with a baby and certain aspects of their

avatar. Eye tracking is used to provide contextual information as they proceed to engage the child available into a latch.

After this phase, the ideas were classified to determine which is most appropriate for prototyping and testing.

3.2.3 *Idea Classification*

Based on these three ideas, the potential application was identified to require three domains, including educational simulation, breastfeeding and healthcare, and immersive technology as presented in Figure 2.

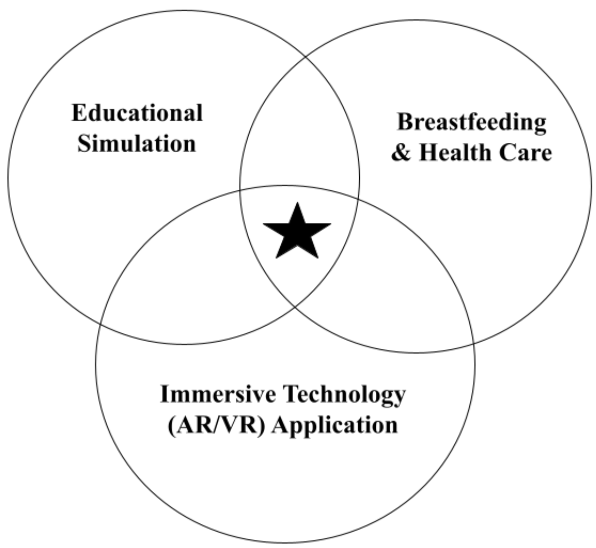


Figure 2: Application Classification

Immersive technologies encompass hardware within the spectrum of the virtuality continuum, including VR, AR, and MR. This thesis focused on the use of VR as it allows to virtually replicate the scenario using 3D models. The second category related to breastfeeding and health education and focused on providing information about breastfeeding while interacting with the 3D models. Lastly, the educational simulation component aimed to leverage an accurate representation of latching to be performed in VR. The combination of these three components allowed practicing and learning latching, an approach commonly used in medical simulation to facilitate skill development [13]. Exposure to simulated environments facilitated practicing the necessary hands-on skills while still being in a safe environment.

3.2.4 *Storyboard*

With a better understanding of the theory and process behind latching, a storyboard was also drafted to outline the steps taken in the application, as seen in Figure 3. After considering all brainstorming ideas, the VR Latching Application was selected as it would be more direct to test usability and implement the latching process within the development time frame. This storyboard was built based on various communications with a content expert. In addition, through feedback received through presentations done within the Virtual Research Rounds of the maxSimHealth[7] research group. A point gathered through the discussion was the inclusion of a tutorial for the participant, as it is very likely that the participants may not have experience with a VR headset. This would allow them time to familiarize themselves with the controls so that they could be more at ease when moving on to the latching instruction.

With this storyboard, the application was designed to have menu buttons that include a tutorial, the start of the application, and settings. For the final prototype, the settings option was removed to be replaced with skin selection and dominant hand choice readily available in the main menu. The tutorial for the storyboard would first have been a video which would then be followed by a simple environment where the participant can experiment with grabbing 3D objects. For the prototype, the video portion was removed. Lastly, during the application, audio and text cues would be provided to the viewer so that they could determine the state of the baby. Pop-ups would be provided on feeding times, baby feeding cues, nipple feeding, areola feeding, and positioning. For the prototype, the amount

7 https://maxsimhealth.com/

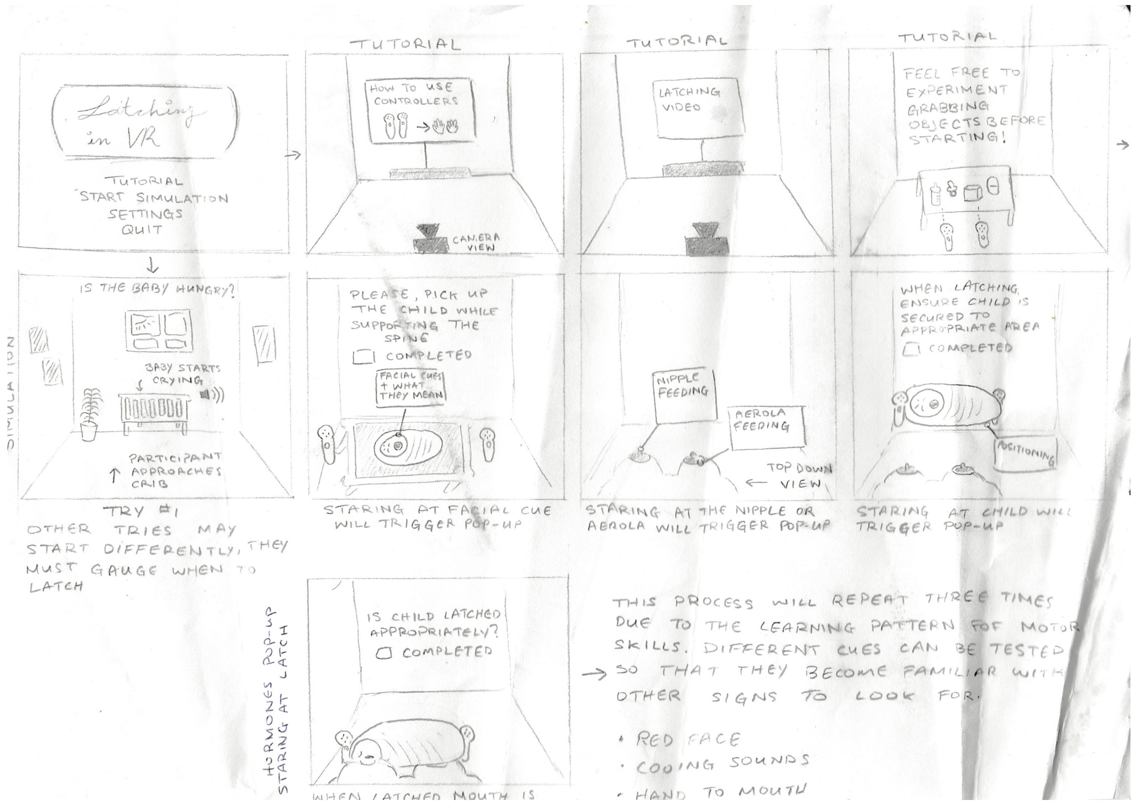


Figure 3: Initial Storyboard Design

of pop-ups was reduced in order to prevent clipping between the various texts. Pop-ups on feeding times and the latching mechanism were two of the pop-ups that were prioritized and shown as crucially relevant information that needed to be presented to the participant.

To properly implement the chosen idea in VR, a virtual scenario was developed for latching, including an interactive component designed to provide information to learn and execute the task. Additionally, the VR application introduces cues to inform when the infant may be in distress. VR interactions support the use of head and eye-tracking to interact with the information provided through the virtual latching process.Since the purpose of the VR latching application is to provide information and hands-on practice, relevant information on breastfeeding and milk production was introduced within the VR scenario as follows [63]:

- The breasts can produce milk as soon as 12 weeks of pregnancy, with the breasts changing in size, appearance, and color.

- Once the baby starts to suckle the breast, the process of milk delivery begins with hormones (oxytocin, prolactin) being released to the mother's brain. It is the prolactin that is released that causes the breast to release milk to the baby.
- Then oxytocin being released starts the flow of milk delivery.

Of the items listed, the first and second points can be implemented using visual and auditory cues to inform that the latching process has begun. This information was also included in a pop-up within the eye tracking as well, to provide more context to the latching action. It was mainly this sucking and latching mechanism that drove the breastfeeding system. Ensuring that a baby establishes this process properly is crucial to protecting the health of both mother and child [63]. Concerns that may arise due to an improper latching technique can include sore nipples for the mother, breast engorgement, mastitis, and possible malnutrition should the milk not be properly released.

The latching process was programmed by taking advantage of the available packages in Unity to collide and attach objects to each other based on the positioning of a socket point. With the socket point placed on the breast, once the child came in contact, it would latch. After the system detects the latch, different feedback is added to simulate the cues present in breastfeeding. The shape of the mouth and the orientation of the child relative to the mother were also adjusted using a code script in C# that would be active upon collision.

3.2.5 *Assets*

All 3D assets that were used during the development of this prototype were acquired through websites such as TurboSquid or Free3D to ensure that there were no copyright violations and were also royalty-free. The use of these assets allowed for a significant reduction in development time as it eliminated the need to design the needed assets by hand. Future development would aim to create unique assets that could be used for this project. The audio was collected in the same manner using websites such as FreeSound and these sounds for the audio feedback that occurs in the VR application. The hands for the application were purchased from the Unity Asset Store [8], as they came with different color options, as well as completed animations that could be applied to each button press of the controller.

3.2.6 *3D Assets*

The VR scene consists of various 3D models selected to recreate a nursery room with toys, a bassinet, a virtual baby, and a board with information about latching, scene customization supporting skin customization for better representation of the avatar skin color, and VR controls, as shown in Figure 4. This design was inspired by the e-book resource by Abbass-Dick et al. which provide visual examples of potential breastfeeding environments [5] and through brainstorming sessions conducted with Dr. Abbass-Dick.

An important additional 3D asset is that of the mother's as it shows the hands and breast used to practice latching (Figure 5). The mother and baby avatars were adjusted in Blender to ensure proper rigging and animations matching latching were reproduced in VR. For example, to ensure proper baby visual cues, the opening and closing of the mouth as seen in Figure 5 were animated using blend shapes synchronized with audio cues for the the swallowing sounds which indicate that the infant is feeding in bursts.

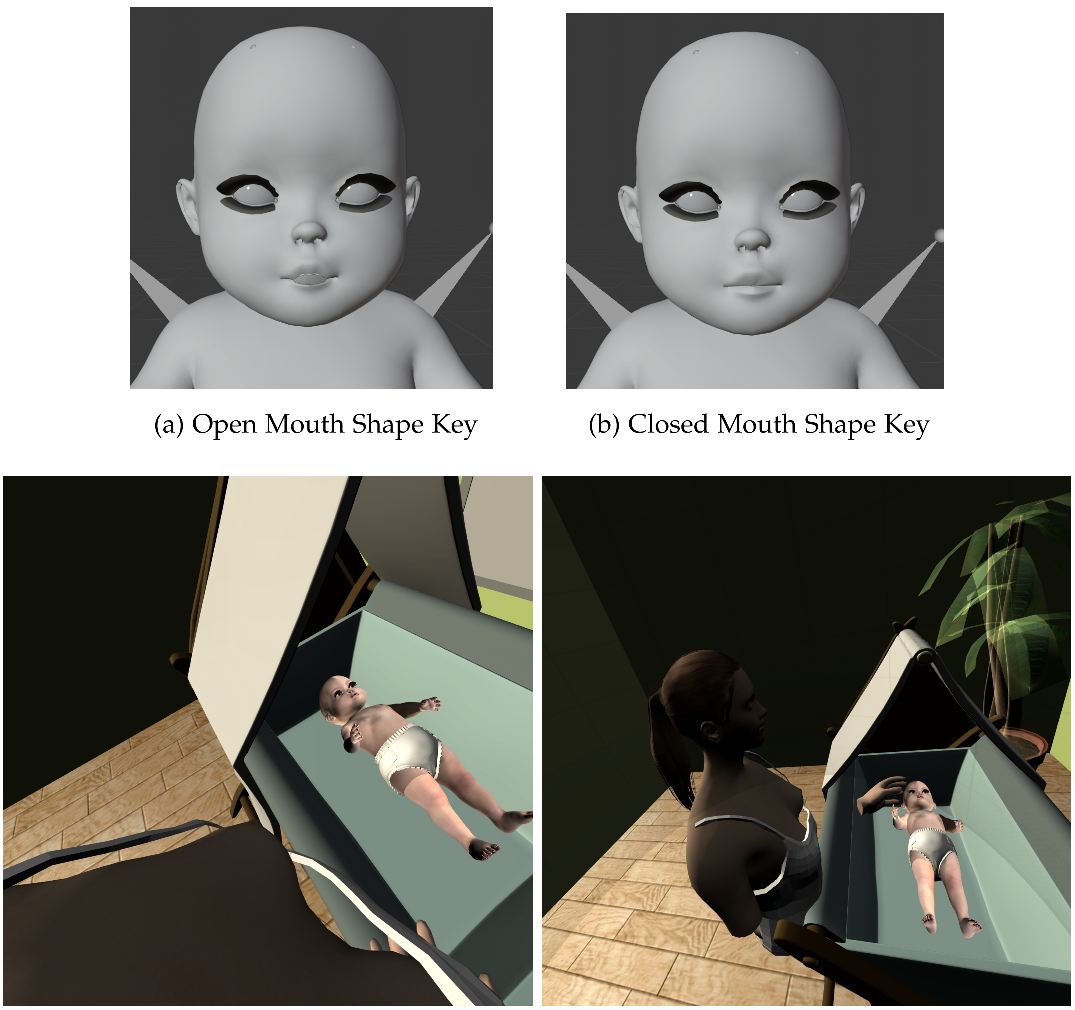
8 https://assetstore.unity.com/packages/3d/characters/realistic-vr-hands-90046

(a) Main menu showing control settings and customization settings

(b) Room 3D assets depicting the information board and ornaments

(c) Baby lying in the bassinet to be held by virtual hands.

Figure 4: Virtual assets used in the latching VR scene



(a) Open Mouth Shape Key (b) Closed Mouth Shape Key

(c) Virtual breast for latching (d) Virtual lactating mother avatar

Figure 5: Virtual baby and mother avatars

3.2.7 *VR Latching Workflow*

Figure 6 shows various screenshots that follow the steps to be followed when using the VR latching application. It is worth indicating that the same process applies to both the head-tracking and eye-tracking versions of the VR experience.

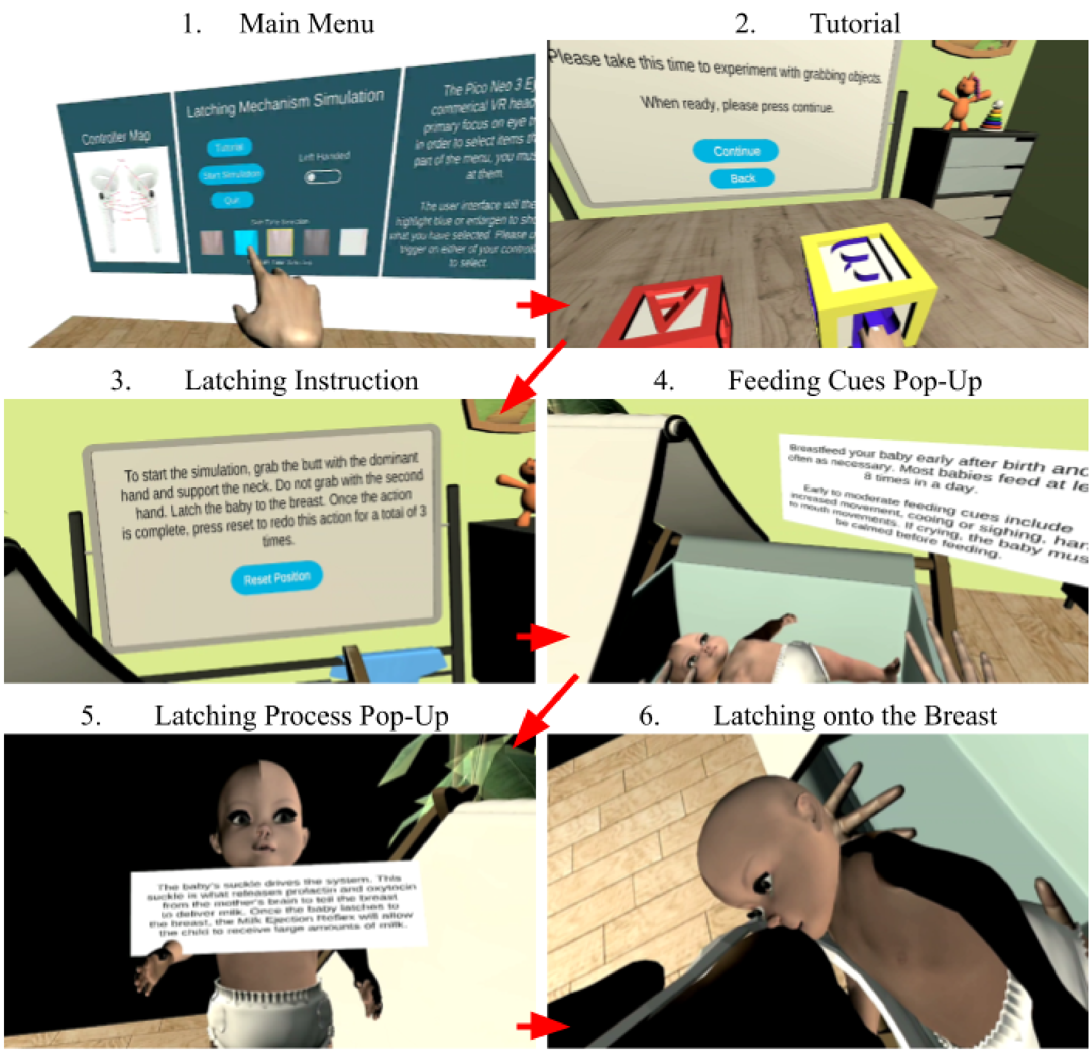


Figure 6: Prototype Flow

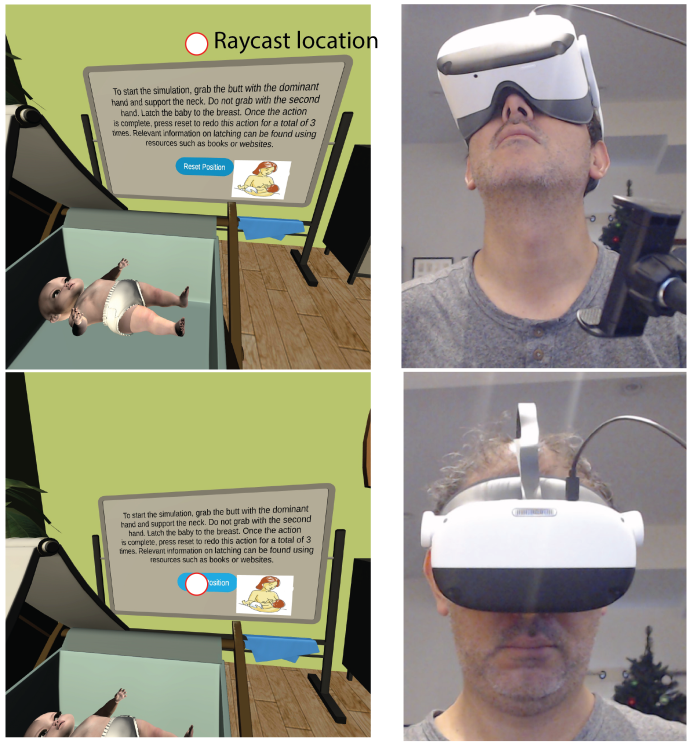
Compared to other prototypes found in related works, such as Virtual Feed [56], customization of the skin of the mother's breasts, hands and child was also included, as these have the potential to increase immersion, presence and embodiment. As being a mother is not restricted to one race, the prototype for this study aimed to address this by adding these options at the beginning of the application as seen in Section 1, the Main Menu in Figure 6. An aspect of immersion is related to how much the player can relate to their avatar, affecting their overall experience in the application [20].

3.2.8 *Head and Eye-Tracking*

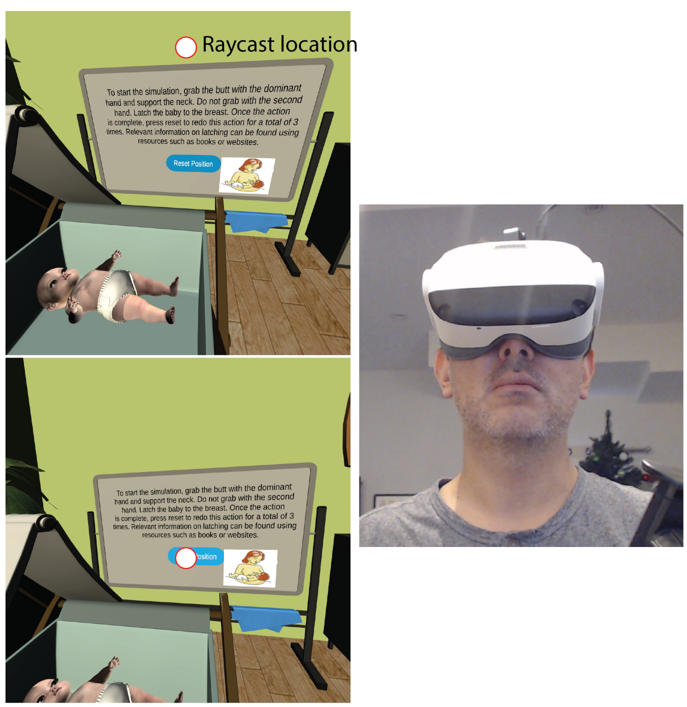
Head and eye-tracking constitute the two main interaction features for menus and information provided during the virtual latching experience. Head tracking was implemented using the position and orientation of the VR headset in addition to a raycast coming out from the headset. The spatial information is provided with the Pico software development kit and is calculated using the cameras and inertial sensors embedded in the headset. Head tracking is commonly used as a "gaze" technique in the absence of eye-tracking, requiring users to move their head to point at specific elements in the scene to trigger interactions. Unlike Head-tracking, eye-tracking uses sensors to follow up eye movements that enables calculating the exact location were both eyes converge, thus bypassing the need for movements. Eye-tracking provides more natural user interactions, and it is slowly becoming a feature included in consumer-level VR headsets. Figure 7 shows a comparison between head and eye-tracking within the virtual latching experience.

3.2.9 *Development Challenges*

Several technical challenges were encountered when designing the Pico Neo 2 and 3 Eye. Development for both devices was limited to 2019.4.5 or 2020 Unity Engine Versions, restricting the packages that could be used in the Unity XR Toolkit. The functionality for grabbing with two hands and having multiple grab points would need to be manually coded in and altered. The manipulation of anchor points and quaternion rotations required repetitive tweaking in order to determine what



(a) Head tracking movement needed to read and activate a menu



(b) Eye-tracking interaction, no head movement needed

Figure 7: Head and eye-tracking comparison

was causing inaccurate rotation. This further increased development time as these changes can only be examined after the application is finished building on the device. For other VR devices such as the Oculus Quest, applications could be simulated in the VR headset while using Unity. However, for the Pico Neo 2 and 3, the preview option was not available.

Blinking and flickering were also inconsistent issues that would occur when observing objects within the scene. This issue could possibly occur when having quick shifts in focus when within the scene or if the participant needed to blink very frequently. This was related to the functionality of the eye-tracking system which tracks all pupillary activity. While this functionality would be useful in the case of mirroring the face of an avatar, for pop-ups this accuracy became an issue. Another problem was related to the skin and lighting of the baby model. While shadow casting was disabled, there still seemed to be issues with lighting on the skin. This was probably related to the textures that were applied once the participant selected a different skin tone in the main menu.

To deal with the problems presented, interaction with the baby was initiated through one hand. Participants were instructed not to use the grip button on the second hand and instead ensure placement of the hand below the neck of the baby. Ensuring that the participant would be able to transfer knowledge on proper hand placements while not encountering rotation flickering of the child. In order to address the blinking, the area that would trigger the pop-up was enlarged. This would make it so that if the participant was looking in the general direction of the object, the text would trigger. Another possible solution that was considered was the implementation of a timer mechanism that would make the text pop-up active for a certain amount of time. This would allow the participant sufficient time to read the text before moving on. The enlargement method was chosen because it was easier to implement and required less development time to tweak than the timer method. For the texture issues related to the baby, most graphics settings were simplified. Shadow casting was turned off, and materials were uploaded directly from the directory instead of being altered using script-based logic.

An additional issue with lighting and rendering occurred that was not possible to solved, causing 3D models to be partially lighted. From troubleshooting, the issue was caused when integrating the Pico Neo software development kit with Unity. This issue has not been experienced when developing for other VR headsets that are better maintained that he Pico Neo at the time of developing this work. Future updates may resolve this issue.

3.3 STUDY DESIGN

A within-subjects design study was chosen for this research to account for a possible small sample size. Latin Square was use to randomize the study's two conditions, A (head tracking and B (eye tracking) among participants to ensure equal but random distribution to minimize carry over effects. The independent variable is the tracking method, which was either head or eye-tracking, and the dependent variables or measures for this study were cognitive load, system usability scoring, heart rate, breastfeeding literacy, and simulation learning effectiveness.

Much of the study design was also inspired by previous works that investigated the viability of different e-Health mediums by content expert Dr. Jennifer Abbass-Dick. A recent paper in 2021 focused on designing an e-Health Breastfeeding Resource with Young Mothers and provided context and more in-depth information on the needs of young mothers [5]. The usage of simple language, incorporation of technology, audiovisual cues and diverse population representation were all concerns mentioned by these mothers and served as preliminary information on what potential stakeholders would want from a breastfeeding resource. With this information serving as the basis, participants for the study were mainly individuals with varying levels of experience which could be used to pilot test the application. After this pilot test, future work would focus on making improvements and conducting a study geared towards specifically how expecting mother and fathers would interact with this program.

3.3.1 *Participants*

Participants were gathered through online communication using social media platforms such as Discord, email, and word of mouth among faculty. All participants volunteered to participate in the study and were informed of their rights through the approved consent form under the REB #17150. In order to reduce the likelihood of bias, all were informed of any potential conflict of interest and no compensation was provided which could have potentially affected the way participants reacted. All of these points were discussed and shown within the consent form (See Appendix A.3).

3.3.2 *Inclusion & Exclusion Criteria*

Inclusion and exclusion criteria needed to be considered in order to recruit participants who would be able to complete the latching task. One criterion is that participants must be able to use immersive virtual reality in seated or standing modes. Another is that they must be older than 18 years. However, there was no restriction on age as older participants could have provided another perspective from a demographic that may not have as much VR experience. They had to be located within the Great Toronto Area so that they could easily access the experiment location. The female gender was preferred, however other genders (Male or Unspecified) also took part as we are targeting expecting mothers and their partners. As mentioned in Chapter 2, the level of education of breastfeeding mothers and their partners has an impact on whether they consider or continue to exclusively breastfeed. It must also be considered that participants who had physio-motor impairments affecting usage of the upper body, blindness, and cognitive impairments had to be excluded due to the nature of VR interactions needed for this project.

3.3.3 *Procedure*

The study was carried out in person in a session lasting 30 to 45 minutes. This amount of time was set to ensure that the participant did not become fatigued while having to complete the two different versions of the software. First, participants were given at least 5 minutes to review and complete the approved consent form (See Appendix A.3). They were then asked to complete a preliminary demographic survey and their current experience with breastfeeding and VR head-mounted displays (HMD). As they became more familiar with the device, they were provided a guide and instructions on the use of their HMD and its controllers. The researcher who conducted the testing then verified the configuration of the VR equipment and ensured that everything was working accordingly. The participant was then asked to put on and adjust the HMD equipment fit and proceed with the introduction of the experiment and its tasks.

The participant was directed to select the appropriate software version according to the order in which they were assigned.

The participants started by entering the main menu regardless of the version, where non-eye-tracking version A used ray-tracing for item selection and eye-tracking version B used eye tracking UI highlighting and selection. Once in the main menu, the participant was provided information on the Pico Neo headset and how to select menu buttons. The mapping of the controllers was also provided so that the participants could familiarize themselves with the buttons they were able to use and the actions to which they were tied. After familiarizing themselves with the controls, participants were asked to select a skin tone to customize their experience. As an initial prototype, five tones were available to be selected ranging from light to dark. For future development, this system would be developed further to provide a color wheel for a more diverse selection to improve feelings of immersion. Once one of the tones had been selected when moving to the tutorial or directly to the application, the hands, breasts, and baby had changed to correspond to the selected tone. Finally, before exiting the menu, participants were also given the option to indicate whether they were left-handed or right-handed. This selection changed which breast was covered, as the dominant hand used to support the rear of the child would be switched.

The tutorial was included to provide participants an environment to experiment with the grabbing mechanics should they have little to no experience in VR. Building blocks fit the theme of the simulation, as they were simple in shape and related to child care, and would also clearly show the highlighting mechanic that was incorporated with eye tracking. As the version of Unity being used did not have the capabilities of two-handed interactions, it was important to inform the participant on how to interact with an object or infant without issue. Once comfortable with the mechanics of grabbing and manipulating 3D objects, the participant clicked on the "Continue" button to move on to the latching experience.

After the participants completed the tutorial or chose to skip this section, the participant then attempted to latch a child to the breast available by interacting with 3D objects within the scene while sitting. The procedure required the participant to pick up and hold the virtual newborn. Then, maneuver them into a latching position comfortable for the child. After the participant achieved an appropriate position, audio cues were triggered from the infant indicating that they were calm enough to feed. These audio cues such as crying or cooing or visual indicators were provided so that the participant knew when to start the latch. Instructions were provided to the participant to practice this process in three consecutive attempts with a button available to reset the state of the scenario should any issues occur. This was incorporated to place emphasis on the practical component of latching and the use of distribution of practice to improve learning. Of the different methods discussed in "Motor Control and Learning - A Behavior Emphasis" by Schmidt et al. [49], this seems the most applicable in this scenario. Within this book, it is suggested that in order for a practical skill to at least be replicated, it must be practiced at least three times. As the participant would continue to practice this skill in future attempts, they would be able to move from just doing, to showing, knowing how it works and then knowing the skill entirely. This is also related to the concept of Miller's Pyramid theory which is often used to assess clinical competence in practical skills and performance [38]. Each latching setup took approximately five to seven minutes.

After completing the latching task three times, the simulation was concluded. Once completed, the headset was removed and the participant was guided to a local desktop owned by the research team and completed a final survey. The participants were asked to complete a survey to gather information on the System Usability Scale, NASA Task Load Index, The Michigan Standard Simulation Experience Scale (MISSES), and the Comprehensive Breastfeeding Knowledge Scale. Answering these surveys took at least five to fifteen minutes to complete. Once the participant completed their first survey, they then repeated the previous steps, testing the second version of the software. If they completed Version A, then Version B or vice versa. After all data was submitted at the end of the second survey, the participants received a physical thank you letter. This letter provided contact information for the researchers, expressed gratitude for their participation, and provided a timeline for the results to be available.

3.3.4 *Data Collection*

The data collection consists of self-reported and metrics from the VR latching experience including usability, cognitive load, simulation evaluation, breastfeeding knowledge, and heart rate.

3.3.4.1 *Usability*

The System Usability Scale is a standardized questionnaire that asks 10 questions to the participant while measuring each response on a Likert Scale ranging from 1 to 5. Each Likert scale provides a range of responses for the participant going from Strongly Agree to Strongly Disagree. Once all responses have been collected, the SUS score is calculated. Scores greater than 80.3 signify high usability, scores between 68 and 80.3 signify average usability, and any score below 68 shows poor usability. On the basis of these scores, it is possible to determine the usability of the system and whether this software would be easy for participants to use. Results would examine answer distribution as well as discuss trends in average mean and standard deviation [48].

3.3.4.2 *Cognitive Load*

Both the Raw NASA TLX and heart rate were used to determine the level of cognitive load and stress that may or may not be experienced when completing the simulation. These correlate well in identifying participant behaviors and how they behave in the simulation. To measure and assess the cognitive load of the participant, as mentioned before, the Raw NASA-TLX scale was used instead of the full NASA TLX which also considers weighted pairs. An example of the scale can be found in Appendix A.4 within the Post Simulation Survey. The scale is measured using a 21-point gradient with increments ranging from low, medium to high. These scales measure the following areas: performance, effort, physical demand, mental demand, temporal demand, and frustration. This assessment method serves as a tool to understand subjective workload within systems that incorporate a human interface [30].

The heart rate of the participants is used as an instrument to identify spikes and trends that could be associated with stress. Physiological measures allow capturing information that can help explain possible impacts on performance/decision-making [58]. The participants used a wearable device such as an Apple Watch which has photodetectors and the ability to emit high intensity green LEDs [32]. When both of these components are combined, it is then possible to detect volumetric changes in blood flow. Blood strongly absorbs the light emitted as it travels through tissue, allowing photo sensors to detect small or large changes in blood volume [32]. The benefit of using a wearable in this case, is ease of use and integration in a non-invasive manner employing a consumer-level technology. Calibration was done with all participants, by giving the device a five-minute period to calibrate to the heart rate of the participant who wore it. Once the device provided a consistent result, the starting heart rate was observed and the active heart rate was continuously collected every three minutes until the simulation was complete.

3.3.4.3 *Simulation Evaluation*

The MISSES assessment method was used as a standardized way of evaluating content validity within simulations or simulators typically used within the field of medical education [50]. Using a Likert scale ranging from 0 to 5, the following domains are evaluated to determine the effectiveness of the simulation: Self-Efficacy, Fidelity, Educational Value, Teaching Quality, and Overall Rating. Self-efficacy within the MISSES targets issues related to the participant's ability to work independently, examining knowledge and confidence when using the simulation. Fidelity within the MISSES evaluates the accuracy of the simulation in comparison to the task that the simulation aims to replicate. Educational Value within the MISSES evaluates the quality of teaching that the simulation provides. Teaching Quality assesses the quality of current resources in supporting latching activity. The Overall Rating was related to the whole breastfeeding VR experience.

3.3.4.4 *Breastfeeding Knowledge*

The Comprehensive Breastfeeding Knowledge Scale was incorporated to gather information on the overall breastfeeding knowledge that participants may have. This scale is measured using 28 items related to breastfeeding and includes the following subscale topics: challenges within breastfeeding, common misconceptions, and understanding of milk supply. This scale was compiled by Abbass-Dick et al. from previously published scales after conducting a broad literature review [4]. This was done to have an assessment method that can be used to evaluate the effectiveness of breastfeeding interventions and identify women or partners who have little knowledge about breastfeeding to provide support and personalized care for breastfeeding women. Each question uses a scale from 1 to 3, with one indicating that you disagree with the statement and three indicating that you agree with the statement. This scale was chosen as a means of assessing overall knowledge of participants in order to get a benchmark of what information they were aware of or if any changes would occur after being introduced to other material in Version B. This scale was also included in the post-survey questionnaire, however it cannot be shown within the appendix.

3.3.4.5 *Open-ended Questions*

Open-ended questions were presented within the MISSES method and separately at the end of the post-task survey. These questions were used as a means of understanding the ideas perceived by the participants after using each version of the latching experience. Within MISSES, these questions asked participants about any comments or suggestions they have about fidelity, educational value, teaching quality, self-efficacy, and overall simulation rating. At the end of the survey, participants also received a section for any feedback from the research team. This information can be used to complement the information on participant reactions and provide open-ended feedback on their overall experience. To view these questions, please refer to Appendix B.2. This information is being used to supplement the quantitative findings and will not go through a qualitative analysis.

3.3.5 *Data Analysis*

Statistical analysis for the data collection results was processed through SPSS. The statistical power for each variable was calculated using G*Power 3.1 to determine if inferential statistics could be used in the study results. If power was to be insufficient, descriptive statistics would be used instead and analyzed to determine trends in the data. Descriptive statistics were also gathered using the Shapiro-Wilks test to determine if each variable was normally distributed and which test would be most effective in analyzing the results. Parametric data were analyzed using a multivariate ANOVA due to the number of dependent variables and the nature of the study within subjects. Non-parametric data was analyzed using an NPAR (Non-parametric) test along with a Paired Wilcoxon Signed Ranks test (t-test) to determine effect size. In order to determine statistical significance, a Friedman test was also used in order to determine the chi-square distribution and the asymptotic significance.

Within the results, first, the scores from the NASA TLX were discussed and then physiological measurements were discussed, as the method of data analysis differed from all other scales used. Compared to the Likert scales used, heart rate is observed over time, highlighting trends, peaks, or falls within the data. A change in heart rate could indicate an increase or decrease in stress depending on the activity the participant is engaged in at the time.

3.4 CHAPTER SUMMARY

This chapter covered the experimental design that was implemented. The experimental design was outlined, showing the development of the prototype and the procedure that the participant will go through during the data collection phase. Recruitment methods are also discussed to highlight the distribution of information about this study, as well as providing an ethics reference to ensure that the consent of the participant is properly gathered. The main dependent and independent variables were also presented to highlight what was observed during the study. Data collection described the instruments that are used to measure the dependent variables of this study. Finally, data analysis discussed how the data would be analyzed in the next chapter.

4 RESULTS

4.1 OVERVIEW

This chapter presents the results obtained from the study. This chapter is organized in sections consisting of participant demographics, SUS, NASA TLX, MISSES broken down into five sections, heart rate, results summary, open-ended questions, and a chapter summary.

4.2 PARTICIPANT DEMOGRAPHICS

A total of 10 participants volunteered for the study. Equal representation of both male and female participants participated in the study. No participant identified as another gender. 50% of participants were between the ages of 18 to 24, 40% were between 25 to 34, and one participant was between the ages of 35 to 55 (See Figure 8). The oldest participant was also one of the only participants to have previous breastfeeding experience as a mother. Half of the participants have had an experience with a VR headset, particularly the Oculus Rift. However, 66.7% indicated that they would only use these a few times during the year while 33.3% said that they had never used one. This lack of VR experience is also highlighted when asked about how much time is spent on average in VR, with 40% having none and the other 10% (one participant) scattered between the other options (See Appendix B.3 for Preliminary Survey Results).

Concerning breastfeeding, 90% of the participants had no prior experience breastfeeding, and 10% had experience breastfeeding since they had already delivered their children. The participant who did have latching experience provided

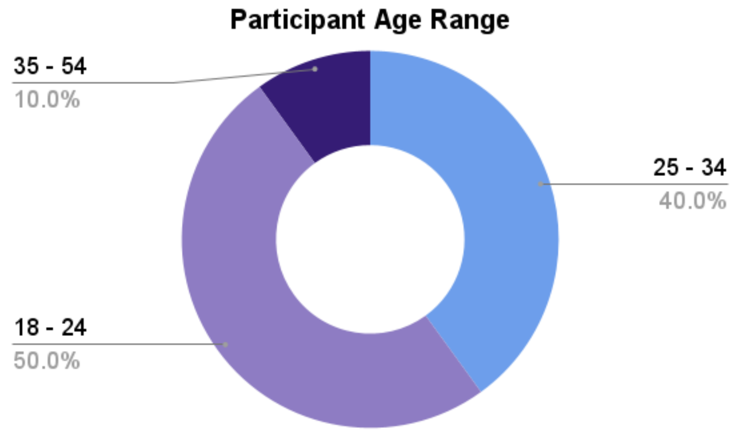


Figure 8: Participant Age Range

the takeaway of "requiring assistance from a lactation consultant due to an inability to latch" (see Figure 9).

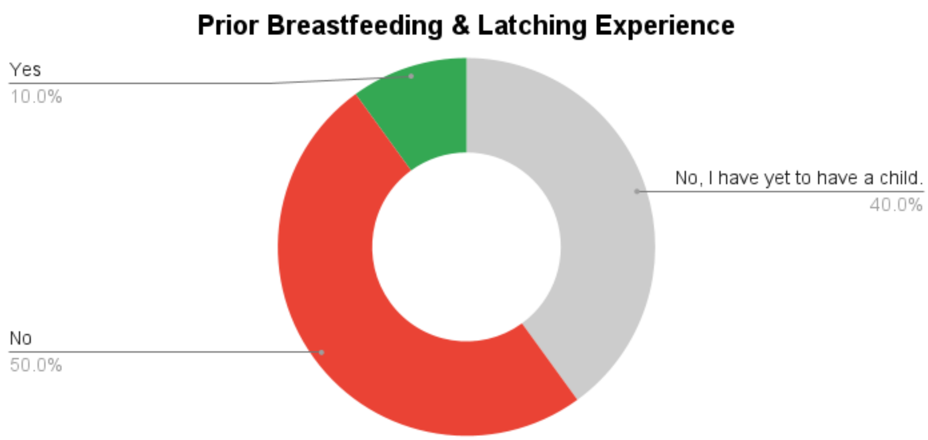


Figure 9: Prior Breastfeeding & Latching Experience

The most popular resources that participants mention that they would use to gather latch information include websites (n = 9), books (n = 8), family / word of mouth (n = 8) and general practitioners (n=8). Other resources such as lactation consultants, audiobooks, games/simulations, and educational institutions had an answer frequency of n = 5 or lower (See Figure 10).

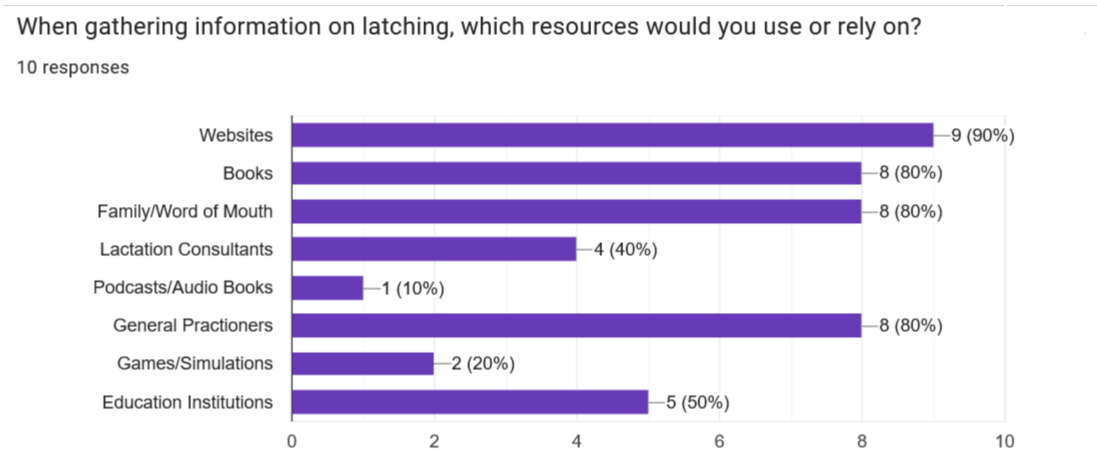


Figure 10: Resource Preference for Breastfeeding Information

4.3 SYSTEM USABILITY SCALE

The SUS results indicated that Version A of the VR Latching Experience (M = 77.25, SD = 9.89) had a higher SUS score than Version B (the one with eye tracking) (M = 73.00, SD = 9.04). Based on these scores both Versions had a good system usability score with a marginal acceptability score. In order for a system to be excellent and acceptable within the acceptability score, the system must have a score of at least 80 or higher. This indicated that for both Versions further improvement is needed on the system in order to have each Version working at an acceptable level. While Version A is closer to this score, there were problems consistent between both Versions that needed to be addressed, as mentioned in the challenges section in Chapter 3. Normality testing produced a test statistic of .947 and a p-value of 0.331, indicating the data followed a normal distribution.

Since the SUS data was parametric and complied with the repeated measures ANOVA assumptions (i.e., normality, equal variance, independence, and no outliers being present), the parametric analysis was conducted. Based on a partial η^2 of 0.199, there is an effect size f of 0.498. Taking into account the sample size, groups, and measurements adjusted to include the six parametric measurements, the statistical power of SUS was determined to be 35.3%. As the statistical power was too low, inferential statistics would not be relevant for this data set. While the sample is insufficient to obtain statistical significance to determine whether the use of eye tracking improves system usability, the SUS response distribution for Version A (Figure 11) and Version B (Figure 12), SUS score, and open feedback provided preliminary information on the preferences and perceptions of the participants.

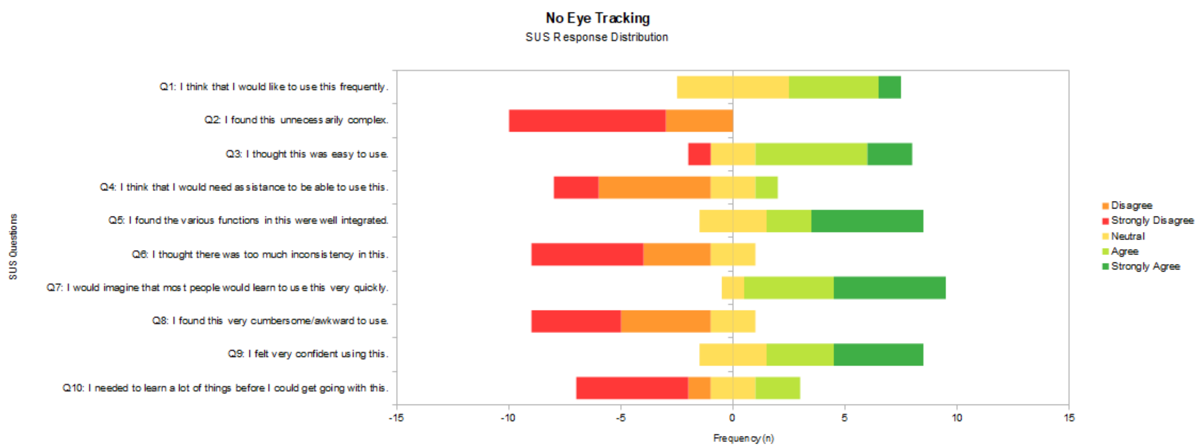


Figure 11: Version A - SUS Answer Distribution

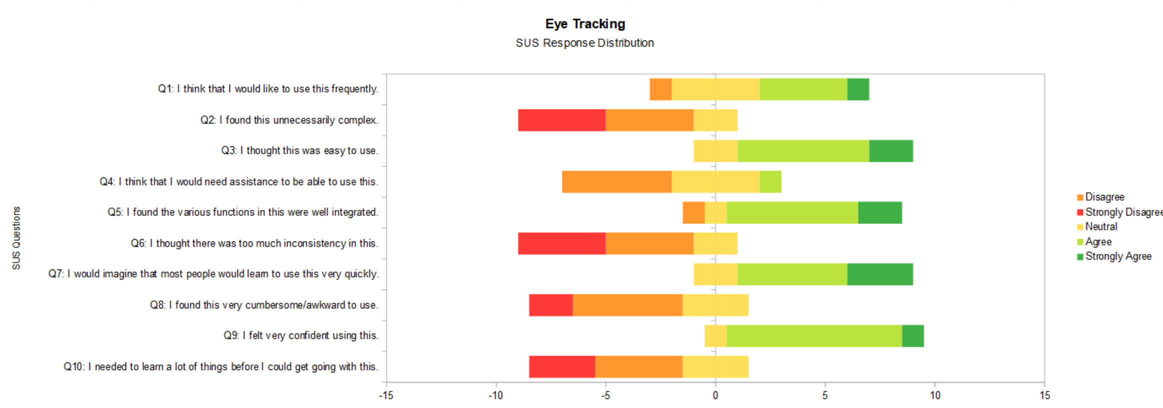


Figure 12: Version B - SUS Answer Distribution

To further understand the reasons for the lack of usability impact, the responses' distribution as well as the open-ended questions were examined. Analyzing the SUS' response distribution between the two Versions, Version A had fewer participants answering neutrally in comparison to eye tracking Version B (See Figures 11 and 12). This meant that the participants were more neutral or disagreed when answering questions where the participant should have agreed with the statement (i.e. Q1: I think that I would use this frequently). Participants highlighted the issues that likely impacted the usability of the system within the open-ended questions (See Appendix B.2). The main problem that most participants had was the pop-up being tied into pupillary activity within eye-tracking Version B. Blinking from the participant could cause issues with the text pop-up as mentioned in Challenges within Chapter 3, making it difficult to read all of the text that was present. This issue would not always occur when engaging with Version B however due to the frequency that participants were encountering this problem, it very likely contributed to a decrease in SUS scores. The eye tracking was implemented this way as the tracking of the pupils ensured that the right pop-up would appear depending on where the focus of the participant was. However, it was not taken into consideration how quickly the focus of the participant would shift from one object to the next while in the scenario.

4.4 Raw NASA Task Load Index

The Raw NASA TLX results indicated that Version A had a slightly higher task load index (M = 41.1, SD = 11.2) compared to Version B (M = 39.3, SD = 5.95). These scores indicated that the cognitive workload for both Versions was somewhat high on a scale ranging from low to very high. Normality testing indicated that these data were also parametric, producing a test statistic of.913 and a p-value of 0.72, indicating that the data follow a normal distribution. As the repeated measures ANOVA assumptions are met similarly to the SUS, the parametric analysis was conducted. Based on a partial η^2 of 0.031 with an effect size f of 0.179. Taking into account the sample size, groups and measurements adjusted to include the 6 parametric measurements, the NASA TLX statistical power was determined to be 8.3% As the statistical power was too low, inferential statistics would not be relevant for these data.

The response distribution presented in Figures 13 and 14 provided more information on cognitive load. The overall values for the workload as mentioned previously were somewhat high for both Versions with slight differences. This designation of a "somewhat high" workload scoring is based and categorized based on the value calculated after testing. At this level of cognitive load, participants require some mental demands and may have higher levels of stress due to the task being completed. This was also not the case for all participants as some found this task harder to complete than others. These challenges likely occurred due to the usability of the system, along with a correlation with the level of experience participants may have with VR. For example, three participants reported high workload (51.6, 56.6, and 58.3) when completing non-eye tracking Version A. This indicated that the cognitive load increased to some extent when eye tracking was not included. While both Versions provide a tutorial on how to use the VR controllers and manipulate objects in the scene, non-eye tracking Version A did not provide any contextual guidance during the latching portion for the participant.

Therefore, the participant had to engage and proceed to complete the task without the guidance of the system or the researcher outside of the preamble. This could have contributed to an increased cognitive load as they must figure out for themselves how to complete a task that they may not be familiar with. Acosta et al. also discuss this concept of scaffolding and improving participant skill and confidence in VR within their study, providing evidence that scaffolding could be effective when implemented appropriately [9]. The scaffolding implemented using eye tracking allowed a new learner to complete a task or a problem that was originally not part of their skill set. The results indicated that this presentation of information using dynamic eye tracking was effective in increasing the student's learning performance. However, to determine if that was the case for this study, we looked at individual results further.

If we look at the individual response distribution for each question posed in the Raw NASA TLX, it can be observed that both Versions had a range of responses with a significant amount of medium scoring, other than Q4, where the desired response should be high. For Version A, the participants felt more confident in completing the task compared to Version B. This was likely due to the inconsistencies the participants had with reading the information from the eye tracking. This issue should be addressed in further interactions to obtain a better indication of the impacts on cognitive load. In mental demand (Q1), while the answers had a greater range in eye tracking Version B, the vast majority of the participants stated that mental demand was medium to approaching high. However, it can also be seen that Version B, had participants state that it had the lowest rating of mental demand. All other questions had similar ratings that ranged in value, making it difficult to determine obvious differences. Both Versions presented varying responses, with two questions having slight differences, indicating that Version B did not have an overall impact on cognitive load.

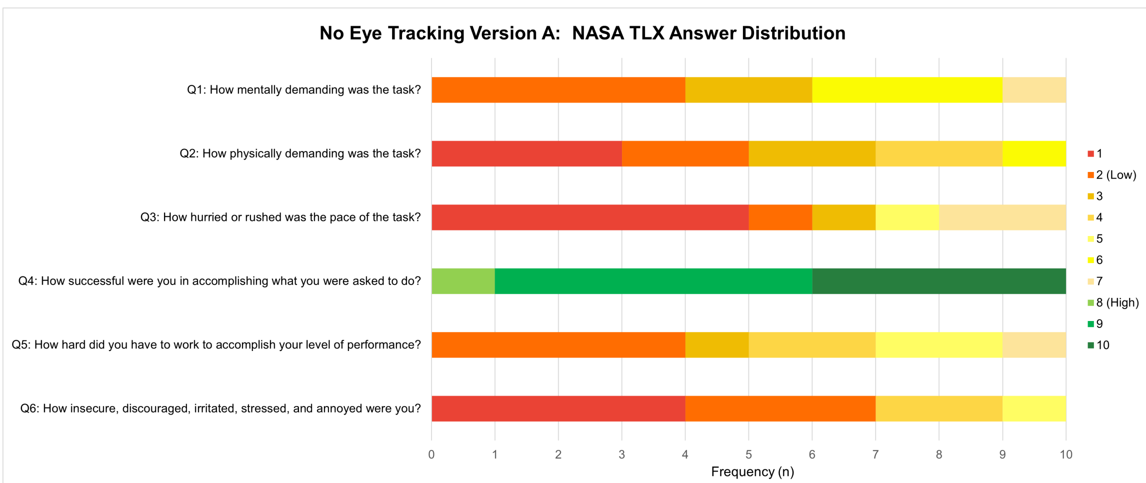


Figure 13: Version A - Raw NASA TLX Answer Distribution

4.5 THE MICHIGAN STANDARD SIMULATION EXPERIENCE SCALE (MISSES)

The MISSES is divided into 5 sections (self-efficacy, integrity, education value, teaching quality, and overall rating) evaluating a range of domains relating to simulation experience; each section was analyzed as a dependent variable. Various papers such as Ramirez et al. take this approach while also compiling the response

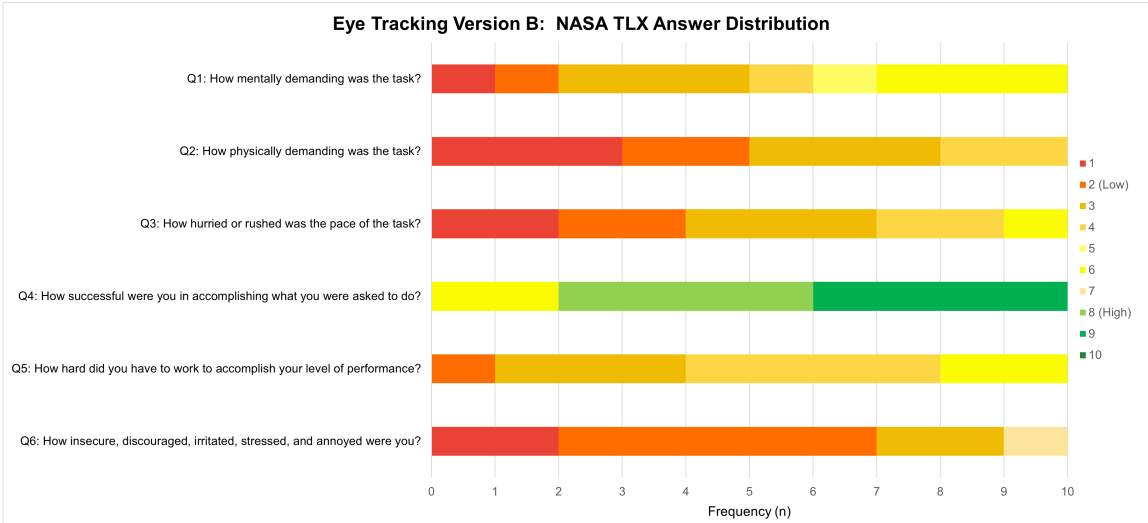


Figure 14: Version B - Raw NASA TLX Answer Distribution

distribution for each section [44]. Based on the normality testing, three of the sections were parametric: self-efficiency, fidelity, and education quality. Two sections, teaching quality and overall rating, were non-parametric and thus required non-parametric analysis. Out of these five sections, Education Value was the only measurement that had statistical power.

4.5.1 *Self-Efficacy*

Results indicated that the non-eye tracking Version A (M = 83%, SD = 0.127) had a higher Self-Efficacy score than that of eye tracking Version B (M = 80%, SD = 0.122). Normality testing indicated that the self-efficacy data have a normal distribution with a test statistic of.947 and a p-value of 0.319. The statistical power was then calculated to be 15.2%, based on a partial η^2 of 0.082 with an effect size f of 0.299. Due to the low statistical power, the self-efficacy analysis considers scores, response distribution, and open feedback.

Although inferential statistics could not be performed, the response distribution shown in Figures 15 and 16 can still be analyzed. Based on the responses, the participants responded similarly for both versions A and B. However, there were

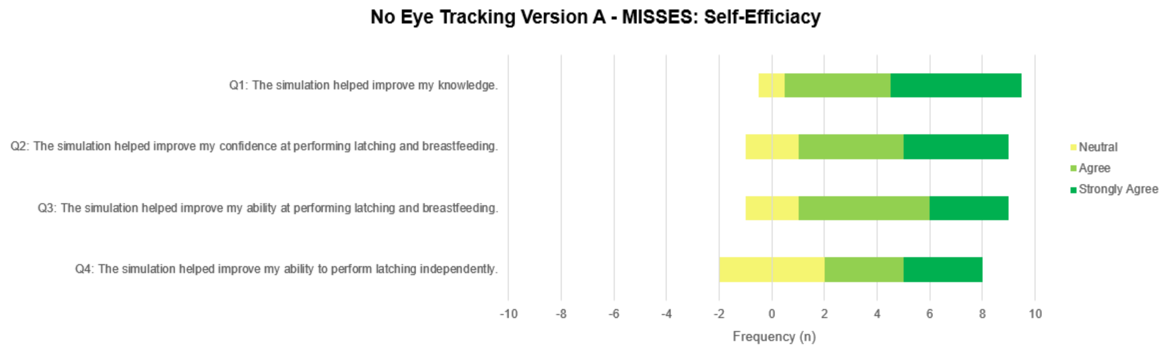


Figure 15: Version A - Self-Efficacy Answer Distribution

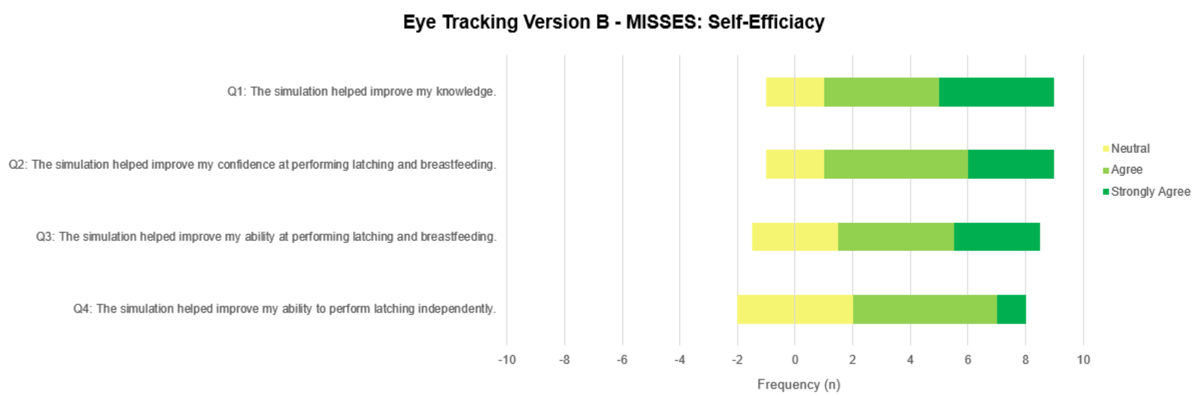


Figure 16: Version B - Self-Efficacy Answer Distribution

slight differences in the number of participants who would agree or strongly agree. More participants in Version A felt that they would strongly agree that the application was effective in improving their self-efficacy in breastfeeding. This could be related to the inherent simplicity of Version A, which did not include additional information. Participants were given the opportunity to focus solely on the psychomotor actions needed without any other distraction, possibly leading to greater confidence in being able to complete the latching task. Version B was still effective in fostering self-efficacy; however, the level of confidence the participants may now have with additional information and guidelines present may not have been as high.

4.5.2 *Fidelity*

The results indicated that the version A of the software had a score (M = 69%, SD = 0.247) that was slightly lower compared to version B (M = 72%, SD = 0.167). Indicating that user believed the accuracy of the simulation in Version B was closer to the task it was aiming to replicate. Normality testing indicated that these data were also parametric with a test statistic of .962 and a p-value of 0.582. Statistical power was then calculated to be 7.8%, based on a partial η^2 of 0.026 with an effect size f of 0.163. Due to low statistical power, the analysis of this data will take into consideration the scores, response distribution, and open feedback.

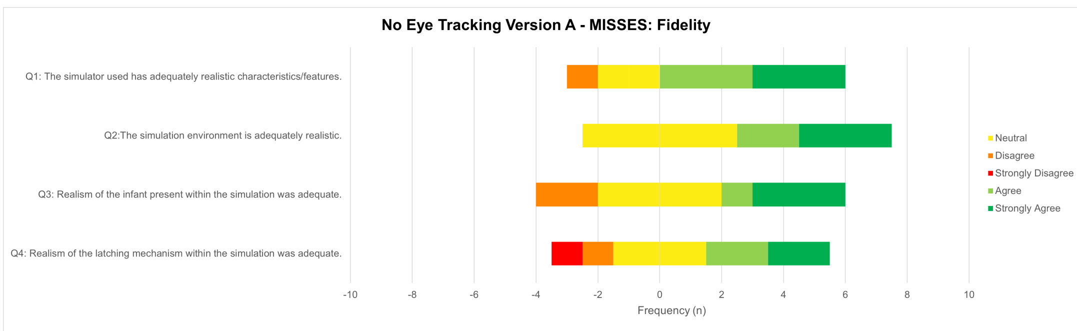


Figure 17: Version A - Fidelity Answer Distribution

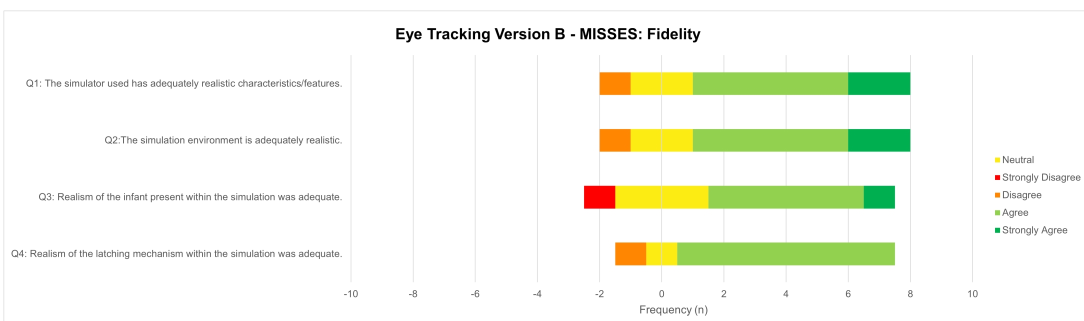


Figure 18: Version B - Fidelity Answer Distribution

Based on the response distribution shown in Figures 17 and 18, results indicated that Version B had higher fidelity results than Version A. Three to four participants scored neutrally in Version A, being unsure of the level of fidelity. Participants using Version B were more likely to agree on the accuracy of fidelity. While the assets did not change, the understanding of fidelity may have changed due to the information that the participant was presented. The more the participant would understand about the latching mechanism, the more likely they would be able to understand its accuracy. Should they not have the information beforehand, it would be difficult to have an expectation for the simulation. It would be beneficial to understand what information participants are aware of beforehand to have a better evaluation of fidelity. The Comprehensive Breastfeeding Knowledge Scale evaluates the knowledge of the participants, but only after they have completed the simulation. For future studies, it would be useful to conduct this questionnaire pre and post-test to observe a clearer comparison and baseline for fidelity.

4.5.3 *Education Value*

Results indicated that the non-eye tracking Version A of the software had a score (M = 65%, SD= 0.108) which was significantly lower than eye tracking Version B (M = 76%, SD = 0.136). Normality testing indicated that these data were also parametric with a test statistic of .964 and a p-value of 0.616. The statistical power was then calculated as 73%, based on a partial η^2 of 0.39 with an effect size f of 0.80. As there is sufficient statistical power, a post hoc analysis did indicate an increased score in educational value between Version A and Version B (65% vs 76%, respectively). These results have statistical significance ($p = 0.040$).

These results showed that eye tracking could improve the educational value of a simulation by providing contextual information to the participant based on the task they are doing. The response distribution shown with Figures 19 and 20 also supports this statement, it can be observed that most participants agree that Version B is an effective learning tool for latching and allowing participants to identify early feeding cues. While Version A still had educational value to the participant, they would have needed to supplement their learning with additional external information or through an intervention. This point was also seen by looking at Q4, which discussed if the simulation was critical to letting participants understand when an appropriate latch has been engaged. Information was provided on an appropriate latch in eye-tracking Version B, yet this information is not fully present in non-eye-tracking Version A other than through player feedback from the baby. Therefore, it contributed to a reduced educational value score, as participants cannot infer this information if they have not been exposed to breastfeeding resources and materials.

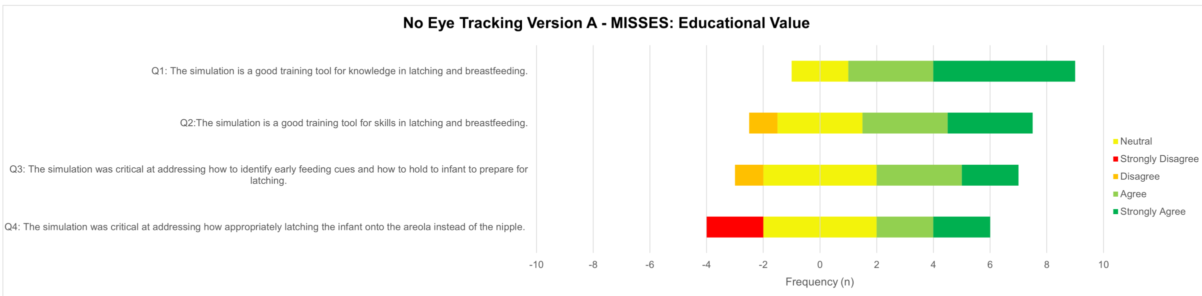


Figure 19: Version A - Educational Value Answer Distribution

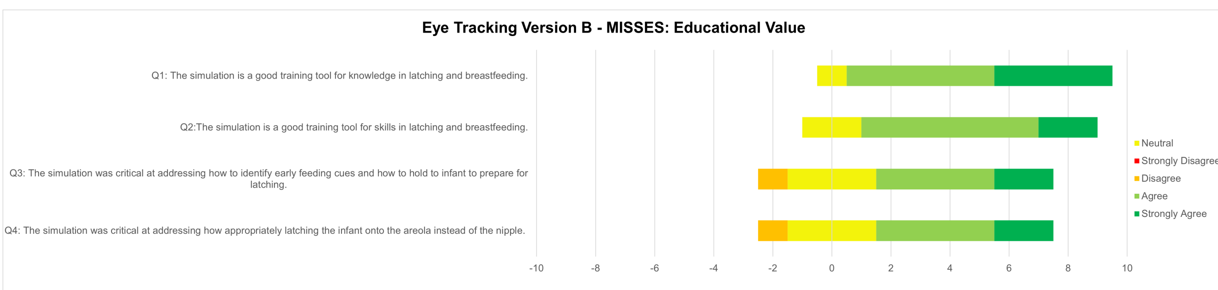


Figure 20: Version B - Educational Value Answer Distribution

4.5.4 *Teaching Quality*

Results showed that Version A (M = 73%, SD = 0.302) scored lower than Version B (M = 85%, SD = 0.127) in terms of teaching quality. This indicated that Version B may have had an impact on teaching quality within the simulation. Normality testing showed that the teaching quality of the simulation data was not normally distributed with a test statistic of .773 and a p-value of <0.001. Therefore, non-parametric analysis was conducted in order to determine if there was statistical power. The Wilcoxon Signed Ranks Test (t test) was conducted to determine the effect size d and achieved power post hoc. The statistical test was done based on means and the differences between two independent means between the two software Version groups. The statistical power was determined to be 19.5% with an effect size of 0.518. As the statistical power was too low, further post hoc analysis of the Wilcoxon Signed Ranks Test was not needed.

Further testing was done to determine the chi-square distribution and the asymptotic significance. After performing Friedman's test, it was determined that there was a statistically significant difference between the teaching quality of the non-eye tracking software A and the eye tracking software B, $\chi^2(1) = 4.00$, $p = 0.046$. The Median scores on Teaching Quality for non-eye tracking Version A and eye tracking Version B were 75% and 80% respectively. As this test was proven to be statistically significant, further post hoc analysis was required. The Friedman test serves as an omnibus test to determine if there are overall differences present; however, it is not able to directly state where these differences are between groups. The signed-rank test with a Bonferroni correction was applied to determine where these differences occurred using different group combinations, the significance level was then set to $p < 0.025$. This meant that if the asymptotic p-value was greater than 0.025, then the result was not statistically significant. Results indicated that while significant during a Friedman test, there was no statistically significant change between both software Versions ($Z = -1.841$, $p = 0.066$) despite the perceived differences between them.

This difference in significance likely occurred due to the nature of the Friedman test and Wilcoxon Signed Rank Test. As mentioned previously, the Friedman test primarily focuses on the differences present for each software Version. While the Wilcoxon Signed Test takes a further look into the difference between specific pairs. It is also important to consider that while both tests may have the same parameters, both are adjusted to different powers. The results collected from the post-simulation survey can still be analyzed to gather findings on the teaching quality of the simulation. Results from Figures 21 and 22 which represent participant response distribution show that over five participants agreed that the teaching quality is predominantly effective for both Versions. There were more participants for non-eye tracking Version A that felt neutral about the teaching quality than eye tracking Version B. This indicated that while most felt that they were able to improve their understanding of lacking, they seemed unsure of the degree. This could likely be due to the absence of contextual information within non-eye tracking Version A.

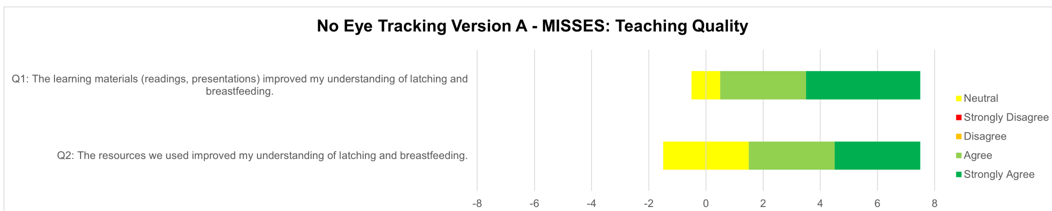


Figure 21: Version A - Teaching Quality Answer Distribution

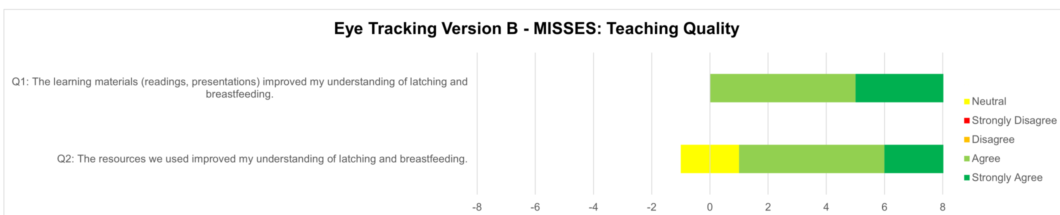


Figure 22: Version B - Teaching Quality Answer Distribution

4.5.5 *Overall Rating*

Results indicated that Version A (M = 82%, SD = 0.114) scored slightly lower than Version B (M = 86%, SD = 0.097). This indicated that Version B may have had an impact on the overall rating within the simulation. Normality testing showed that the overall rating was not normally distributed with a test statistic of .695 and a p-value of <0.001. Non-parametric analysis was then conducted to determine the statistical power. The statistical power was determined to be 12.6% with an effect size of 0.378. As the statistical power was too low, further post hoc analysis of the Wilcoxon Signed Ranks Test was not needed.

Further tests were also conducted to gather the χ^2 distribution and the asymptotic significance. After performing Friedman's test, it was determined that there was no statistically significant difference between the teaching quality of the non-eye tracking software A and the eye tracking software B, $\chi^2(1) = 0.667$, $p = 0.414$. The Median scores on Overall Quality for both non-eye tracking Version A and eye tracking Version B were 80%. Due to the Friedman test results indicating that there was no significance in the data, post hoc analysis was not suggested.

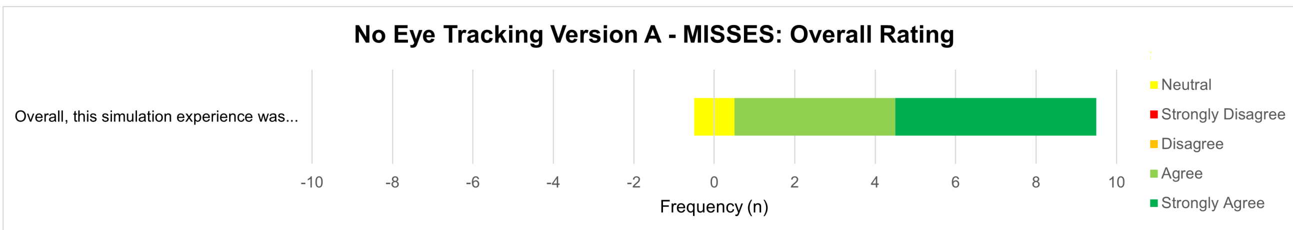


Figure 23: Version A - Overall Rating Answer Distribution

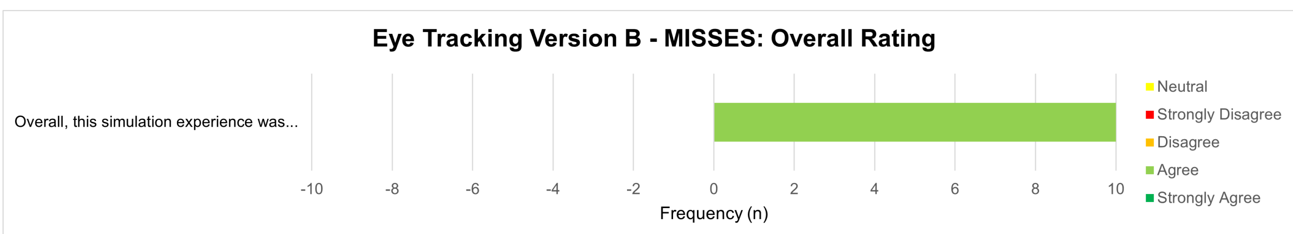


Figure 24: Version B - Overall Rating Answer Distribution

The compiled results from the post-simulation survey indicated that the overall rating of the simulation would be at least 75% or higher with the exception of one participant. These results can also be supported by Figures 23 and 24 which provided the response distribution for both versions. As the overall rating was one question, these results are representative of what the participant thought about the simulation experience as a whole. Along with the overall rating score from the Likert scale, participants were also if any changes were necessary when evaluating both versions. Results from the overall rating portion of the survey indicated that for both simulations, 50% of the participants believed that minor adjustments need to be main in order to use this software for training. This highlighted the potential both simulations have with or without eye tracking, to allow individuals to gain psychomotor practice for a skill that is fairly complex to replicate in real life without having a child.

4.6 COMPREHENSIVE BREASTFEEDING KNOWLEDGE SCALE

Results indicated that the Version A had a score (M = 83.6%, SD= 0.062) which was slightly lower in comparison to the Version B (M = 85.8%, SD = 0.064). Normality testing indicated the data was normally distributed with a test statistic of .940 and a p-value of .238Statistical power was then calculated to be 50.6%, based on a partial η^2 of 0.275 with an effect size f of 0.616.

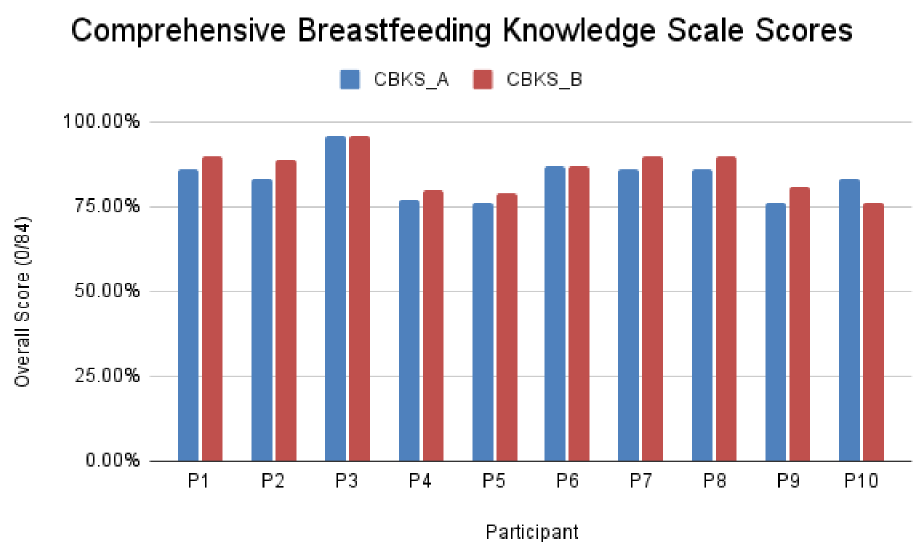


Figure 25: Comprehensive Breastfeeding Knowledge Scale Scores

CBKS responses indicated that Participant 3 was the only participant above the age of 25, that already had experience breastfeeding as a mother of 2. It was interesting to see that scoring remained consistent, while still not achieving 100%. This showcases that even participants who may have experienced breastfeeding may still lack knowledge on specific topics such as breastfeeding when a mother is sick, suckling from a breast or bottle, and cancer prevention and breastfeeding.

Some participants also had varying or low-scoring responses when discussing whether formula feeding is a good method of involving fathers or partners in the breastfeeding process. It was difficult to also identify whether the simulation had a direct impact on breastfeeding knowledge, as this measurement evaluated general breastfeeding knowledge. The CBKS was used for this study in order to identify the overall level of knowledge participants had within their age bracket. However, for future projects, it would be more effective to ask specific latch-related questions, as it would be easier to analyze changes in results after the participant uses the simulation. This test should also be conducted pre and post-test in future works in order to gather more direct comparisons on whether the participant's knowledge was affected.

4.7 PHYSIOLOGICAL MEASUREMENTS

The measured heart rate focused on observing the physiological reactions of the participants while performing the latching task. As heart rate is related to stress, this was a useful measurement to corroborate the results of cognitive load. Normality testing showed that the heart rate of participants was not normally distributed. Therefore, a non-parametric analysis was conducted. The heart rate results indicated that the Version A had a mean heart rate (M = 83.5%, SD= 18.8) that was slightly lower in comparison to the mean heart rate of Version B (M = 84.7%, SD = 15.6). Further non-parametric testing with the Signed Rank test was conducted in order to determine the effect size d and achieved power post hoc. The statistical power was determined to be 5.2% with an effect size of 0.069.

The chi-square distribution and asymptotic significance were also determined to analyze significance. After conducting the Friedman test, it was determined that there was no statistically significant difference between heart rates of the non-eye tracking Version A and the eye tracking Version B $\chi^2(1) = 0.400$, $p = 0.527$.

The Median scores on Heart Rate for both non-eye tracking Version A and eye tracking Version B were 80.9 BPM and 83.3 BPM respectively. The median scores represented the midpoint of the data, which is determined through the ranking of observations from the study and finding that observation in ranked order. Due to these results indicating that there was no significance in the data, a post hoc was unnecessary.

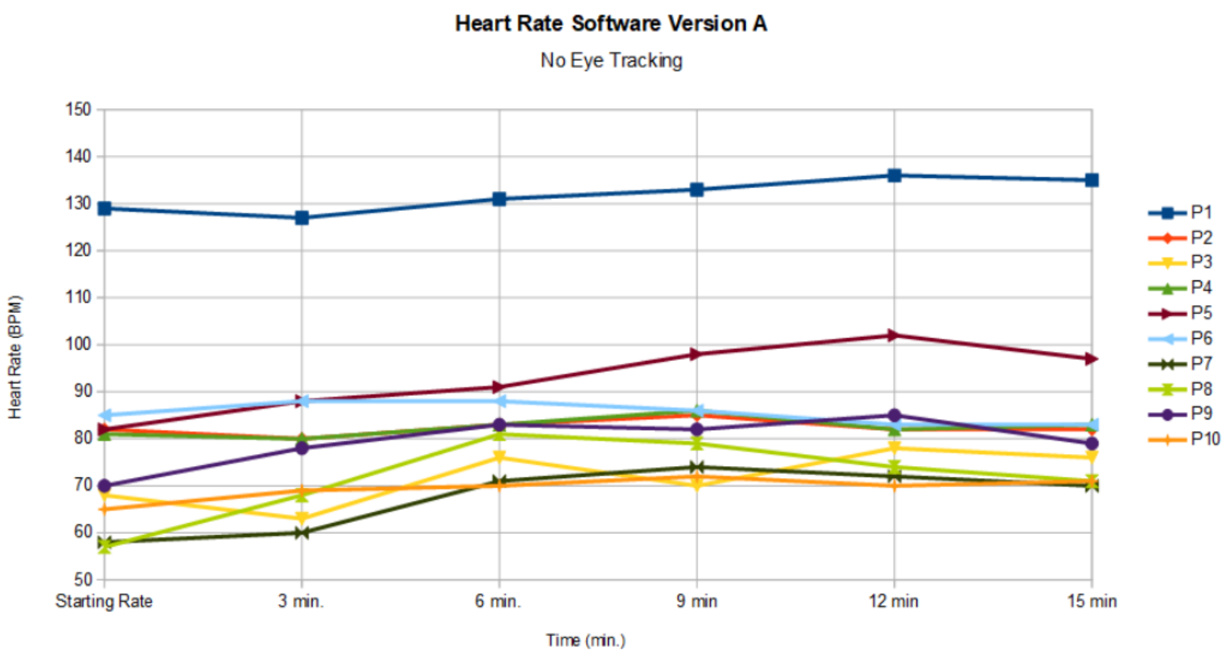


Figure 26: Version A - Heart Rate Line Graph

Individual results from the post-simulation study have been compiled into a line graph for easier analysis. Figures 26 and 27 showed individual changes in heart rate for both software versions. It can be seen that each participant had spikes in heart rate during the simulation during both versions that pointed to moments of discomfort or anxiety. After an informal discussion with participants, it was identified that these spikes would occur when the participants began engaging with the task of latching, highlighting higher stress and cognitive load as the task was being performed. The heart rate of all participants would also end at a higher BPM than their starting rate. Another trend that was present was that once the participant went to complete the second software, regardless of order,

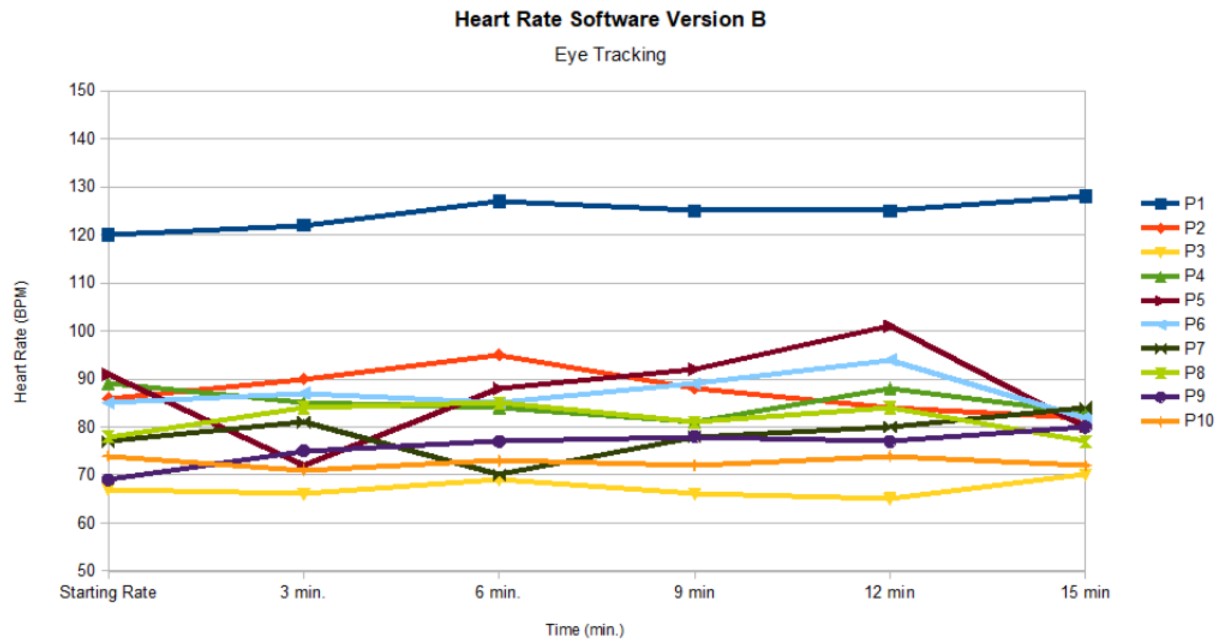


Figure 27: Version B - Heart Rate Line Graph

the participant had an overall lower heart rate trend than what was present in their first trial. This likely occurred because the participant got used to the task, reducing the amount of stress that would be present when trying to complete a new task.

Participant 1 may appear to be an outlier however, through discussion and repeated measurements of the resting heart rate, it was determined that this measurement was accurately their resting heart rate. This heart rate was likely impacted due to participant weight gain and its related impacts on heart rate.

4.8 RESULTS SUMMARY

The results of the study indicated that there is promise in including eye tracking in VR experiences and simulations, particularly when dealing with quality of education. Based on the results, education quality was the only measurement that presented statistical significance when examining both groups. This shows that eye tracking does improve educational value significantly compared to versions that do not include it. However, looking at all other measurements, there seems to only be slight differences between both versions. The CBKS scores also indicate that most participants have some knowledge of breastfeeding, however, none were able to achieve a perfect score. Indicating that there are still misconceptions about breastfeeding and its impact on raising a child.

4.8.1 *Open-Ended Questions*

In addition to quantitative results, open-ended feedback was also collected from participants in an open-ended manner during two parts of the post-VR survey. The compiled responses can be found in the Appendix B.2. Responses were sorted into a table based on the version that was being discussed and the nature of the feedback, first, when completing the MISSES portion of the survey and at the end when asking for overall comments on the entire study. Some comments mentioned that it was "difficult to hold the child at first" and that "smoother control of the baby may be more immersive" (n =5). This circled back to one of the challenges present during development of not having access to the VR input package which allowed for two-handed interactions. This would be addressed by using a headset with eye-tracking that could used in more recent Unity updates. Other comments (n=3) discussed the issue with eye-tracking, stating that there was an inconsistent issue with blinking or flickering with the application. These participants indicated that they could not fully read all the content within the application because of this reason. As this was a challenge that was mentioned during development, the solution implemented was not effective enough to resolve this issue.

There was other interesting feedback provided from participants as some would think aloud or discuss how they felt as they were completing the simulation. Three participants discuss an empathetic response based on the audiovisual feedback, expressing surprise at the motivation they had engage in the latching process or attempt to soothe the baby. These responses can be further investigated in future works in order to determine different means of motivation users while in the VR simulation.

4.9 CHAPTER SUMMARY

This chapter focused on compiling and analyzing the results of the studies conducted. Most participants had neutral to positive results when evaluating both versions. Although part of the original hypothesis of eye tracking that significantly improved usability could not be proved, the cognitive load, fidelity, education value, teaching quality, overall rating, and knowledge of breastfeeding in the simulation showed improvement with the inclusion of eye tracking. These results also showed that most measures were not statistically significant other than educational value. This indicated that eye tracking was an effective means of improving other major components of the simulation. Future work would need to investigate usability more in-depth with a larger sample size to determine its adaptability with a diverse audience.

5 CONCLUSION

5.1 CONCLUSION

This Master's in Computer Science thesis presents the development and user study of a VR breastfeeding latching experience. Various metrics, including cognitive load, simulation effectiveness, system usability, and breastfeeding knowledge, were examined from 10 participants. The goal of this research was to answer What are the usability, cognitive load, presence, task completion, and educational value effects of using VR head and eye tracking as an interaction mechanism for breastfeeding latching? From the preliminary results, valuable insights into the VR experience were gathered that allowed to answer the research question. First, the usability of the eye-tracking version (or Version B) of the system was hindered by issues related to the eye-tracking implementation, as sudden eye movements and blinking interfered with triggering and actions and accessing content. Despite such a shortcoming in terms of user interaction, there were no significant differences in usability compared to the head tracking version (or version A). Overall, the eye tracking nuances were comparable to the nuances caused by requiring participants to move the head to activate and access content, both of which were found to be usable according to the System Usability Scale results. In terms of cognitive load, lower workload was found in the eye-tracking version compared to the non-eye-tracking. Similarly to usability, the raw NASA TLX scores produced no significant differences, indicating somewhat high workload that requires refinement to bring the scores down to low with scores between 0 and 9 (current results stand between 41.1 and 39.3 for Version A and Version B, respectively). The high cognitive load found in Version A can be explained by participants to think about actions and spend more time figuring them out when aiming with their heads. The previous preliminary results aligned with heart rate monitoring, that allow identifying spikes associated with challenges during the interactions with the eye-tracking version having more spikes than head tracking, which is consistent with the difficulties experienced with the eye tracker.

Regarding the educational value, the preliminary results show a significant difference of Version B over Version A. This underscores the positive impact of eye tracking on educational aspects within the VR breastfeeding experience. This difference can be attributed to the ease of use associated with eye-tracking despite the nuances, when it worked, the participants were able to easily interact with the environment and access information without second guessing the location of the raycast by moving their heads. Additionally, the teaching quality results were similar for both versions albeit not being significant. In terms of knowledge about breastfeeding, the response distribution indicates that with the exception of the one participant with prior breastfeeding experience, all other participants improved their understanding of breastfeeding after the study.

Self-efficacy results favored the head tracking version over the eye-tracking one, but without any significant differences, and analyzing the response distribution does not provide clear insights into what could have provoked the slight difference. It is worth noting that both versions rated high in self-efficacy, indicating that participants felt confident about the interactions. Regarding fidelity, while the results were partially high between 69% and 72%, the response distribution does not indicate the reasons for the slight difference, but highlights an issue with participants not understanding what they were evaluating.

5.1.1 *Hypotheses*

Based on the preliminary results, the following list summarizes the hypotheses with the findings from the user study.

- Eye-tracking interactions will result in higher usability than head tracking interactions. This hypothesis is rejected, as the head tracking version had higher usability, caused by the nuances found with the eye tracker implementation caused by sudden eye movement and blinking.

- Eye-tracking interactions will result in lower cognitive load than head tracking interactions. Eye tracking had lower cognitive load than head tracking. After analyzing the results, this was an interesting outcome given the issues reported by participant. It is interesting to see that, despite the eye tracker nuances, head tracking required more workload from the participants.
- Eye-tracking interactions will result in higher educational value than head tracking interactions. This hypothesis was corroborated as the preliminary results indicate a higher educational value when using the eye tracker.

5.1.2 *Research Contributions*

As research is still lacking in areas such as midwifery and breastfeeding, more research is needed to determine the effectiveness of adding VR into this field. The literature review that was conducted highlighted the small number of works that involve midwifery professionals and related students. Along with showcasing that there are not many solutions that evaluate and look at the practical skill elements associated with breastfeeding. Virtual Feed, Virtual Parent, and Real Baby - Real Family are one of the few solutions that have explored VR breastfeeding or handling of a child. As more studies are conducted, more information can be gathered on the effectiveness of VR tools for midwifery.

The development of this project has contributed more evidence and support to the development of VR breastfeeding resources, which remain scarce compared to traditional resources. More literature will provide a stronger basis for future studies, hopefully leading to an increase in resources available for both mothers, fathers, and/or partners.

The inclusion of skin customization of the mother's breasts, hands, and child along with the choice of approaching the experience while being left-handed or right-handed is unique to this study and has not been done within this specific field. The addition of this aspect addresses one of the main issues of VR software designed around a one-size-fits-all design methodology, providing an immersive and customized experience that the user may more effectively relate to.

5.2 LIMITATIONS

The participant sample size and recruitment was certainly limiting factor within this study, especially occurring post-COVID-19. This impacted the sample size of the study, therefore reducing the statistical power as a result. Due to this, further research with larger sample sizes would be needed to evaluate the effectiveness of a breastfeeding experience with VR with eye tracking. Additionally, the state of eye tracking of the Pico Neo headset had limitations that contributed to user experience issues regarding stability in the presence of blinking. A scenario requiring additional research to better understand the impacts of consumer-level eye-tracking.

5.3 RECOMMENDATIONS

When conducting further studies within VR specifically within breastfeeding, it will be crucial to use the most up-to-date software and packages in order to ensure the best functionality. Another aspect of the simulation that was hindered was the manipulation of the child due to limited access to two handed interactions. While these packages may be more developmental, they will allow for much more refined actions and replication of actions. As for eye-tracking, it still shows great potential in order to improve educational quality in simulation. When implementing this feature into projects for that purpose, developers should consider a timer based activation system in order to avoid the flickering problems that were apparent within this study. The time amount would need to be experimented with and could be determined through quick play tests. As for the placement for the related information with eye tracking, it would be useful to follow the suggestions mentioned in Chapter 2, which highlighted keeping the associated knowledge spatially relevant to the object that it is attached to. As well as, ensuring that the difficulty and amount of information is scaffolded in a manner that is easy for the user to digest.

5.4 FUTURE WORK

Future work for this project would include gathering a team that would aid in addressing the design challenges that were present when creating this initial pilot test. Other headsets would need to be tested to determine which would be more usable for use with the integration of eye tracking. The Pico Neo could also continue to be developed if additional programming could address the flickering of text due to the participant blinking. A timer mechanism could be used to activate the text and allow it to remain once it has been looked at. This idea would also require testing to determine the timing and perfect implementation so that it does not inhibit the user.

Other paths of future research could investigate potential motivational factors such as empathy for users which could be used to improve engagement. Creating a study which specifically investigates the latching knowledge of the participant during pre-and-post surveys rather than after they have completed the simulation. This would allow for a better understanding of knowledge improvement within breastfeeding. A specific scale only pertaining to latching related questions could also be designed to target this specific information.

A

APPENDIX A: LITERATURE SYNTHESIS & STUDY DESIGN DOCUMENTS

A.1 Table 3: Synthesis Table

Related Works Synthesis Table

Title	Authors	Venue/ Journal	Date of Pub.	Research Summary	Sample Size
Playful Reflection: Impact of Gamification on a Virtual Reality Simulation of Breastfeeding	Kymeng Tang, Kathrin Gerling, Vero Vanden Abeele, Luc Geurts, Maria Aufheimer	ACM DL/ CHI '23	2023	This paper did a comparative study between the previous virtual reality simulation in breastfeeding done versus the gamified version. It was noted that overall the breastfeeding perception did not change between the two versions, but the gamified version provided more effort and temporal demand as they were made aware of their progress and what needed to be done. This did however affect the fidelity of the simulation and reduced the seriousness of the task.	34
Simulation for breastfeeding support during the COVID-19 pandemic in Turkey: A quasi-experimental study.	Gürkan, Kübra Pınar ; Bektaş, İlknur ; Yücedağ, Mehtap ; Yılmaz, Özgür	Taylor & Francis Online/ Health Care for Women International	2023	This paper investigated the implementation of a breastfeeding simulation for parents that required support during COVID-19. Most participants that were recruited were expecting mothers. Results indicate that the self-efficacy or success of mothers was higher when using the breast simulation model instead of the standard traditional means. Researchers indicate that these simulations could be useful to decrease hospital visits during times of pandemics and provide a safer alternative when needing to be socially distant.	73
Virtual Feed: Design and Evaluation of a Virtual Reality Simulation Addressing the Lived Experience of Breastfeeding	Kymeng Tang, Kathrin Gerling, Luc Geurts	ACM DL/	2022	A VR breastfeeding experience that takes advantage of hand tracking for input. As well as using the VR controller to determine the movement of the child within the simulation. This was predominantly a qualitative study that sought to look at the perspectives and thoughts of the participants.	19
Opportunities in Designing HCI Tools for Lactation	Jessica de Souza, Kristina Chamberlain,	ACM DL/CHI '22 Extended	2022	This study investigated the perspectives of lactation consultants towards the incorporation of	6

Consulting Professionals	Sidhant Gupta, Yang Gao, Nabil Alshurafa, Edward Jay Want	Abstracts		technology into their practice. Challenges and opinions were identified such as the lack of psychomotor options and detailed diagnosis while not being face to face. Different technology solutions were proposed in order to possibly address these concerns. VR was not considered.	
Pababy: An Interactive System for First-time Parents to Learn Neonatal Nursing	Jianhui Liu, Yijun Zhao, Jiadi Wang, Chenyi Xie, Fangyuan Cheng, Jintao Nie, Ge Yan, Cheng Yao, Leijing Zhou, Preben Hansen, Fangtian Ying, Guanyun Wang	ACM DL/CHI '22 Extended Abstracts	2022	Pababy by Liu et al. is a interactive system and simulator that takes advantage of various sensors to provide feedback to the participant through a 2D application on an iPad. This develops further on the traditional usage of infant dolls used by parents to allow for psychomotor practice. Positive and negative feedback are provided to the participant along with haptics to simulate tactile responses. Results indicated that participants were very willing to use this system however further breakdown of steps and more learning modes could be applied as the child gets older.	7 (experts and parents)
Immersive Speculative Enactments: Bringing Future Scenarios and Technology to Life Using Virtual Reality	Adalberto L. Simeone, Robbe Cools, Stan Depuydt, João Maria Gomes, Piet Goris, Joseph Grocott, Augusto Esteves, Kathrin Gerling	ACM DL/CHI '22	2022	This paper focused on creating different immersive enactments that would be used to allow users to experience an event or experience that they could have in the future. Most of these were required to be open-ended and interactable so that the user could take full advantage of the scenario. Results, specifically for the Virtual Parent scenario, indicate that users had an average experience and were able to empathize with the feeling of having a child. However, as they could not interact with the baby fully, this scenario only provides a general experience without teaching the necessary breastfeeding skills.	20 (for Virtual Parent Scenario)
Challenges and Opportunities for Playful Technology in Health Prevention: Using Virtual Reality	Kymeng Tang; Kathrin Gerling; Luc Geurts	IEEE Xplore/ 2022 IEEE Conference on VR	2022	This paper followed the original study done by Tang et al. on the Virtual Feed VR experience. For this study, Tang et al. focus on creating a comparative study investigating the incorporation	10

to Supplement Breastfeeding Education				of playful elements into the experience and how that would affect the overall reception of the application. Results indicate that the addition of these elements made the breastfeeding process more explicit rather than implicit, which made the process much clearer for participants. While it may affect the seriousness of the simulation, participants still expected these elements due to previous experiences or assumptions on VR applications.	
Paternal Education and Its Impact on Breastfeeding Initiation and Duration: An Understudied and Often Overlooked Factor in U.S. Breastfeeding Practices.	Nicole M. Hackman, Kristin K. Sznajder, and Kristen H. Kjerulff	PubMed/ Breastfeed Medicine	2022	This study was conducted as a cross-sectional study between the roles of mother and father during breastfeeding. Results indicated that there was a correlation between the father's level of education and the mother's likelihood of initiating breastfeeding and continuing to do so.	2,839 couples
Opportunities and Challenges of Virtual Reality in Healthcare – A Domain Experts Inquiry	Andreas Halbig, Sooraj K. Babu, Shirin Gatter, Marc Erich Latoschik, Kirsten Brukamp, Sebastian von Mammen	Frontiers/ Virtual Reality in Medicine	2022	Researchers Halbig et al. conducted a medical expert survey with healthcare practitioners in order to gather their opinions on the incorporation of VR for practicing medically based skills. Most participants agree that these simulations would be useful in a variety of scenarios but would require customization and simplicity in order for them to consider incorporating it into medical practice.	102 HCPs
Learning Outcomes of Immersive Technologies in Health Care Student Education: Systematic Review of the Literature	Ryan, Grace V ; Callaghan, Shauna ; Rafferty, Anthony ; Higgins, Mary F ; Mangina, Eleni ; McAuliffe, Fionnuala	PubMed/ Journal of Medical Internet Research	2022	This paper focussed on evaluating learning outcomes typically found within immersive technology and healthcare student education. It was identified that most students include medical or nursing students and no midwifery students. As well as, learning gain being equivalent to traditional resources. The main learning outcomes that these immersive projects focus on include satisfaction, becoming self-efficient and engagement.	29 studies

Understanding the Role of Technology to Support Breastfeeding	Kymeng Tang, Kathrin Gerling, Luc Geurts, Katta Spiel	ACM DL/CHI '21: Proceedings of the 2021 CHI Conference	2021	Tang et al. conducted a mixed-methods approach to explore parents' perspectives in breastfeeding and the role of technology in that setting. They found that most individuals in Central Europe had positive attitudes towards breastfeeding and good theoretical knowledge. However, most technology surrounding it tended to convey factual information rather than making reference to the lived experience that parents go through. These technologies would predominantly target the mother and lacked the recognition of individual experiences.	175 survey responses and 12 interviews
Using Simulation to Teach Breastfeeding Management Skills and Improve Breastfeeding Self-Efficacy	Elaine Webber, Nadine Wodwaski, Renee Courtney	PubMed/ Journal of Perinatal Education	2021	This study aimed to create a simulation for nursing students to use in order to improve breastfeeding education and self-efficacy. Specifically nursing students, they would be paired and take turns conducting an examination and communicating with the patient. As this was all qualitative in nature, they were able to identify trends however there was no quantitative data to be used to conclusively say which simulation fidelity type was the most effective. However, regardless of fidelity, both simulations provided positive effects for students.	77 students
Development and evaluation of a telehealth-based simulation to improve breastfeeding education and skills among nursing students.	Villegas, Natalia ; Cianelli, Rosina ; Cerisier, Kysha ; Fernandez-Pineda , Madeline ; Jacobson, Forest ; Lin, Haiyi Helen ; Sanchez, Heather ; Davenport, Eloise ; Zavislak, Kristin	Elsevier/ Nurse Education in Practice	2021	This study focused on investigating the effectiveness of tele-health based education for students. As there are no main training courses that could aid nurses in breastfeeding education and conducting examinations, researchers wanted to determine if this could be a viable approach. Results indicate that the simulations proposed required little improvement and would be useful for overcoming distance for those who have little to no access to healthcare.	205 students
Impact of Doula-Led Lactation Education on Breastfeeding Outcomes in Low-Income, Minoritized Mothers.	Adetola F. Louis-Jacques, Shanda Vereen, Ivonne Hernandez, Sarah G. Običan, Tara F. Deubel, Elizabeth	PubMed/ Journal of Perinatal Education	2021	This study examined the effects of providing doula-facilitated breastfeeding interventions for a group racial diverse, low-income mothers. Scores increased significantly in women who were exclusively breastfeeding or supplementing	121

	M. Miller, Diane L. Spatz,, Roneé E. Wilson			breastfeeding with the addition of formula. Community, doula-led support was seen as an effective means of improving breastfeeding rates and infant health as costs would be significantly less than individual care and could potentially be considered under the Medicaid program which provides reimbursements for these services.	
HMD-Based Virtual and Augmented Reality in Medical Education: A Systematic Review	Xuanhui Xu, Eleni Mangina, Abraham G. Campbell	Frontiers/ Virtual Reality in Medicine	2021	This was another systematic review that investigated the current state of VR and AR within the field of medical education. Findings provide information on the most commonly used head-mounted displays, comparisons to traditional methods, and the trend timeline of publication releases and relevance.	47 studies
Virtual Reality in Health Care: Bibliometric Analysis	Christian Matthias Pawassar, Victor Tiberius	PubMed Central /JMIR Serious Games	2020	Bibliometric analysis of annual publication numbers for virtual reality in healthcare and related keyword clusters. Useful to support trends and areas of growth.	356 publications
Development and evaluation of a high-fidelity lactation simulation model for health professional breastfeeding education	Anna Sadovnikova, Samantha A. Chuisano, Kaoer Ma, Aria Grabowski, Kate P. Stanley, Katrina B. Mitchell, Anne Eglash, Jeffrey S. Plott, Ruth E. Zielinski & Olivia S. Anderson	Springer Link/ International Breastfeeding Journal	2020	A real-life lactation simulation developed into a breast chest plate that can be used to demonstrate hand expression, engorgement massage, breast pump usage, etc. As it is high fidelity to the task that is being completed, it was able to increase the learner's lactation knowledge and psychomotor skills. The main issue that participants had with the simulation was the inaccuracies associated with the quality of the skin and how certain medical conditions were being represented using the silicone,	32 residents
Interventions to promote exclusive breastfeeding among young mothers: a systematic review and meta-analysis	Christa Buckland, Debra Hector, Gregory S Kolt, Paul Fahey, Amit Arora	PubMed/ International Breastfeeding Journal	2020	Buckland et al. focused on gathering information from the USA and Chile about trends for interventions for breastfeeding with younger mothers. Peer counseling as well as using it in combination with telephone support or antenatal education was the most	9 studies (sys. review)

				popular. It is important to note that many papers were excluded from the review due to many studies including mothers above the age of 25.	
Investigating the effectiveness of school-based breastfeeding education on breastfeeding knowledge, attitudes, and intentions of adolescent females.	Celina Reyes, Caroline Barakat-Haddad, Wendy Barber, Jennifer Abbass-Dick	Elsevier/ Midwifery	2019	Study which looked into breastfeeding education in adolescent females and the addition of a short intervention for improved breastfeeding literacy. It was found that most students learn significantly from this intervention and the majority support the integration of breastfeeding knowledge during education.	77
The effectiveness of simulation health education to mother breastfeeding skill between two groups in the rural area of Riau, Indonesia.	Agrina, Febriana Sabrian, Reni Zulfitri, Arneliwati, Herlina, Ari Pristiana Dewi	Elsevier/ Enfermeria Clinica	2018	This paper examined the effect of simulation health education within breastfeeding in a rural area of Indonesia. The study was conducted using a between-subjects design, with a control group and an intervention group. After being taught using a 3D simulation technique, results show that breastfeeding skill was better than that of the control group to a significant degree.	26
"Real Baby - Real Family"- Holdable tangible baby VR	Yuya Mochizuki, Rex Hsieh, Daiki Agatsuma, Takaya Asano, Marika Higashida, Tatsuya Nishikizawa, Akihiko Shirai	ACM DL/VRIC '17	2017	This paper focused on the creation of a simulation that would allow the user to physically interact with a baby through haptics, a holdable device and making the baby look like the players using the device. Users were able to empathize somewhat with the child, with participants rating similarity and immersion at 2.27 out of 4. Which indicates a need for further improvement on the diversity available. Further results from other conferences indicate that this VR simulation did convince at least 50% of participants to consider having a child after being able to hold and interact with a child that is similar to them.	19
Pregnancy eHealth and mHealth: user proportions and characteristics of	Wallwiener, S., Müller, M., Doster, A. et al.	Springer Link/ Archives of Gynecology and	2016	An analysis of proportions and characteristics for women that are using eHealth and mHealth resources for pregnancy. Younger women had a	220

pregnant women using Web-based information sources—a cross-sectional study		Obstetrics		larger tendency of using mHealth resources while one's influenceability impacted overall relevance to all information types.	

A.2 VR LATCHING APPLICATION USE CASE

Use Case Element	Breastfeeding Simulation Education: Latching and Positioning Your Child
Application	Virtual Reality (Pico Neo 2 Eye and 3 Pro Eye)
Primary Actor	Expecting mothers or those curious about breastfeeding will likely be the predominant actors as they will likely be the most affected by education on this topic. Other actors may still include students, nurses, midwives, and lactation consultants as they would be the primary audience for this simulation.
Precondition	Mothers or students would need a reason to use and learn from this tool (e.g. working towards completing higher education or having the birth of their first child)
Trigger	Possible triggers for the use of this specific use case include: ● Initial education on breastfeeding for parents; first teaching your baby how to latch. ● Post-secondary education on breastfeeding and the latching process in relation to nursing or midwifery.
Basic Flow	The basic flow of the mixed-media application would start with a short introduction to breastfeeding while following the purpose of the simulation. Going on to explain the anatomical workings of the latching mechanism that occurs between the child and the breast, frequently asked questions, and offering a test space that would allow mothers to practice positioning their child without risk. 1. The user opens the application 2. The user is prompted with an introduction to provide a start to scaffold the information to be learned in the simulation. 3. User is then introduced to the VR component of the application, showing the 2D information in a 3D format. Including more information on visuals, angling of the baby, visual cues, etc. 4. Users are then allowed to finish by experimenting based on the new information learned within a structured sandbox environment.
Alternate Flows	1. The use case could include a more segmented portion that

	would allow for experimentation of the positioning of the baby before latching. Occurring after the user has been introduced to the relevant materials. 2. Participants could also be given the option of learning how to engage in latching with two babies, which would require a slight change in content delivery. As well as adding a requirement that the user would need to coordinate using two controllers.

A.3 PARTICIPANT CONSENT FORM

Consent Form

Please complete the required sections of this form in order to provide consent for participation.

* Indicates required question

Ontario Tech University

Consent Form to Participate in a Research Study (17150)

Title of Research Study: Virtual reality latching simulation, an immersive guided versus immersive non-guided comparative study.

Name of Principal Investigator (PI):
Alvaro Joffre Uribe Quevedo PhD

PI's contact number(s)/email(s):
alvaro.quevedo@ontariotechu.ca - (905)-721-8668 x2615

Names(s) of Co-Investigator(s), Faculty Supervisor, Student Lead(s), etc., and contact number(s)/email(s):
Adam Dubrowski, Supervisor (adam.dubrowski@ontariotechu.net)
Jennifer Abbass Dick, Knowledge Expert (jennifer.abbassdick@ontariotechu.ca)
Gabrielle Hollaender, Student Lead (gabrielle.hollaender@ontariotechu.net)
Bill Ko, Collaborator (bill.ko@ontariotechu.net)
Stephen Saunders, Collaborator (stephen.saunders1@ontariotechu.net)

Departmental and institutional affiliation(s):
Faculty of Business and Information Technology, Faculty of Health Science

External Funder/Sponsor: NSERC (COVID-19 Supplement Grant)

Introduction:
You are formally invited to participate in a research study entitled Virtual reality latching simulation, an immersive guided versus immersive non-guided comparative study. Through this consent form, you are being asked if you would like to participate in the current research study. Please be sure to read the necessary information about this study presented in this form. This consent form will provide details on study's procedures, risks and benefits so that you may consider them before deciding to take part in this study. There is no time limit to this decision, please feel free to take your time when considering your participation. If you require any clarification, you may ask the Principal Investigator (PI) Alvaro Joffre Uribe Quevedo or study team to answer any questions or concerns that you may have. You are free to tell family and friends about your participation in this study. Any participation in this study is voluntary.

This study has been reviewed by the Ontario Tech University Research Ethics Board [17150] on [March 30, 2023].

Please be sure to read this consent form carefully, and ask the accompanying Researcher any questions that you might have about the study. If you have any questions about your rights as a participant in this study, complaints, or adverse events, please contact the Research Ethics Office at (905) 721-8668 ext. 3693 or researchethics@uoit.ca.

Purpose:
Virtual Reality continues to become more prevalent to complement teaching within medical education, healthcare, and simulated training. These solutions allow for the use of immersive learning pedagogies (e.g. experiential learning, game-based learning) while also providing a safe learning environment for experimentation with minimal risk. Even while rapidly growing, it is important to acknowledge that there is still a gap in quantitative and qualitative data surrounding the effectiveness of learning outcomes and their impacts for some sectors. In the case of Public Health and breastfeeding, with limited mediums to use for resources, exploring these new technologies could be beneficial to educate parents. Especially during a times of a pandemic where resources can be limited to being non-physical.

Therefore, the purpose of this research within information technology is to study the level of immersion surrounding a single interaction, the usability of virtual reality and how immersive-guided versus immersive non-guided can impact the effectiveness of a simulation. Through the use of eye tracking, further contextual information can be added to scaffold and guide the user when within a simulation. This is meant to make the application easier to use for individuals not familiar with this type of software and provide relevant information when learning something new. You have been invited to participate in this study because as you have the ability to use virtual reality hardware sitting or standing. As well as being over 18 years of age and not being affected by physio-motor impairments, cognitive impairments or blindness.

Procedures:
The study will take place in person in one session lasting 30 to 45 minutes. A total of 10 participants will be participating in this study. You will be;

1) given at least 5 minutes to review and complete this consent form
2) asked to complete a preliminary survey on demographics and your current experience with breastfeeding and virtual reality head mounted displays.
3) provided a guide and instructions on the use of their head mounted display and its controllers.
4) verify the configuration of the VR equipment and ensure everything is working accordingly
5) asked to put on and adjust the fit of the head-mounted display equipment and proceed through the introduction for the experiment and its tasks.
6) attempting to latch a child to the breast available to the participant and interacting with 3D objects within the scene, while sitting. The procedure will require you to pick up and hold a virtual newborn. Then, maneuver them into an latching position comfortable for the child. The scenario and contextual cues such as crying stopping or visual indicators will be provided so that the participant may know when to continue. This will be done through three consecutive tries. Each latching set up will take approximately five to seven minutes.
7) completing the latching task three times therefore finishing the simulation. Once completed, the headset will be removed and you will be guided to a local desktop owned by the research team to completed a final survey. You will be asked to complete a survey to gather information on the System Usability Scale, NASA Task Load Index, The
Michigan Standard Simulation Experience Scale (MiSSES) and the
Comprehensive Breastfeeding Knowledge Scale. Answering these surveys will take five to fifteen minutes to complete.
8) submitting the data through at the end of the survey, and will be presented a physical thank you letter.

Potential Benefits:
The potential benefit of this research study is to create additional resources to aid in the health literacy of breastfeeding. This study is specifically looking at the mechanics surrounding the latching and feeding of a baby when breastfeeding. This study will allow for expecting parents or those with an interest in latching, to learn more about the process in a more experiential manner. As this is done in virtual reality, the participant will be able to practice the associated motor skills that accompany breastfeeding. This material is often difficult to learn about as information availability ranges from meetings with lactation consultants or 2D to 3D videos of the mechanism in action. Neither of which offer further exploration of the model or an environment to learn to properly attach the baby without involving the child directly. Expecting mothers or partners usually would not have the opportunity to practice these techniques until the child has already been born or through the usage of an inanimate placeholder (e.g. a doll).

Expecting mothers, their partners, nurses, midwives and lactation consultants would then have an alternative means through virtual reality of developing a spatial model on these concepts outside of traditional media or direction from professionals. This also can provide benefits in the field of medical education by teaching these methods and concepts to future professionals. Participants will also benefit by experiencing immersive eye-tracking guided and non-guided VR applications for non-entertainment applications. The eye-tracking will seek to provide more contextual information in the scenario so that the user can make more informed decisions on the item they are focusing on. This can potentially increase their awareness with respect to the importance of virtual reality.

Potential Risk or Discomforts:
It is possible that you may experience fatigue or motion sickness while using the head-mounted display. Participants are allowed to take breaks between interactions. To reduce the possibility of encountering motion sickness, fatigue or physical discomfort, the tasks that you will be asked to perform will occur in short intervals of 5-7 minutes per each task.

COVID-19:
Please note, there is a risk of contracting the COVID-19 virus when participating in face to face research.There may be additional risks to participating in this research during the COVID-19 pandemic that are currently unforeseen and, therefore, not listed in this consent form. We ask that you reschedule your study visit to participate in the research study if you a) have any
new or worsening symptoms associated with COVID-19 (See list of COVID-19 symptoms),
b) have COVID-19 as confirmed by a test, and/or c) have been in close-contact with someone with confirmed or suspected COVID-19.

At this time, the university has a mask mandate in effect. This means that you will be required to wear a mask inside any building on our university campus. The researchers you will be working with will also be wearing a mask.

Use and Storage of Data
All data outside of the consent form will be collected through two digital surveys provided by the research team through Google Forms. The first being a preliminary survey which with gather basic demographic information. Some information that would be gathered includes age range, gender, virtual reality experience, role of interest in the latching process, etc. As there is a question pertaining to gender there is an option of not providing this information allowing for further anonymity. No emails or names will be collected during this survey. The second survey takes place after the session using the virtual reality head mounted display, aiming to gather information about the results of the session. Both surveys will not ask for any information that holds the expectation of privacy and will be anonymized. Data will be anonymized through the deletion of any emails that were used to book the session and any corresponding timestamps in association to the session.

Collected data and corresponding consent forms will be kept confidential by Alvaro Joffre Uribe Quevedo on an encrypted Google Drive as well as an external hard drive and will not be available to individuals outside of the research team. Data will be retained for one year (March 2024) to use towards the development of papers and after that data all will be deleted through permanent deletion. All information collected during this study, including your personal information, will be kept confidential and will not be shared with anyone outside the study unless required by law. You will not be named in any reports, publications, or presentations that may come from this study.

Confidentiality:

Your privacy shall be respected. No information about your identity will be shared or published without your permission, unless required by law. Confidentiality will be provided to the fullest extent possible by law, professional practice, and ethical codes of conduct. Please note that confidentiality cannot be guaranteed while data is in transit over the Internet. This research study includes the collection of demographic data which will be aggregated (not individually presented) in an effort to protect your anonymity. Despite best efforts, it is possible that your identity can be determined even when data is aggregated.

Voluntary Participation
Your participation in this study is voluntary and you may partake in only
those aspects of the study in which you feel comfortable. You may also decide not to be in this study, or to be in the study now, and then change your mind later. You may leave the study at any time without affecting your relationship with the university or research team members.

You may refuse to answer any question(s) you do not want to answer, or not answer an interview question by saying, 'pass'.

Right to Withdraw:

If you withdraw from the research project at any time, any data or human biological materials that you have contributed will be removed from the study and you do not need to offer any reason for making this request. Any data that had been gathered prior from that participant will be deleted along with any identifiers that could be traced back to the participant.The information that is collected will be held in strict confidence and discussed only with the research team. You have the option to withdraw from the study and have your data destroyed. This must be done before the session ends. After you leave the experiment it will be difficult to link the data back to you for removal as the data will be anonymized through the deletion of any emails that were used to book the session and any corresponding timestamps in association to the session. You are not required to give a reason for withdrawing from the study.

Conflict of Interest:

Researchers have an interest in completing this study. Their interests should not influence your decision to participate in this study. The study focuses on the assessment of the simulation Your grades will not be affected in any way by participating in the study.

Compensation, Reimbursement, Incentives:
As a participant, you will not incur any expenses as the result of participating in this study. There will not be reimbursement for travel or transportation as arriving to the study will be the responsibility of the participant. The participant will not suffer any disadvantage or reprisal for withdrawing should they no longer wish to participate in the study.

Debriefing and Dissemination of Results:
Data gathered from the participant will be saved and anonymized on the research team's private G-Drive and encrypted external hard drive. You can email the Principal Investigator, Dr. Uribe Quevedo, with any questions regarding the data recorded. You will have access to shared aggregated data upon completion of the study. Data should be available to you by the latest April 2023. Due to removal of identifiable data from the consent form and data submission, researchers will not know whose data they are looking at. If you wish to learn about overall study results, you may contact a research team member or the principal investigator by email.

Participant Rights and Concerns:

Please read this consent form carefully and feel free to ask the researcher any questions that you might have about the study. If you have any questions about your rights as a participant in this study, complaints, or adverse events, please contact the Research Ethics Office at (905) 721-8668 ext. 3693 or at researchethics@ontariotechu.ca. If you have any questions concerning the research study or experience any discomfort related to the study, please contact the researcher Alvaro Joffre Uribe Quevedo at alvaro.quevedo@ontariotechu.ca or (905)-721-8668 x2615.

By signing this form you do not give up any of your legal rights against the investigators, sponsor or involved institutions for compensation, nor does this form relieve the investigators, sponsor or involved institutions of their legal and professional responsibilities.

1. 1. I have read the consent form and understand the study being described. *

   2. I have had an opportunity to ask questions and my questions have been answered. I am free to ask questions about the study in the future.

   3. I freely consent to participate in the research study, understanding that I may discontinue participation at any time without penalty. A copy of this Consent Form has been made available to me.

   Do you consent to participating in this study?

   Mark only one oval.

   ⬭ Yes

   ⬭ No

Version Date
January 18th, 2023

A.4 SAMPLE POST SIMULATION SURVEY

Post Simulation Survey Forms

This survey presents the participants with surveys relating to the simulation, breastfeeding, usability, and cognitive load. These surveys include the System Usability Scale, NASA Task Load Index, The Michigan Standard Simulation Experience Scale (MiSSES) and the Comprehensive Breastfeeding Knowledge Scale. If you have any questions or concerns, please be sure to communicate with one of the researchers present.

* Indicates required question

System Usability Scale

In the development of systems and software, the system usability scale is a simple, ten-item Likert scale providing a view on the participant's perception of usability.

1. I think that I would like to use this frequently. *

Mark only one oval.

	1	2	3	4	5	
Stro	◯	◯	◯	◯	◯	Strongly Agree

2. I found this unnecessarily complex. *

Mark only one oval.

	1	2	3	4	5	
Stro	◯	◯	◯	◯	◯	Strongly Agree

3. I thought this was easy to use. *

Mark only one oval.

	1	2	3	4	5	
Stro	◯	◯	◯	◯	◯	Strongly Agree

4. I think that I would need assistance to be able to use this. *

Mark only one oval.

	1	2	3	4	5	
Stro	◯	◯	◯	◯	◯	Strongly Agree

5. I found the various functions in this were well integrated. *

Mark only one oval.

	1	2	3	4	5	
Stro	◯	◯	◯	◯	◯	Strongly Agree

6. I thought there was too much inconsistency in this. *

Mark only one oval.

	1	2	3	4	5	
Stro	◯	◯	◯	◯	◯	Strongly Agree

7. I would imagine that most people would learn to use this very quickly. *

Mark only one oval.

	1	2	3	4	5	
Stro	◯	◯	◯	◯	◯	Strongly Agree

8. I found this very cumbersome/awkward to use. *

Mark only one oval.

	1	2	3	4	5	
Stro	◯	◯	◯	◯	◯	Strongly Agree

9. I felt very confident using this. *

Mark only one oval.

	1	2	3	4	5	
Stro	◯	◯	◯	◯	◯	Strongly Agree

10. I needed to learn a lot of things before I could get going with this. *

Mark only one oval.

	1	2	3	4	5	
Stro	◯	◯	◯	◯	◯	Strongly Agree

NASA Task Load Index

Definitions

Mental Demand: How much mental and perceptual activity was required (e.g., thinking, deciding, calculating, remembering, looking, searching, etc.)? Was the task easy or demanding, simple or complex, exacting or forgiving?

Physical Demand: How much physical activity was required (e.g., pushing, pulling, turning, controlling, activating, etc.)? Was the task easy or demanding, slow or brisk, slack or strenuous, restful or laborious?

Temporal Demand: How much time pressure did you feel due to the rate or pace at which the tasks or task elements occurred? Was the pace slow and leisurely or rapid and frantic?

Performance: How successful do you think you were in accomplishing the goals of the task set by the experimenter (or yourself)? How satisfied were you with your performance in accomplishing these goals?

Effort: How hard did you have to work (mentally and physically) to accomplish your level of performance?

Frustration Level: How insecure, discouraged, irritated, stressed and annoyed versus secure, gratified, content, relaxed and complacent did you feel during the task?

Pairwise sub-scale comparisons

You will now be presented with a series of pair of rating scale factors. For each pair, choose the factor that was more important to your experience in the task you recently performed.

11. Pair 1 *

Mark only one oval.

- Effort
- Performance

12. Pair 2 *

Mark only one oval.

- Temporal demand
- Frustration

13. Pair 3 *

Mark only one oval.

- Temporal demand
- Effort

14. Pair 4 *

Mark only one oval.

- Physical demand
- Frustration

15. Pair 5 *

Mark only one oval.

- Performance
- Frustration

16. Pair 6 *

Mark only one oval.

- Physical demand
- Temporal demand

17. Pair 7 *

Mark only one oval.

- Physical demand
- Performance

18. Pair 8 *

Mark only one oval.

- Temporal demand
- Mental demand

19. Pair 9 *

Mark only one oval.

- Frustration
- Effort

20. Pair 10 *

Mark only one oval.

- Performance
- Mental demand

21. Pair 11 *

Mark only one oval.

- Performance
- Temporal demand

22. Pair 12 *

Mark only one oval.

- Mental demand
- Effort

23. Pair 13 *

Mark only one oval.

- Mental demand
- Physical demand

24. Pair 14 *

Mark only one oval.

- Effort
- Physical demand

25. Pair 15 *

Mark only one oval.

- Frustration
- Mental demand

26. How mentally demanding was the task? *

Mark only one oval.

1	2	3	4	5	6	7	8	9	10
◯	◯	◯	◯	◯	◯	◯	◯	◯	◯

27. How physically demanding was the task? *

Mark only one oval.

1	2	3	4	5	6	7	8	9	10
◯	◯	◯	◯	◯	◯	◯	◯	◯	◯

28. How hurried or rushed was the pace of the task? *

Mark only one oval.

1	2	3	4	5	6	7	8	9	10
◯	◯	◯	◯	◯	◯	◯	◯	◯	◯

29. How successful were you in accomplishing what you were asked to do? *

Mark only one oval.

1	2	3	4	5	6	7	8	9	10
◯	◯	◯	◯	◯	◯	◯	◯	◯	◯

30. How hard did you have to work to accomplish your level of performance? *

Mark only one oval.

1	2	3	4	5	6	7	8	9	10
◯	◯	◯	◯	◯	◯	◯	◯	◯	◯

31. How insecure, discouraged, irritated, stressed, and annoyed were you? *

Mark only one oval.

1	2	3	4	5	6	7	8	9	10
◯	◯	◯	◯	◯	◯	◯	◯	◯	◯

The Michigan Standard Simulation Experience Scale (MiSSES)

This evaluation framework has been designed to provide a means for assessment and providing the option of assessing entire range of domains identified through a review of simulation literature.

Self-Efficacy

These questions address issues of knowledge, confidence, and ability to work independently.

32. The simulation helped improve my **knowledge**.

Mark only one oval.

	0	1	2	3	4	5	
I do1	◯	◯	◯	◯	◯	◯	I strongly agree

33. The simulation helped improve my **confidence** at performing latching and breastfeeding.

Mark only one oval.

	0	1	2	3	4	5	
I do1	◯	◯	◯	◯	◯	◯	I strongly agree

34. The simulation helped improve my **ability** at performing latching and breastfeeding.

Mark only one oval.

	0	1	2	3	4	5	
I do1	◯	◯	◯	◯	◯	◯	I strongly agree

35. The simulation helped improve my ability to perform latching **independently**.

Mark only one oval.

	0	1	2	3	4	5	
I do1	◯	◯	◯	◯	◯	◯	I strongly agree

36. **Comments/suggestions** regarding the simulation that may improve your self-efficacy:

Fidelity

Aspects of fidelity to assess could include suspension of disbelief, visual characteristics, tactile characteristics, procedural authenticity, etc.

37. The simulator used has adequately realistic characteristics/features.

Mark only one oval.

	0	1	2	3	4	5	
I doı	◯	◯	◯	◯	◯	◯	I strongly agree

38. The simulation environment is adequately realistic.

Mark only one oval.

	0	1	2	3	4	5	
I doı	◯	◯	◯	◯	◯	◯	I strongly agree

39. Realism of the infant present within the simulation was adequate.

Mark only one oval.

	0	1	2	3	4	5	
I doı	◯	◯	◯	◯	◯	◯	I strongly agree

40. Realism of the latching mechanism within the simulation was adequate.

Mark only one oval.

	0	1	2	3	4	5	
I doı	◯	◯	◯	◯	◯	◯	I strongly agree

41. **Comments/suggestions** regarding the simulation to improve the fidelity during the training session.

Educational Value

Knowledge and skills are two components of educational value.

42. The simulation is a good training tool for **knowledge** in latching and breastfeeding.

Mark only one oval.

	0	1	2	3	4	5	
I doı	◯	◯	◯	◯	◯	◯	I strongly agree

43. The simulation is a good training tool for **skills** in latching and breastfeeding.

Mark only one oval.

	0	1	2	3	4	5	
I doı	◯	◯	◯	◯	◯	◯	I strongly agree

44. The simulation was critical at addressing how to identify early feeding cues and how to hold to infant to prepare for latching.

Mark only one oval.

	0	1	2	3	4	5	
I doı	◯	◯	◯	◯	◯	◯	I strongly agree

45. The simulation was critical at addressing how appropriately latching the infant onto the areola instead of the nipple.

Mark only one oval.

	0	1	2	3	4	5	
I doı	◯	◯	◯	◯	◯	◯	I strongly agree

46. Comments/suggestions regarding educational value of the simulation.

Teaching Quality

These questions assess the quality of resources that support the activity.

47. The learning materials (readings, presentations) improved my understanding of latching and breastfeeding.

Mark only one oval.

	0	1	2	3	4	5	
I doı	◯	◯	◯	◯	◯	◯	I strongly agree

48. The resources we used improved my understanding of latching and breastfeeding.

Mark only one oval.

	0	1	2	3	4	5	
I do	◯	◯	◯	◯	◯	◯	I strongly agree

49. Comments/suggestions regarding teaching quality of the simulation.

Overall Rating

50. Overall, this simulation experience was...

Mark only one oval.

	0	1	2	3	4	5	
I do	◯	◯	◯	◯	◯	◯	I strongly agree

51. Please check the one statement below with which you most agree.

For the evaluation of this simulation:

Check all that apply.

- [ ] The simulation requires extensive improvements before it can be considered for use in training.
- [ ] The simulation requires minor adjustments before it can be considered for use in training.
- [ ] The simulation can be used in training, but should be improved slightly.
- [ ] The simulation can be used in training with no improvements made.

52. Please suggest any changes you would make to the simulation.

53. What specific changes would you suggest to improve your learning experience?

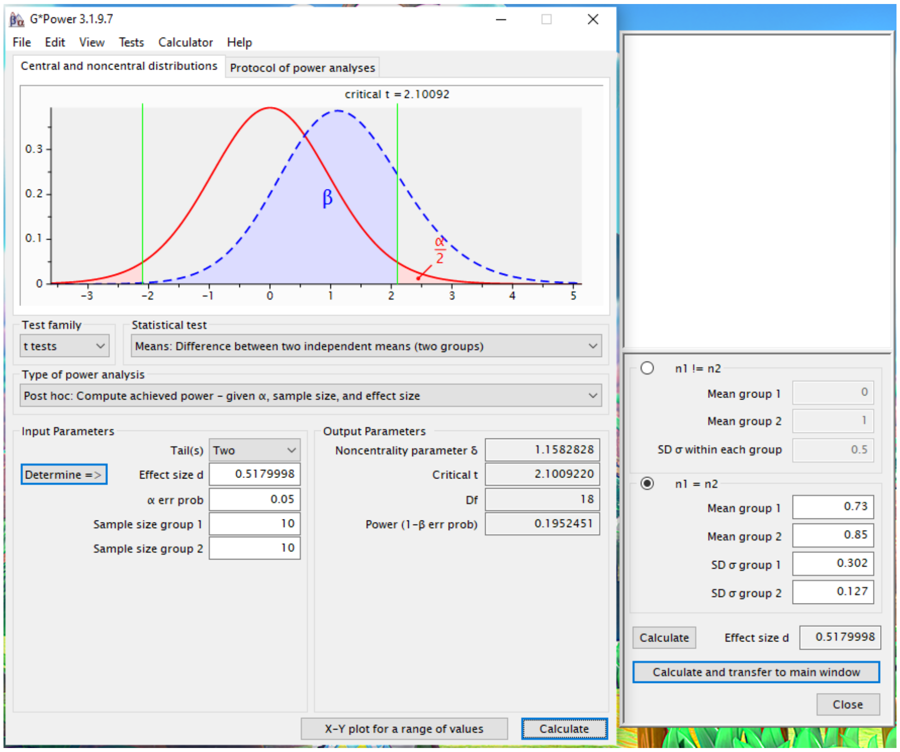
Version Date
October 27th, 2022

B

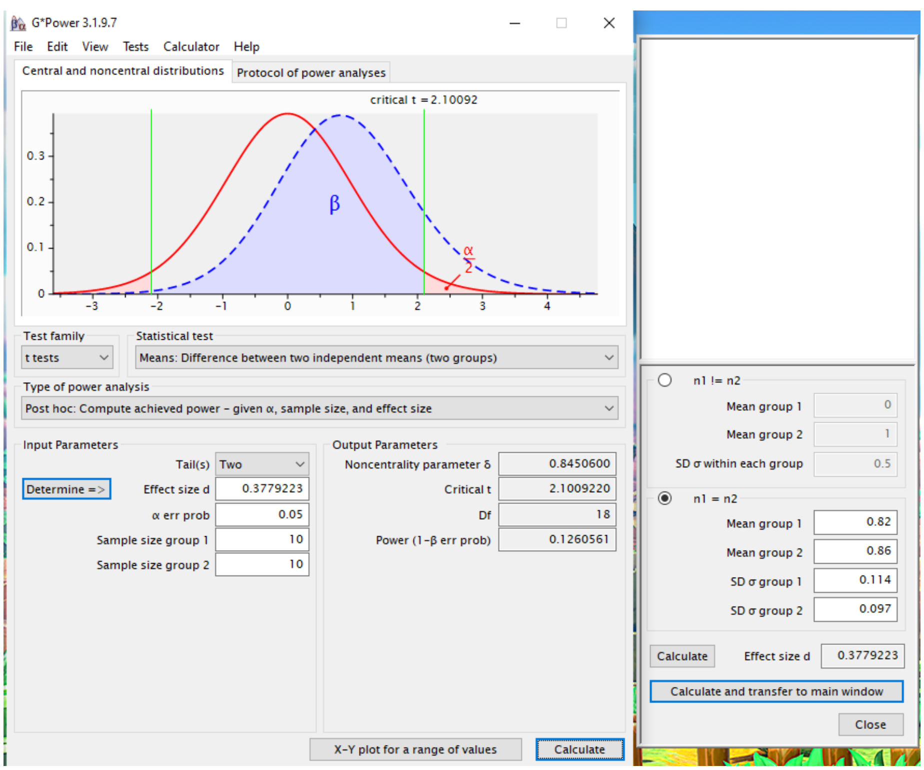
APPENDIX B: DATA COLLECTION & RESULTS

B.1 STATISTICAL POWER CALCULATIONS

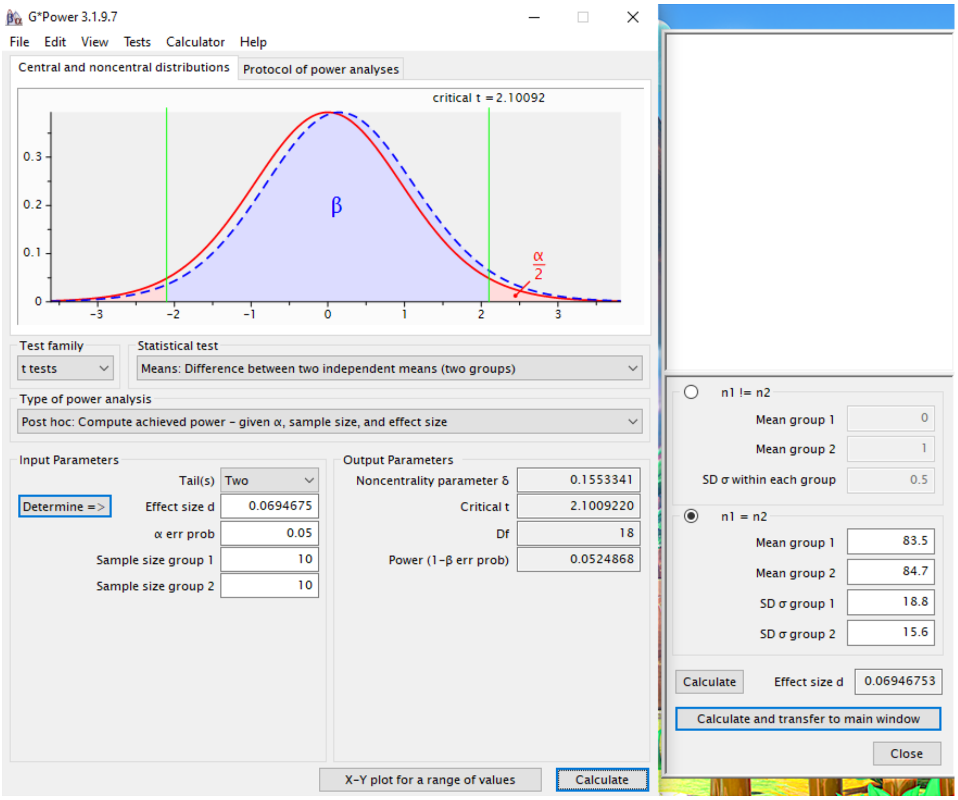
Teaching Quality Statistical Power



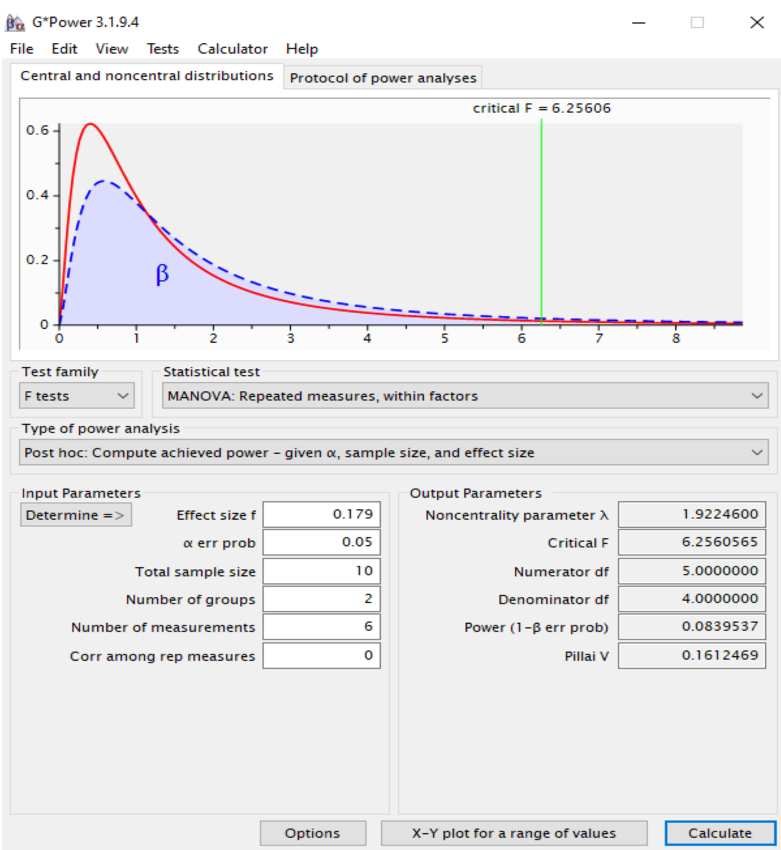
Overall Rating Statistical Power



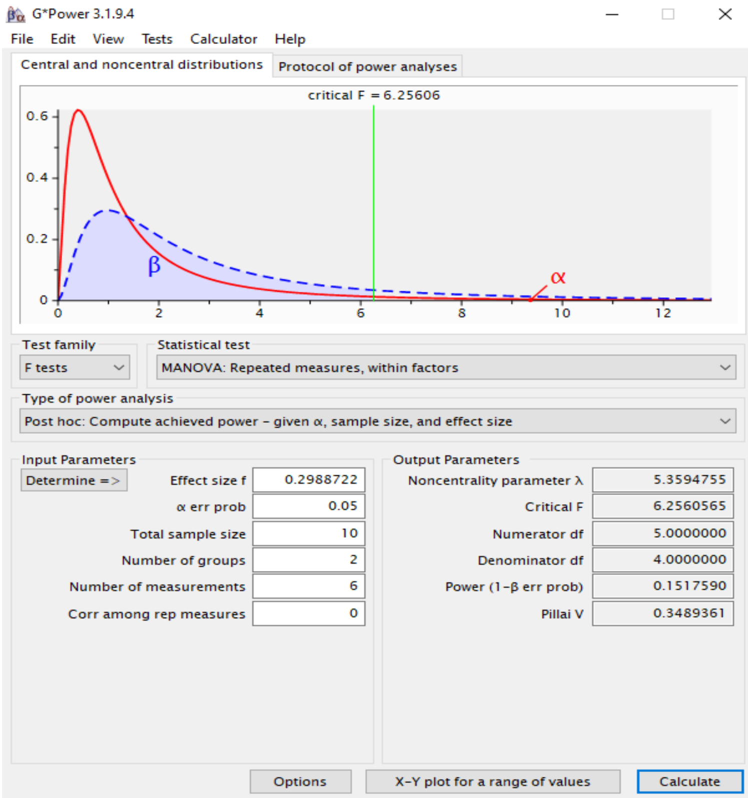
Heart Rate Statistical Power



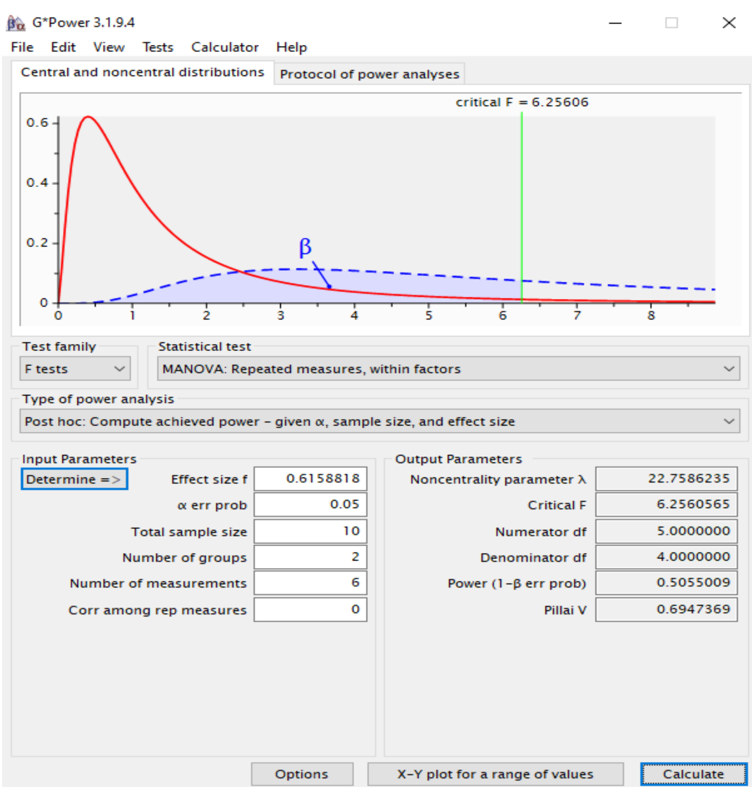
Raw NASA TLX Statistical Power



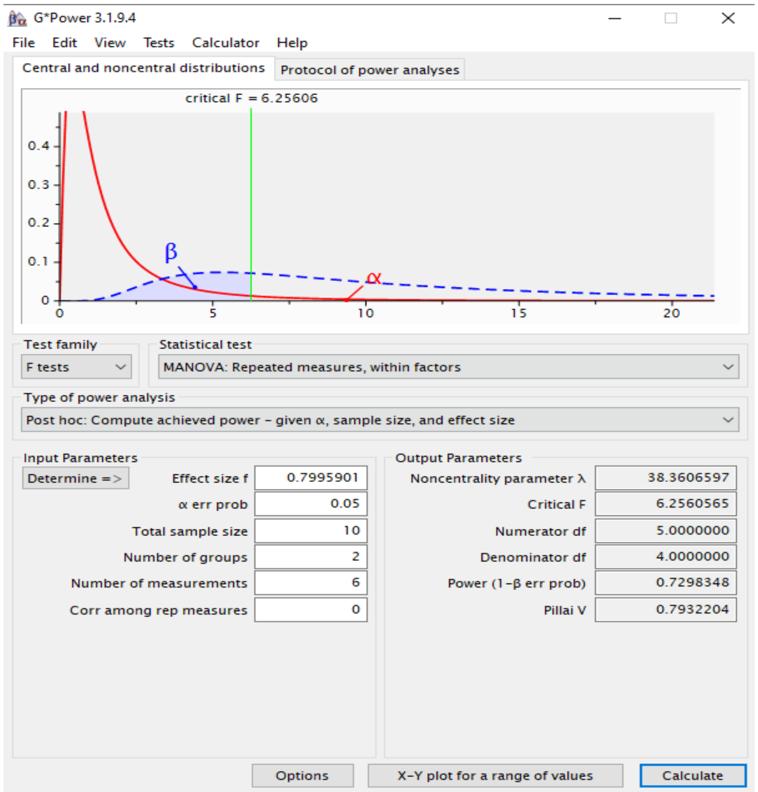
Self Efficacy Statistical Power



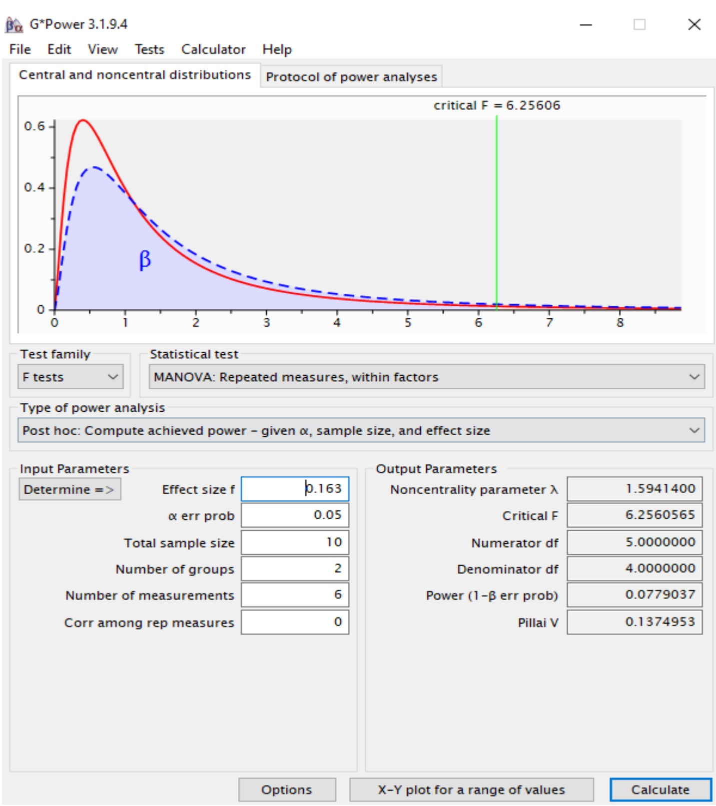
CBKS Statistical Power



Educational Value Statistical Power



Fidelity Statistical Power



B.2 QUALITATIVE RESULTS

Open-ended Comments

Post Simulation Survey Results

Version A (No Eye-tracking)	**Version B (Eye-tracking)**
It is difficult to hold the child at first, although I'm sure that is true in real world scenarios as well.	VR may be challenging to interact with for first-time users, but the simulation is structured in a straightforward and clear way.
Smoother control of the baby while handling may be more immersive as well as additional feedback from the baby ie. burping, GI functions, etc	It was effective for me to learn about breastfeeding even though I don't have breasts.
This simulates the reality of breastfeeding well, and repetition would build my confidence.	Difficulty with latching at start, but it became more clear.
More detail could be added to the infant model, though this is a minor concern as it does not necessarily affect the teaching value of the simulation	A lot of useful experience/information but eye tracking mechanism is more useful as it gives more context clues
The position of the hand when you want to hold the baby can be better. Sometimes you have to twist your wrist to put the baby in the correct position.	The visual component and direct interaction that VR offers seems more useful in latching instruction than other methods like videos or literature
This simulates the reality of breastfeeding well, and repetition would build my confidence.	An excellent and educational simulation that could use very minor refinements to optimize the user experience
I felt a sense of urgency when hearing the baby cry that may be attributed to parental instinct of some sort, but I felt a strong urge to be fast paced in order to stop the baby from crying.	Difficulty with latching at start, but it became more clear.
The simulation can become even closer to the real-life experience because sometimes there could be more struggles for the baby to latch on. But this simulation is definitely helpful for first time mothers.	None! As someone with no experience this was easy to use and helpful/educational
Fantastic start in terms of simulation of latching, would benefit greatly if there was added detail or animations that show more realistically how difficult it can be to latch (maybe even a version with a more difficult baby)	It was pretty frustrating to want to read the information being presented within the simulation, but due to eye tracking it would blink or move when scanning the information with my eyes - making it hard to read the info.

At times the simulations would not respond to movement and quickly adjust.	At certain times the baby would move at random, slightly taking away from experience.
The baby asset struggled at times to latch.	Felt urgency with the baby crying.
Again, great start and good for introducing men to what it is like for their wives/partners/counterparts/etc. that are doing the feedings but would benefit from more detail.	With more refinement experience will offer an excellent simulation
This experience did not have any text cards.	The content was very informative, however- when I blinked it disrupted the view therefore I wasn't able to read it fully.
The teaching approach can be improved. It needs more details about how and exactly where the baby should latch on and what mothers should do when the babies wouldn't latch on properly.	The issue I experienced with the text during eye tracking was it would make the text disappear as soon as I looked away from an object. I think this could be fixed with a short timer on the text that would give a few seconds to read it before it goes away, maybe if you stare at an object for long enough to avoid having it trigger and appear constantly as well.
I can see this helping a lot of people in a way that is easy to understand and imparts the information better than watching a video or reading about it.	I found this simulation to be useful for not just mothers but for fathers as well. It'll be good practice for mothers as it gives useful info about breastfeeding, especially for parents who have their first child.
An excellent and educational simulation that could use very minor refinements to optimize the user experience	More visual cues, over all this is a very informative and interesting experience!

B.3 PRELIMINARY SURVEY RESULTS

Latching in VR: Preliminary Survey

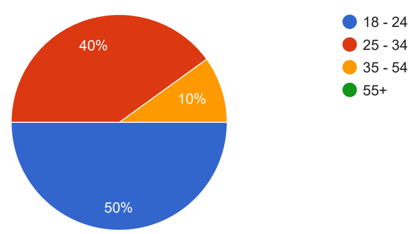
10 responses

Publish analytics

Age Range

Copy

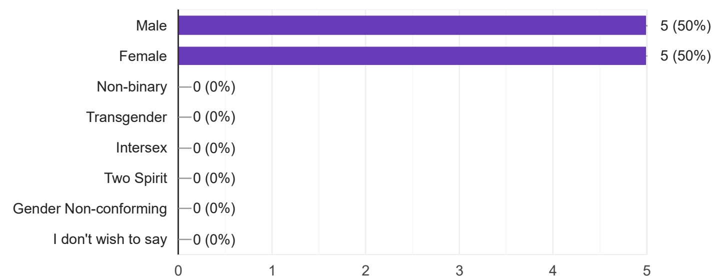
10 responses



Gender:
Please check one or more options that reflect your gender.

Copy

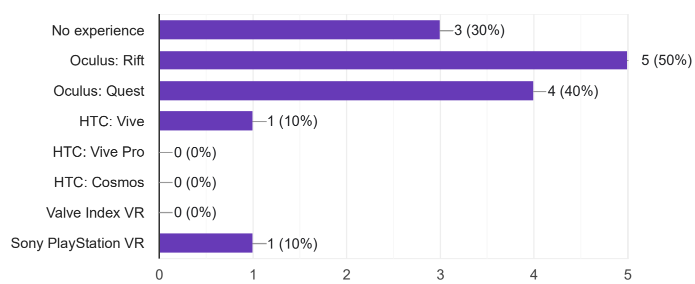
10 responses



Do you have any experience with the following Virtual Reality Head Mounted Display (VR HMD) listed? Please mark all appropriate answers.

Copy

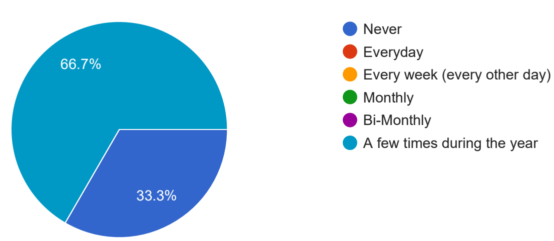
10 responses



How often are you using a VR HMD?

Copy

9 responses



How much time do you spend on average, in VR?

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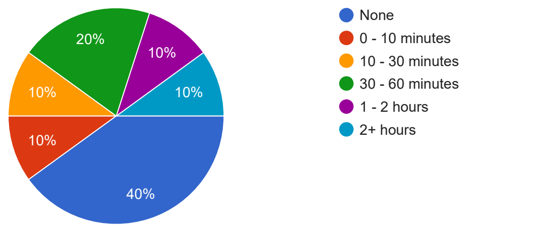
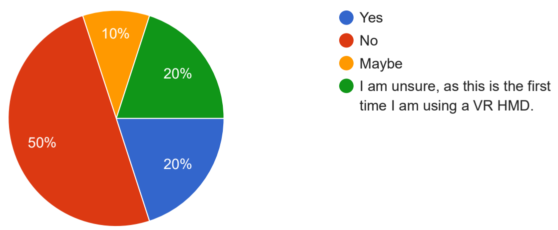
10 responses



Have you every gotten tired or experienced motion sickness while using a VR HMD?

Copy

10 responses

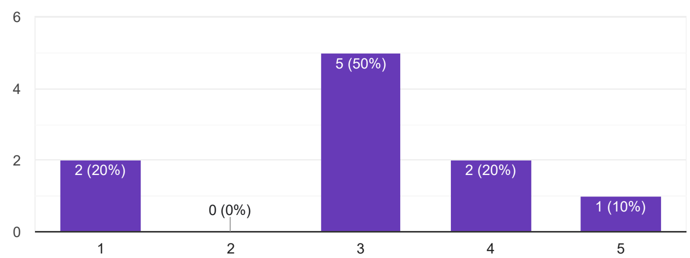


Prior Knowledge on Latching with Breastfeeding

What significance does latching have to you, as an individual?

Copy

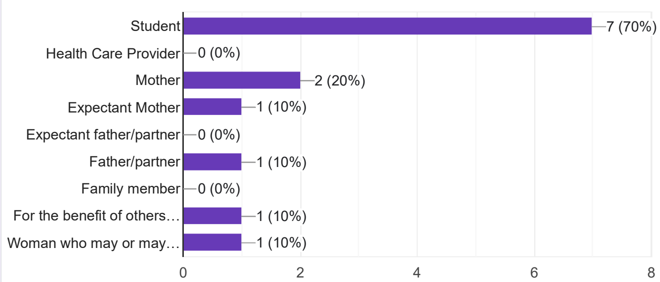
10 responses



In what role are you interested in learning the lactation process?

Copy

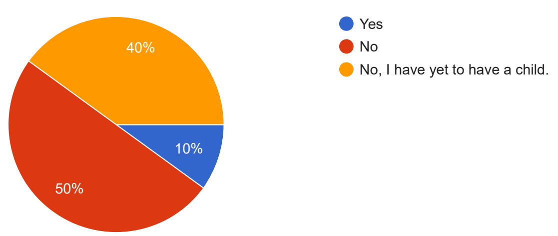
10 responses



Have you had any prior experience latching an infant for breastfeeding?

Copy

10 responses



If yes, what are your main takeaways and suggestions for those that have yet to experience it?

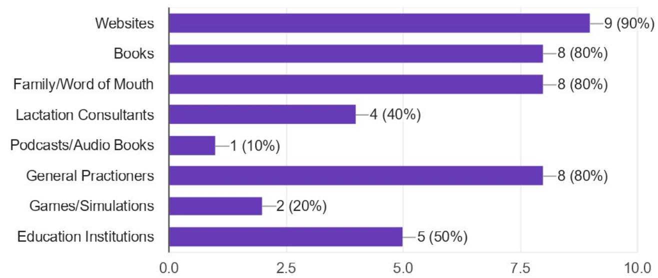
1 response

I required assistance from a lactation consultant due to inability to latch.

When gathering information on latching, which resources would you use or rely on?

Copy

10 responses



Version Date

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