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VR Disability Simulation Reduces Implicit Bias Towards Persons with Disabilities

Tanvir Irfan Chowdhury, Sharif Mohammad Shahnewaz Ferdous, and John Quarles

Abstract—This paper investigates how experiencing Virtual Reality (VR) Disability Simulation (DS) affects information recall and participants' implicit association towards people with disabilities (PwD). Implicit attitudes are our actions or judgments towards various concepts or stereotypes (e.g., race) which we may or may not be aware of. Previous research has shown that experiencing ownership over a dark-skinned body reduces implicit racial bias. We hypothesized that a DS with a tracked Head Mounted Display (HMD) and a wheelchair interface would have a significantly larger effect on participants' information recall and their implicit association towards PwD than a desktop monitor and gamepad. We conducted a 2x2 between-subjects experiment in which participants experienced a VR DS that teaches them facts about Multiple Sclerosis (MS) with factors of display (HMD, a desktop monitor) and interface (gamepad, wheelchair). Participants took two Implicit Association Tests before and after experiencing the DS. Our study results show that the participants in an immersive HMD condition performed better than the participants in the non-immersive Desktop condition in their information recall task. Moreover, a tracked HMD and a wheelchair interface had significantly larger effects on participants' implicit association towards PwD than a desktop monitor and a gamepad.

Index Terms—Virtual Reality, Implicit Association Test, IAT, Bias, Disability Simulation, Immersion, Presence, Learning, Information Recall, Head-Mounted Display, HMD.

1 Introduction

A Reasonable accommodation is a modification or adjustment to a job, the work environment, or the hiring process [1]. These modifications enable an individual with a disability to have an equal opportunity not only to obtain a job but also successfully perform their job tasks to the same extent as people without disabilities (PwoD). Even though many companies provide a modified environment for people with disability (PwD), the workplace might still be a challenge for PwD. Related to this, the Individuals with Disabilities Education Act (IDEA) that was passed in 1975, mandates the provision of a free and appropriate public school education for eligible students ages 3–21. Eligible students are those identified by a team of professionals as having a disability that adversely affects academic performance and as requiring special education and related services. One way to raise awareness regarding the challenges of PwD is by using Disability Simulation (DS). According to Flower et al., [2] DS refers to "an approach to modifying attitudes regarding people with disabilities is to place people without disabilities in situations that are designed for them to experience what it is like to have a disability". DS can be a useful means of not only educating PwoD about various disabilities but also teaching them how to make the environment amicable for PwD. In this paper, we investigate the impact of displays (e.g., an immersive head-mounted display) and interfaces on the effectiveness of a DS.

The intended outcome of a DS is to strengthen empathy and positive attitudes towards PwD. This is because humans are thought to be hard-wired to help others in need [3]. One of the way researchers investigated this altruistic behavior of human is using a technique called perspective taking (PT). In PT, participants are asked to imagine themselves in another person's shoes. Previous research shows that exercises where participants are asked to imagine what it would be like to be someone else under specific circumstances, reduce prejudice and attenuate negative stereotypes [4]. However, PT requires substantial cognitive resources and can be challenging to achieve. Even if a person attempts to take on the cognitive challenge of PT to mentally put themselves in another persons shoes, he or she may fail to fully grasp the urgency or the reality of the other person's situation [5].

An alternative to the PT experiment is using embodied experiences (EE). In EE, the participant feels the embodiment illusion. Immersive VR system that uses Head Mounted Display (HMD) often occludes the participant's own body from his/her view. VR can provide users with vivid visual sensory information about the simulated environment, however, lack of self-representation may prevent the participant from experiencing the VE to the fullest. Thus it is common for such systems to include a virtual representation of a body that is depicted from the first-person perspective [6]. This virtual representation of the participant is called self-avatar. A self-avatar is a co-located avatar that can replicate the user's body posture and motions using body-tracking systems [7]. When the participant experiences the illusion that the co-located self-avatar has effectively replaced their body at a physical and functional level, this

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is known as the embodiment illusion. Ahn et al. found that EE not only led to greater self-other merging compared to PT but also lead participants to voluntarily spend twice as much effort to help persons with colorblindness compared to participants who had only imagined being colorblind [5].

To measure association towards a concept or stereotype, the Implicit Association Test (IAT) [8] is a widely used metric. The IAT measures the strength of associations between concepts (e.g., people of color, PwD) and evaluations (e.g., good, bad) or stereotypes (e.g., athletic, clumsy). The IAT measures attitudes and beliefs that people may be unwilling or unable to report. The IAT many times shows an implicit attitude that might not be known earlier. Implicit attitudes are manifest as actions or judgments that are under the control of automatically activated evaluation, without the performer's awareness of that causation [9]. For example, someone might self-report no preference when they associate females to fields like math, science, or engineering. However, despite significant progress made, many people implicitly associate women with a lack of qualities needed to be successful scientists. This may contribute to discrimination and prejudice against women in those fields [10].

In this paper, we conducted a study to evaluate how DS's displays and interfaces affect implicit associations towards PwD. Specifically, we replicated our previous study [11] where we investigated how interfaces and displays can affect the sense of presence, involvement in a DS, and information recall after the DS experience. Results of the current study agreed with the previous study in that information recall was more effective with immersive displays than non-immersive displays. Our primary novel contribution in this paper is that we incorporate the IAT to evaluate how learning facts about disability with various displays and interfaces can impact the participants' implicit associations towards PwD.

2 BACKGROUND AND RELATED WORK

2.1 Implicit Association Test

The IAT measures the strength of associations between stereotypes (e.g., people with disability, people of color, etc.) and evaluations (e.g., good, bad) [8]. The main idea is that making a response is easier when closely related items share the same response key. There are many types of IAT available e.g., Skin-tone ("Light Skin - Dark Skin" IAT), Disability ("Disabled - Abled" IAT), Sexuality ("Homosexual - Heterosexual" IAT), etc. Researchers have been using the IAT to test the bias towards various concepts. Previous research has shown that experiencing ownership over a dark-skinned body reduces implicit racial bias. [12], [13]. Banakou et al. explained how the IAT is used as a measure of association between categories for any individual [14]. Their study that replicates this [12] not only found similar results but also reported that the effect lasts at least one week after the end of the exposure [14].

2.2 Immersion, Involvement, and Presence

Physical immersion can be defined as a function of the simulator's technology [15], [16], [17]. In virtual environments, immersive systems generally use head-tracking technology along with the minimization of real-world stimuli [18]. The degree of physical immersion is an active literature topic and it is generally thought that increasing the immersion of a virtual environment will produce a stronger sense of presence.

The literature is replete with studies that not only attempt to categorize factors of presence but also highlight simulator attributes that influence an individual's sense of presence [19], [20]. To experience presence, both involvement and immersion are necessary [19]. According to Moreno et al. [21], HMDs are more immersive and users may experience higher presence in HMDs, which is commonly measured through questionnaires, such as the Witmer and Singer Presence Questionnaire (PQ) [19]. Similarly, the $PIFF^2$ is commonly used to evaluate presence in video games. $PIFF^2$ is also considered a validated metric to measure involvement (a motivational continuum toward a particular object or situation), and flow (subjective cognitive-emotional evaluation) in the game [22].

2.3 Disability Simulation

Several approaches have been implemented to foster more positive attitudes toward PwD. Flower et al. [2] summarizes some of the categories as- showing films presenting a positive image of people with disabilities, educating PwoD about PwD using accurate information, and interaction between individuals with and without disabilities in an equal-status relationship. However, the categories of DS strategies have sometimes been criticized for a reported lack of evidence of their effectiveness [23]. Despite the lack of data regarding its effectiveness and the concerns about negative experiences, DS remains a common approach to attempt a positive modification of attitudes regarding PwD [24]. VR has been used previously in raising disability awareness. Pivik et al. [25] illustrate that VR is effective in teaching children with and without disabilities about accessibility and attitudinal barriers. However, it is unclear how VR displays and interfaces affect people's implicit associations towards PwD.

2.4 Education in Virtual Environments

VR has been used to teach complex skills in many fields for a long time e.g., conventional flight simulators [26], surgical simulators [27] etc. Advancements of technology allowed VR to reach a large number of population which makes it a very useful medium to be used in education [28], [29], [30]. VEs can be used to make learning more interesting and fun with the purpose of improving motivation and attention. Additionally, the usage of VEs in education is also cost-effective. The VR environment can replicate any real-world setting such as landscapes, mountains, buildings, complex natural events, and many more [31]. A VR based disaster training can take advantage of this fact, which would otherwise not be possible due to a high cost associated with building the simulation.

Educational VR systems have been developed to help students to learn conceptual information and principles. For example, researchers have prototyped immersive VR systems for mathematics education [32], [33] and for learning complex principles of physics [34]. Maria el al. [35]

describes the design, evaluation, and lessons learned from a project involving the implementation of an immersive virtual environment for children called NICE (Narrative-based, Immersive, Constructionist/Collaborative Environments). The goal of the NICE project was to construct a test-bed for the exploration of virtual reality as a learning medium.

2.5 The Relationship between Presence and Learning

The relationship between presence and learning is unclear because many studies have found conflicting results. According to Schank et al. [36], feeling present (i.e., feeling that the consequences of actions played in virtual environments and simulations are real) can dramatically improve learning outcome. In a study related to the memorization of object information, Mania et al. [37] found evidence that higher rendering quality significantly increases object recognition. Several researchers have investigated the effects of various components of immersive VR [38], [39], as well as interaction techniques [40] on memorization of spatial layouts of objects. Sowndararajan et al. [41] found that even when a greater emphasis on learning new information that is not bound to the specifics of the VE, users performed significantly better in a procedural memorization task when they used a more immersive VE.

2.6 Cybersickness

While immersive VR technology allows the users to feel a higher degree of presence in the virtual environment, the user can also experience some negative side effects such as disorientation, nausea, headaches, and difficulties with vision [42]. When caused by virtual reality these effects are known as cybersickness or simulator sickness (SS). Besides human factors (i.e., age, gender, previous experience) [42], simulator factors have an impact on cybersickness as well, such as exposure duration, the field of view (FOV), interpupillary distance (IPD), position-tracking error, refresh rate, lag, and scene complexity. Factors such as long exposure, bigger FOV, and incorrect IPD amongst others can induce increased cybersickness. Previous research on navigational controls showed that the degrees of freedom (DOF) of the navigational control can have a positive relation with cybersickness: the more DOF, the larger cybersickness [42].

3 HYPOTHESES

The main goal of this research is to investigate the effect of VR based DS on implicit association towards people with disability. To reach our goal we replicated our previous study [11] while adding a new metric of IAT score. Thus, we have two separate sets of hypotheses.

1) Hypotheses related to implicit association towards PwD: **H1—H2a**.
2) Hypotheses related to Presence, Involvement, and Information Recall: **H3—H7**.

H1: Experiencing a disability simulation will significantly change participants' implicit association towards PwD.
H2: Experiencing a DS with an immersive display - a tracked HMD - will have a significantly larger effect on participants' implicit association towards PwD than a non-immersive display - a desktop monitor.
H2a: Experiencing a DS with an immersive interface - a wheelchair - will have a significantly larger effect on participants' implicit association towards PwD than a non-immersive interface - a gamepad.
H3: Using an immersive display - a tracked HMD - in a VE will improve user's sense of presence in a VR-based DS compared to a non-immersive display - a desktop monitor.
H4: Using an immersive interface - a wheelchair - will improve the user's sense of presence in a VR-based DS compared to a non-immersive interface - a gamepad.
H5: An immersive display - a tracked HMD - will significantly increase the user's experience of cybersickness in a VR-based DS.
H6: With an immersive display - a tracked HMD - users will demonstrate significantly improved information recall compared to a non-immersive display - a desktop monitor.
H7: With an immersive interface - a wheelchair - users will demonstrate significantly improved information recall compared to a non-immersive interface - a gamepad.

TABLE 1: Descriptive statistics for participants' information for our four study conditions (section 4.3.1).

Conditions	Male	Female	VR Experience	Mean Age (SD)
Oculus-WC	12	6	3	19.4 (4.9)
Oculus-GP	10	8	2	21.2 (4.0)
Desktop-WC	11	8	3	20.7 (5.0)
Desktop-GP	9	7	3	20.0 (4.3)

4 METHODS

4.1 Participants

We recruited 71 unpaid undergraduate students from the University of Texas at San Antonio (28 of them were female) for the experiment. Participants were recruited without any known mental or physical impairments. All participants had a normal or corrected-to-normal vision. The mean age of the participants was 20.3 years (SD 4.6). Only 11 of them had prior VR experiences of using Google Cardboard once or twice, but none have used Oculus DK2. Table 1 lists the descriptive statistics of the participants for our four study conditions (section 4.3.1).

4.2 Apparatus

We used Unity 5, a multi-platform game development engine from Unity Technologies to design our VE. An Oculus Rift DK2 HMD was used for our immersive display condition, which has a resolution of 960 x 1080 pixel per eye with a refresh rate of 60 Hz and a 100-degree field of view. For our non-immersive condition, we used a 27 inch Dell desktop monitor of Full HD (1920 X 1080) resolution.

A high-performance computer was used in this study to render the VE. The system was equipped with Intel (R) Core (TM) i7 processor (3.30 GHz), 16GB DDR3 RAM, NVIDIA GeForce GTX 980 display card with 4GB of dedicated video memory, and a 64-bits Windows 8.1 Pro operating system.

Communication between our Unity3D application and the gamepad is trivial as Unity3D game engine has build-in support for getting input from a gamepad. However, we created a server-client setup for the communication between the physical wheelchair and our Unity3D application. Unity3D application acted like a server and the two phones connected to the wheels of the physical wheelchair acted like two clients who continuously send rotation rate (section 4.2.1) of the corresponding phone. Figure 1 shows our system schematic which illustrates how the different components in our study interact with each other.

We used a UE 4000 Headphones for the audio. Two navigation interfaces - a wheelchair (WC) and a gamepad (GP) - were used to navigate in the virtual world.

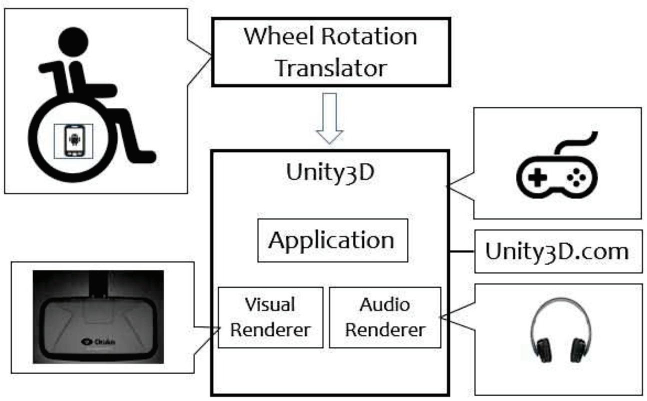

Fig. 1: The system schematics for two Oculus conditions (i.e., Oculus-WC and Oculus-GP). Wheelchair was used in the Oculus-WC condition and Gamepad was used in the Oculus-GP condition.

4.2.1 Navigation Interface: Wheelchair

Fig. 2: Front and side view of the actual wheelchair used in the study.

In Oculus-WC and Desktop-WC conditions, participants interacted with a real wheelchair to navigate in the virtual world. The wheelchair was mounted on top of two bike trainers with an Android phone attached to each wheel (figure 2). Although each of the bike trainers was equipped with resistance, we did not use it as using the resistance would make the participants tired very quickly. While the physical wheelchair was stationary, the rotation rate captured from two phones' two gyro-meters were used to control the avatar's movement in the VE. The rotation rate is given as a Vector3 representing the speed of rotation around each of the three axes in radians per second. We only used rotation rate around the Z-axis as the phones were rotating around only the Z-axis. To avoid any unintentional movement, there was a threshold value of 0.8 radian per second. Any value below this threshold was considered as wheel not rotating. Based on the rotation of two wheels, the virtual avatar can have four possible movements-

- **No movement:** No rotation of any wheels.
- **Move forward:** Both wheels rotate forward. Avatar's speed is determined by the average of the rotation rate of both wheels.
- **Turn left:** Right wheel rotates forward but the left wheel is still.
- **Turn right:** Left wheel rotates forward but the right wheel is still.

4.2.2 Navigation Interface: Gamepad

In Oculus-GP and Desktop-GP conditions, the participants used a Microsoft Xbox 360 wireless controller to control their movement in the VE.

4.3 Study Design

4.3.1 Study Conditions

We choose to recruit university students for our user study. They are familiar with using computers in their daily life for studying, doing homework, playing games, etc. In our study, one of the interfaces is a gamepad, a gaming accessory that is known to most of the participants. As the VR accessories are becoming affordable for the consumer, we chose one of the popular HMD called Oculus Rift.

To examine our hypotheses, we considered a 2 X 2 ("two by two") between-subjects factorial design. The two independent variables of our user study are - display and navigation interface. The two levels of the independent variable display are immersive - an Oculus HMD - and non-immersive - a desktop monitor. The two levels of the independent variable navigation interface are an immersive interface - a wheelchair - and a non-immersive interface - a gamepad. Combining these two independent variables we have our four conditions in total. These four conditions are- Wheelchair interface with Oculus (Oculus-WC), Wheelchair interface with Desktop (Desktop-WC), Gamepad interface with Oculus (Oculus-GP), Gamepad interface with Desktop (Desktop-GP). Participants were assigned to one of the four conditions randomly (counterbalanced). In all four conditions, participants were asked to navigate around the virtual model of the AT&T center and listen to the information about MS presented as audio at specific markers located around the virtual AT&T center (figure 6).

4.3.2 Virtual Environment

Each year people with MS (along with their family and friends) gather together at AT&T center and participate in an annual fund-raising walk. In our DS, we developed a

Fig. 3: Four conditions- a) Oculus-WC (top-left), b) Oculus-GP (top-right), c) Desktops-WC (bottom-left), and d) Desktop-GP (bottom-right).

virtual model of the AT&T center. Similar to the real walk, participants in our study had to navigate around the virtual AT&T center. They also had to listen to the audio information presented along their path. The actual perimeter of AT&T center that was modeled in the VE was around 1.75 KM (figure 4 shows the bird's eye view of the virtual AT&T center). Generally, it takes 20–25 minutes to complete the whole path at normal walking speed. In the VE, navigation capability was revoked while the information was playing to ensure minimal distraction and to ensure no participant misses any information. This makes the VE experience last for approximately 30–35 minutes. The camera was in a first-person view mode. In Oculus-WC, and Oculus-GP conditions, if the participant looked down, they could see their virtual avatar sitting in a wheelchair (figure 5).

Fig. 4: Birds eye view of virtual AT&T center's top view (path of participants shown using arrows).

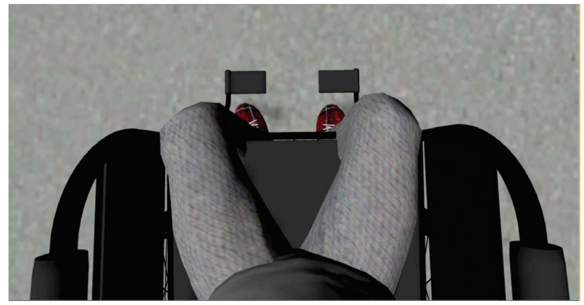

Fig. 5: Participant looking at their self avatar sitting in a wheelchair.

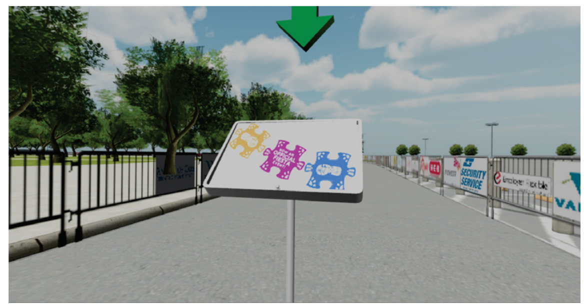

Fig. 6: View of a participant listening information about MS in front of a virtual information board.

In our VE, we choose to present the information in audio format because from our pilot study we found that hearing the information in audio is less distracting than reading the same information as text, likely due to the resolution limitations of the DK2 HMD. To motivate the participants, we gave them trophies as they progressed along the virtual AT&T center's path.

4.4 Procedure

The study procedure consisted of the following four consecutive steps:

4.4.1 Consent

At the beginning of the study, each person had to sign an ethics board approved consent form to participate in the study.

4.4.2 Pre-Study IAT and Introduction

Then the participants took an IAT. After that, a brief introduction was given about the system and what they are expected to do in the study. Here is the text that was read to the participant-

> "You have to follow the path in front of you. There are some information boards in your path. You need to go to those boards, and when you are near enough, you will hear information playing through your headphone. You can use [name of the Navigation Interface] to navigate (i.e., move and turn) in the VE. However, when you are listening to the information, you can not move or turn. When the information playing is done, the board will disappear. Then you can move to the next board.

Go to each board in your path until you reach the finish line."

4.4.3 Study Experience

After the brief introduction, the participants were asked to sit in the wheelchair if they were assigned to one of two wheelchair conditions i.e., Oculus-WC or Desktop-WC. However, for Oculus-GP or Desktop-GP conditions, the participants were seated in a traditional revolving chair. In all four conditions, they wore the headphone. When a participant was comfortable enough to start the study, we started the VR experience. The participants navigated through the AT&T center and had to stop each information board placed along their path. They listened to the audio information while waiting in front of the board. The movement capability was restricted while the audio was playing. When audio was finished, they could start moving again. The whole VR experience continued for about 30–35 minutes.

4.4.4 Post-Study Questionnaire

After finishing the VR experience, the participants took another IAT. Then fill out a Multiple Sclerosis Questionnaire (MSQ), which consists of questions about the Multiple Sclerosis information presented in the VE. They also filled out a Simulator Sickness Questionnaire (SSQ) and a Presence Questionnaire (PIFF^2). In general, the whole study took approximately 45–50 minutes per participant (VE experience + questionnaire). Participants did not receive any financial benefit.

5 METRICS

We used two standard questionnaires- a Simulator Sickness Questionnaire (SSQ) [43] and a Presence Involvement Flow Framework (PIFF^2) [22] Questionnaire. SSQ is a standard 16 items questionnaire where each item asks about participants' different physiological discomforts. SSQ has three sub-scales of scores-***nausea***, ***oculomotor***, and ***disorientation***. The ***SSQ total*** score is calculated from these three subscales. The PIFF^2 is a 14 items questionnaire where each item asks about participants' sense of presence, involvement, or flow. To measure implicit association, we used IAT (section 5.1). We created Multiple Sclerosis Questionnaire (MSQ) to measure the performance of information recall task.

5.1 Implicit Association Test (IAT)

A Disability IAT measures implicit association by requiring participants to quickly sort pictures (representing PwoD and PwD) and words (positive or negative) into groups as fast as possible. Figure 7 shows the pictures and words used in the test. A group is formed combining pictures and words of different categories. The four possible groups are-

1) symbols representing PwoD combined with positive words.
2) symbols representing PwD combined with negative words.
3) symbols representing PwoD combined with negative words.
4) symbols representing PwD combined with positive words.

Category	Items			
Good	Attractive, Laughing, Fabulous, Friend, Glad, Adore, Cheer, Enjoy			
Bad	Failure, Yucky, Horrific, Nasty, Angry, Detest, Ugly, Selfish			
Disabled Persons				
Abled Persons				

Fig. 7: Words and pictures used in the Disability-IAT.

In a particular sorting task, the participant had to sort the pictures and words into two of the four groups, for example, group 1 vs group 2 or group 3 vs group 4.

All IAT scores were calculated using the method described in [8], which results in a smaller correlation between repeated test scores compared to previous IAT calculations. When the IAT is done repeatedly, we expect to see a small reduction on the average in the second measurement [44]. The IAT scores are dimensionless; they represent a summary measure of the differential reaction times and accuracy of detection for the categorizations above. Longer reaction times and greater inaccuracies in categorizing in sorting task **group 1** vs **group 2** than the sorting task **group 3** vs **group 4** results in a IAT score. This is interpreted as a greater preference for PwoD. Similarly, the lower reaction times and lower inaccuracies in the same grouping results in an IAT score, which is interpreted as a greater preference for PwD.

We are, however, primarily interested in the difference between the two IATs taken by the participant before and after experiencing the VR DS, i.e., ΔIAT = post_IAT - pre_IAT. Our hypothesis (H2) was that mean ΔIAT would show a greater preference towards PwD by the participants in immersive conditions than the participants in the non-immersive conditions.

5.2 Multiple Sclerosis Questionnaire (MSQ)

In the VE, the participants were presented various information about MS. All the information was collected from the website of the National Multiple Sclerosis Society. Virtual information boards were placed in the path of the participants. When the participants approach these virtual boards, audio information about MS is played. After finishing the VR experience, the participants were tested on how well they were able to recall that information. We created a questionnaire, named Multiple Sclerosis Questionnaire (MSQ), which consists of multiple-choice questions. The MSQ has 11 questions in total. Every question carried the equal weight of 30 towards the final MSQ score. For each question a score of 30 was selected mainly to avoid fractions in the result. For example, some questions had multiple answers and participants would score 10 if the questions had three correct answers but the participant selected only one. The full questionnaire can be found here [45].

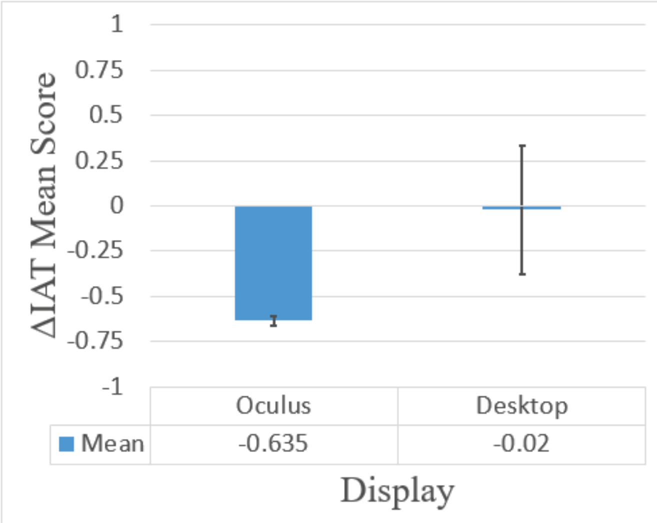

Fig. 8: Bar chart showing means and standard errors of ΔIAT by display condition.

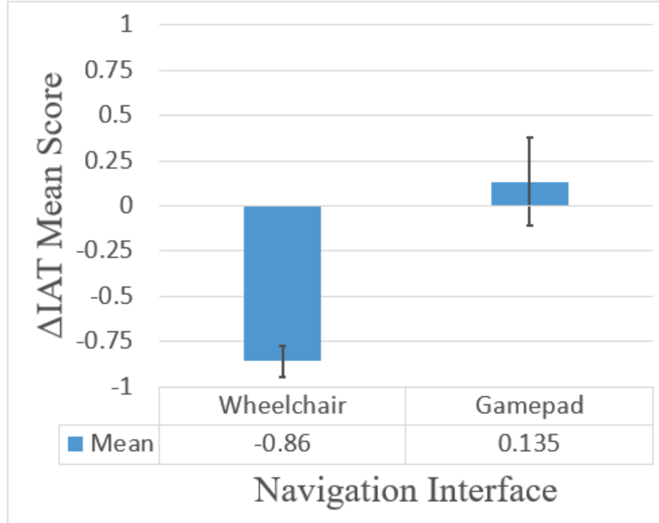

Fig. 9: Bar chart showing means and standard errors of ΔIAT by navigation interface condition.

6 RESULTS

6.1 IAT Score

A Shapiro-Wilk test ($p > 0.05$) and a visual inspection of their histograms, normal Q-Q plots and box plots showed that the IAT scores were approximately normally distributed for both display and interface group.

A two-way repeated measure Anova was conducted that examined the effect of display and interface on the change in participant's bias towards persons with disabilities after experiencing the disability simulation.

Main effects analysis showed that the change in bias towards PwD was significantly greater for participants who were in immersive Oculus HMD condition than the participants in non-immersive desktop condition, F (1, 67) = 15.241, ($p < 0.001$), q partial $\eta^2 = 0.185$. Figure 8 displays bar chart showing means and standard errors of ΔIAT by display condition. We also found a statistically significant main effect of the interface which showed that the change in bias towards PwD was greater for participants who were in the wheelchair interface condition than the participants in the gamepad interface condition, F (1, 67) = 42.985, ($p < 0.001$), q partial $\eta^2 = 0.391$. Figure 9 displays bar chart showing means and standard errors of ΔIAT by navigation interface condition. However, we did not find any statistically significant interaction effect of display and interface on the change of bias towards PwD, F (1, 67) = 0.135, p = 0.714, q partial $\eta^2 = 0.002$. Figure 10 displays bar chart showing means and standard errors of ΔIAT by individual four conditions.

6.2 MSQ Score

A Shapiro-Wilk test ($p > 0.05$) and a visual inspection of their histograms, normal Q-Q plots and box plots showed that the MSQ scores were approximately normally distributed for both display and interface group.

A two-way repeated measure Anova was conducted that examined the effect of display and interface on participant's ability to recall the information learned in virtual reality disability simulation. There was a statistically significant interaction between the effects of display and interface on participants' information recall task, F (1, 67) = 7.451, p = 0.008, q partial $\eta^2 = 0.100$.

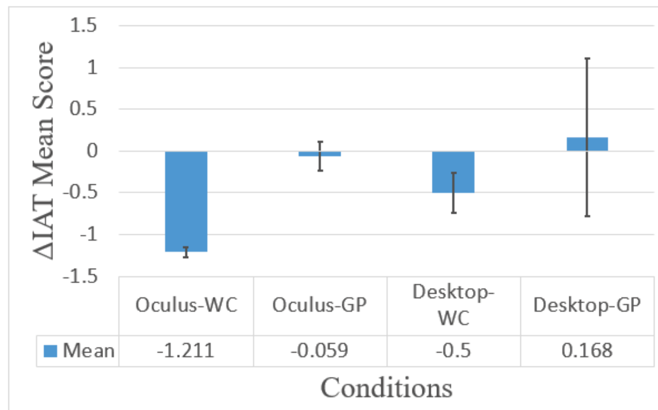

Fig. 10: Bar chart showing means and standard errors of ΔIAT for four conditions separately.

Simple main effects analysis showed that participants who were in immersive Oculus HMD condition (M = 232.916, SD = 38.230) scored higher in their information recall task than the participants in non-immersive desktop condition (M = 222.985, SD = 37.488) but not significantly (p = 0.308). Figure 11 shows the bar chart. There was no significant difference between participants' in two interface conditions (p = 0.516).

6.3 PIFF^2 Score

A Shapiro-Wilk test ($p > 0.05$) and a visual inspection of their histograms, normal Q-Q plots and box plots showed that the PIFF^2 subscale scores were approximately normally distributed for both display and interface group. Two of the subscales of PIFF^2- Presence, and Involvement had statistically significant results.

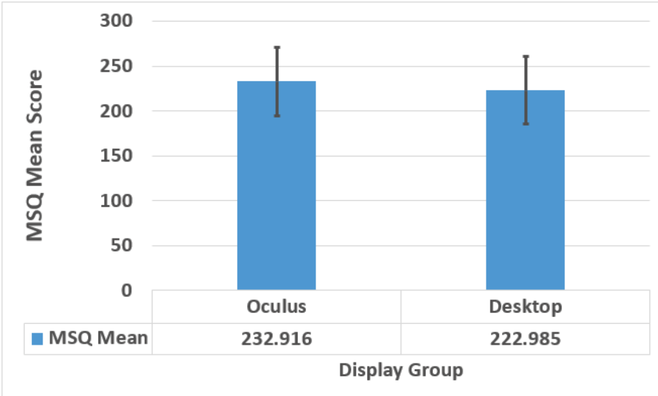

Fig. 11: MSQ mean score comparison for immersive Oculus display vs nonimmersive Desktop display.

TABLE 2: Descriptive statistics for sub-scale of the PIFF[2].

Sub-scale	Condition	Mean (SD)	N
Presence	Oculus	13.111 (2.856)	36
	Desktop	10.457 (3.381)	35
	Wheelchair	12.756 (3.022)	37
	Gamepad	8.764 (3.482)	34
Involvement	Oculus	6.305 (2.053)	36
	Desktop	5.028 (1.599)	35
	Wheelchair	6.405 (2.153)	37
	Gamepad	4.882 (1.297)	34

6.3.1 *Presence*

A two-way repeated measure Anova was conducted that examined the effect of display and interface on participant's sense of being present in virtual reality disability simulation. There was a statistically significant interaction between the effects of display and interface on participants' sense of presence, F (1, 67) = 7.729, p = 0.007, q partial $\eta^2 = 0.103$.

Simple main effects analysis showed that participants who were in immersive Oculus HMD condition felt more present than the participants in non-immersive desktop condition $(p < 0.001)$. We also found the main effect of interface with p = 0.005, which means that participants in wheelchair condition felt more present than the participants in the DS. Table 2 lists the descriptive statistics for Presence and Involvement.

6.3.2 *Involvement*

A two-way repeated measure Anova was conducted that examined the effect of display and interface on participant's involvement in virtual reality disability simulation. There was a statistically significant interaction between the effects of display and interface on participants' involvement, F (1, 67) = 4.930, p = 0.030, q partial $\eta^2 = 0.069$.

Simple main effects analysis showed that participants who were in immersive Oculus HMD condition were more involved in VE than the participants in non-immersive desktop condition (p = 0.003). We also found a main effect of interface with $(p < 0.001)$, which means that participants in wheelchair condition were more involved than the participants in the DS. Table 2 lists the descriptive statistics.

6.4 SSQ Score

A Shapiro-Wilk test (p $>$ 0.05) and a visual inspection of their histograms, normal Q-Q plots and box plots showed that the three subscales of SSQ scores were approximately normally distributed for both display and interface group. SSQ total and two of the subscales of SSQ- Nausea, and Disorientation had statistically significant results. Table 3 shows the descriptive statistics for sub-scales of the SSQ questionnaire.

6.4.1 *Nausea*

A two-way repeated measure Anova was conducted that examined the effect of display and interface on participant's symptom of nausea in virtual reality disability simulation. There was a statistically significant interaction between the effects of display and interface on participants' level of nausea, F (1, 67) = 4.956, p = 0.029, q partial $\eta^2 = 0.069$.

Simple main effects analysis showed that participants who were in immersive Oculus HMD condition felt the symptom of nausea more than the participants in non-immersive desktop condition $(p < 0.001)$. However, there was no significant difference between participants' in two interface conditions (p = 0.139).

6.4.2 *Disorientation*

A two-way repeated measure Anova was conducted that examined the effect of display and interface on participant's symptom of disorientation in virtual reality disability simulation. There was a statistically significant interaction between the effects of display and interface on participants' level of disorientation, F (1, 67) = 4.562, p = 0.036, q partial $\eta^2 = 0.064$.

Simple main effects analysis showed that participants who were in immersive Oculus HMD condition felt the symptom of disorientation higher than the participants in non-immersive desktop condition (p = 0.003), but there was no significant difference between participants' in two interface conditions (p = 0.746).

6.4.3 *SSQ Total*

A two-way repeated measure Anova was conducted that examined the effect of display and interface on symptoms of overall cybersickness in VR disability simulation. There was a statistically significant interaction between the effects of display and interface on participants' SSQ total score, F (1, 67) = 4.543, p = 0.037, q partial $\eta^2 = 0.063$.

Simple main effects analysis showed that participants who were in immersive Oculus HMD condition felt the symptoms of cybersickness higher than the participants in non-immersive desktop condition $(p < 0.001)$. However, there was no significant difference between participants' in two interface conditions (p = 0.154).

7 DISCUSSION

The purpose of this work was twofold- a) validate our previous findings [11] and b) investigate how VR based disability simulation can affect implicit association towards PwD. We have divided our discussion into two parts-

TABLE 3: Descriptive statistics for the four sub-scales of the SSQ questionnaire.

Sub-scale	Condition	Mean(SD)	N
Nausea	Oculus	70.490 (40.040)	36
	Desktop	29.982 (29.913)	35
Oculumotor	Oculus	69.693 (26.803)	36
	Desktop	42.231 (33.106)	35
Disorientation	Oculus	80.040 (56.799)	36
	Desktop	41.362 (52.572)	35
SSQ-Total	Oculus	93.091 (39.581)	36
	Desktop	36.438 (32.049)	35

1) Hypotheses related to Presence, Involvement, and Information Recall.
2) Hypotheses related to implicit association towards PwD.

7.1 Hypotheses related to Presence, Involvement, and Information Recall

For the current study's analysis, we conducted a two-way Anova to investigate the interactions between the display and navigation interface. This is in contrast to our previous study where we conducted a one-way Anova. However, the main effect section of the two-way Anova result enables us to compare the current results to the previous results.

Within the literature, the sense of presence is often related to another similar concept called immersion. These two terms are sometimes used interchangeably, but they are different by definition. Immersion is a description of the technology and can be an objective description of what a particular VR system provides. Presence is a subjective state, the psychological sense of "being there" in a VR. Cummings et al. examined the degree of correlation between immersion - defined as a technological quality of media - and presence - defined as the psychological experience of "being there" [46]. They found that increased levels of user-tracking, the use of stereoscopic visuals, and wider fields of view of visual displays are significantly more impactful than improvements to most other immersive system features, including quality of visual and auditory content. Looking at our two display conditions, Oculus HMD vs Desktop monitor, one would expect that Oculus HMD provided more immersion, which was confirmed in our results. Main effect results from our two-way Anova analysis (section 6.3.1) suggest that the participants who experienced the VE in an immersive condition felt more sense of presence than the participants in a non-immersive condition. Previous research also agrees with our findings e.g., Moreno et al. [21] - "users feel a higher sense of presence with higher immersion i.e. when they use an HMD". Scores from another dimension of PIFF[2], Involvement, also suggests that in immersive conditions participants felt more involved with the VE than in the non-immersive conditions. This result aligned with previous research results - to experience presence, both involvement and immersion are necessary [19]. Based on the discussion, we can accept our hypothesis **H3**, which states that using an immersive display - a tracked HMD - in a VE will improve user's sense of presence in a VR-based disability simulation a compared to a non-immersive display - a desktop monitor.

Results from the main effect section of a two-way Anova in our current study suggest that participants in the wheelchair interface conditions felt a stronger sense of presence than the participants in the gamepad interface conditions. This result is different than the result of our previous study in which we did not find any significant differences between the two navigation interfaces. While we do not know exactly what factors are involved in this change in results, we think this might be an effect of both perspective-taking and embodied experience. While the information presented in the VE helped them to think about the PwD, receiving that information while sitting in a wheelchair gave them a vivid embodied experience. We believe physical wheelchair creates a unique experience for the participants. This could potentially have an impact on empathy towards people in wheelchairs. Therefore, we can accept our hypothesis **H4**, which states that using an immersive interface - a wheelchair - in a VE will improve the user's sense of presence in a VR-based DS as compared to a non-immersive interface - a gamepad.

Results from our two-way Anova analysis (section 6.4) suggest that participants who experienced the VE in the immersive - tracked HMD - condition felt more cybersick than the participants in the non-immersive - desktop monitor - condition. This result also supports findings from our previous experiment **H5**. Similar to the previous research [47], we believe the increased symptoms of cybersickness in immersive display condition are due to the visually-induced perception of self-motion as the participants had to navigate in the VE. As the virtual movement in the VE appeared different than what their physical body was experiencing, this may have caused a conflict between their visual and vestibular systems. This conflict was likely the cause of the cybersickness experienced by the participants.

MSQ mean score result (section 6.2) shows that in immersive HMD conditions participants were able to recall the information more effectively than the participants in non-immersive conditions. We believe there are several potential reasons why the group in immersive HMD condition performed well such as their higher sense of presence, unique experience (in the immersive conditions where they could see their avatar in the virtual wheelchair from a first-person perspective), and human nature (a tendency to feel for others in need). However, the MSQ mean score between the two groups in this study- immersive Oculus HMD condition (M = 232.916, SD = 38.230) vs non-immersive desktop condition (M = 222.985, SD = 37.488) was not statistically significant (p = 0.308) where MSQ mean score between the two groups in our previous study [11]- immersive (M = 244.68, SD = 29.70) vs non-immersive (M = 226.94, SD = 35.08) was statistically significant (p = 0.026). All things being equal, we expected to have the same result in this study too. However, to our surprise, while the MSQ mean score in the non-immersive group remains about the same between two studies, MSQ mean score by the participants in the immersive HMD condition dropped by twelve points. A deeper observation revealed that while the condition (immersive HMD condition in current study vs immersive condition in our previous study [11]) was similar in terms of hardware specification, the cybersickness symptoms reported by the participants in immersive HMD conditions was very high in our current study: immersive (M = 93.091, SD = 39.581) than the previous study immersive (M = 13.97, SD = 9.454). Previous cybersickness research usually attributes the factors of sickness to three categories 1) hardware: the VR device and its configuration; 2) software: the VR content; and 3) individual: the user who interacts with the VR environment [48]. Due to the fact that we had two different sets of participants, we do not have control over how the participants experience cybersickness symptoms with the same hardware and software configuration. We believe the higher level of discomfort might be a crucial factor why the MSQ mean score dropped in our current study. In other words, cybersickness may have played a role in our results. Thus we can not accept our hypothesis **H6**, which states that the participants in the immersive display conditions will demonstrate **significantly** improved information recall as compared to non-immersive display users. More research is needed to investigate this outcome.

For hypothesis **H7**, similar to our previous study, we did not find any statistical evidence that the wheelchair on its own was better than the gamepad interface for the information recall task. We think that participants who used Desktop-WC condition may have felt a disconnection between their interaction with the wheelchair and the display of the VE. That is, in the Desktop-WC condition the virtual wheelchair was not visible because of the fixed camera position.

7.2 Hypotheses related to implicit association towards PwD

The intended outcome of a DS is to grow more empathy and reduce negative associations towards people with disability. Previous research has shown that sharing the same basis of feelings and thoughts of another person through perspective-taking can even lead to costly self-sacrifice during helping [3]. It is thought that the bias towards a stereotype is likely to be rooted in our personality and previous experience and it can only be modified with great effort [12]. That is why we believe simulations such as our VR DS can play a huge role in changing implicit association towards PwD. Results from our user study suggest that most of the participants experienced a change in IAT score post-experiment, which supports our hypothesis **H1**.

Results from the IAT score (section 6.1) suggest that in immersive conditions participants' post_IAT scores were significantly lower than the pre_IAT scores, meaning the participants had less negative associations with PwD. This supports our hypothesis **H2**. There are several potential reasons why this may have occurred. **First**, in both immersive conditions, the HMD gave a strong sense of presence of "being there" in VR. This increased sense of presence in the VE may have enabled the participants to concentrate more on the information that they received in the VE. This information may have been a large contributing factor to their reduced post_IAT score. **Secondly**, the unique embodied experience participants had in the two immersive conditions where they could see their avatar in the virtual wheelchair from a first-person perspective might also play a role. This unique experience may have enabled them to connect with people with MS on a personal level. **Moreover**, there may be a potential relationship between immersion and the intention of disability simulations, which is to raise awareness and promote empathy.

In other areas of implicit association besides toward PwD, VR is an effective approach in changing implicit associations, such as racial bias. Previous research has shown that using a whole-body ownership illusion where immersive virtual reality was used to enable people to step into the "skin" of a differently raced body can reduce their implicit bias against people who are different based on the color of the skin [12]. In our current research, we demonstrate that VR DS can at least temporarily reduce negative implicit associations against people with disability. Based on the previous findings from Banakou et al. on reducing implicit racial bias with VR, the effect may last at least one week and maybe more. More research is needed to investigate the longer lasting effects of VR DS [14].

Since our study is the first attempt (to the best of our knowledge) to investigate implicit associations towards PwD in a VR DS, we believe more research is needed to investigate this further. However, we need to treat the interpretation of the IAT with caution. The IAT score should not be used as an indicator of a PwoD's prejudice against PwD. Instead, IAT score feedback should be used as an educational device to raise awareness about implicit bias and how it may affect one's interactions with others. Here is a quote from Mahzarin Banaji [49], one of the creators of IAT, talk about the test-

> "I would be the first to say that you can never use the IAT and say, 'Well, were going to use it to hire somebody', or 'We're going to use it to put someone on the jury'. One can have these implicit biases and also have a big fat prefrontal cortex that makes us behave in ways that are opposed to the bias."

While IAT is being used in many studies it is not immune to criticism. According to meta-analysis done by Forscher et al., implicit attitude can be changed. However, the method used to measure implicit attitude can greatly affect the outcome of the test. Specifically, the score can be affected by a combination of factors, such as measurement error, task-switching ability of the participant, inhibition of impulses, and guessing, etc [50].

8 Conclusion and Future Work

In this paper, we presented a between-subjects study that investigated the effects of immersive virtual environment displays and interfaces for one aspect of learning - information recall - in a disability simulation-style environment and how it can affect implicit associations towards PwD. We investigated the effects of display (i.e., immersive - HMD, non-immersive - Desktop monitor) and interface (wheelchair, gamepad) to test our hypotheses. The results from our experiment expand upon our earlier work [11]. That is, immersive VR DS can be used not only to teach participants the facts about disability but it can also be a useful means to reduce negative implicit association towards PwD.

While our current study explores the idea of embodied experience via a virtual avatar sitting in a wheelchair, we believe this embodied experience can be further improved using a full-body tracking system. In our future studies, we aim to evaluate the effect of improved embodiment experience on bias towards PwD. We expect that with immersive VEs, disability simulation (DS) could be a helpful means to raise awareness and empathy towards PwD. In our future work, we also plan to investigate the longer-term effects of immersive VR-based DS on implicit bias and whether this change in implicit bias transfers to interactions with real PwD.

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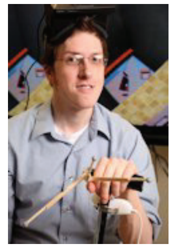

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