A Manipulating Simulator for Electric-Powered Wheelchair Utilizing Virtual Reality Technology

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***Abstract*—Electric-powered wheelchairs have provided individuals with mobility challenges significant opportunities to explore the outdoors, engage in work, and participate in activities. However, operating them can be demanding and sometimes result in serious accidents and injuries. In response, we have developed a driving simulator for electric powered wheelchairs utilizing virtual reality technology. It is worth noting that virtual reality experiences frequently induce motion sickness. In this study, we introduced this simulator and conducted an evaluation to assess the occurrence of motion sickness.**

Keywords—electric-powered wheelchair, simulator, virtual reality, mobility challenges, motion sickness

I. Introduction

Individuals with mobility challenges faced difficulties in venturing outdoors until the invention of the self-propelled wheelchair in the 17th century [1] [2]. In the 20th century, the modern manual wheelchair was invented and has been widely used to this day. The first motorized wheelchair was introduced in 1916, followed by the invention of the first electric-powered wheelchair in 1953 [3].

The development of compact yet powerful electric motors and long-lasting batteries has facilitated the widespread adoption of electric-powered wheelchairs. These wheelchairs can be operated by individuals with weak arm strength using special devices such as a gaming joystick. Electric-powered wheelchairs have provided individuals with mobility challenges significant opportunities to explore the outdoors, engage in work, and participate in activities.

However, operating electric-powered wheelchairs requires extensive experience to maintain proper lane positioning on pedestrian paths and alongside roadways over long distances. Fine manipulation techniques are also necessary to navigate through an office to reach a desk or enter a small restroom stall with an electric-powered wheelchair. Additionally, boarding trains and buses can be challenging as the wheelchair-accessible door openings are often narrow.

Individuals with poor manipulation skills are indeed at risk of encountering dangerous situations when operating electric-powered wheelchairs. Awkward manipulation of these wheelchairs can result in collisions with objects on the floor or with pedestrians walking or running along the same path. Furthermore, failed manipulation attempts may increase the risk of being struck by a car or, in certain cases, falling down from a train platform.

We have developed a manipulation simulator for electric-powered wheelchairs utilizing virtual reality (VR) technology. This simulator provides individuals with the opportunity to practice wheelchair manipulation repeatedly in a safe environment.

To enable prolonged practice sessions, it is crucial to design software that helps users mitigate motion sickness while using the simulator. VR experiences have been known to occasionally induce severe motion sickness [4]. Therefore, we conducted an evaluation to assess the occurrence of motion sickness during simulator usage.

II. MATERIALS AND METHODS

A. Participants

A total of eight male college students participated in the study, with ages ranging from 20 to 24 years and a mean age of 21.8 years. All participants were in good health and had normal vision or vision corrected to normal.

Before participating, all participants provided written informed consent after a thorough explanation of the study's purpose and procedures. The experiments conducted strictly adhered to international ethical standards set by the World Health Organization (WHO) and followed institutional guidelines. The purpose and procedures of the study were approved by the institutional ethical committee.

B. Apparatus and Procedure

The participants in the study wore a head-mounted display (HTC Vive™, Taiwan) and engaged in a custom-made manipulating simulator of electric-powered wheelchair. To track the participants' movements and behavior, two infrared sensors (HTC Vive™ Lighthouse) were installed in the room. These sensors automatically detected the position of the head-mounted display, which had an infrared light source embedded in it.

The participants' body positions and postures were captured by the sensors and transmitted to the computer in real-time, allowing for synchronization with the VR view presented in the head-mounted display. Additionally, head motion sensors were integrated into the head-mounted display to adjust the VR view according to the participant's head position.

All the visual presentations were controlled by specialized applications programmed in Unity (Unity Technologies, San Francisco, CA, USA) and C# (Microsoft, Tokyo, Japan). The applications were run on a desktop computer equipped with a Core i7 processor and a gaming video card.

A participant was seated on a conventional wheelchair while wearing a head-mounted display and instructed to interact with a simulator (Fig. 1). The participant's task was to navigate a distance of 300 meters while avoiding striped traffic cones placed on the floor (Fig. 2). The electric-powered wheelchair was controlled using a gaming joystick that was positioned on a desk in front of the participant (T. 16000M FCS, Thrustmaster, Oregon, USA).

Fig. 1. The manipulating simulator for electric-powered wheelchair utilizing virtual reality technology

Following a single trial, the participant was asked to provide ratings for various items, including the sensation of motion sickness, feelings of nausea during turns with the electric-powered wheelchair, the ease of manipulation, visibility of gaming graphics, and user interface displayed in the head-mounted display. The participant also rated their experienced motion sickness in relation to car, train, boat and plane rides. Each rating was based on a 5-point scale that was presented on the display. Following the rating process, the participant was asked to reflect and provide introspection based on his manipulating electrical-powered wheelchair.

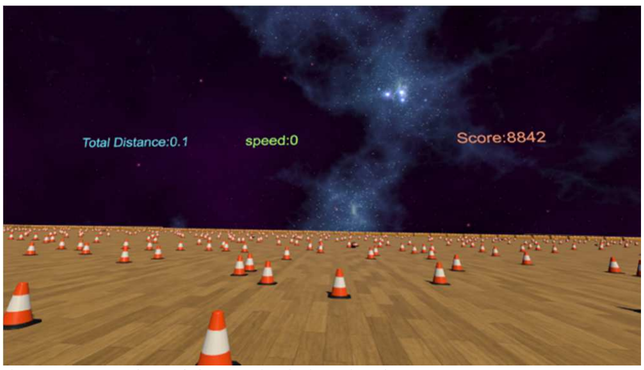

Fig. 2. Screenshot of the manipulating simulator

Pearson's correlation coefficients were calculated among the items with using SPSS statistical software package (IBM SPSS ver. 28 for windows, Tokyo, Japan). Statistical significance was set at $p<0.05$.

III. RESULTS AND DISCUSSION

Table 1 displays the average ratings for each item. In the rating scale, a score of 1 represents "disagree" while a score of 5 represents "agree." The results suggest that the visibility of graphics (#4) and user interface (#5) were deemed sufficient for the participant to successfully complete the trial.

TABLE I. RATING OF EACH ITEM A)

item	#1	#2	#3	#4	#5	#6	#7	#8	#9
mean	3.25	3.63	4.38	4.25	3.38	2.50	2.00	3.13	4.00
SE	0.59	0.53	0.32	0.41	0.46	0.53	0.50	0.88	0.60

A. Item numbers denote the sensation of motion sickness (#1), feeling of nausea during turns with the electric-powered wheelchair (#2), the ease of manipulation (#3), visibility of gaming graphics (#4), and user interface (#5) displayed in the head-mounted display, experienced motion sickness in relation to car (#6), train (#7), boat (#8) and plane (#9) rides, respectively.

Table 2 displays significant correlation coefficients between various items. The sensation of motion sickness (#1) was correlated with the feeling of nausea during turns with the electric-powered wheelchair (#2). Additionally, there were correlations observed between experienced motion sickness in relation to car (#6) versus train (#7), and boat (#8) versus plane (#8). These findings suggest that susceptibility to motion sickness in real transportation does not necessarily indicate susceptibility to motion sickness in the VR environment of our manipulation simulator.

TABLE II. PERSON'S CORRELATION COEFFICIENTS AMONG THE ITEMS A),B)

		#1	#2	#3	#4	#5	#6	#7	#8	#9
#1	r=	1.00	.781*	0.30	-0.26	-0.05	0.68	0.67	0.61	0.51
	p=		0.02	0.46	0.54	0.91	0.06	0.07	0.11	0.20
#2	r=	.781*	1.00	-0.09	-0.10	-0.14	0.41	0.54	0.55	0.67
	p=	0.02		0.83	0.81	0.75	0.32	0.17	0.16	0.07
#3	r=	0.30	-0.09	1.00	0.03	0.70	0.05	0.11	0.04	0.09
	p=	0.46	0.83		0.94	0.05	0.90	0.79	0.93	0.83
#4	r=	-0.26	-0.10	0.03	1.00	0.59	0.08	0.17	-0.21	-0.36
	p=	0.54	0.81	0.94		0.12	0.85	0.68	0.62	0.38
#5	r=	-0.05	-0.14	0.70	0.59	1.00	0.04	0.23	-0.42	-0.26
	p=	0.91	0.75	0.05	0.12		0.93	0.58	0.31	0.53
#6	r=	0.68	0.41	0.05	0.08	0.04	1.00	.935**	0.13	-0.11
	p=	0.06	0.32	0.90	0.85	0.93		0.00	0.75	0.79
#7	r=	0.67	0.54	0.11	0.17	0.23	.935**	1.00	0.00	-0.06
	p=	0.07	0.17	0.79	0.68	0.58	0.00		1.00	0.89
#8	r=	0.61	0.55	0.04	-0.21	-0.42	0.13	0.00	1.00	.785*
	p=	0.11	0.16	0.93	0.62	0.31	0.75	1.00		0.02
#9	r=	0.51	0.67	0.09	-0.36	-0.26	-0.11	-0.06	.785*	1.00
	p=	0.20	0.07	0.83	0.38	0.53	0.79	0.89	0.02	

A. Item numbers denote the sensation of motion sickness (#1), feeling of nausea during turns with the electric-powered wheelchair (#2), the ease of manipulation (#3), visibility of gaming graphics (#4), and user interface (#5) displayed in the head-mounted display, experienced motion sickness in relation to car (#6), train (#7), boat (#8) and plane (#9) rides, respectively.

B. Single asterisk (*) and double asterisks (**) denote $p<0.05$ and $p<0.01$, respectively

Motion sickness in VR environments can indeed be a significant obstacle to training users in fine manipulation of electric-powered wheelchairs. Users often experience nausea and vertigo, leading them to give up training sessions. However, it's worth noting that this motion sickness is not directly related to sickness experienced in real environments.

In an article by Chang and her colleagues [4], they reviewed many studies on motion sickness in VR and identified several factors that contribute to its occurrence. To prevent motion sickness and allow for effective training, optimizing the software and hardware components of the VR system is crucial. Here are some key considerations:

Limiting visual field: Narrowing the field of view within the VR environment can help reduce the incidence of motion sickness. By focusing the user's vision on specific areas and avoiding excessive peripheral movement, the likelihood of experiencing discomfort can be minimized.

Reducing delayed latency: Minimizing the latency between the user's body movements and the corresponding motion graphics in the VR environment is essential. Delays can lead to a disconnect between the user's proprioceptive and visual feedback, which can contribute to motion sickness. Decreasing this latency improves the synchronization and enhances the user's sense of presence within the VR environment.

Decreasing display flicker: Flickering on the VR display can also contribute to motion sickness. Optimizing the display technology to reduce flickering and provide a stable visual experience is important. High-quality displays with fast refresh rates and reduced motion blur can help alleviate discomfort.

High-performance computer: A powerful computer is necessary to ensure smooth and responsive graphics rendering in the VR environment. Lag or dropped frames can disrupt the user's immersion and increase the likelihood of motion sickness. Investing in a high-performance computer system capable of handling the demanding graphics requirements of VR can significantly improve the user experience.

Appropriate display: Choosing the right display for the VR system is crucial. Factors such as resolution, refresh rate, and field of view should be considered. Higher-resolution displays with higher refresh rates can provide a more realistic and comfortable experience, reducing the risk of motion sickness.

By addressing these factors and optimizing the software, hardware, and overall VR experience, it is possible to mitigate motion sickness and create a more suitable environment for users to train and learn fine manipulation skills with electric-powered wheelchairs.

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REFERENCES

[1] Website: https://whill.inc/jp/column/05_history#i (viewed on June 12, 2023)

[2] Website: https://blog.sciencemuseum.org.uk/history-of-the-wheelchair/ (viewed on June 12, 2023)

[3] Website: https://lith-tech.com/history-of-the-electric-wheelchair/ (viewed on June 12, 2023)

[4] E. Chang, H-T Kim, B Yoo, “Virtual relaity sickness: a review of causes and measurements,” International Journal of Human-Computer Interaction vol. 36, pp.1-25, July 2020.