Improving wheelchair driving performance in a virtual reality simulator

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Abstract—In this study, we measured if practice of a wheelchair activity in a virtual reality simulator (entering an elevator) improved wheelchair positioning skills in naïve, healthy adults. Performance was assessed immediately after practice, two days later (retention) and in a real-world equivalent task (transfer). The influence of augmented feedback on retention and transfer was also assessed. Forty participants were randomized to either an augmented feedback group (who received information on collisions and on task completion time) and a no-feedback group. Following training, both groups improved their wheelchair positioning abilities. Learning was maintained at retention and skills transferred to the real-world wheelchair. Augmented feedback did not procure any additional effects. Practice in a virtual reality simulator significantly improved wheelchair positioning skills. Higher performance gains could be achieved by providing task-specific feedback.

Keywords—power wheelchair, simulator, performance, learning, transfer

I. INTRODUCTION

Learning power wheelchair (PW) driving requires the acquisition of both basic skills, such as turning, going backwards and braking, as well as complex skills such as avoiding obstacles, maneuvering in constrained spaces, and positioning the chair in order to reach for objects [1]. Without training, PW-related accidents are frequent, resulting in injuries to the driver, others or damage to the environment [2].

Virtual reality may provide a good opportunity for new PW users to safely practice more complex skills. Indeed, over the past two decades, a number of PW simulators have been proposed [3]. The McGill Wheelchair Simulator, or miWe, [4] runs on a regular computer and provides a first person, 3D perspective view, presented on a computer screen in front of the user (Fig. 1). It is controlled using a regular joystick, and parameters such as speed and acceleration correspond to a real PW. Several virtual scenarios have been designed, based on an analysis of users’ needs [5], such as entering/exiting an elevator, entering an adapted transport vehicle and street crossing.

Acquisition of motor skills can be enhanced through augmented feedback (AF), or feedback provided in addition to the natural sensory feedback (auditory, visual, etc.) experienced by a participant [6, 7]. In recent work [8], we showed that when naïve, healthy adults learned to drive on the miWe simulator, both those receiving AF and those not receiving AF improved in terms their PW skills, in terms of task completion time and number of collisions. Skills learned in the simulator also transferred to real PW driving. In addition, participants who received AF improved more in terms of speed-accuracy trade-off than those without AF. However, the performance measures used in that study (time and number of collisions) were quite general in that they quantified the complete task. In this study, we wanted to know if performance improved in a task-specific performance measure, and if AF improved learning and retention, compared to no AF.

II. METHODS

A. Participants

Forty healthy adult participants, with no prior wheelchair experience, were recruited for the study. After providing verbal consent, they were randomly assigned to the AF or no AF group.

B. Procedures

The experiment consisted of a virtual test task, a real test task and a virtual practice task; all were variations of an ‘elevator’ activity, which involved driving in a corridor up to an elevator call button, pressing the call button, then entering the elevator. In the real condition, participants had to press an actual call button. In the miWe simulator, participants pressed the space bar on the keyboard; this could only be done when they were within arm reach (i.e., distance of one “wheelchair unit” or less), which was indicated as a glowing red icon. Participants were instructed to perform the activity as quickly as possible, without collisions.

Funded by a grant from the AGE-WELL Network, Canada
They first completed the real test task (using a real PW), followed by the virtual test task. They then performed the practice trials (18 repetitions), either with AF (AF group) or without AF (no AF group). This was followed by performance of the virtual test task. Participants then returned two days later for another virtual test task (retention) and a real test task (transfer).

C. Data collection and analysis

The performance measure we used was the distance from the wheelchair to the call button. For the virtual test task, the miWe simulator recorded the PW's position in the environment and we calculated the minimal distance to the call button. In the real environment, a ruler was placed on the floor and a webcam was positioned above the call button. We noted the time in the video when the person had pressed on the button and measured the distance to the wheelchair using the scale obtained on the ruler. A repeated measures ANOVA was used to analyze changes in wheelchair to call button distance in both the real and virtual test tasks, with time (pre/post/retention) as within subject factor and group (AF/no AF) as between subject factor.

![Fig. 2. Mean distance (and standard deviation) from call button in miWe elevator task for pre training, post training and at recall, for the AF and no AF groups.](image)

Fig. 2. Mean distance (and standard deviation) from call button in miWe elevator task for pre training, post training and at recall, for the AF and no AF groups.

![Fig. 3. Mean distance (and standard deviation) from call button in real elevator task for pre training, and transfer, for the AF and no AF groups.](image)

Fig. 3. Mean distance (and standard deviation) from call button in real elevator task for pre training, and transfer, for the AF and no AF groups.

III. Results

Figure 2 shows the changes in the distance between the wheelchair and call button in the virtual task. Results indicate that participants decreased the reach distance with practice in the miWe simulator and that these changes were maintained at the retention task (p<0.05). There were no differences between the two groups (p>0.05). As for the real task (Fig. 3), participants were on average 3.2 cm closer to the button on the transfer test 2 days after simulator training, when compared to the initial test. This effect was significant (p < .001). Although the feedback group improved more than the control group on this outcome, the effect, however, was not significant.

IV. Discussion

Our study shows that performance improved during an elevator task after practice in a virtual reality simulator: participants stopped their wheelchair closer to the call button before they activated it. These gains were retained at retention, in the virtual test task. Transfer to real world performance was also observed. Positioning the wheelchair in order to reach for objects is an important PW driving skill [1]. What is also interesting is that no particular instructions had been given to participants with respect to how to position their wheelchair, in either the real or virtual tasks, in order to activate the call button. Thus, participants implicitly learned to improve their performance. One interpretation is that, as participants acquired better control over their PW, they were better able to stop closer to the target. There were however no differences in retention or transfer between the AF and no AF groups. This may be due to the fact that no specific AF was provided related to the positioning of the wheelchair. It is possible that in more complex tasks, AF is useful only if it provides information related to specific task components and related performance outcomes.

V. Conclusion

In earlier work [8], we had shown that performance in a virtual elevator task improved in terms of task completion time and number of collisions; that learning was retained and transferred to an equivalent real world task. In this study, we also show that performance in the ability to position the wheelchair also improved, even though no specific instructions on wheelchair positioning were given. Thus, the miWe simulator may be helpful in the training of PW driving skills.

REFERENCES