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Virtual Reality Grocery Shopping Simulator: Development and Usability in Neurological Rehabilitation

Abstract

Few virtual reality programs have been designed to retrain performance of activities of daily living for people undergoing neurological rehabilitation. This is despite the advantages of using this type of approach, including task-specific practice of meaningful and relevant activities. This paper summarizes the development of a grocery shopping simulator which uses a novel approach to interaction between the user and the program. The shopping simulation program underwent usability testing with patients participating in neurological rehabilitation. The results indicated that patients found the program easy and enjoyable to use and felt it would be a useful part of a rehabilitation program.

1 Background

There is increasing interest in the use of virtual reality in neurorehabilitation (Brochard, Robertson, Medee, & Remy-Neris, 2010; Crosbie, Lennon, Basford, & McDonough, 2007; Henderson, Korner-Bitensky, & Levin, 2007). Two main approaches have emerged: the use of customized programs designed for rehabilitation purposes (Housman, Scott, & Reinkensmeyer, 2009; Lange, Flynn, Proffitt, Chang, & Rizzo, 2010; Piron et al., 2010) and the use of commercial interactive gaming consoles designed for the general public (Joo et al., 2010; Saposnik et al., 2010; Williams, Soiza, Jenkinson, & Stewart, 2010). The use of commercial gaming consoles within clinical settings is widespread (National Stroke Foundation, 2010; Wiihabilitation, 2011) and their uptake may be attributed to their accessibility, affordability, relatively sophisticated technology, and publicity (CBS News, 2008; Elsworth, 2008). These games were not designed for rehabilitation settings, resulting in several disadvantages to their use, including not addressing the specific goals and needs of patients. Furthermore, scoring and feedback is designed for use in the general population and may be discouraging for people rehabilitating from a neurological condition (Lange, Flynn, & Rizzo, 2009).

Alternatively, there are now several examples of virtual reality programs designed specifically for use in rehabilitation (Cameirao, Badia, Oller, & Verschure, 2010; Housman et al., 2009; Lange et al., 2010; Piron et al., 2010). While these programs have predominantly been designed to remediate motor

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impairments, there are also several examples of programs that have been designed to retrain activities of daily living. Examples include programs designed to simulate automobile driving (Akinwuntan et al., 2005), hot drink preparation (Edmans et al., 2006, 2009), grocery shopping (Lee et al., 2003; Rand, Katz, & Weiss, 2007) and use of an automatic teller machine (Fong et al., 2010). There are several advantages in using an activity retraining approach in rehabilitation. Firstly, the programs are based on practice of tasks that are likely to be relevant and meaningful to patients. Stroke survivors have previously described the importance of resuming everyday activities and reported how inability to perform these activities results in reduced quality of life (McKevitt, Redfern, Mold, & Wolfe, 2004; Pound, Gompertz, & Ebrahim, 1998). Secondly, there is increasing evidence for the effectiveness of using a task-specific approach to rehabilitation (Bayona, Bitensky, Salter, & Teasell, 2005; French et al., 2007; Hubbard, Parsons, Neilson, & Carey, 2009). Task-specific rehabilitation has been described as "improvement of performance in functional tasks through goal directed practice and repetition" (Hubbard et al.) and research has shown increased functional reorganization when tasks are meaningful (Bayona et al.). Furthermore, it is recommended that practice should occur in context and that virtual environments may provide enhanced ecological validity when compared to activities in traditional rehabilitation environments (Shumway-Cook & Woollacott, 1995). Thirdly, the use of virtual reality may increase the scope of tasks practiced in hospital environments. For example, while it may not be practical for therapists to practice grocery shopping with patients due to lack of time and resources, training the patient to practice this activity in a virtual environment is potentially safer, more convenient, and more time-efficient.

Usability assessment of virtual reality programs is thought to be an integral part of the development process and should precede further clinical evaluation (Burridge & Hughes, 2010; Hubbard et al., 2009). The extent to which a program is usable may impact on whether the intended user accepts or rejects the program. Usability is traditionally associated with five main attributes: (1) Learnability: the program should be easy to learn without too much training time, (2) Efficiency: Once users have learned to use the program, they should be able to use the program productively, (3) Memorability: Users should be able to recall how to use the program after periods of nonuse, (4) Errors: Users should make errors infrequently, and be able to recover from errors relatively easily when they do occur, and (5) Satisfaction: Users should find the program pleasant to use (Nielsen, 1993). Usability assessment should occur with the intended users and may involve observation of users interacting with the tool or user feedback (e.g., through questionnaires) and logging actual use (Nielsen). Creating user-friendly virtual reality programs for patients with neurological conditions may be particularly challenging, due to the complex combination of physical, cognitive, and perceptual deficits that the person may be experiencing (Mayo et al., 1999) and the demographics of the population, who are typically older and may not feel comfortable using new technologies (Melenhorst, Rogers, & Bouwhuis, 2006).

This paper describes the development and usability assessment of a grocery shopping simulation program for neurological rehabilitation clients. The aim of the project was to produce a program that had high usability and would be regarded by occupational therapists as being a clinically useful rehabilitation tool. Previous shopping simulation programs used within neurological rehabilitation settings have been described and have shown some promising results; however, limitations in the design have been apparent and the programs have not undergone rigorous evaluation (e.g., through a randomized controlled trial). Lee et al. (2003) developed a virtual supermarket in which the environment was viewed using a head-mounted display and navigation occurred using a joystick. Piloting of the program revealed that participants ($n = 5$) learned how to use the program over time; however, they had difficulty using the joystick to navigate throughout the environment. Rand et al. used a video capture system to develop the VMall, a shopping simulation program in which the user's image is captured and displayed within the virtual environment and arm movements are used to select desired aisles and objects. A series of evaluation studies (Rand et al., 2007; Rand, Katz, & Weiss, 2009; Rand, Weiss, & Katz, 2009) has shown that participants enjoyed using the program and had improvements in upper limb function and improved ability to multitask following use of the program. While the VMall program has demonstrated promise, there are some drawbacks in terms of the method of interaction between the user and the environment. Use of the video capture system involves the person viewing himself or herself within the virtual environment, which may not appear realistic to some users. In addition, the user does not navigate through the supermarket aisles as one would in the real world. Smith, A. Barrow, R. Barrow, and Harwin (2007) describe a shopping simulation program with more naturalistic interaction; however, this program does not appear to have undergone clinical evaluation.

The process of development of a new approach to shopping simulation and findings from usability testing are detailed below.

2 Methods

2.1 Development of the Shopping Simulator

The task of grocery shopping was chosen as it has previously been reported that this task is highly important to stroke survivors when resuming usual roles on return home (Lord, McPherson, McNaughton, Rochester, & Weatherall, 2004) and because it is infrequently practiced in rehabilitation hospitals (Richards et al., 2005), possibly due to the time and logistics involved in a shopping trip.

Once the task was chosen, a focus group was conducted with four occupational therapists currently working in neurological rehabilitation at the Repatriation General Hospital in Adelaide, South Australia, and a biomedical engineer involved in the design of the simulator. The content of the focus group was audiorecorded and themes from the group were noted. Aspects of design thought to be important to occupational therapists were: (1) Versatility: Therapists wanted a program that was useful for a diverse group of users and addressed both the activity of shopping as well as the remediation of impairments, for example, practice of reaching, visual scanning, and executive functioning. Furthermore,

Figure 1. *A participant using the shopping simulator.*

therapists wanted the user to be able to access the program by either sitting or standing. (2) Realism: Therapists emphasized the need for all aspects of the simulator to be as realistic as possible. This included a realistic environment, objects within the environment, and interaction between the user and the simulator. (3) Flexibility: Therapists felt that the program would have increased clinical utility if it incorporated associated skills such as money management, meal planning, and shopping list making.

Based on feedback from the focus group, the grocery shopping simulator was developed (Lim, Laver, Crotty, & Reynolds, 2011). The hardware of the simulator consisted of a large touch screen on which the supermarket environment was displayed and a purpose-built shopping cart handle to navigate within the virtual supermarket interfaced via a USB port (see Figures 1 and 2).

The shopping cart handle was designed for intuitive control, and does not replicate the motor capability requirement for handling a real shopping cart.

Navigation within the virtual supermarket has been simplified to moving forward and backward, and turning 90° at a time. This enables users to navigate through the aisles and turn to face objects. Pushing the cart handle forward corresponds to a forward on-screen movement with increasing speed as the handle is pushed forward more. Backward movements have been similarly integrated when the cart handle is pushed backward. Turning

Figure 2. *Screenshot of the virtual environment.*

the cart trolley handle requires the user to turn the handle a certain amount, which then sets the virtual view to automatically turn 90° in the corresponding direction.

The electronic and mechanical system for the shopping trolley handle was designed once its means for virtual navigation was decided. A potentiometer is used to facilitate the tracking of the forward and backward movements, and two switches are used to detect the two directions in which the cart handle can be turned. The cart handle is spring-loaded at the pivot point, so that it returns to the middle rest position when no physical force is applied to it. Steering and turning the cart handle is possible using one or both hands. The touch screen enables users to reach and select the desired objects from the supermarket and place them into the trolley. This method of interaction was thought to be more intuitive than alternatives, such as the use of a joystick, mouse, or keyboard. The virtual supermarket is composed of three aisles displaying food items and associated prices, signage indicating the content of each aisle, and a staffed checkout area. The virtual environment is composed only of real-world elements, as virtual features (such as mini-maps and visual guidance) were deemed to add another layer of unnecessary complexity that would require learning. The top of the shopping cart is displayed onscreen and the user is able to check the cart contents (and total cost) at any time by either touching the trolley on the touchscreen or proceeding to the checkout.

2.2 Assessment of Usability

The study was given ethics approval by the Southern Adelaide Health Service/Flinders University Human Research Ethics Committee. A case study design was used in order to examine the usability of the simulator in depth with a variety of patients.

2.3 Participants

Participants were recruited from an inpatient neurological rehabilitation ward at the Repatriation General Hospital, a 300-bed public hospital in Adelaide, South Australia. Patients approached to be involved in the study were identified via communication with the ward Occupational Therapists. Eligible patients were participating in rehabilitation for a neurological condition and had the physical, cognitive, emotional, and visual ability to be able to attempt using the simulator (as determined by the treating Occupational Therapist). Since the study was a pilot study, a small sample size of 15 participants was targeted and recruitment and usability testing took place over a four-day period. Eligible patients were approached and provided with written and verbal information about the study; caregivers were invited to attend the usability assessment if interested.

2.4 Procedure

Patients participating in the study attended a one-off individual session with the study Occupational Therapist. The session began with an introduction to the purpose and equipment of the shopping simulator and a demonstration of how to use the simulator, including navigating through the aisles, turning, selecting objects, checking cart contents and proceeding to the checkout. The participant was then given practice time to become familiar with the environment. Following this, the participant was timed to complete a set task in which he or she started at the entry to the supermarket, selected four items from a shopping list (provided on a piece of paper) and proceeded to the checkout. For willing participants, this task was repeated to determine if learning occurred and whether the participant became faster over time. The study Occupational Therapist made observational

Table 1. *Description of Participants*

ID	Age (years)	Gender	Neurological Diagnosis	FIM on admission to the stroke rehabilitation unit
1	84	F	L MCA stroke	38
2	60	M	R pontine stroke	41
3	79	F	L MCA stroke	47
4	77	F	Multiple sclerosis	67
5	86	F	Guillain–Barré syndrome	69
6	60	F	R thalamic stroke	76
7	88	F	L MCA stroke	59
8	71	M	R thalamic stroke	53
9	77	M	R capsular stroke	47
10	74	F	L MCA stroke	74
11	60	M	R stroke	80
12	87	F	Stroke	57
13	63	F	L stroke	56
14	81	F	R MCA stroke	83
15	80	M	L MCA stroke	NA

Note. NA = not available.

notes on any difficulties the participant was having in using the simulator and documented comments relating to usability made by participants while trialing the program. The participant then completed a questionnaire which measured his or her interest and satisfaction in regard to the simulator. The questionnaire included eight items with a Likert scale for response. Questions included in the questionnaire are displayed in Appendix 1. The participant was also asked about positive aspects or advantages of using the program, and suggestions as to any improvements he or she felt should be made. Demographic information was collected from the participant's medical case notes, including age, gender, diagnosis, and functional independence measure (FIM) score on admission to the unit.

3 Results

Twenty-two patients were identified as being eligible to participate in the project by ward Occupational Therapists; however, only 15 patients were available during the assessment times. All 15 patients approached consented to participate, suggesting a high level of interest in the project. Descriptions of participants are presented in Table 1.

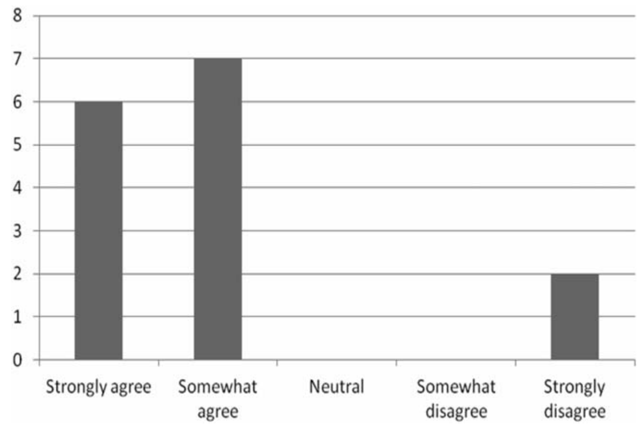

Figure 3. *"I found the program enjoyable to use."*

The majority of participants ($n = 13$) found the program enjoyable to use (see Figure 3).

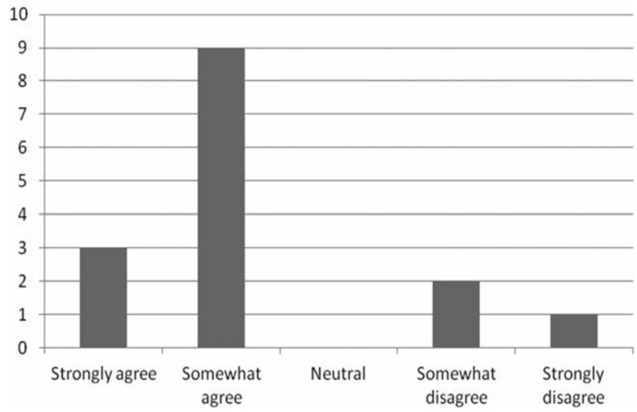

Figure 4. *"Overall, I found the program easy to use."*

Responses to the questionnaire indicated that while most ($n = 14$) participants felt the program would be a useful rehabilitation tool, a smaller number ($n = 6$) felt that the program would be directly useful as part of their own rehabilitation program. When asked to rate ease of use of the program, although four of the participants found interacting with the program to be frustrating, most of the participants ($n = 9$) reported that they found it easy to learn to use the program and most of the participants ($n = 12$) reported that overall they found the program was easy to use (see Figure 4).

When asked about the most beneficial aspects of the program, one participant reported feeling that it would be useful for developing eye-hand coordination skills, while another participant felt that use of the program would improve upper limb coordination and help develop the user's thinking skills. Three participants reported they felt the program would be particularly useful for younger people and people who used computers. One participant commented on the benefit of having a safe practice environment, and another participant felt that one of the advantages of the program was that it could be used at home.

Suggestions for improvement were provided by six participants; three of the participants felt that improvements could be made to improve the control of the shopping cart handle, while another participant felt it would be easier to select objects using a button on the handle rather than reaching forward to touch the screen. Two participants reported that they had difficulty seeing the objects on the screen (even while wearing glasses); they therefore suggested that the display screen be larger. In regard to the nature of the task, one participant suggested that it would be better if one was able to remove items from the shopping cart; and another participant felt that more aisles and produce could be added to the supermarket.

While using the program, several additional comments were noted by the study Occupational Therapist. One participant questioned the relevance of the program to their rehabilitation stating that at home they had someone do the shopping for them. Other comments included that the task became easier with familiarity and that it was not as easy as it looked. Participants asked the Occupational Therapist several questions throughout the task, for example, Where is the counter? and Are all of the milk one litre?

The results from the repeated time trials of 12 participants showed that all participants improved on their second attempt at the task (see Figure 5).

The study Occupational Therapist noted that in general, participants learned how to use the program quickly. The main area of difficulty related to turning the shopping cart handle, with some participants applying insufficient force to turn it, and some feeling the need to correct the turning, fearing that they had turned too far, when the automated 90° turn was activated. When first using the simulator, four participants also needed reminders and further instruction on how to select grocery items, tending to touch and drag the item into the cart rather than touching the item and subsequently touching the cart. Three participants were not willing to repeat the set task. One of these participants (Participant 4) became too frustrated with the program to continue and indicated low levels of satisfaction with the program via the questionnaire. The other two participants (Participants 1 and 5) reported relatively high levels of satisfaction with the program; however, they reported that they had difficulty in learning to use the program. These three participants did not take significantly longer to complete the first time trial than other participants. The participant who took the longest to complete the set task reported finding the program difficult to learn; however, the participant

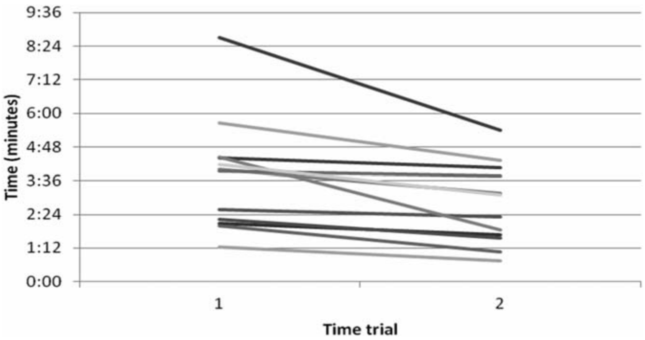

Figure 5. *Time taken to complete a prescribed shopping task on the first and second attempts (n = 12).*

still reported finding the program to be enjoyable and to be a useful activity in rehabilitation.

4 Discussion

This project resulted in the development of a grocery shopping simulation program suitable for use in clinical rehabilitation settings. Feedback from patients involved in the usability testing suggested that the simulator was easy and enjoyable to use. Observation of patients using the simulator revealed that patients learned how to use the program relatively quickly and easily and became more proficient with time and practice.

Interestingly, while the shopping cart handle interface was designed to be more intuitive and easier to use within a neurological rehabilitation population, this was the aspect of the program that required the most practice to master. This appears to be related to the person becoming familiar with the calibration of the handle as difficulties arose when participants wanted to turn. As turning is only activated visually after a slight turn on the shopping cart handle, participants needed to adjust to the automatic 90° turn. Furthermore, it is thought that despite the practice required to master this aspect of the program, this method of interaction would still be more user-friendly than other alternatives, such as a keyboard, mouse, or joystick.

Importantly, the task appeared to be valued by participants, with most reporting that using the simulator would be useful for other rehabilitation patients, and six of the participants reporting that using the simulator would be useful as part of their own rehabilitation. These findings suggest that patient selection when applying the program in rehabilitation is crucial and that the program is likely to be most useful for a select group of rehabilitation patients rather than a part of rehabilitation for all patients. Participants in the study suggested that the simulator would be most beneficial for patients who were younger and enjoyed using computers. Three of the participants involved in the usability testing were over the age of 80 and it is possible that younger patients may have been more receptive to using the program as part of their own rehabilitation program.

It is pleasing that participants in the study became proficient in using the simulator within one introduction session, suggesting that ongoing practice could be performed independently, thereby potentially increasing the patients' time spent engaged in therapeutic activities without an associated increase in staffing.

While formal feedback has not yet been sought from occupational therapists, the shopping simulator appears to meet the needs identified by the therapists in the focus group (i.e., versatility, realism, and flexibility), though some of the adjunct tasks such as meal planning and money management would need to be guided by the treating therapist.

Initial use of the shopping simulator appears promising; however, further research is required to assess the validity of the virtual shopping task when compared to shopping in a real-world environment. Furthermore, usability assessment with a larger group of participants would be beneficial and allow exploration of usability within different subgroups, for example, younger patients participating in rehabilitation following traumatic brain injury, or older patients with early-onset dementia.

5 Conclusion

This project resulted in the use of a shopping simulator that addresses the needs of occupational therapists and has demonstrated high usability with neurological rehabilitation clients. Further research into the validity of the program is required.

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Appendix 1: Questionnaire Items

1	2	3	4	5	6	7
Strongly agree			Neutral			Strongly disagree

1. This program would be useful as part of my rehabilitation program.
2. This program would be useful as part of a rehabilitation program for others.
3. I found the program enjoyable to use.
4. I found the program cumbersome to use.
5. Learning to use the program was easy for me.
6. Interacting with the program was frustrating.
7. Interacting with the program requires a lot of mental effort.
8. Overall, I found the program easy to use.