Training Multitasking in a Virtual Supermarket: A Novel Intervention After Stroke

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KEY WORDS
- activities of daily living
- condition, operant
- stroke
- task performance analysis
- user–computer interface

OBJECTIVE. To explore the potential of the VMall, a virtual supermarket running on a video-capture virtual reality system, as an intervention tool for people who have multitasking deficits after stroke.

METHOD. Poststroke, 4 participants received ten 60-min sessions over 3 weeks using the VMall. The intervention focused on improving multitasking while the participant was engaged in a virtual shopping task. Instruments included the Multiple Errands Test–Hospital Version (MET–HV) in a real mall and in the VMall.

RESULTS. Participants achieved improvements ranging from 20.5% to 51.2% for most of the MET–HV measures performed in a real shopping mall and in the VMall.

CONCLUSIONS. The data support the VMall's potential as a motivating and effective intervention tool for the rehabilitation of people poststroke who have multitasking deficits during the performance of daily tasks. However, because the sample was small, additional intervention studies with the VMall should be conducted.

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Despite intensive and costly rehabilitation, the participation in everyday life of people after stroke is restricted (Gottlieb et al., 2002; Hartman-Maeir et al., 2007; Pettersen, Dahl, & Wyller, 2002). During rehabilitation, there appears to be insufficient training of instrumental activities of daily living (IADLs) such as shopping, use of transportation, and cooking (Bode, Heinemann, Semik, & Mallinson, 2004; Richards et al., 2005; Steultjens et al., 2003) because they are often time-consuming and technically difficult to implement. In addition, persisting impairments in motor, sensory, and cognitive abilities may affect the person's ability to return to his or her premorbid activities (Jorgensen, Nakayama, Raaschou, & Olsen, 1999). Meta-cognitive deficits (Chevignard et al., 2000; Fortin, Godbout, & Braun, 2003), mainly executive functions and multitasking deficits (Burgess et al., 2006), have been found to limit return to daily life activities. Therefore, development of novel intervention tools is needed that will allow repetitive training of real-life tasks to improve multitasking while the person is still in a rehabilitation program. This training may facilitate greater transfer to function in the real world.

Virtual reality (VR)–based technologies are one of the emerging tools that appear to have great potential for use in rehabilitation (Barrett et al., 2006; Weiss & Katz, 2004; Weiss, Kizony, Feintuch, & Katz, 2006). VR involves the use of advanced technologies to produce a simulated (i.e., virtual) environment that users perceive as comparable to real-world objects and events (Rizzo, Buckwalter, & Neumann, 1997). VR has been shown to be a suitable tool for cognitive rehabilitation because it allows a more comprehensive, ecologically valid, and controlled environment (Brooks & Rose, 2003; Lo Priore, Castelnuovo, & Liccione, 2003). Virtual environments may offer a way to systematically assess and treat executive functions and multitasking difficulties because virtual tasks are carried out within the context of the demands found in everyday tasks (Rizzo, Buckwalter, & Van der Zaag, 2002). For example, Zhang et al. (2001) used a virtual kitchen scenario in which a 30-step process for preparing soup was scored for component skills such as information processing, problem solving, logical sequence, and speed of responding; for all components, participants with brain injury showed significantly worse performance when compared with healthy volunteers.

Virtual environments have been used as an intervention tool to improve performance in comparable real-life settings. For example, teenagers with severe learning disabilities who practiced shopping in a virtual supermarket were able to shop more quickly in a real supermarket than those who used other, nonsupermarket virtual environments (Cromby, Standen, Newman, & Tasker, 1996). McComas, MacKay, and Pivik (2002) reported a significant change in real-world street safety performance of children <10 years who participated in three trials focused on pedestrian safety within a virtual city environment compared with children who used an unrelated VR program. Katz et al. (2005) demonstrated that for poststroke participants with visual–spatial neglect, practice in a virtual street crossing environment improved their street crossing performance in both virtual and real street crossing settings tested immediately after the intervention. Lam, Man, Tam, and Weiss (2006) reported greater increases in knowledge, skills, and self-efficacy of 26 poststroke participants in using the mass transit railway after receiving 10 sessions with a two-dimensional virtual simulation of the mass transit railway or with a multimedia educational program as compared with a control group.

Treatment for people with executive function and multitasking difficulties is based on the principle of providing the person with opportunities to choose, plan, and problem solve during everyday tasks and, especially, during complex novel tasks or situations (Burgess, Weitch, Cosello, & Shallice, 2000; Katz & Hartman-Maeir, 2005). However, relatively few systematic attempts to treat multitasking deficits have been reported; these mainly include patients with traumatic brain injury or elderly people (Levine et al., 2000, 2007; Manly, Hawkins, Evans, & Woldt, 2002). Moreover, the use of virtual environments has focused on assessment of executive function deficits rather than on treatment (Christiansen et al., 1998; Lo Priore et al., 2003; McGeorge et al., 2001; Zhang et al., 2001).

In this study, we assessed the potential of a virtual supermarket, the VMall (Rand, Katz, Shahar, Kizony, & Weiss, 2005), as an intervention tool for people after stroke presenting deficits in executive functions and multitasking and to examine their ability to multitask while engaged in a shopping task in both a virtual and a real mall setting.

Method

Participants

Four poststroke participants (3 men, 1 woman), ages 53–70 years, volunteered to participate in this exploratory study. Inclusion criteria included (1) a unilateral, first-occurring stroke (as determined by a computed tomography scan or magnetic resonance image); (2) discharge home from subacute rehabilitation; (3) no cognitive or language deficit as determined by scores >26 points out of 30 on the Mini-Mental State Examination (Folstein, Folstein, & McHugh, 1975); (4) no unilateral visual neglect as assessed using Star Cancellation from the Behavioral Inattention Test (Wilson, Cockburn, & Halligan, 1987); (5) no depression as demonstrated by scores <5 on the Geriatric Depression Scale (Van-Marwijk et al., 1995); and (6) evidence of deficits in executive functions as demonstrated by two subtests from the Behavioral Assessment of Dysexecutive Syndrome (Wilson, Alderman, Burgess, Emslie, & Evans, 1996), the Zoo Map and Rule Shift Cards. The Zoo Map subtest is sensitive to executive function deficits (Norris & Tate, 2000), and we considered a profile score of ≤1 to indicate deficits in executive functions.

The participants had not experienced VR before the study; 1 participant used a computer for work, and another used a computer for leisure time. The other 2 participants did not use a computer at all. The lack of prior experience with such technologies was not considered to be a limitation because the Interactive Rehabilitation Exercise (IREX; www.gesturetekhealth.com) VR system is operated via natural user movements rather than standard interface devices. Moreover, a practice period was given before the intervention.

All participants lived at home with a spouse and walked independently (1 participant used a cane). Three participants were able to use both hands for interaction within the VMall, and 1 participant used mainly her unaffected hand because her affected side was quite weak. To encourage participants to use their weaker upper extremity for shopping in the VMall, we occasionally during the intervention provided them with only one red glove. Because the VMall has a red glove function that ensures that the virtual environment can be activated only by virtually touching it with a red glove, participants were forced to use their weaker side. All participants were relatively independent in basic activities of daily living with FIM™ scores (Granger, 1998) ranging from 101 to 120 of a maximum of 126 points, and they were moderately to severely dependent in IADLs, performing on average 13% to 48% of their prestroke IADLs. Participants' demographic and illness information and their scores on baseline assessments are shown in Table 1.

Table 1. Participant Demographic, Illness Information, and Baseline Assessments

Poststroke Participants	Z. L.	M. V.	D. V.	Y. I.
Demographic and illness information				
Age (years)	53	62	60	70
Gender	M	F	M	M
Hemisphere of stroke	Left	Right	Right	Right
Time poststroke (months)	9	6	5	27
Activities of daily living				
FIM™ (18–126)	117	101	120	116
IADLs (percentage of prestroke activities)	21.7	26.0	47.8	13.0
Shopping item from the IADL questionnaire (0–3)	0	1	1	0
Cognitive and executive functions and depression				
Mini-Mental State Examination (0–30)	26	28	26	30
Geriatric Depression Scale (0–15)	4	4	3	2
Star Cancellation (0–54)	53	52	52	53
Zoo Map (profile score 0–4)	0	0	0	1
Rule Shift Cards (profile score 0–4)	3	1	1	1

Note. IADLs = instrumental activities of daily living.

Instruments

VR Platform. The intervention was provided by the GestureTek's GX VR platform (www.gesturetekhealth.com/), a video-capture VR system (Weiss, Rand, Katz, & Kizony, 2004). Users stand or sit in a demarcated area with a chroma key backdrop viewing a large video screen that displays simulated environments. A single camera films the user and displays his or her image within the virtual environment. The user's movements are processed on the same plane as screen animation, text, graphics, and sound, which respond in real time. Therefore, the user sees him- or herself in the virtual environment and interacts using his or her own natural movements (Weiss et al., 2004). This system has been used in rehabilitation and has been shown to be suitable for use with patients experiencing motor deficits, cognitive deficits, or both (Kizony, Raz, Katz, Weingarden, & Weiss, 2005; Rand, Katz, & Weiss, 2007; Reid, 2002; Sveistrup, 2004).

VR Environments. The VMall is a virtual supermarket that encourages planning, multitasking, and problem solving while practicing an everyday shopping task (Rand et al., 2005). The products are virtually selected and placed in a shopping cart using upper-extremity movements. It has been shown to be a valid assessment tool that differentiated between a group of healthy people and a group of people after stroke (Rand et al., 2007) and correlated with performance in a complex shopping task in a real mall (Rand, Basha-Abu Rukan, Weiss, & Katz, 2009). During the sessions, we also used several virtual games that run on the same VR platform and have been adapted for rehabilitation (IREX's Birds & Balls, Soccer, Snowboard, and Volleyball; Kizony, Katz, & Weiss, 2003).

Multiple Errands Test–Hospital Version (MET–HV). We used the MET–HV (Knight, Alderman, & Burgess, 2002), referred to henceforth as the MET, to assess multitasking while completing a complex shopping task in a real mall. Two similar versions of this assessment were formulated, one for preintervention and one for postintervention. The MET consists of three tasks that the user is required to perform in a mall-like setting while following certain rules (i.e., buy six items, find out four items of information, and meet the tester at a certain time at a preset location). The tester observes the participant, recording mistakes of different kinds. The scoring in this study is based on work carried out by Morrison, Ryan, and Savre (2006). The MET consists of separate scores for three types of mistakes: (1) inefficiency (e.g., when the participant takes too long to select a birthday card or spends too much money), (2) rule breaking (e.g., the same store is entered twice), and (3) insufficient use of strategies (i.e., when a required strategy is not used, such as not planning before performing a task). In addition, total mistakes are scored, which includes all mistakes made in all three categories while executing the tasks, in addition to the number of partial and complete mistakes made while completing the task. An example of a partial mistake is buying a bottle instead of a can of a soft drink; an example of a complete mistake would be not buying a can of soft drink.

The MET has been found to have ecological validity in that it was moderately correlated to functions in everyday life (Alderman, Burgess, Knight, & Henman, 2003; Dawson et al., 2005a, 2005b). The MET has also been shown to distinguish between patients and healthy controls (Alderman at al., 2003; Knight et al., 2002).

Virtual MET (VMET). The VMET is an adapted version of the MET used within the VMall. We formulated two versions of this assessment, one for preintervention and one for postintervention. The VMET consisted of the same number of tasks (items to be bought and information to be obtained) as the MET, but the products were changed to those that could be found in the VMall (Rand et al., 2007).

IADL Performance. We assessed IADL performance using the IADL questionnaire (Lawton, Moss, Fulcomer, & Kleban, 1982), which evaluates the participant's capacity to perform eight different IADL tasks independently (e.g., cooking, transportation use, taking medication, and shopping). Each IADL activity is scored on a 3- or 4-point scale; the total score ranges from 0 (*totally dependent*) to 23 (*independent in IADL*). The percentage of prestroke activities (the number of tasks performed at the time of the study out of the number of tasks performed before the stroke) was compared before and after intervention.

Procedure

The study followed a pretest–posttest design. Multitasking with the MET and VMET was assessed before and after a 3-week intervention period (a total of ten 60-min sessions) using the VMall. The sessions were provided by an experienced occupational therapist and focused on improving multitasking and functional shopping while performing in the virtual environment. The participants did not receive additional occupational therapy intervention during this period. All assessments were performed by a second experienced occupational therapist trained to administer the tests. The Institutional Review Boards of the university and the rehabilitation hospital approved the study, and participants signed informed consent before entering the study.

The intervention took place in the rehabilitation hospital in a quiet room in which the VR system was located. The participants came from their homes especially for this treatment. Each 60-min session included the use of the VMall (approximately 45 min) in addition to different GX games (approximately 15 min) to add variety to the session and make it more functionally relevant. The sessions focused on shopping or shopping-related tasks that required planning, multitasking, and problem solving. The sessions included, for example, planning and shopping for a picnic lunch to take to a soccer game (i.e., buying the grocery items in the VMall and then playing the virtual soccer game). Another task required that the participant acquire specific information about products for a long trip to a ski resort and then play a virtual snowboard game. In yet another task, the patient was required to listen for announcements to identify which sale products to buy while shopping from a prepared list. Because the VMall is a virtual environment, it is a dynamic tool that enables variations on tasks, thus facilitating the practice of executive function abilities while shopping for virtual products.

Statistical Analysis

We carried out data analysis using SPSS for Windows (Version 11.5; SPSS, Inc., Chicago). Descriptive statistics were used to characterize the sample. In addition, we calculated the percentage of improvement for each participant for the MET and VMET using the equation of (posttest score – pretest score) / (pretest score × 100) (Paolucci et al., 2003; Shah, Vanclay, & Cooper, 1990). A percentage decrease in mistakes means a percentage improvement in ability.

Results

All participants reported enjoyment from the therapeutic sessions; they found the sessions to be challenging and relevant to their rehabilitation, and they were all disappointed that the intervention lasted only 10 sessions.

The total number of mistakes and the three types of mistakes for the MET and the VMET before and after intervention are presented in Table 2 for each of the 4 participants. The percentage decreases from pre- to postintervention are reported. Overall, the participants made fewer mistakes in postintervention testing in comparison to preintervention testing, both in the VMET and in the MET. In three instances, a percentage decline in performance postintervention was seen (M. V. broke more rules in the VMET, Z. L. broke more rules in the MET, and Y. I. made more mistakes using efficient strategies in the VMET).

Figure 1 presents the means and standard deviations of the percentage improvement (i.e., decrease) in the total number of mistakes and the three types of mistakes in both the MET and the VMET for the 4 participants. A mean percentage of improvement ranging from 20.5% to 51.2 % was achieved for all of the mistake categories except for Use of Strategies mistakes in the VMET, for which the mean

Table 2. Three Types of Mistakes and Total Number of Mistakes in the Multiple Errands Test (MET) Performed Within the Virtual Mall (VMET) and Real Mall (MET), Pre- and Postintervention for Each Participant Separately

	VMET			MET		
Subject	Pre	Post	% Decrease	Pre	Post	% Decrease
Total number of mistakes[a]						
D. V.	79	38	52	70.5	39	45
Y. I.	83	35	58	41	40	2
M. V.	92	60	35	64	27	58
Z. L.	93	77	17	92	53	42
Rule break mistakes						
D. V.	5	3	40	3	1	67
Y. I.	3	1	67	4	0	100
M. V.	1	4	+75[b]	2	3	50
Z. L.	4	2	50	2	4	+50[b]
Nonefficiency mistakes						
D. V.	12	5	58	5	2	60
Y. I.	9	4	56	4	1	75
M. V.	9	9	0	7	6	14
Z. L.	9	5	44	9	4	56
Use of strategies mistakes						
D. V.	9	4	56	8	4	50
Y. I.	1	4	+75[b]	7	3	57
M. V.	8	4	50	9	3	67
Z. L.	8	8	0	4	4	0

[a]The total number of mistakes is made up not only of the three types of mistakes presented but also by the partial and complete mistakes of completing a task as required.

[b]A plus sign indicates that an increase in the number of mistakes occurred postintervention.

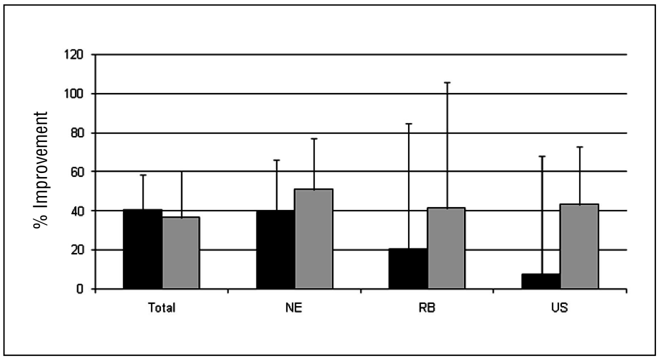

Figure 1. Percentage of improvement means and standard deviations of the 4 participants of the total number and three types of mistakes for the Multiple Errands Test performed in the virtual mall (gray histograms) and in the real mall (black histograms).

Note. The first two histograms show the total number of mistakes, the third and forth histograms show nonefficiency (NE) mistakes, the fifth and sixth histograms show rule break (RB) mistakes, and the seventh and eight histograms show use of strategy (US) mistakes.

improvement was only 7.7%. Note that the large standard deviations indicate the great variance between the participants' abilities.

In addition, many social rules were broken during the preintervention MET. For example, D. V. asked shopkeepers for help in an incorrect and illogical manner. He was also apprehensive of how the salespeople would respond to his queries. Y. I. twice sat down at a table occupied by people unknown to him even though many other tables were available. M. V. approached shoppers as if they were salespeople and asked questions they could not answer. Such inappropriate social behaviors were not apparent during the postintervention test.

Regarding general IADL performance, a slight percentage of improvement was seen in the total scores of the postintervention IADL measure for 2 participants: Y. I. and Z. L. each improved by 1 point on the shopping item, which resulted in a percentage improvement in IADL performance of 17.3% and 26%, respectively. The IADL performance of the other 2 participants did not change. Thus, after the intervention, all 4 participants still needed to be accompanied to shop and did not reach a level of full independence.

Discussion

In this preliminary study, we assessed the potential of the VMall as an intervention tool for the treatment of participants after stroke who presented deficits in executive functioning and multitasking. Four participants took part in a 10-session intervention consisting primarily of shopping tasks within a virtual supermarket. The therapeutic goals were suited to each participant's functional level and focused on improving their multitasking abilities.

The percentage improvement (decrease in mistakes) on most of the measures within the MET and VMET for all 4 participants was substantial; the participants made fewer mistakes postintervention in comparison to preintervention. In addition, the participants demonstrated more confidence in the real mall task and broke fewer social rules during postintervention testing, despite the fact that such rules were not practiced in the VMall. There were also several negative findings; a percentage of decline in performance postintervention was seen in three instances (M. V. broke more rules in the VMET, Z. L. broke more rules in the MET, and Y. I. made more mistakes in the use of efficient strategies in the VMET), and Z. L. did not improve in the use of strategies for both the VMET and the MET. These results do not detract from our overall appraisal of the VMET's potential merit given the relatively short duration of the intervention (only 10 sessions).

The VMall intervention was based on the general principles of strategy and goal management training, providing opportunities to choose, plan, and problem solve (Katz & Hartman-Maeir, 2005; Levine et al., 2000, 2007; Toglia, 2005). The VMall was designed to teach and give opportunities to practice the use of strategies aimed at compensating for executive functions and multitasking difficulties (e.g., writing down the task in an organized way, categorizing the products into groups before shopping, marking the tasks when they had finished). These findings demonstrate the potential to improve executive functions and multitasking deficits using an intervention that provides such opportunities, which is especially important because, to date, only a few studies have examined improvement in executive functions and multitasking, especially for patients after stroke (Levine et al., 2000, 2007; Manly et al., 2002; Sammer, Reuter, Hullmann, Kaps, & Vaitl, 2006).

An important clinical objective when using VR for treatment is to demonstrate that the abilities trained within a virtual environment will transfer to a patient's ability to perform real-world activities (Katz et al., 2005; Rose et al., 2000; Weiss et al., 2006). After intervention, we assessed performance of these activities as performed in a real mall by means of the MET. The postintervention improvement apparent in the MET may indicate that a transfer of skills was achieved during the VMall intervention. Moreover, the participants gained independence in their abilities to perform everyday activities related to shopping and cooking. On completion of the intervention, the participants were interviewed, and several reported that they had become more involved in the weekly shopping; they remarked that they started to help in making shopping lists and even accompanied their spouse to the supermarket. Some of the participants reported that they resumed cooking, using recipes and shopping for required ingredients. These were activities that they had not engaged in before the VMall intervention. These findings are similar to those reported by others (Cromby et al., 1996; Katz et al., 2005; Lam et al., 2006; McComas et al., 2002), whose participants also showed improved performance in the real world after training in a virtual environment.

In contrast to the other virtual environments reported earlier, which trained executive function deficits or daily function by focusing primarily on cognitive aspects of the task, shopping within the IREX-based VMall entailed both cognitive and motor elements. Researchers have recently recommended that motor and cognitive training be carried out concurrently (e.g., performing a functional–cognitive task such as sorting objects while using the paretic upper extremity vs. just exercising shoulder flexion of the paretic upper extremity; Akinwuntan et al., 2006), because this training will lead to greater preparation for real-life situations (Haggard, Cockburn, Cock, Fordham, & Wade, 2000). The difficulty with performing tasks that require multitasking is the result of cognitive–motor interference (Haggard et al., 2000), which occurs when one aspect of a task interferes with another. Thus, VR intervention, when used with video capture systems such as the one used in this research, has an added benefit of integrating dual motor and cognitive components of performance.

Limitations and Future Research

This study's main limitation was the small group of participants who underwent the intervention. Consequently, the findings should be considered preliminary. The participants were not balanced for gender or time since stroke onset, which might have increased the generalization of this study's findings. We recommend that further research continue to examine the VMall's effectiveness with larger groups of participants after stroke in addition to other clinical populations. We also recommend that the repertoire of the tasks within the VMall be expanded by including additional stores such as a bookstore and a fast-food restaurant. Because of the VMall programming structure's flexible design, these changes can be made easily. The VMall would thereby be able to provide meaningful environments for a variety of different clinical populations from different age groups.

We did not find that performance of IADLs in real life improved after the intervention. This lack of improvement may be partly due to confounding factors such as the lack of independent mobility resulting from loss of driving licenses (Akinwuntan et al., 2006) or difficulties in functional use of the upper extremity and mobility (Lai, Studenski, Duncan, & Perera, 2002), which may have limited the participants' ability to perform IADL tasks. It is also possible that the IADL questionnaire used in this study, which assesses seven IADL tasks in addition to shopping, was not sensitive enough to demonstrate actual changes in IADL. The 3-point scale for rating shopping may not have been sensitive enough (e.g., going shopping with a companion vs. not going shopping at all). Finally, a clinical intervention consisting of only 10 sessions was likely not of sufficient length or intensity to achieve transfer to all other IADL areas; therefore, a longer period of intervention may prove to be beneficial.

The VMall environment currently has several limitations to use as a tool for executive function intervention. To date, it includes only a virtual supermarket. The future addition of stores to the VMall (e.g., bookstore, fast-food restaurant) would add variety and interest to the treatment sessions. The current VMall does not have a mechanism for paying for the products bought; during the current intervention, the use of money was practiced outside of the virtual environment when it was found to be clinically relevant for the participant.

Conclusion

On the basis of these preliminary findings, the VMall appears to have potential for use as a motivating and effective intervention tool for the rehabilitation of patients after stroke presenting with executive function and multitasking difficulties. The VMall permitted repetitive practice of an IADL task in a safe, realistic, and interesting manner that encouraged the participants to train for multitasking activities similar to those necessary for participation in everyday living. ▲

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