Rehabilitation tools along the reality continuum: from mock-up to virtual interactive shopping to a living lab

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ABSTRACT

The purpose of this study was to compare shopping performance using the 4-item test, between three types of environments; a real environment (small, in-hospital "cafeteria"), a store mock-up (physical simulation) and a virtual environment (Virtual Interactive Shopper-VIS), in a post-stroke group compared to a control group. To date, 5 people with stroke and 6 controls participated in the study. Participants performed the original 4-item test ("buy" 4 items) in the VIS and the store mock-up as well as a modified 4-item test ("buy" 4 items with budget constraints) in all three environments. Results were analyzed descriptively and findings to date, indicate that the post-stroke group performed more slowly than the control group. In addition, in both groups, the time to complete the test within the VIS was longer than in the store mock-up and the cafeteria. Performance in the VIS, the store mock-up and the cafeteria were correlated in the post-stroke group. Finally, participants' responses to their experience in the VIS were positive. The preliminary results of this small sample show that the test within the VIS is complex and realistic and may be used to assess and train the higher cognitive abilities required for shopping.

1. INTRODUCTION

Shopping is one of the most significant and meaningful instrumental activities of daily living (IADL), yet only a small percentage of the post-stroke population continues to engage in this and other complex life tasks (Hartman-Maeir, et al., 2007; Rand et al, 2007). In addition, although research into the effects of aging on various life habits has grown substantially in recent years, there is insufficient knowledge on how older adults perform in complex life situations, partly due to technical limitations of measurement tools. Mitchell's (http://livinglabs.mit.edu/) concept of "Living Labs as a research paradigm for sensing, prototyping, validating and refining complex solutions in multiple and evolving real life contexts" is a potential solution to this difficulty, and may be considered the definitive realization of participatory design to identify true user behaviour (Følstad, 2008). One of the goals of a "Living Lab" is to assess and train behaviour in complex settings, and to find ways to overcome environmental barriers in order to enable inclusive participation by all people, including post-stroke and elderly populations.

Computer simulations of complex settings enable the analysis of performance from various viewpoints in a precise way, as well as the evaluation of various solutions to accomplish specific tasks (e.g. using a specific cognitive strategy) before their implementation in a real environment. In addition, complex tasks can be validated and tested in people with disabilities interacting with the simulations, for future use in a Living Lab. The two main options for simulating a real-life activity are to use a virtual environment (Kizony et al., 2008) or a physical mock-up environment.

A number of virtual supermarkets, running on desktop computers, were found to be valid for assessment of the higher cognitive abilities (i.e., executive functions (EF)) needed for shopping. (Castelnuovo et al., 2003;Josman et al., 2008; Klinger et al., 2004; Lee et al., 2003). Rand et al. (2005) developed the Virtual

Mall (VMall), a virtual supermarket that runs on a video-capture VR system which has the advantage of integrating and assessing both motor and cognitive aspects of task performance, thus making it similar to real life activities. Rand et al. (2009) demonstrated the ecological validity of the VMall as an assessment of EF during a shopping task in elderly and post-stroke subjects. The main disadvantages of the VMall are the somewhat complex set-up needed for its operation (e.g., a "green screen") and the limited options of adding additional stores or budget management to increase task complexity (i.e. cognitive and motor demands of the task). More recently, the Virtual Interactive Shopper (VIS) was developed on the SeeMe video capture VR system (Brown et al., 2011). It enables the creation of a shopping mall composed of different stores that can be changed and adapted according to the habits and preferences of the shopper, including the need to handle a budget.

Performance of complex IADL tasks within VEs and comparison of performance on the continuum from a virtual supermarket, to a store mock-up and a real shopping task has not yet been studied. This will enable the examination of the relationships between shopping performance in these three environments which complement one another for the purposes of rehabilitation assessment and treatment. It will also help in understanding the use of VEs to train skills in the clinical setting and whether these skills transfer to real world life situations.

The objectives of this study were: 1) to compare shopping behavior with the original and modified 4-item tests between persons post-stroke and healthy controls (in terms of time to complete the tests and number of errors). 2) to compare the performance in the 4- item test in three different environments: a real environment (small, in-hospital "cafeteria"), a store mock-up (physical simulation), and a virtual environment (VIS); and 3) to determine the participants' responses to the shopping experiences in the VIS in terms of their enjoyment and perception of its similarity to real life.

## 2. METHODS

2.1 Participants

Six healthy adults (five women, one man), aged 56-77 years (mean ± SD = 63.5 ± 9.3) and five people (two women, three men) who had a stroke, aged 65-82 years (74.8 ± 6.6), participated in this study. All participants with stroke were inpatients at a Geriatric Rehabilitation Center. Time since stroke ranged from 1 to 7.5 months. Their mean Functional Independence Measure score was 88.4 (SD = 19.5) (maximum score is 126) and the mean of their Mini Mental State Exam scores was 26.4 (SD = 4.8).

2.2 Instruments

The environments tested were:

(1)   Virtual Interactive Shopper (VIS), a virtual environment of a 3-store mall that operates on a video-capture VR system, SeeMe (Fig. 1) (http://www.virtual-reality-rehabilitation.com/products/seeme). It is possible to assess and train the use of money with a virtual wallet.

(2)   A store mock-up that was created in the Geriatric Rehabilitation Hospital at the Sheba Medical Centre (Fig. 2).

(3)   Cafeteria in the Geriatric Rehabilitation center at the Sheba Medical Centre that served as the location of shopping in a real setting (Fig. 3).

Outcomes were measured during performance of two versions of the 4-item test: 1. the original 4-item test (Rand et al., 2007) in which the subject is instructed to "buy" 4 items (VIS: 1 kg of sugar, 500 ml bottle of soda, 1 kg package of rice and 500 ml bottle of orange juice) within a virtual supermarket while the list is visible during the test. The test was also performed in the mock-up using a different list of items (1 liter carton of milk, 1 liter bottle of chocolate milk, 500 ml package of salt, 1 kg package of flour). This test was not administered in the cafeteria since the use of money is not required. Rand et al. (2007) reported significant differences in performance of this test between healthy adults and people with stroke, within the VMall; 2. A modified 4-item test which was developed for the current study in which the subject is instructed to "buy" 4 items. In the modified version, subjects have budget constraints so that they must decide between buying cheaper or more expensive items. In this scenario, the shopping list is also visible to the subject during the test. To avoid learning effects three different versions were created and used in all three environments; the VIS (package of pasta, package of yellow cheese, loaf of bread, container of yoghurt), the store mock-up (carton of milk, package of white cheese, can of corn, package of chicken soup mix) and the cafeteria (items were chosen according to availability and prices in the cafeteria).
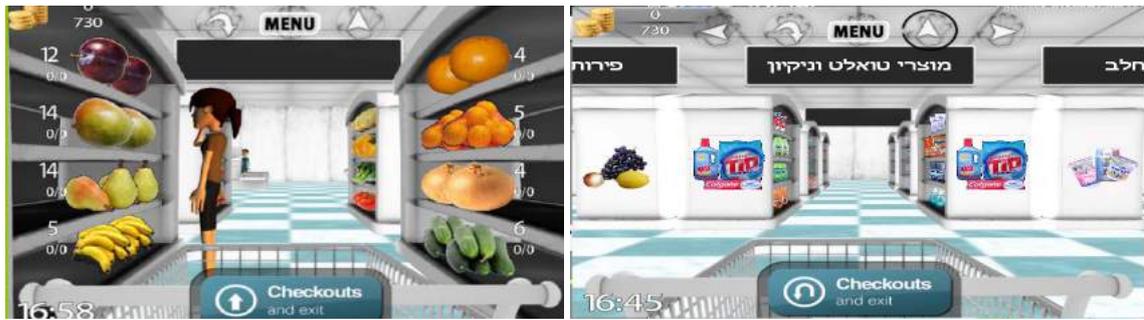
Figure 1. *Two screenshots of the Virtual Interactive Shopper (VIS).*

Figure 2. *Two views of the store mock-up.*

Figure 3. *Sheba Medical Center cafeteria.*

In both versions of the 4-item tests, the time to complete the test (from the moment the subject said that he was ready to start until he said that he had finished) and the number of errors (e.g., buying the wrong item or not buying an item on the list) were recorded. In the modified version, an additional type of error was recorded concerning the budget handling, i.e., spending more than the specified amount. In addition, in the VIS, the locations visited within the VE by the subject were recorded by the software.

The Short Feedback Questionnaire (SFQ) (Kizony et al., 2006) was used to record participants' responses to the shopping experiences in the VIS in terms of their enjoyment and perception of its similarity to real life. The questionnaire is composed of six items that assesses the participant's (1) feeling of enjoyment, (2) sense of being in the environment, (3) success, (4) control, (5) perception of the environment as being realistic and (6) whether the feedback from the computer was understandable. Responses to all questions are rated on a 5-point scale (1 – not at all and 5 – very much). An additional question inquires whether the participants felt any discomfort during the experience.

2.3   Procedure

The study was approved by the Ethics committee of the Sheba Medical Center, Tel Hashomer, Israel, and each subject signed an informed consent before participating. The order of testing environments was

randomized between the subjects. In the VIS, two practice trials were given before the 4-item tests were performed. In the first practice trial, the subject was asked to buy a basketball; the researcher explained how to navigate within the VIS and then gave the subject an opportunity to navigate to the toy store and buy the item. The purpose of the second practice was to enable the subject to become familiar with the virtual supermarket; the subject was asked to enter the supermarket and navigate in the main shopping area in order to scan the various aisles. Thereafter the subject was asked to buy toilet paper which was located in an aisle that was not part of either of the 4-item tests in the study protocol. Subjects completed the SFQ after they performed both 4-item tests within the VIS. The original and the modified 4-item tests was administered within the mock-up store after a short explanation about the structure of this model. The modified 4-item test was administered in the cafeteria.

2.4   Data analysis

Descriptive statistics of performance in all outcome measures will be presented in this preliminary study due to the small sample size.

3. RESULTS

The time to complete both versions of the 4-item tests in all environments, for two groups, is presented in Fig. 4. The time to complete the original and modified 4-item tests within the VIS was longer than the time to complete a similar test within the physical store mock-up for both groups. The time to complete the test in the cafeteria was similar to the time it took to complete test in the mock-up store. The control group completed the tests in a shorter time. The least difference between the groups was noticed in the real environment.

In Fig. 5, performance of the individuals on each test within the VIS and the mock-up store as well as in the cafeteria are presented. The relationship between the time taken to complete the test within the VIS and the mock-up store or the cafeteria tended to be stronger for the stroke group especially in the modified 4-item test (Fig. 5B & D).
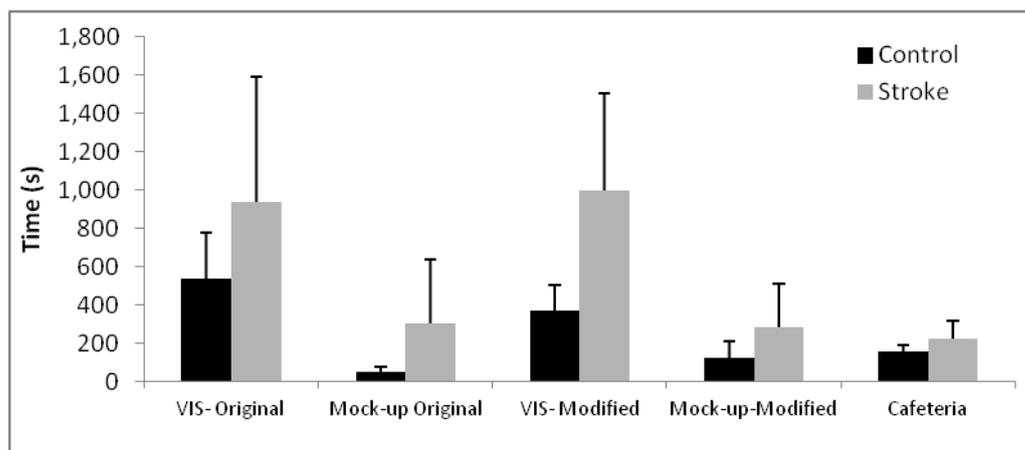

Figure 4. *Mean (+SD) time to complete the two versions of the 4-item test (original and modified) in the environments.*

Analyzing the number of errors in each group showed that, in the original 4-item test in the VIS, all participants made at least one error. However, the total number of errors for the post-stroke group was 12 (n=5) and for the control group was 8 (n=6). Only one subject from the post-stroke group made an error in the same test in the mock-up store. In the modified version of the test in the VIS, one subject from the post-stroke group and two subjects from the control group made errors (total for stroke=4 and control= 2). In the same test in the mock-up store, three subjects from the post-stroke group and two from the control group made errors (total for stroke=5 and control= 3). In the cafeteria, one subject from the post-stroke group and two from the control group made errors (total for stroke=1 and control= 4).

Fig. 6 illustrates the locations visited by one of one subjects with stroke (aged 74 years) and one control (aged 77 years) within the virtual supermarket during the adapted 4-item test. It can be seen that the subject with stroke wandered around the virtual supermarket more than the control subject.

Participants' (n=11) subjective perceptions of their experience within the VIS were positive, as reported in the SFQ; they enjoyed the task (mean = 4.2 ± 0.9) and reported that it appeared to be realistic (4.2 ± 0.9).
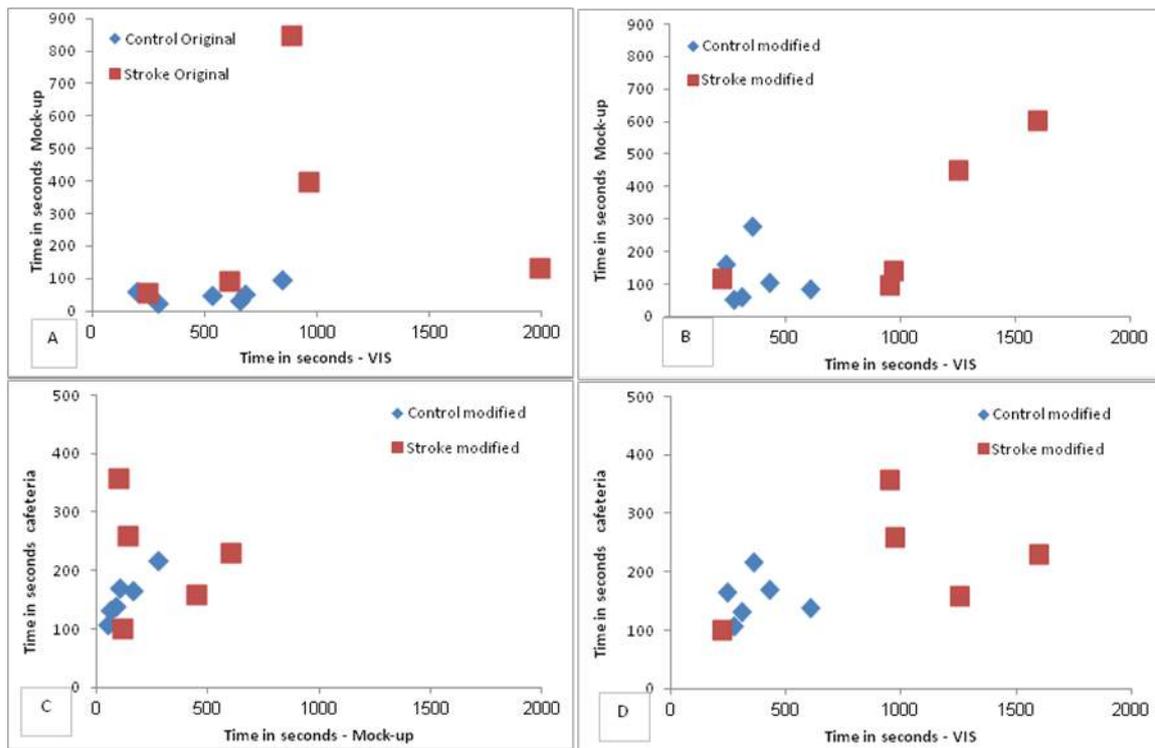
Figure 5. *Relationships between the times to complete each test in the different environments; A. Original test in the VIS and Mock-up; B. Modified test in the VIS and Mock-up; C. Modified test in the Cafeteria and Mock-up; D. Modified test in the VIS and Cafeteria*
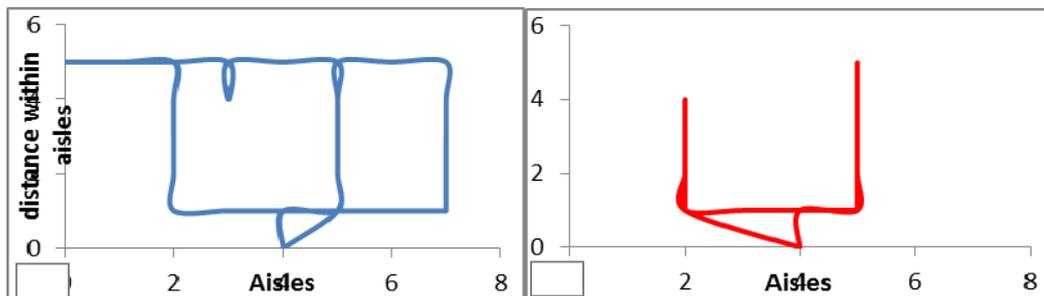
Figure 6. *Locations visited within the virtual supermarket of A. a subject post-stroke and B. a control subject*

4. DISCUSSION AND CONCLUSION

The preliminary results of this small sample show that the task within the VIS is complex and realistic and may be used to assess and train the higher cognitive abilities needed for shopping.

Time to complete the original 4-item test within the VIS was longer than the time reported by Rand et al. (2007) for both groups. This may be explained by the differences in VR systems used for the two studies (as mentioned in the introduction).

Due to the small sample, to date, no statistical tests were performed but there was a tendency for the post-stroke group to perform more slowly than the control group in all environments and that this difference was more remarkable in the simulations (virtual and physical) than in the cafeteria (real). In addition, the time to complete the tests, in both groups, was longer in the VIS than in the Cafeteria or the store mock-up. These results may indicate that the test within the VIS might have been more difficult than the tests in the store mock-up or a the cafeteria that were used in this study. However, in the post-stroke group it appears that the times to complete the modified 4-item test in the VIS were related with both the store mock-up as well as the cafeteria (Fig. 5B & 5D). This, although needs to be cautiously interpreted due to the small sample, may indicate that similar skills are needed to complete the tests in these environments.

The analysis of the number of errors revealed that, overall, only a few errors were made by each group. This is currently being further examined in terms of the types of errors and the ability of participants to self-correct.

One of the main advantages of using VR for evaluating performance of complex tasks is the outcome measures provided by the software. The illustration of the locations visited by the subject within the VIS presented in Fig. 6, is an example for the difference in strategies used by the participants to complete the test within this environment. The person with stroke appeared to use a less efficient strategy to locate and "buy" the items by wandering around the virtual supermarket and entering unnecessary aisles. If carried out in real world, such a strategy (or, in fact, perhaps the absence of any strategy) would require greater effort (i.e., walk longer distances) in order to perform shopping activities.

Finally, similar to previous studies using VEs (e.g., Rand et al., 2007; 2009) the positive responses of the participants indicate that the VIS may be used in rehabilitation as a training tool for improving real life participation.

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