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A virtual shopping task for the assessment of executive functions: Validity for people with stroke

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The importance of assessing executive functions (EF) using ecologically valid assessments has been discussed extensively. Due to the difficulty of carrying out such assessments in real-world settings on a regular basis, virtual reality has been proposed as a technique to provide complex functional tasks under a variety of differing conditions while measuring various aspects of performance and controlling for stimuli. The main goal of this study was to examine the discriminant, construct-convergent and ecological validity of the Adapted Four-Item Shopping Task, an assessment of the Instrumental Activity of Daily Living (IADL) of shopping. Nineteen people with stroke, aged 50–85 years, and 20 age- and gender-matched healthy participants performed the shopping task in both the SeeMe Virtual Interactive Shopping environment and a real shopping environment (the hospital cafeteria) in a counterbalanced order. The shopping task outcomes were compared to clinical measures of EF. The findings provided good initial support for the validity of the Adapted Four-Item Shopping Task as an IADL assessment that requires the

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use of EF for people with stroke. Further studies should examine this task with a larger sample of people with stroke as well as with other populations who have deficits in EF.

Keywords: Virtual reality; Executive functions; IADL; Stroke; Ecological validity

INTRODUCTION

Stroke is a leading cause of disability and functional limitations in adulthood. A major consequence is cognitive impairment, which significantly affects quality of life and participation in daily activities (McKinney et al., 2002; Tatemichi et al., 1994; Zinn, Bosworth, Hoenig, & Swartzwelder, 2007). Executive functions (EF) are defined as high-level cognitive functions involved in the control and regulation of lower-level cognitive processes (Alvarez & Emory, 2006). Deficits in EF often manifest as difficulties in initiating or inhibiting actions, cognitive flexibility, and learning new tasks. These difficulties may exist even when a person's basic cognitive abilities are intact (Elliott, 2003; Shallice & Burgess, 1991). Deficits in both cognitive and EF abilities are common after stroke and often lead to dependence in Instrumental Activity of Daily Living (IADL), such as shopping (Brown, Rempfer, Hamera, & Bothwell, 2006; Leśniak, Bak, Czepiel, Seniow, & Członkowska, 2008; Poulin, Korner-Bitensky, Dawson, & Bherer, 2012).

The importance of assessing EF using ecologically valid assessments has been discussed extensively (e.g., Burgess et al., 2006; Katz & Maeir, 2011). The optimal way to do this is to assess performance of a complex task such as shopping in the real world, as suggested by Shallice and Burgess (1991) who developed the original Multiple Errands Test (MET) and by Hamera and Brown (2000) who developed the Test of Grocery Shopping Skills. However, these tests are time consuming and need a budget to be carried out and thus are often not practical in rehabilitation settings. In addition, in order to re-assess a client after therapy and to compare performance between different populations (e.g., stroke vs. control subjects) consistency of the environments and stimuli can be helpful.

Virtual reality (VR) technology was first used in the mid 1990s to address the challenge of performing ecologically valid assessments via the creation of functional virtual environments that enable users to respond and perform in ways that are similar to real-world experiences (Rizzo, Buckwalter, Neumann, Kesselman, & Thiebaux, 1998; Weiss & Jessel, 1998). The use of virtual environments enables the assessment of complex functional tasks under a variety of differing conditions (Chan, Shum, Toulopoulou, & Chen, 2008; Rand, Katz, & Weiss, 2007; Rand, Weiss, & Katz, 2009b; Rizzo &

Kim, 2005; Kizony, 2011; Kizony, Levin, Hughey, Perez, & Fung, 2010; Parsey & Schmitter-Edgecombe, 2013). VR provides clinicians with unique tools including the recording and analysis of performance, adjustment of levels of difficulty, provision of immediate feedback that contributes to learning, and supervision of client performance (Weiss, Kizony, Feintuch, Rand, & Katz, 2011; Zell et al., 2013). Relative to the simple stimuli used in most psychological research, VR appears to engage the sensorimotor system more fully thereby increasing its potential to stimulate responses that are more realistic in the psychological and behavioural domains (Bohil, Alicea, & Biocca, 2011).

Parsey and Schmitter-Edgecombe (2013) suggest that there is considerable additional potential for applications of technology, including virtual reality, for assessment of and intervention in cognitive dysfunction. Parsons (2011, 2015) suggested that the extent to which a given virtual environment will achieve ecological validity will depend on its verisimilitude and veridicality such that the tasks performed within it correspond to key aspects of real-world activities and environments, and provide outcome measures relevant to the practical problem being investigated. Kizony (2011) reviewed a number of virtual environments for cognitive rehabilitation with the emphasis of using this technology in the context of clinical models for assessment and intervention in neurological rehabilitation.

A number of virtual shopping environments have been developed over the last decade that simulate the supermarket environment for the purpose of evaluating and treating EF deficits in people with head injuries or stroke (e.g., Raspelli et al., 2012). Shopping has been selected by these researchers as an activity that typifies IADL in general, that is essential to regain participation in everyday life and that is meaningful for most people (Thompson et al., 2011). This activity includes tasks such as comprehending a store's layout, forming a strategy to identify the location of products of different types and cost, differentiating between products that appear similar but vary in size, quality or flavour, and keeping track of items purchased. These actions require the use of EF and pose significant challenges to people with stroke (Insel, Morrow, Brewer, & Figueredo, 2006; Rempfer, Hamera, & Brown, 2003).

The Virtual Action Planning–Supermarket (VAP-S) (Klinger, Chemin, Lebreton, & Marié, 2004) is a desktop virtual supermarket in which the subject is asked to buy seven items. It has been tested on a variety of clinical populations including those with mild cognitive impairment and stroke (Josman et al., 2014; Werner, Rabinowitz, Klinger, Korczyn, & Josman, 2009). Performance in the VAP-S was found to predict results of the Observed Tasks of Daily Living–Revised (OTDLR), an IADL measurement that simulates several activities, such as taking medication, in people with stroke (Josman et al., 2014). However, correlation with performance in a real-world environment was not assessed.

Motivated by the desire to implement virtual tasks that would give greater weight to functional movements (e.g., arm reach) beyond those required by operating a mouse or keyboard, Rand, Katz, Shahar, Kizony, and Weiss (2005) developed the Virtual Mall (VMall) supermarket environment that was run on the 2D camera-tracking GestureTek IREX-based system. In this system the user sits or stands in front of a monitor and camera; a coloured backdrop placed behind the user enables removal of his figure from the real environment and inserting it into the virtual environment. Interaction within the virtual environment is done with natural arm movements such as reaching. Fourteen post-stroke participants and 93 healthy participants from three age groups (children, young adults and older adults) performed the Four-Item Shopping Task in which they shopped for four grocery products located in two different aisles on both the top and middle shelves (Rand et al., 2007). A board displaying the written list of items was placed beneath the monitor that displayed the VMall. Outcome measures included the time it took to shop for the four items, the order of products bought and the products bought by mistake. Significant differences were found between each of the three healthy groups and the stroke group who had a significantly longer execution times compared to healthy participants. In a second study, Rand, Basha-Abu Rukan, Weiss, and Katz (2009) developed and tested the VMET, a virtual rendition of the MET. People with stroke performed less well on both the MET and VMET than controls. In addition, people with stroke had high correlations between the MET (performed in a real mall) and the VMET and between both the MET and VMET and the Behavioral Assessment of the Dysexecutive Syndrome (BADS; Wilson, Alderman, Burgess, Emslie, & Evans, 1996) Zoo Map subtest as well as Lawton and Brody's (1969) IADL questionnaire. Raspelli et al. (2012) used a desktop-based VMET version that was developed via the NeuroVR software (www.neurovr.org). Similar to Rand et al.'s results, they found differences in performance of the VMET between people with stroke and healthy controls. They also found correlations between performance of the VMET and measures of attention.

Although these results were encouraging, several limitations of the virtual tasks were noted; for example, they did not include the use of money and keeping track of a budget, an aspect of a complex IADL that requires intact EF. Moreover, recent improvements in camera tracking technology, and specifically of the Kinect sensor (Xbox, Kinect camera (n.d.)) enable the tracking of 3D movements via a simpler setup than previously possible (Weiss, Sveistrup, Rand, & Kizony, 2009; Zhang, 2012). The Kinect is an interface that permits interactions within virtual environments such as virtual shopping that are more natural than mouse or keyboard-based VEs. That is, the participant uses gestures to select items and navigate which are more similar to actions in a real shopping environment. The Kinect, now in wide use in rehabilitation, is a natural successor to the original camera tracking systems including Gesture Tek's GX/IREX and Sony's PlayStation II EyeToy (Weiss et al., 2009).

The main goal of this study was to examine the validity of an adapted virtual version of the original Four Item Shopping Task that requires budget management as a functional test for EF post-stroke. The specific objectives were (1) to investigate discriminant (between groups) validity by comparing the virtual shopping performance of clients with stroke to an age- and gender-matched control group using a user-friendly, camera tracking (Kinect) VR system; (2) to examine construct-convergent validity by determining the relationships between virtual shopping (i.e., performance of the adapted Four-Item Shopping Task) and clinical measures of executive functioning including two subtests from the BADS and two subtests from the Executive Function Performance Test (EFPT; Baum, Morrison, Hahn, & Edwards, 2007); and (3) to examine ecological validity by identifying the relationship between performance of the Adapted Four-Item Shopping Task in a real-world cafeteria and the Virtual Interactive Shopper (VIS) virtual shopping environment. We hypothesised that the control group would perform significantly better in the virtual task, clinical measures and shopping in the cafeteria relative to the group with stroke. We also hypothesised that significant correlations would be found among virtual shopping outcomes, clinical measures of EF and the real-world cafeteria shopping task, within each group.

METHODS

Participants

The stroke group included 19 people, aged 50–85 years. Participants were included in the study if they were up to 12 months post-stroke, could walk independently indoors (with or without an ambulatory aid), had been independent in basic and instrumental activities of daily living prior to the stroke, and used to shop in a supermarket. They were excluded from the study if their score on the Mini Mental State Examination (MMSE; Folstein, Folstein, & McHugh, 1975) was less than 18, they showed signs of unilateral spatial neglect (i.e., score < 51 on the star cancellation test of the Behavioural Inattention Test (BIT; Wilson, Cockburn, & Halligan, 1987) or had language problems that prevented them from understanding the instructions. The control group included 20 age- and gender-matched healthy participants who scored above 23 on the MMSE and had no pathology affecting the central nervous system.

Convenience sampling was used to recruit both groups of participants. The stroke group was recruited from a large rehabilitation centre.

Environments

Virtual supermarket environment: SeeMe Virtual Interactive Shopper (VIS) (Virtual Reality Rehabilitation, SeeMe System (n.d.)). SeeMe is a camera tracking VR system that can be installed on any laptop with a good quality graphics card (e.g., N-VIDEA) and displayed on any standard TV monitor. The Kinect 3D sensor (Xbox, Kinect camera (n.d.)) captures movement of the user's body (Sugarman, Weisel-Eichler, Burstin, & Brown, 2011). The VIS is a SeeMe supported virtual mall shopping environment (Hadad et al., 2012). Currently the mall includes three different stores: a supermarket, shown in Figure 1A and B, a toy store, and a hardware store. The types (e.g., products from a specific country), quantities, and locations of the products in each store can be easily adjusted. The participant navigates within and between the shopping aisles by "touching" directional arrows and selects the desired products by "hovering" over photos of the products. When a product is touched, its name is voiced. Upon selection, an image of the product is placed in a virtual shopping cart. The shopping list and the contents of the cart (i.e., the products already purchased) can be viewed at any time by "touching" the menu icon. Products that were purchased by mistake can be removed from the cart. A detailed report of the shopping activity is generated upon completion of the task including which products were selected and when they were selected, whether products purchased by mistake were returned, the total cost of the purchased items, and distance traversed while shopping. Note that the

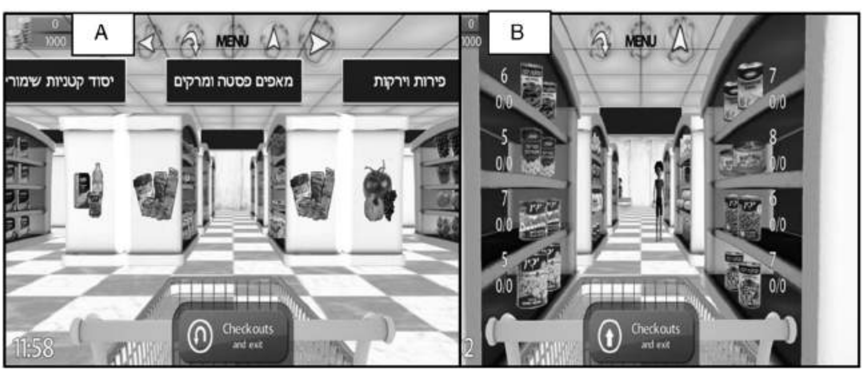

Figure 1. The virtual interactive shopper. (A) a view of some of the aisles and (B) a view within an aisle. The menu button and shopping cart appear on the screen throughout the task.

variable “distance traversed” refers to the distance moved by participants as they progressed through the virtual supermarket making their purchases. This is a computer unit and has no inherent meaning in terms of real-world distances. A higher value for distance traversed is indicative of a longer route taken in the shop.

Real-world environment: Hospital cafeteria. The cafeteria is located in the rehabilitation centre and offers a variety of hot and cold drinks, sandwiches, pastries and snacks. Although this setting differs from a typical supermarket, its various products are displayed on several adjacent shelves and refrigeration units making it a reasonable alternative as an accessible, real-world shopping opportunity.

Measures

Adapted Four-Item Shopping Task (Hadad et al., 2012)

The Adapted Four-Item Shopping Task was modified from the original task (Rand et al., 2007) where the participant is requested to purchase four different products located in two different store aisles. In the adapted version, the assessment of budget management was added; participants are given a pre-set amount of money that is greater than the total cost of the products they need to purchase. While shopping, the participant needs to consider the product brand (some brands are more expensive than others, e.g., 1% milk is more expensive than 3% milk) and buy all four items without going over the specified budget; the products are priced such that care needs to be taken in order to keep within the budget.

The Adapted Four-Item Shopping Task was performed in the VIS and in the real-world environment: the hospital cafeteria. Outcomes included the time taken to buy/select the first item, total time to buy the four items, number of errors (items on the list that were not bought and the number and type of items bought by mistake), discrepancies between the amount of money that participants were allowed to spend and the actual amount that was spent, distance traversed while shopping (only in the VIS) and the amount of assistance received from the cashier, rated on a scale of 1 (no assistance) to 10 (full assistance) (only in the cafeteria).

Short Feedback Questionnaire (SFQ; Kizony, Rand, Katz, & Weiss, 2006)

This is a 7-item questionnaire that queries the user’s sense of presence and any discomfort they may have felt during the experience. The first six items assess 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. The seventh item queries whether participants felt any discomfort during the experience. Responses are rated on a scale of 1–5 where 1 = not at all and 5 = very much, and a mean score is calculated for the first 6 items. Concurrent validity was established with the Presence Questionnaire (Witmer & Singer, 1998) and significant moderate correlations were found ($r = .55$, $r = .74$ for various virtual environments) (Kizony et al., 2006).

Zoo Map and the Rule Shift Cards subtests from the BADS (Wilson, et al., 1996)

This evaluation assesses EF deficits and aims to predict daily problems arising from difficulties in these functions. Each subtest profile score ranges from 0 (low function) to 4 (high performance). The Zoo Map subtest examines a patient's ability to plan, when the plan consists of two phases: the pre-planning stage (formulation) and the phase of execution (execution) (Allain et al., 2005). The Rule Shift Cards subtest examines the patient's ability to respond to rules that change. This subtest assesses mental flexibility in switching from one rule to another, attention, the ability to correct errors, and to monitor behaviour (Wilson et al., 1996). The inter-rater reliability was found to be high and significant in both subtests: Rule Shift Cards ($r = .98–1.00$) and Zoo Map ($r = .90–1.00$) whereas test-retest reliability correlations were low (Rule Shift Cards $r = -.08$; Zoo Map $r = .39$). Ecological validity was measured using the Dysexecutive Questionnaire; significant correlations were found between the subtests (Rule Shift Cards: $r = -.45$; Zoo Map: $r = -.46$) and significant others' ratings of executive problems (Wilson et al., 1996).

Telephone Use and Bill Payment subtests of the Executive Function Performance Test (EFPT; Baum et al., 2007)

The EFPT evaluation examines EF components such as initiation, planning, correction of errors and maintaining safety, and uses a structured cue system that enables the examiner to intervene during the testing procedure. The Telephone Use subtest requires the subject to call a store and ask for certain pieces of information, such as their opening hours. The Bill Payment subtest involves having the subject write cheques as payment of two bills and to balance the financial status of the account. Each subtest is scored according to the level of cueing required for the various EF components. The higher the final score, the more severe the EF impairment. Both subtests were shown to have a high level of internal reliability ($r = .79, .89$, respectively). The EFPT distinguished between people with mild and moderate stroke as well as between both groups and a healthy population of controls (Baum et al., 2008).

Additional clinical measures used for description of participants' level of BADL, motor (for the stroke group) and cognitive performance (for both groups)

Functional Independence Measure (FIM; Hamilton, Granger, Sherwin, Zielezny, & Tashman, 1987)

The FIM assesses 18 components of basic activities of daily living such as dressing and was used in this study to characterise the functional status of the participant. Each activity is graded on a 7-point scale with a total score range between 18 and 126. This assessment has been studied extensively, its reliability and validity are well established (Passalent, Tyas, Jaglal, & Cott, 2011) and it was found suitable to use with stroke patients (Ring, Feder, Schwartz, & Samuel, 1997).

Fugl-Meyer Assessment upper extremity part (FMA; Fugl-Meyer, Jääskö, Leyman, Olsson, & Steglind, 1975)

The FMA assesses the motor impairment of the upper extremity after stroke. Each movement is graded on a 3-point scale, and the total score for the upper extremity ranges from 0–60 points where a higher score represents more active movements. This test is one of the most commonly used instruments in rehabilitation and its validity and reliability have been well established (Chae, Johnston, Kim, & Zorowitz, 1995; Fugl-Meyer et al., 1975; Wood-Dauphinee, Williams, & Shapiro, 1990).

Clock Drawing Test (CDT; Rouleau, Salmon, Butters, Kennedy, & McGuire, 1992)

The CDT is a widely used test that assesses a wide range of cognitive as well as EF abilities (e.g., planning) (Mainland & Shulman, 2013). In the current study we used the quantitative scoring method developed by Rouleau et al. (1992) where the score ranges from 1 (worst performance) to 10 (excellent performance). The Clock Drawing Test has high criterion validity with the Executive Interview (EXIT 25), an assessment of EF (Royall, Mulroy, Chiodo, & Polk, 1999), and has been shown to be a valid screening method for mild cognitive impairment (Yamamoto et al., 2004); it is highly correlated with the MMSE, as well as other cognitive tests, and is sensitive to cognitive change with good predictive validity (Parsey & Schmitter-Edgecombe, 2011; Mainland & Shulman, 2013).

Procedure

Following approval to conduct the study from the Sheba Medical Center Helsinki committee, participants meeting the inclusion criteria signed an informed consent form. The BADS Zoo Map and the Rule Shift Cards subtests and the EFPT Telephone Use and Bill Payment subtests were administered. The participants then performed the Adapted Four-Item Shopping Task in the VIS and in the cafeteria in a counterbalanced order. Prior to performance of the task in the VIS the participants performed two training tasks (for a total of 2–10 minutes) in the VIS in order to become familiar with navigation and selection options. The first training task was performed in the toy store and the second in the supermarket.

Statistical analyses

The IBM SPSS statistical software package Version 21.0 (IBM Corporation, Armonk, NY) was used to analyse the data. Due to the abnormal distribution of the data according to the Shapiro-Wilk's Test, non-parametric tests were used to examine the study hypotheses. The Mann-Whitney U test (U) and the Chi-square test (χ^2) were used to examine differences between the stroke and control groups in the performance of the Adapted Four-Item Shopping Task, the clinical assessments of executive functioning and the SFQ. Spearman's rho test was used to determine the relationships among performance of Adapted Four-Item Shopping Task in the VIS and in the real-world cafeteria and clinical assessments, in each of the groups. The level of significance was set at .05. Due to the large number of comparisons in the outcome measures of the adapted shopping task, the Bonferroni correction was used to adjust the levels of significance. The number of comparisons (according to number of outcome measures) of the adapted task in each of the setting (i.e., the VIS and the real-world cafeteria) was five, and thus the new level of significance was set to .01 ($.05/5 = .01$).

RESULTS

Descriptions and between-group comparisons of demographic and performance variables on the screening tests are provided in Table 1. The participants in the control group had significantly more years of education than the stroke group. The mean and median scores of both groups in the MMSE and the CDT were high and not indicative of deficits in basic cognitive abilities; the MMSE and CDT scores of the control group were significantly higher than the stroke group. All participants had shopped in a supermarket as part of their weekly routine.

TABLE 1
Description and comparison of demographic variables and screening tests between groups

Group	*Research* ($N = 19$)			*Control* ($N = 20$)				
	Mean (*SD*)	*Median*	Range	*Mean* (SD)	*Median*	*Range*	*U*	*p*
Age (years)	69.4 (9.88)	70.0	50–84	66.7 (8.96)	65.5	50–84	155	.33
Educ (years)	12.2 (3.6)	12.0	8–20	14.9 (3.0)	15.0	11–20	110.5	.02
FIM	88.8 (14.8)	91.0	55–114	N/A	N/A	N/A	N/A	N/A
MMSE	27.2 (2.8)	28.0	18–30	28.7 (1.2)	29.0	26–30	117.0	.03
CDT	8.3 (1.8)	9.0	5–10	9.9 (0.5)	10.0	8–10	69.5	.0001
FMA[a]	46.4 (10.3)	51.0	17–54	N/A	N/A	N/A	N/A	N/A

Group		Research ($N = 19$) Prevalence %		Control ($N = 20$) Prevalence %		χ^2 ($df = 1$)	p
Gender	Male	12	63.2	7	35.0	3.09	.08
	Female	7	36.8	13	65.0		
Dominance	Right	18	95.0	19	94.7	0.01	.97
	Left	1	5.3	1	5.0		
Occupation[b]	Work	6	31.6	10	50.0	1.37	.24
	Retired	13	68.4	10	50.0		
						χ^2 ($df = 2$)	p
Frequency of shopping[b]	> 1/ week	9	47.4	10	50	2.25	.33
	1/ week	8	42.1	10	50		
	< 1/ week	2	10.5	0	0		

[a]FMA = Fugl Meyer Assessment for affected arm; CTD = Clock Drawing Test.
[b]For the stroke group, information refers to status prior to the stroke.
Educ = education; FIM = Functional Independence Measure; MMSE = Mini-Mental State Exam.

Six participants were diagnosed with a right-sided stroke, seven with a left-sided stroke, and six with vertebra-basilar stroke. The stroke was ischaemic in 15 participants and haemorrhagic in four participants. Time since stroke ranged between 1 and 32 weeks with a mean of 8.9 weeks and a standard deviation of 7.5 weeks.

Differences between the groups: Adapted Four-Item Shopping Task (discriminant, between-group validity)

The performance and between-group comparisons of the tasks in the VIS and in the cafeteria are presented in Table 2. In the performance of the Adapted Four-Item Shopping Task in the VIS, the control group required significantly less time to purchase the first item, less time to complete the shopping task (i.e., to purchase all items), and the distance they traversed was significantly shorter. Figure 2 shows representative trajectories traversed by two participants (one with stroke and one control) within the VIS during the Adapted Four-Item Shopping Task. The control participant was more efficient while performing the tasks.

In the performance of the Adapted Four-Item Shopping Task in the cafeteria, the control group exceeded the budget significantly less frequently and required less assistance from the cashier. Further analysis showed that significantly more participants from the stroke group exceeded the budget than controls (3; 15%) ($\chi^2 = 7.79$, $p = .005$). There were two additional significant differences before Bonferroni correction; the control group required less time to complete all purchases and made fewer errors. Due to the differences between the groups in the number of years of education we performed Spearman's rho test between the Adapted Four-Item Shopping Task (in both

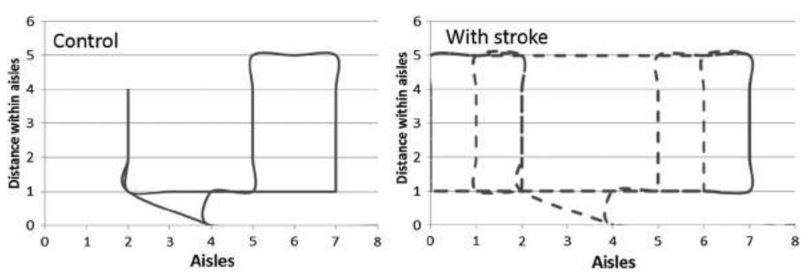

Figure 2. Trajectory traversed by two participants while performing the adapted Four-Item Shopping Task in the VIS; on the right is a 74-year-old participant with stroke and on the left a 74-year-old participant from the control group. The participant from the control group made minimal number of transitions in the VIS and entered only the aisles that were needed for purchasing the items. In contrast, the participant with stroke travelled a longer distance and entered unnecessary aisles, thus performing the task in a less efficient and organised manner.

TABLE 2
Performance and comparison between groups of the adapted Four-Item Shopping Task in the VIS and in the Cafeteria

	Stroke Group ($N = 19$)			*Control group* ($N = 20$)				
	Mean	*Median*	*Range*	*Mean*	*Median*	*Range*	*U*	*p*
Time in seconds until the first purchase (VIS)	158.42 (90.64)	153	54–374	82.35 (33.57)	74.5	37–146	81.50	.002
Time in seconds for total purchase (VIS)	651.11 (363.00)	548	222–1592	324.6 (101.94)	309.5	175–606	55.50	.001
Amount of numerical errors (VIS)	1.11 (1.45)	0	0–4	0.60 (1.05)	0	0–4	157.00	.29
Budget exceeded (NIS) (VIS)	5.63 (10.24)	0	0–31	3.20 (9.21)	0	0–35	159.00	.27
Distance traversed in "Jumps" (VIS)	47.37 (10.91)	41.5	26–80	32.95 (12.69)	33.0	16–72	81.00	.002
Time in seconds until the first purchase (Cafeteria)	31.11 (27.65)	28	4–106	26.25 (16.39)	20.0	10–65	189.50	.98
Time in seconds (Cafeteria)	235.21 (85.91)	220	101–400	169.00 (55.61)	165.5	80–270	99.00	.011
Numerical errors (Cafeteria)	1.05 (1.65)	1	0–6	0.30 (0.66)	0	0–2	123.00	.029
Budget exceeded (NIS) (Cafeteria)	1.94 (5.16)	0.6	0–22.9	0.39 (1.48)	0	0–6.6	111.00	.007
Help from cashier (Cafeteria)	4.37 (2.41)	5	1–8	2.35 (1.50)	2.0	1–6	96.50	.008

Notes: Significance level after Bonferroni correction was set to $p = .01$. VIS, Virtual Interactive Shopper.

environments) and education. We found one significant correlation, only in the control group, between distance traversed in the VIS and years of education (rs = −.49; p = .028). The remaining correlations were not significant.

Differences between the groups: Clinical assessments of EF

The performance results and between-group comparisons in the BADS and EFPT subtests are presented in Table 3. The control group performed significantly better on the Rule Shift Cards, the Telephone Use Task and the Bill Payment Task.

Relationships between performance in the Four-Item Shopping Task in the VIS and cafeteria, and clinical assessments of EF (convergent and ecological validity)

Table 4 provides the correlations between the Adapted Four-Item Shopping Task and the clinical assessment of EF and the correlations between performance in the VIS and performance in the cafeteria. In general, better performance in the clinical assessments of EF was related to better performance in the VIS in both groups, but with fewer correlations in the stroke group. However, better performance in the clinical assessments of EF was related to better performance in the cafeteria only in the control group. In addition, significant correlations were found between performance of the Adapted Four-Item Shopping Task in the VIS and in the cafeteria in the control group (four correlations) and the stroke group (one correlation).

TABLE 3
Performance and comparison between groups of clinical assessments for executive functions

	Stroke group (N = 19)			*Control group (N = 20)*				
	Mean (SD)	*Median*	*Range*	*Mean (SD)*	*Median*	*Range*	*U*	*p*
BADS Zoo Map	0.89 (0.74)	1	0–2	1.55 (1.47)	1.0	0–4	151	.25
BADS Rule Shift Cards	1.84 (1.34)	2	0–4	3.25 (0.98)	3.5	1–4	76.50	.001
EFPT Telephone Use	3.11 (3.43)	2	0–13	0.95 (1.47)	0	0–5	114.50	.026
EFPT Bill Payment	7.63 (4.40)	7	1–17	2.55 (2.67)	2.0	0–9	57.00	.001

TABLE 4

Correlations between performance in clinical assessments of EF and the Adapted Four-Item Shopping Task and correlations between performance in the Adapted Four-Item Shopping Task in the VIS and the Cafeteria for each group

	Stroke (*N* = *19*)					*Control* (*N* = *20*)						
	BADS Zoo Map Profile Score	*BADS Rule Shift Cards Profile Score*	*EFPT Telephone Use Profile Score*	*EFPT Bill Payment Profile Score*	*Time in seconds until the first purchase Cafeteria*	*BADS Zoo Map Profile Score*	*BADS Rule Shift Cards Profile Score*	*EFPT Telephone Use Profile Score*	*EFPT Bill Payment Profile score*	*Time in seconds until the first purchase Cafeteria*	*Time in seconds for total purchase Cafeteria*	*Number of errors VIS*
Time in seconds until the first purchase (VIS)		−.53*		.57*						−.49*		
Time in seconds for total purchase (VIS)			.55*	.56*				.51*			.47*	
Distance traversed in "Jumps" (VIS)					61.**		−.57**					

(*Continued*)

TABLE 4 Continued.

	Stroke (N = 19)					*Control (N = 20)*						
	BADS Zoo Map Profile Score	*BADS Rule Shift Cards Profile Score*	*EFPT Telephone Use Profile Score*	*EFPT Bill Payment Profile Score*	*Time in seconds until the first purchase Cafeteria*	*BADS Zoo Map Profile Score*	*BADS Rule Shift Cards Profile Score*	*EFPT Telephone Use Profile Score*	*EFPT Bill Payment Profile score*	*Time in seconds until the first purchase Cafeteria*	*Time in seconds for total purchase Cafeteria*	*Number of errors VIS*
Time in seconds until the first purchase (Cafeteria)						−.48*						
Time in seconds for total purchase (Cafeteria)						−.67**		.51*				
Number of errors (Cafeteria)						−.62**			.59**			.46*

Participants' subjective experience of the VIS

There were no significant differences between the groups in their experience of the VIS, therefore results were combined for both groups. Participants' SFQ scores ranged between 2.8 and 5 with a mean score $\pm$ *SD* of 4.1 $\pm$ 0.6 and a median of 4.2. Level of discomfort ranged between 1 and 4 with a mean score $\pm$ *SD* of 1.7 $\pm$ 1.1 and a median of 1. The very occasional reports of discomfort were mainly attributed to difficulty in getting oriented within the VIS. Only one participant (from the control group) suffered from a very short-term eye strain.

DISCUSSION

The growing availability of virtual reality technology in rehabilitation centres has led to its use as an assessment and intervention tool for people with stroke (e.g., Jansari et al., 2014; Josman et al., 2014). As presented above, VR has many assets that make it a promising adjunct to conventional therapy. It appears to be particularly appropriate in cases where ecologically relevant tasks are needed for cognitive, and especially for EF assessment and intervention. In order to use this technology to overcome the challenge of efficiently assessing the EF required for performance of complex activities of daily living, it is important that the validity of the assessment procedures is demonstrated. Thus, the main goal of this study was to examine several types of validity of the virtual version of the Adapted Four-Item Shopping Task. The findings support our key hypotheses regarding its ability to differentiate between the control and stroke groups as well as the presence of significant relationships between performance of the virtual and real-world tasks and EF as assessed via accepted clinical measures.

Differences between the groups in the Adapted Four-Item Shopping Task, particularly in time to make the first purchase and total time to complete the task (make all purchases), are consistent with the findings of Rand et al. (2007) who used the original Four-Item Shopping Task. Their comparison of the performance of individuals post-stroke and healthy individuals showed that time but not number of errors differentiated between these groups. In the current study, participants with stroke traversed a significantly greater distance than the control group, a variable that was not measured by Rand et al. (2007). This finding indicates that the participants in the stroke group were less efficient in their performance of the shopping task and that they did not use an effective cognitive strategy to plan their shopping route. The effective use of a cognitive strategy is known to enhance the accuracy and efficiency of task performance (Toglia, Rodger, & Polatajko, 2012) and is linked to good executive functioning (Toglia, Goverover, Johnston, & Dain, 2010; Toglia, Johnston, Goverover, & Dain, 2010). However, this finding may also be attributed to the higher level of education in the control group that was correlated with a shorter distance traversed in the VIS. Higher education was correlated to better cognitive abilities and executive functioning (van Hooren et al., 2007).

Josman et al. (2014) found differences in the performance of a shopping task in the VAP-S environment between people with stroke who have deficits in EF and healthy controls. In contrast to the current study, they did not find differences in time and distance traversed but did find differences in other measures (e.g., they had made fewer correct actions), indicating that people with stroke were less efficient in their performance. Poor performance in the VAP-S environment was also found in other populations with EF deficits such as mild cognitive impairment (Werner et al., 2009).

In the current study, the stroke group clearly had greater difficulty performing clinical assessments of EF compared with the control group. These findings are in line with those of Baum et al. (2008), who showed significant differences in scores on the EFPT between post-stroke patients and healthy subjects. The deficits in EF of the stroke group in the current study, as demonstrated by their scores in the clinical assessments, appear to account for the differences between the groups in performance of the virtual shopping task. The lack of difference between the groups in the BADS Zoo map subtest is in accordance with the findings by Josman et al. (2014); indeed this test likely has a floor effect and should be further studied.

The key difference between the original and adapted versions of the Four-Item Shopping Task was the need for budget management in the latter. Significantly more participants from the stroke group exceeded the budget and the amount of money by which the budget was exceeded was significantly higher in this group when the task was performed in the real-world cafeteria. The differences between the groups were not significant in the VIS. These findings may be explained by the way the money spent in the VIS is monitored relative to the real-life setting; in the VIS, the participants selected the cart icon and then totalled the cost of the items bought. This choice of feedback presentation likely caused both the stroke and the control groups to have difficulty in keeping track of the budget. Indeed, in a later version of the VIS, feedback regarding the amount of money available is displayed on the screen at all times. To summarise, the between-groups differences found in the current study support the construct validity of the virtual version of the Adapted Four-Item Shopping Task.

Nevertheless, it is important to discuss the motor and information processing speed aspects of the virtual task in the current study. Although most of the participants had good function of their affected upper extremity, and most of them used their less-affected arm to perform the shopping task, one can argue that the between group differences may be attributed, in part, to these aspects and not only to EF deficits. The difference found in the distance traversed, as explained above, is indicative of a less efficient strategy to perform the task, showing that the difference between the groups can be attributed to more than just the motor aspect. With regard to information processing speed, this was not assessed in the current study, but we note that since the virtual stimuli in the VIS (e.g., food items) do not move or disappear, as is usually the case in virtual games, the speed of interaction is primarily determined by the user and minimally influenced by the virtual environment. The potential influence of motor and information processing speed on participant performance should be further examined in future studies.

Several moderate correlations were found between the performance of the Adapted Four-Item Shopping Task and clinical assessments of EF in both groups. These correlations indicate that better executive skills in the clinical assessments were associated with better and more efficient performance on the shopping task, i.e., less time and shorter distance traversed. These results are consistent with studies in which the performance of a virtual shopping task in a post-stroke sample was examined; correlations were found between performance in the VAP-S environment (Josman et al., 2014) and in the VMall (Rand et al., 2009) and scores on BADS subtests. To summarise, the current study provides partial support for the convergent validity of the Adapted Four-Item Shopping Task when performed in a virtual environment.

The VIS environment was a novel, unfamiliar environment for the participants, and as such, they needed to learn how to operate and navigate within it. Moreover, the Adapted Four-Item Shopping Task is a complex task that requires finding groceries and making comparisons between them in order not to exceed the budget. Connor and Maeir (2011) suggested that routine tasks carried out in a familiar environment place a minimal demand on EF abilities whereas even a slight increase in a task's demands or its context (e.g., the environment in which it is to be performed) requires the use of EF. Specifically, novel situations such as the one encountered in the VIS, require participants to use judgement, problem-solving and effective performance strategies, similar to the abilities necessary to accomplish the clinical assessments of EF administered in this study. Thus, a complex task performed in an environment such as the VIS that simulates the types of abilities needed to perform complex daily life tasks or to perform tasks in an unfamiliar environment appears to be appropriate for assessing how individuals cope with complex daily life situations that require adequate executive functioning abilities.

In addition to discriminant (between-group) construct validity and convergent validity of the virtual Adapted Four-Item Shopping Task as a tool to assess EF, it is important to consider the extent to which performance of the virtual task and the performance of the same task in the real world are similar, i.e., the ecological validity of the task. In the current study we addressed this issue by examining the relationships between the Adapted

Four-Item Shopping Task performed in the VIS and the same task performed in a hospital cafeteria. In the stroke group, better performance in the VIS was significantly related to better performance in the cafeteria. In the control group, several correlations were found in the same direction. However, the finding that longer time to purchase the first item in the virtual environment was correlated with a shorter time to purchase the first item in the cafeteria was unexpected and will need to be investigated further in future studies. To summarise, these results provide partial support for the ecological validity of the Adapted Four-Item Shopping Task. Additional support for the ecological validity can be seen in the participants' feedback on their experience in the SFQ. Indeed when looking into the two questions that query the sense of presence and realism of the environments, about 70% of the participants responded 4 or 5 out of 5 for these questions. This indicates that they felt as if they were inside the environment and that it resembles a realistic shopping environment.

The extent to which performance in a virtual environment resembles performance in a real environment has been discussed in the literature where better performance in a virtual environment was related to better performance in the real environment. For example, Rand et al. (2009a) reported high correlations between the MET performed in a real mall and the VMET performed in the VMall in people with stroke.

The relatively small number of correlations found in the current study may be explained by certain differences in the environments. The hospital cafeteria is small and provides fewer opportunities for problem solving than the VIS. Moreover the cashier tends to help the customers and performance is dependent on the number of customers that happen to be in line. Indeed, the people with stroke used the cashier's help significantly more often than the control group. This points to the advantage of using virtual environments as an assessment of complex daily tasks in a consistent way for monitoring change in performance after intervention (Rizzo & Kim, 2005). The ability to control the stimuli and, hence, the level of task difficulty, enables clinicians to reduce the impact of ambient environmental influences such as help from another person who will not always be available to the clients.

Analysis of the pattern of correlations within each group showed that in the stroke group performance of the virtual task was correlated, on the one hand, with performance in the clinical assessments of EF and, on the other hand, with performance of the shopping task in the cafeteria. However, no correlations were found between performance in the clinical assessments and performance of the shopping task in the cafeteria. In contrast, in the control group, performance in the clinical assessments was correlated to performance in the cafeteria. Moreover, similar to the stroke group, performance of the virtual task was correlated to performance in the clinical assessments as well as performance in the cafeteria. These results emphasise the importance of conducting ecological assessments rather than relying solely on paper-and-pencil tests in order to identify executive dysfunction in the performance of daily life activities.

The clinical implications of the results of this study are somewhat limited by the relatively small sample size as well as the use of a real-world setting (hospital cafeteria) that was not representative of a large supermarket as used in the VIS. In addition, although most of the correlations between years of education and performance in the Adapted Four-Item Shopping Task were not significant, some of the rho values were above .30 and may be significant with a larger sample. Thus, it may be that the differences between the groups in this variable may have affected the results. Finally, since participants' information-processing speed was not tested (e.g., via visuo-motor or tapping tests), its effect on differences between the groups and correlations with EF cannot be ruled out.

CONCLUSIONS

The findings of the current study provide good initial support for the validity of the Adapted Four-Item Shopping Task as an assessment of a daily activity that requires the use of EF for people with stroke. Rehabilitation techniques and conventional methods are limited in terms of their ecological validity, resulting in difficulty in detecting the acquisition of new knowledge and skills (Rizzo, Schultheis, Kerns, & Mateer, 2004). The use of virtual reality in rehabilitation is clearly advantageous since it enables simulation of diverse life situations for conducting assessments that cannot always be performed in real-life environments. The ability to provide a dynamic and ecological assessment of function assists clinicians by helping them understand the person's behaviour and how to improve functional performance in everyday life (Rizzo & Kim, 2005; Rose, Brooks, & Rizzo, 2005). Further studies should examine this task with a larger sample of people with stroke as well as with other populations who have deficits in EF. Moreover, further studies should examine the same task when implemented on various technologies, such as tablets. In addition ecological validity should be further examined by comparing performance in the virtual Adapted Four-Item Shopping Task with performance of a similar task in a supermarket as well as its predictive value for the ability to perform other instrumental activities of daily living.

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