



The Relationship Between Verbal Fluency Performance and Online Grocery Shopping in Participants with and Without Moderate to Severe Traumatic Brain Injury

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Abstract

Objectives: To determine whether phonemic and semantic verbal fluency performance, as indicated by the total number of correct words generated, is correlated with greater independence and efficiency in completing an online grocery shopping task in participants with and without moderate to severe TBI.

Methods: Forty-four participants with and without moderate to severe TBI completed tasks of verbal fluency and an online grocery shopping task. Participants also rated their perception and use of online shopping.

Results: Participants with moderate to severe TBI produced significantly fewer total correct words for both verbal fluency conditions, took significantly longer to shop for 14 grocery items, and executed a significantly greater number of searches for items when shopping when compared to controls. Those in the TBI group reported significant difficulty with completing online shopping tasks.

Conclusions: Those with moderate to severe TBI report chronic cognitive-linguistic sequelae post injury that interfere with the ability to complete IADLs like grocery shopping. These findings lend support to previous research that has suggested that the administration of verbal fluency tasks may be an effective way to screen for overall level of independence in completing IADLs in a population with moderate to severe TBI.

Keywords: Acquired brain injury, word generation tasks, instrumental activities of daily living

Introduction

Survivors of moderate to severe traumatic brain injury (TBI) often

report a number of chronic and disabling cognitive-linguistic impairments that may adversely affect a survivor's ability to independently complete instrumental activities of daily living (IADLs) upon discharge from rehabilitation. IADLs are complex tasks, such as grocery shopping, that enable an individual to live independently within a community, and the ability to complete these tasks is associated with overall quality of life [1-3]. Previous research has suggested a relationship between performance on phonemic and semantic verbal fluency tasks, as indicated by the total number of correct words generated for each category within each task condition, and the level of independence and efficiency in completing IADLs in populations with TBI [4-7]. Since verbal fluency is a cognitive-linguistic function that appears to be particularly susceptible to the effects of TBI [8-11], performance on these types of tasks may be particularly useful as a screening tool to predict who may need assistance with this type of task, and the level of assistance that is required, prior to discharge from a rehabilitation facility.

A growing body of research has examined the relationship between phonemic and semantic verbal fluency and IADL performance in populations with TBI [4-7]. Collectively, these studies suggest that greater production of correct words, along with fewer set-loss and repetition errors, is associated with greater independence and efficiency in everyday tasks, including meal preparation [6] and grocery shopping [6]. However, findings vary by task, with some studies reporting associations specific to meal preparation only [4], grocery shopping [5], and financial management [7]. More recently, Tzadok and colleagues [7] investigated the utility of the Internet-based Bill-Paying Task as a measure of executive function

in individuals with and without TBI. Participants completed an online bill-paying task using a mock credit card, with performance evaluated across initiation, organization, sequencing, safety, judgement, and task completion. They also completed a Semantic Verbal Fluency test [12], requiring generation of category-based words (*animals, fruits and vegetables, and vehicles*) within 60 seconds per condition. Results indicated that individuals with TBI required significantly more cuing and time to complete the bill-paying task, compared to controls. Moderate correlations were observed between bill-paying performance and semantic verbal fluency, such that poorer task performance was associated with fewer correct words generated.

Previously, the investigators of the present study [5] conducted a pilot investigation that explored the relationship between phonemic and semantic verbal fluency performance, as indicated by the total number of correct words generated, and grocery shopping in three participants with moderate to severe TBI and three controls, all of whom were matched on age, education, and gender so that they did not significantly differ. Using the *Delis-Kaplan Executive Function System* [13], participants were asked to generate as many words as possible within a 60-second time allotment for the categories of *boys' names* and *animals* in the semantic condition, and for the letters *F, A,* and *S* in the phonemic condition. Grocery shopping performance was measured using the *Test of Grocery Shopping Skills* [14]. Shopping efficacy was measured by the accuracy of the item, its size and its cost, and total time on the shopping task, the number of aisles and sections of the store that were visited (referred to as a redundancy score), and the number of solicited and unsolicited requests for assistance. Cralidis and Salley [5] found that only performance on the tasks of phonemic verbal fluency was associated with greater shopping efficiency in terms of both speed and overall accuracy. Participants who generated a greater number of correct words for the letter *A* on the phonemic condition also spent significantly less time in shopping for the 10 grocery items. Participants who produced more repetition errors on the phonemic verbal fluency condition only, required a significantly greater time to shop. Shopping efficiency,

defined as the ability to locate all grocery items while visiting as few areas of the grocery store as needed, was significantly correlated with participants who generated a greater number of total correct words for all three conditions on the phonemic verbal fluency task only. No significant correlations were observed between shopping and semantic verbal fluency performance.

The present investigation sought to extend and augment the findings obtained by the authors [5] in their pilot study by exploring verbal fluency performance and completion of a grocery shopping task in a larger cohort of participants with and without moderate to severe TBI. In contrast to the original pilot investigation, participants were not restricted from participation due to age and the shopping task was completed virtually. Three hypotheses were established for this investigation. First, participants with moderate to severe TBI will perform more poorly on phonemic and semantic verbal fluency tasks, as measured by the total number of correct words generated, when compared to controls. Second, performance on both verbal fluency tasks, as assessed by the total number of correct words produced, will be correlated with overall shopping efficiency, defined as the ability to locate all grocery items as quickly as possible, in the correct quantity and at the lowest possible price, while conducting as few searches as needed in order to complete the task. Last, participants with moderate to severe TBI will report greater difficulty in navigating the online shopping task, as measured by a Likert-type rating scale created specifically by the investigators for this study, in comparison to controls.

Materials and Methods

Twenty-two participants (four males, 18 females) with moderate to severe TBI and twenty-two participants (four males, 18 females) without TBI volunteered to participate in this investigation. All participants were paired so that they did not significantly differ relative to age, education, or gender. Refer to Table 1 for clinical data regarding the respective groups. This investigation was initiated after obtaining Institutional Review Board approval and consent.

	TBI		Control		t	df	p
	M	SD	M	SD			
Age	46.50	12.28	46.77	12.60	-0.07	42	.942
Education	15.77	1.88	16.68	1.46	-1.79	42	.080

Table 1: Comparisons between TBI and Control groups on age and education, in years

Participants with moderate to severe TBI were recruited from acquired brain injury support groups throughout the United States. Participants without TBI were recruited from support groups for spouses, friends, and caregivers of TBI survivors throughout the United States. All participants met the following inclusion criteria: 1) Adults at least 21 years of age; 2) native speakers of American English; 3) completion of at least high school; 4) right-handed; 5) able to give legal consent to participate; 6) no history of drugs, alcohol, or other substance abuse; 7) no history of any psychiatric or neurological disorder other than TBI; 8) no history of learning or developmental disability; 9) medically stable at the time of the study; 10) no presence of any motor speech disorder; 11) normal or corrected vision and hearing; 12) adequate upper extremity abilities to use fingers to control a computer mouse and/or trackpad and keyboard; 13) proficient in basic internet skills, including the ability to use search terms, navigate a web browser, locate a web address, and use email functions; and 14) proficient ability to use the audio, video, and screen-sharing functions of Zoom®, a virtual communications platform. In addition, participants in the moderate to severe TBI group also met the following inclusion criteria: 1) diagnosis of a moderate to severe TBI as indicated by an initial Glasgow Coma Scale [15] between three and eight as confirmed by written

documentation from the participant's physician; and 2) at least six months or more post-brain injury. All participants in the TBI group sustained head trauma in adulthood. All participants were screened informally for receptive and expressive language, using an informal measure created by the authors specifically for this investigation, and word finding and retrieval deficits using the *Boston Naming Test* [16].

All participants were given the following test measures: the Verbal Fluency Subtest from the Delis-Kaplan Executive Function System [13] to assess phonemic and semantic verbal fluency; the Online Grocery Shopping Task-2, a modified version of the regional Online Grocery Shopping Task created by Barnes and colleagues [17] to assess shopping performance; and a 7-item, Likert-type rating scale, created by the investigators specifically for this study, to measure participants' perceptions of and frequency of online shopping.

The *Verbal Fluency Subtest* was administered according to the respective published guidelines in the Examiner's Manual for the D-KEFS [13]. The D-KEFS demonstrates good reliability, with adequate to high internal consistency and stable test-retest performance. It also demonstrates strong validity, including well-established construct, convergent, and discriminant validity,

supported by a large, demographically stratified normative sample. For the phonemic condition, all participants were instructed to produce as many words as possible that began with the letters F, A, and S, individually. Participants were asked to refrain from generating names of people, places, and numbers. For the semantic condition, participants were instructed to generate as many words as possible for the semantic categories of *animals* and *boys' names*. Participants were allotted 60 seconds to complete each trial under each condition.

Responses from the Verbal Fluency Subtest were analyzed for the following: 1) Phonemic fluency *F, A, and S* total correct responses for each letter; 2) Phonemic fluency total correct raw score; 3) Semantic fluency *animals* and *boys' names* total correct responses for each semantic category; 4) Semantic fluency total correct raw score; 5) Phonemic and semantic verbal fluency total number of set-loss errors; and 6) Phonemic and semantic verbal fluency total number of repetition errors. These analyses were completed in accordance with procedures expressed in the examiner's manual for the D-KEFS [13].

The *Online Grocery Shopping Task-2* was given to measure grocery shopping performance. Participants were instructed to access Walmart's Pick Up and Delivery Service at <https://walmart.co/grocery> by using a laptop or desktop computer or tablet. Participants logged into the website using credentials created by the investigators for this investigation. Participants were given a written list of 14 pre-designated grocery items and were asked to find the correct items, in the correct size or quantity, and at the lowest price. Examples of items included 'Great Value® apple juice, 64 oz.,' 'Freshness Guaranteed® blueberry muffins, 14.5 oz., 4 count,' and 'Great Value® white bread, 1 loaf.' If an item was unavailable, participants were told to find the most equivalent item in the closest size or quantity, and at the lowest possible price. Performance on the *Online Grocery Shopping Task-2* was analyzed for the following: 1) Total shopping time, in minutes; 2) Total number of correct items placed in the cart; 3) Total number of items selected at the correct price; 4) Total number of items selected in the correct size or quantity; and 5) Total number of searches executed to locate the 14 items. Participants were further instructed to take as much time as they needed to complete the shopping task, but not to waste time. Total shopping time was calculated from the time the participant logged into the website to the time when the last grocery item was placed in the cart. Participants were not required to complete checkout procedures.

Participants were asked to complete a 7-item, Likert-type rating scale, created by the investigators specifically for this study, that explored participants' overall perception of and frequency of online grocery shopping and non-grocery, online shopping. The 5-point scale was coded from 1, indicating 'Never,' to 5, indicating 'Very Frequently.'

All data collection were conducted virtually using Zoom®, a cloud-based video conferencing service that allows individuals to communicate virtually through video and audio. Zoom® was accessed through the university by using the investigators' individual email addresses. Zoom® was equipped with the following security features: compliance with the Health Insurance Portability and Accountability Act (HIPAA), the ability to securely record and store sessions, the requirement of user-specific authentication, and real-time encryption. Data were collected using a Dell Optiplex 3280 AIO desktop computer with Windows 10 and a IPEVO V4K Ultra High Definition 8 MP USB Document Camera in order to screen share all testing materials, including the online shopping task, with participants. All participants reaffirmed consent verbally prior to the beginning of data collection. Data collection was conducted one-on-one and scheduled with the participant's approval. Each session was assigned a unique password that was known only to the investigators and the participant. All test measures were presented both orally

and in written format using document share, and all responses were written and recorded on Zoom® for later review and analysis. All data was collected in a secure, private location. All online data were password-protected and secured in a password-protected computer. Only the investigators had access to the passwords. Data were printed only when needed and was kept in a secured, locked file cabinet that could only be accessed by the investigators. During the online shopping task, participants' engagement on the Walmart platform was observed via participant-enabled screen share on Zoom®, and were recorded and saved under a password known only to the investigators for later analysis.

Statistical Analyses

To explore performance of both participant groups on the phonemic and semantic verbal fluency tasks, the investigators conducted independent t-tests procedures; because the direction of the relationship was not specified, all comparisons were tested using a two-tailed p-value of .05. To explore performance of both participant groups on the *Online Grocery Shopping Task-2*, the investigators conducted Mann-Whitney U tests. To compare perception of and use of internet shopping for both participant groups on the Likert-type rating scale, the investigators conducted independent t-test procedures. To explore the relationship between performance on the verbal fluency measures and the *Online Grocery Shopping Task-2*, the investigators performed Kendall's tau correlations procedures.

Results

Phonemic verbal fluency

The means, standard deviations, and *t-test* results for the total number of correct words, set-loss errors, and repetition errors generated by participants with and without moderate to severe TBI on the phonemic verbal fluency task only are presented in Table 2. The findings indicated that participants with moderate to severe TBI ($M=35.91$, $SD=10.87$) produced significantly fewer total correct words for all three letter conditions when compared to controls ($M=44.68$, $SD=7.68$; $t(42)=-3.09$, $p=.004$). Set-loss and repetition errors occurred infrequently; therefore, no statistical analyses were performed.

Semantic verbal fluency

The means, standard deviations, and *t-test* results for the total number of correct words produced for the semantic verbal fluency tasks for both participant groups are presented in Table 3. The results indicated that participants with moderate to severe TBI ($M=38.77$; $SD=7.82$) generated significantly fewer total correct words for both semantic categories of animals and boy's names when compared to the NBD group ($M=47.64$, $SD=7.79$; $t(42)=-3.77$, $p=.001$). Set-loss and repetition errors occurred infrequently; therefore, no statistical analyses were performed.

The Online Grocery Shopping Task-2 (OGST-2)

The means, standard deviations, and Mann-Whitney U tests results for the total shopping time, in minutes; total number of correct items placed in the cart; total number of items selected at the correct price; total number of items selected in the correct quantity; total number of items selected in the correct size or amount; and total number of searches completed to locate the 14 items are presented in Table 4. Participants with moderate to severe TBI ($M=19.25$, $SD=9.69$) spent significantly more time shopping for the grocery items when compared to the control group ($M=9.81$, $SD=3.07$; $p<.001$). Participants with moderate to severe TBI ($M=19.14$, $SD=8.26$) conducted a significantly greater number of searches in comparison to the NBD group ($M=16.32$, $SD=6.33$, $p=.016$). No significant differences between the groups were observed for the total number of correct items placed in the cart; total number of items selected at the correct price; the total number of items selected at the correct quantity; and the total number of items selected in the correct size or amount.

Variable	TBI		Control		t	df	p
	M	SD	M	SD			
Total correct F words	11.59	3.22	13.95	2.72	-2.63	42	.012
Total correct A words	10.41	4.46	13.23	3.38	-2.36	42	.023
Total correct S words	13.91	4.46	17.50	3.46	-2.93	42	.005
Total correct phonemic fluency	35.91	10.87	44.68	7.68	-3.09	42	.004

Table 2: Comparisons between TBI and Control groups on phonemic verbal fluency

Variable	TBI		Control		t	df	p
	M	SD	M	SD			
Total correct animal names	19.27	5.24	24.23	4.71	-3.30	42	.002
Total correct boy's names	19.45	4.16	23.86	3.62	-3.75	42	.001
Total correct semantic fluency	38.77	7.82	47.64	7.79	-3.77	42	.001

Table 3: Comparisons between TBI and Control groups on semantic verbal fluency

Variables	TBI		Control		U*	p
	M	SD	M	SD		
Total time spent in shopping for the 14 items	19.25	9.69	9.81	3.07	56.5	<.001
Total number correct items placed in cart	12.50	1.50	12.82	1.05	220.0	.589
Total number correct price	12.82	1.50	12.95	1.36	231.5	.794
Total number correct quantity	12.86	1.58	13.32	0.95	218.0	.536
Total number correct size or amount	12.77	1.45	12.95	1.09	233.0	.824
Total number item searches	19.14	8.26	16.32	6.33	142.0	.016

Table 4: Comparisons between TBI and Control groups on the online grocery shopping task

* Mann-Whitney U test

The 7-item, Likert-type rating scale: Self-perception of online shopping

The means, standard deviations, and t-test results for the Likert-type rating scale are displayed in Table 5. The only significant difference observed between the groups was in the ease of online shopping.

Those with moderate to severe TBI ($M=3.62, SD=1.02$) had greater difficulty completing the online shopping task in comparison to participants in the control group ($M= 4.55, SD=.67; t(34.3)=-3.49, p=.001$). There were no significant differences between the groups on any of the other items on the rating scale.

Variables	TBI		Control		U*	p
	M	SD	M	SD		
Frequency online shopping	3.27	0.94	3.86	1.04	-1.99	42 .054
Ease of online shopping ^a	3.62	1.02	4.55	0.67	-3.49	34.3 .001
Enjoyment of online shopping	3.43	1.03	3.86	0.99	-1.41	41 .165
Frequency to walmart.com	2.55	1.26	2.23	0.87	0.97	42 .336
Frequency of non-grocery only	3.36	1.18	3.86	0.99	-1.53	42 .135
Frequency of grocery only ^a	2.18	1.37	2.05	0.90	0.39	36.3 .698
Tendency of online grocery only ^a	2.10	1.48	1.82	0.80	0.76	30.3 .453

Table 5: Comparisons between TBI and Control groups on the 7-item rating scale: Self-perception of online shopping

^aEqual variances not assumed

Relationships between performance on the phonemic and semantic verbal fluency tasks and the *OGST-2*

The correlations between performance for both verbal fluency tasks and performance on the *OGST-2* participants with moderate to severe TBI only are presented in Table 6. Three significant negative correlations were observed. The total time shopping for the 14 grocery items was significantly shorter for participants with moderate to severe TBI who were able to generate a greater number of total

correct words for the semantic category of *animals* only ($Tb=-.343, p=.029$), and for both semantic categories of animals and boys' names, together ($Tb=-.362, p=.020$). Participants with moderate to severe TBI who completed fewer searches for the 14 items during the shopping task generated a significantly greater number of total correct words for the semantic category of boys' names only ($Tb=-.353, p=.029$).

	Phonemic Verbal Fluency Total Correct				Semantic Verbal Fluency Total Correct		
	F Words	A Words	S Words	Overall	Animal Names	Boy's Names	Overall
Online Grocery Shopping Task							
Time shopping for the 14 items	.055	-.140	-.032	-.075	-.343*	-.235	-.362*
Number correct items in cart	.041	.000	-.035	.054	-.015	.181	.059
Number correct price	-.037	.031	-.058	.000	.139	.089	.133
Number correct quantity	.000	.060	.017	.069	.070	.197	.150
Number correct size/amount	.047	-.119	-.062	-.005	.091	-.077	.040
Number item searches	-.033	-.089	-.052	-.064	-.101	-.353*	-.205

Table 6: Kendall's tau-b correlations between verbal fluency and the online shopping task variables for participants with moderate to severe traumatic brain injury (n = 22)

* $p < .05$

Discussion

This investigation endeavored to expand and augment the findings previously published by the authors in their initial study [5] that explored the utility of verbal fluency tasks to predict who may or may not have difficulty completing an IADL such as grocery shopping following moderate to severe TBI in a larger cohort of participants.

Participants with moderate to severe TBI generated significantly fewer total correct words for all conditions on both phonemic and semantic verbal fluency tasks. The findings remained significant for each individual letter under the phonemic condition and for both semantic categories on the semantic condition. These findings support previous investigations that have demonstrated that both phonemic and semantic verbal fluency performance are equally affected following TBI [8, 9, 11, 18-20]. On the online grocery shopping task, participants with moderate to severe TBI took significantly longer to shop for all 14 grocery items and executed a significantly greater number of searches in order to locate all items. No other significant differences were observed between the groups relative to the total correct number of grocery items placed in the cart; total number of items at the correct price; total number of items in the correct quantity; and total number of items in the correct size or amount. In part, the lack of significance on other aspects of the shopping task may be explained by the fact that our participant groups were overwhelmingly female, as previous research has demonstrated that online grocery shoppers tend to be primarily female [21-23]. Thus, it is possible that female shoppers may also be more efficient shoppers. Another possible explanation for the lack of significance in the present investigation may reflect the fact that a greater number of people shopped online for groceries during 2020 when compared to previous years [24, 25]. It is possible that some participants had more experience in navigating an online shopping platform. On the Likert-type rating scale that probed for self-perception of online shopping, those with moderate to severe TBI reported significantly greater difficulty with virtual shopping when compared to controls. An analysis of the correlations between performance on the verbal fluency tasks and online grocery shopping for participants with moderate to severe TBI only suggested that those who generated a greater number of total correct words for the semantic category of *animals* took significantly less time to shop for all 14 items, and also produced a significantly greater total number of correct words for both semantic verbal fluency categories. A significant correlation was also observed between the total number of searches needed

to locate all 14 items and the generation of *boys' names*; that is, those with moderate to severe TBI who made fewer searches on the shopping task produced a significantly greater number of total correct words for the semantic category of *boys' names*.

The present findings partially replicate those of our earlier pilot study [5], as participants with moderate to severe TBI produced significantly fewer correct words for the letter A on the phonemic verbal fluency task. In contrast to the pilot study which found phonemic fluency to be associated with shopping efficiency the current results showed that semantic verbal fluency was significantly related to overall shopping efficiency (i.e., time to task completion and number of searches). Differences in sample size may account for these discrepancies. These findings are consistent with prior work [4, 7], demonstrating that reduced semantic verbal fluency is associated with decreased efficiency in complex everyday tasks such as meal preparation and financial management.

In essence, verbal fluency tasks have a meaningful utility in post-acute rehabilitation settings as a measure that affords one means by which to gauge functional independence. These tasks may help clinicians to identify individuals who are more likely to require additional support in the execution and management of complex, multi-step daily activities. This has direct relevance for discharge planning, as performance on verbal fluency tasks could contribute to decisions regarding level of supervision, need for outpatient services, caregiver involvement, or transition to a higher level (i.e., skilled nursing, assisted living) upon community re-entry. Moreover, the use of verbal fluency tasks may also be useful, when combined other assessments, in providing a more comprehensive overview of real-world abilities following moderate to severe TBI.

Limitations and Future Directions

This study has several limitations that should be considered when interpreting the findings. The relatively small sample size (N=44) may limit statistical power and the generalizability of our results. Future research should focus on the recruitment of a greater number of participants that include not only those with moderate to severe TBI, but also concussion. Additionally, the sample was characterized by gender imbalance which may further constrain the applicability of findings across populations. It is also suggested that future research should address racial and ethnic diversity among survivors of TBI. Another recommendation is to include an equal distribution of gender between the participant groups. An exploration of the effect of age-

related declines on verbal fluency performance is also suggested. Age-related declines, particularly on semantic verbal fluency tasks only, have been consistently reported in the existent literature [26-28], with younger adults performing significantly better, as indicated by the total number of correct words generated, when compared to older adults. It may be prudent to focus investigative efforts on performance on tasks of phonemic verbal fluency as age-related differences in performance, as also indicated by the total number of correct words produced, have been less consistent in comparison to semantic verbal fluency [26, 27, 29-32]. The use of a non-standardized Likert-type rating scale may have introduced concerns regarding measurement reliability and validity. Another consideration is the collection of data using Zoom, a cloud-based platform that is used for virtual collaborations. The sample may reflect a bias toward individuals with greater digital literacy and access to technology, potentially limiting representativeness. Last, an exploration of the specific executive functions that may contribute to efficacious performance on verbal fluency tasks is also indicated, and may help to aid in the development of appropriate treatment techniques to improve overall independence and efficiency in completing various IADLs.

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Declaration of Interest Statement: The authors report that there are no competing interests to declare.

Gexin also requires a list of abbreviations, stating: "authors should follow the guidelines in the Council of Biology Editors Style Manual, 5th edition. All other abbreviations should be defined when first used and listed in a footnote; Abbreviations PDF". While most abbreviations were introduced in the body of the paragraph I just wanted to draw attention to this requirement just in case.

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