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The Use of Non-Immersive Virtual Reality as a Functional Rehabilitation Tool for Older Adults with Cognitive Decline

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NON-IMMERSIVE VIRTUAL REALITY AS A FUNCTIONAL REHABILITATION TOOL FOR OLDER ADULTS WITH COGNITIVE DECLINE

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Abstract

There is currently no cure for age-related cognitive decline or dementia and current pharmacologic interventions have had limited success at improving daily functioning. Consequently, older adults who experience cognitive decline require assistance with daily activities, which can be quite expensive and lead to caregiver burden. Repeated performance of everyday tasks has been shown to improve performance but requires supervision and direction by another person. The present study evaluated a low-cost computer training program that will use non-immersive virtual reality to enable participants with dementia or cognitive decline to independently practice meaningful everyday activities (e.g., meal preparation). Participants (N= 8) with self-reported cognitive decline underwent daily training sessions on one of two different everyday tasks for one week. Baseline and post-training (within 48 hours of the last day of training and at one month post training) testing was done with real objects and tasks and included both trained and comparable untrained tasks. Results indicated that those mild cognitive impairment (MCI) were the only ones to show benefit from the training in terms of errors post intervention. Results also indicated a relationship between a screener of global cognition and post intervention time to completion, such that those with higher baseline cognition needed less time to complete the trained task post intervention.

INTRODUCTION

Overview of Dementia

In 2012, research conducted by the World Health Organization (WHO) concluded that 7.7 million individuals around the world are newly diagnosed with dementia each year, and with our current aging population, this number is only likely to increase (World Health Organization, 2012). Further research conducted by WHO in 2017 estimated that around 50 million people worldwide are living with dementia currently (World Health Organization, 2017). In particular, Alzheimer's, the disease thought to lead to the most common variant of dementia which has no cure, makes up about 60-70 % of these cases each year (World Health Organization, 2012). Furthermore, dementia remains one of the costliest conditions of modern medicine (Wimo, Winblad, & Jönsson, 2010), both in the actual financial cost of the functional disability associated with the disease (Hill, Fillit, Thomas, & Chang, 2006**)**, as well as the increased caregiver burden often placed upon family members of those suffering from dementia (Razani et al., 2007**)**.

Dementia and Everyday Function

The two cardinal features of all variants of dementia are major cognitive dysfunction that leads to severe functional impairment and disability (Payne et al., 1998). While declines in the cognitive abilities and everyday function of individuals suffering from dementia are both deleterious, the symptom of function disability is the factor most associated with increased financial cost (Wimo et al., 2010), caregiver burden (Hill et al., 2006), and generally poorer health outcomes for individuals such as medication mismanagement (El-Saifi, Moyle, Jones, & Tuffaha, 2018). The importance of functional disability is further emphasized by the fact that

even when modern medications for dementia succeed in improving cognition, they often do not drastically improve the everyday function of afflicted individuals (Feldman et al., 2003**).** Mild cognitive impairment (MCI), thought of as a prodromal state of dementia, is distinguished from dementia in that it does not cause significant impairment to everyday function of individuals. However, emerging evidence has found that even in healthy cognitive aging and the early stages of MCI, subtle changes in everyday function may be present, and that these early changes represent a strong predictor for future decline and conversion to dementia (Farias et al., 2017). Given this emerging evidence, as well as evidence that suggests MCI may represent a critical period for early interventions to delay disease progression and perhaps even revert to a healthy cognitive status, the need for targeted interventions of everyday function remains critical for this population.

Models of Functional Decline

As previously stated, emerging evidence has suggested that subtle changes in everyday function can be found in healthy aging and the early stages of MCI, and that these subtle functional changes are associated with increased risk for conversion to dementia (Farias et al., 2017). Furthermore, this emerging evidence has led to the refinement of our understanding of functional decline in MCI and dementia, with a new model (Farias & Giovannetti, in press) now suggesting that functional decline actually follows a similar path as the cognitive decline noted in healthy cognitive aging, MCI, and dementia. Given the subtle nature of these newly studied early functional changes, it is not surprising that older models often did not capture these discrepancies, as their focus instead was on overt breakdowns in everyday action and did not believe that individual domains of cognition were involved in these errors, rather, that they reflect gross brain dysfunction (Scwartz, Mayer, FitzpatrickDeSalme, & Montgomery, 1993). In

2008, however, Giovannetti and colleagues (2008) redefined our understanding of functional decline, particularly in terms of how individual domains of cognition related to everyday function, with the new omission-commission model, which suggested that the overt errors in everyday tasks often observed in individuals with dementia broadly fell into two categories: omissions, in which portions of the task are not completed and which were highly correlated with both episodic memory (Giovannetti et al., 2008) and damage to the hippocampus (Seidel et al., 2013), and commissions, in which steps of the task are completed but are performed highly inaccurately and which were highly correlated with both executive function (Giovannetti et al., 2008) and damage to the frontal lobe (Seidel et al., 2013). Additionally, in 2014, Selgiman and colleagues (Seligman, Giovannetti, Sestito, & Libon, 2014) further refined this model, particularly in terms of assess mild changes in daily functioning, by introducing the "micro-error", which represented subtle, inefficiencies in everyday tasks, though not inherently incorrect, are associated with progressively worse error monitoring and increased risk for future decline (Rycroft, Giovannetti, Divers, & Hulswit, 2018).

Approaches to Rehabilitation

Historically, research on neurocognitive rehabilitation has primarily focused on individuals who have suffered a traumatic brain injury (TBI) or stroke, with two primary techniques of rehabilitation focusing on remediation of deficits if possible and the creation of compensatory strategies with preserved cognitive abilities (Stringer, 2017). In terms of remediation of cognitive abilities, particular domains of cognition that are often targeted are attention, executive function and memory (Stringer, 2017). While these techniques have been shown to benefit some individuals, a growing emphasis of increasing the ecological validity of neurocognitive rehabilitation remains of high importance, as the ultimate goal of this

rehabilitation is to help individuals to reach their optimal level of functioning in day to daily life (Winson, Wilson, & Bateman, 2016). Furthermore, there has been a recent shift in the literature at attempting to translate neurocognitive rehabilitation techniques that have benefited individuals suffering from TBI or stroke into other populations, particularly those suffering from or who are high risk for cognitive decline and dementia (Coyle, Traynor & Solowij, 2015), as we have limited treatment options for these individuals and even neurocognitive rehabilitation techniques that have been found to be beneficial often produce less benefit in individuals with larger impairment (Stringer, 2017). Proposed approaches to neurocognitive rehabilitation for individuals with MCI and dementia have varied from compensatory strategy-based interventions using alarms and memory notebooks (Schmitter-Edgecombe, Howard, Pavawalla, Howell & Rueda) to repeated practice of a single task attempting correct errors before they occur, in keeping with errorless learning theory (Clare et al., 2000). While both approaches have been shown to benefit some individuals, approaches that apply errorless learning theory may be particularly valuable as they can be done in a format to better address the growing desire for these interventions to improve the everyday function of those with MCI and dementia (Foloppe, Richard, Yamaguchi, Etcharry-Bouyx, & Allain, 2015).

Virtual Reality in Neurocognitive Rehabilitation

A proposed solution to this need for cost-efficient neurocognitive rehabilitation techniques for individuals with MCI and dementia that also have high ecological validity has been the incorporation of technologies and virtual environments, as these tools are likely to be cost-efficient, require less clinician supervision, and may translate best to the issues individuals face in day-to-day life (Giovannett et al., 2019). In particular, a recent case study on the use of virtual reality-based training to improve everyday function in an individual with severe dementia

due to probable Alzheimer's disease has been of particular interest to the field (Foloppe et al., 2015). In this study, Foloppe and colleagues compared everyday task training with real objects to virtual objects while also examining neuropsychological and everyday function following the intervention. Results from this study showed improved function in the individual, and was the first of its kind to show that training done on a virtual system could improve functioning in the real world for this population. While the results from this case-study remain exciting to the field, there were a number of limitations to this study. Given that the research done by Foloppe and colleagues (2015) was a case-study, the generalizability of interventions of this nature is still in question. Additionally, given the severity of impairment of the individual in the case study, it is not surprising that they retained little functional gains at a six month follow up assessment. Additionally, the outcome measure chosen by Foloppe and colleagues (2015), task accomplishment, is limited as other more subtle measures of improvement may be investigated.

Proposed Study

The present study sought to add to this field by applying similar methods to the Foloppe study (Foloppe et al., 2015), with some additional elements. The first aim of the present study involved the recruitment of multiple individuals with a range of impairment and utilized a more detailed outcome analysis of everyday function. The addition of more participants served to examine the generalizability of this intervention and decipher who may benefit most from this kind of intervention. The addition of additional outcome measures served to characterize everyday function more accurately. While task completion is an important outcome, other outcomes such as: speed of task accomplishment (task efficiency), errors of executive function that are not captured by task accomplishment (ie. commissions, Giovannetti et al., 2008), and subtle inefficiencies that have been correlated with increased future impairment (ie. "micro-

errors", Seligman et al., 2014), were examined as outcome measures with real objects following training on the virtual system. The second aim of the present study was to examine if participant characteristics (age, depression, and global cognitive ability) were related to post-test scores. For aim 1, it was hypothesized that changes will be largest in time to completion and micro-errors. For aim 2, it was hypothesized that baseline cognitive function, age and depression will predict follow-up everyday function, such that individuals with greater cognition at baseline, of lower age, and reporting less depression, will retain improved everyday function at the follow-up compared to individuals with lower cognitive abilities at baseline.

METHOD

Participants

Participants of this study included 8 older adults with a range of cognitive impairment. Previously, 6 participants, who had a range of cognitive impairment (subjective cognitive complaints, MCI), were referred by local neurologists or identified and recruited from community memory screens. In order to examine the effects of the intervention more fully across a range of cognitive impairment, two additional participants with moderate cognitive impairment (MMSE score = 17-19) were recruited. Inclusion criteria included fluency in English and being least 65 years of age. Participants also had to have an informant that they have regular contact with that can answer questions about their current level of functioning. Exclusion criteria included a history of traumatic brain injury, Huntington's disease, Parkinson's disease, ADHD, and schizophrenia. To illustrate potential difference across populations, participants were given a cognitive status designation following entry into the study. Participants 1-4 reported cognitive decline, though fell in cognitively normative range on global cognition screener and were thus designated as having "subjective cognitive complaints". Participants 5 and 6 fell in a range consistent with MCI in prior research (Arevalo-Rodriguez et al., 2015) and were thus designated as "MCI" for the purposes of the present study. Participants 7 and 8 fell in a range consistent with moderate cognitive impairment/dementia in prior research (Arevalo-Rodriguez et al., 2015). See Table 1 for sample characteristics.

Table 1. Sample Characteristics

ID	Age	Cognitive Status	Sex	Race	MMSE	GDS
1	66	Subjective Complaints	Male	African American	30	12
2	67	Subjective Complaints	Male	Caucasian	29	2
3	70	Subjective Complaints	Female	Caucasian	27	4
4	93	Subjective Complaints	Female	African American	25	16
5	84	MCI	Female	African American	23	0
6	88	MCI	Female	Caucasian	24	12
7	71	Dementia	Male	Caucasian	17	2
8	93	Dementia	Male	Caucasian	19	2

*****MMSE = Mini Mental Status Exam, GDS = Geriatric Depression Scale

Procedures and Measures

Measures

Demographic Information. Demographic data to be collected included age, gender, and race.

Global Cognitive Functioning. The Mini-Mental Status Exam (MMSE) is a brief, screening pencil-and-paper measure of global cognitive status (Tombaugh & McIntyre, 1992). The MMSE consists of 11 questions that are grouped into seven categories representing different domains of cognitive function (Tombaugh & McIntyre, 1992). The MMSE generally has demonstrated high test-retest reliability in samples of healthy individuals and those demonstrating moderate cognitive impairment (*r*s =.8-.95; Tombaugh & McIntyre, 1992). In terms of validity, the MMSE generally has high sensitivity when administered to individuals with moderate to severe cognitive impairment due to dementia (87%; Tombaugh & McIntyre, 1992).

Everyday Functioning. The Naturalistic Action Test (NAT) is a performance-based measure of everyday functioning in which participants complete three everyday tasks. The NAT

has good internal consistency (Schwartz, Segal, Veramonti, Ferraro, & Buxbaum, 2002), it has been shown to correlate with the Functional Impairment Measure (r = 0.5) in participants with stroke (Schwartz et al., 2002) and with caregiver ratings of activities of daily living/instrumental activities of daily living in people with dementia (Giovannetti et al., 2002). The modified lunch and breakfast tasks were chosen to be administered due to their similar levels of difficulty (Giovannetti et al., 2019).

Depression. The Geriatric Depression Scale-Short Form (GDS; Herrmann et al., 1996) was completed by participants at the baseline assessment, immediate post-training assessment, and one-month follow-up assessment. Data from the baseline assessment are used in this study. The GDS short form is a 10-item self-report questionnaire that asks whether or not they have experienced symptoms related to depression in the last two weeks. In terms of validity, the GDS short form highly correlates with the previously validated long form (*r* = .89; Lesher & Berryhill, 1994) and has demonstrated a sensitivity of 85% for major depressive disorder in an outpatient sample (Herrmann et al., 1996). In terms of reliability, the GDS has demonstrated high test-retest correlations (*r* = .84; Yesavage et al., 1982).

Study Timeline

Participants were assigned to train on one of two tasks in a counterbalanced form: 1. making a **breakfast** consisting of toast with butter and jelly and coffee with cream and sugar and 2. packing a **lunchbox** with a peanut butter and jelly sandwich, a drink, and a snack. These tasks are derived from the Naturalistic Action Test (Schwartz et al., 2002), a performance- based measure of everyday functioning. For the initial assessment, participants were asked to perform both tasks with real objects while being video recorded for scoring purposes (hereafter the

administration of these two tasks for assessment purposes will be referred to as the Naturalistic Action Test; NAT). Following the initial assessment, participants underwent training on one of the NAT tasks. The task on which participants were trained was counterbalanced across participants, so that half of the participants were trained on the lunch task and the other participants were trained on the breakfast task. Training took place using the Virtual Kitchen for four days. During training, participants were given feedback about their performance on the trained task. Feedback was provided following several guidelines. Cues during the training were given to participants after 30 seconds of inactivity, when incorrect actions were performed, or when "clumsy" errors occurred (errors due to the virtual kitchen and not participant performance). Participants were required to complete the kitchen task 10 times (or for 30 minutes) with feedback at each training session. If they were unable to complete 10 trials, the training session ended after 30 minutes. One to two days after the four days of 30-minute training sessions, the immediate assessment was administered. The immediate assessment included both everyday tasks (lunch, breakfast) with real objects (i.e., Naturalistic Action Test; NAT) to examine if training on the virtual kitchen translated to everyday actions with real objects and whether improvement is specific to the everyday task that was trained. Finally, following one month after the immediate assessment, individuals received a follow up assessment in which the individual again performed both everyday tasks with real objects (i.e., Naturalistic Action Test; NAT) to examine if they retained any benefit.

Analysis Plan

To test aim 1, reliable change indices (RCIs) of the everyday action performance before vs. after training (immediate and one-month) for all outcome measures (time to completion, total

omission errors, total commission errors, and total micro-errors) were calculated. To test aim 2, correlations between baseline cognition (MMSE), baseline depression (GDS) and age and immediate and one month follow-up outcome variables for both the trained and untrained NAT tasks were calculated.

RESULTS

Trained Task RCIs

Between baseline and the immediate follow up assessment, participant 5 showed a trending significant decrease in omission errors, and significant reduction in commission errors. At the one month follow up, participant 5 retained some long-term benefit from training by retaining a trending significant reduction in commission errors. Participants 7 and 8 showed significant increases in task completion time at the one month follow up and immediate follow up assessments respectively. Following this pattern, participants 7 and 8 also had significant increases in micro-errors at these same time-points. While participants 7 and 8 were able to complete more of the task following the intervention, it appears that this caused them to take an excess amount of time to complete the task. Given previous research that older adults make an increasing number of micro-errors during task performance due to goal decay, this result was unsurprising (Divers et al., 2021). No other significant changes were found. See Table 2 and Table 3.

Table 2. Post intervention RCIs for Trained Task at the Immediate Follow Up Assessment

ID	Completion Time	Omission Errors	Commission Errors	Micro-Errors
1	-0.2	-0.19	0	-0.25
2	-0.47	0	-0.56	0.25
3	-1.01	-0.19	0	-0.25
4	-0.02	0	0	-0.76
5	0.83	-1.67*	-2.26**	0.25
6	-0.51	-0.19	0	-1.02
7	1	-0.19	-0.57	1.53
8	2.78**	-0.93	1.13	5.09**

** indicates significance at the 95% level of confidence, * indicates significance at the 90% level of confidence

Table 3. Post intervention RCIs for the Trained Task at the 1 Month Follow Up Assessment

ID	Completion Time	Omission Errors	Commission Errors	Micro-Errors
1	-0.14	-0.19	0	0
2	-.37	0	-0.56	0.25
3	-1.15	-0.19	-0.57	-0.76
4	-0.07	0	0	-0.76
5	-0.15	-0.19	-1.7*	-0.25
6	-0.79	-0.37	-0.57	-0.76
7	2.12**	0.37	0.57	2.29
8	0.4	0.37	0	0

** indicates significance at the 95% level of confidence, * indicates significance at the 90% level of confidence

Untrained Task RCIs

Between baseline and the immediate follow up assessment, participant 5 showed a significant increase in micro-errors. Between the baseline and both the immediate and one month follow up, participant 6 showed a significant increase in omission errors. No other significant changes were found. See Table 4 and Table 5.

Table 4. Post Intervention RCIs for the Untrained Task at the Immediate Follow Up Assessment

ID	Completion Time	Omission Errors	Commission Errors	Micro-Errors
1	-0.14	0	0.51	0.38
2	-0.28	-0.33	0	-0.75
3	-0.2	0	0.51	-0.56
4	-0.38	-0.33	-0.51	-0.56
5	0.53	-1	-0.51	3.76**
6	-0.88	1.67*	0	-1.13
7	-0.26	0.67	0.51	-0.94
8	1.43	-0.33	0.51	1.5

** indicates significance at the 95% level of confidence, * indicates significance at the 90% level of confidence

Table 5. Post Intervention RCIs for the Untrained Task at the 1 Month Follow Up Assessment

ID	Completion Time	Omission Errors	Commission Errors	Micro-Errors
1	-0.22	0	0	0.19
2	-0.35	-0.33	1.02	-0.75
3	-0.33	0.33	0.51	-0.75
4	-0.52	-0.33	-0.51	-0.38
5	0.09	-0.33	0.51	0.19
6	1.03	1.67*	0.51	-0.94
7	0.19	0.33	-1.02	-0.19
8	0.88	-0.33	0.51	-0.19

* indicates significance at the 90% level of confidence

Predictors of Post Intervention Change

There was significant relationship between baseline global cognition and both pre-immediate follow up and pre-one month follow up time to completion RCIs for the trained task. This correlation was such that higher baseline global cognition was related to decreased time to completion RCIs at both follow ups for the trained task. No other significant relationships were noted between predictors and RCIs for both the trained and untrained tasks. See Table 6 and 7.

Table 6. Correlations among participant characteristics and trained task RCIs

	1	2	3	4	5	6	7	8
1. Age	-							
2. MMSE	-0.46	-						
3. GDS	0.26	0.38	-					
4. Immediate Time	0.48	-0.75*	-0.28	-				
5. 1 Month Time	-0.05	-0.73*	-0.28	0.59	-			
6. Immediate Omissions	-0.36	0.36	0.54	-0.57	-0.05	-		
7. 1 Month Omissions	0.1	-0.68	-0.41	0.75*	0.8*	-0.04	-	
8. Immediate Commissions	0.2	-0.05	0.35	0.2	-0.04	0.48	0.32	-
9. 1 Month Commissions	-0.12	-2.8	0.3	0.2	0.59	0.64	0.61	0.67
10. Immediate Micro-Errors	0.27	-0.63	-0.54	0.91**	0.47	-0.39	0.8	0.42
11. 1 Month Micro-Errors	-0.4	-0.55	-0.45	0.37	0.91**	0.88	0.69	-0.13

** indicates significance at the $p < .01$ level, * indicates significance at the $p < .05$ level

Table 7. Correlations among participant characteristics and untrained task RCIs

	1	2	3	4	5	6	7	8
1. Age	-							
2. MMSE	-0.46	-						
3. GDS	0.26	0.38	-					
4. Immediate Time	0.32	-0.4	-0.54	-				
5. 1 Month Time	0.1	-0.56	-0.63	0.91**	-			
6. Immediate Omissions	-0.01	-0.16	0.37	-0.61	-0.51	-		
7. 1 Month Omissions	0.04	-0.07	0.31	-0.6	-0.6	0.93**	-	
8. Immediate Commissions	-0.48	-0.12	-0.23	0.17	0.36	0.32	0.17	-
9. 1 Month Commissions	-0.03	0.46	-0.3	0.2	-0.09	-0.2	-0.01	-0.09
10. Immediate Micro-Errors	0.28	-0.17	-0.44	0.72*	0.54	-0.68	-0.49	-0.31
11. 1 Month Micro-Errors	-0.02	-0.18	-0.15	0.53	0.58	-0.55	-0.55	-0.02

** indicates significance at the $p < .01$ level, * indicates significance at the $p < .05$ level

DISCUSSION

Dementia is a rising global health concern that is known for its deleterious impacts on everyday function (Hill et al., 2006; World Health Organization, 2017) While pharmacological treatments exist for dementia, they largely fail at restoring everyday functioning of patients (Feldman et al., 2003). Previous research by Foloppe and colleagues (2014), which made use of a similar, non-touch screen virtual environment and intervention protocol, found that repeated practice of everyday activities on a virtual system can significantly improve functioning with real world objects in a single case study on dementia. The present study sought to replicate and extend these findings by including multiple participants of various levels of impairment, both for generalizability and to assess who this type of intervention may be most beneficial for. The present study also sought to extend past research by assessing multiple kinds of functional outcomes and by examining if participant characteristics were significantly related to post-intervention changes.

In the present study, there were significant decreases for multiple kinds of functional errors in one of the MCI designated participants for the task that they received the intervention on. For untrained task, there were significant increases in various kinds of errors at the immediate and one month follow up for both of the MCI designated participants. For the dementia designated participants, there were increases in both time to completion and micro-errors on the task they were trained on. While the original hypotheses were that time to completion and micro-errors would show the most post-intervention decreases, given that they are theoretically the easiest to improve upon, the findings do align with broader literature showing that as older adults take more time to complete everyday tasks, their micro-errors increase (Divers et al., 2021). Older adults who were designated as having subjective complaints,

though normative levels of functioning on screener did not show any significant changes following intervention.

One of the aims of the present study was to begin to identify which populations of older individuals may benefit most from this kind of intervention. While only one of the two MCI designated participants showed substantial changes in the task they were trained on, both participants with MCI showed declines on the tasks they were not trained on. It is therefore possible that, while an intervention like this may not lead to large improvements in task performance for those with MCI, it may work to stave off further decline. Comparatively, normative cognition and dementia participants did not show benefit from the intervention, and even showed decline respectively. It is likely that participants designated as subjective cognitive complainers with normative cognition simply did not have much room to improve upon from the start, given that their average amount of omission and commission errors at pre intervention was .5 for the trained task.

For dementia designated participants, while they did show some non-significant improvement in some areas (e.g., participants 8's immediate follow up omission RCI = -.93), they showed increased time to completion and subsequent increases in the number of micro-errors made. Previous research on functional performance using similar tasks have sometimes employed scoring systems focused on how many steps (e.g., pack a sandwich, beverage, and snack) and/or sub-steps (e.g., sandwich = spread peanut butter, spread jelly, wrap sandwich in foil, pack sandwich in lunch box; Divers et al., 2021). Based on a post-hoc, sub-step analysis focused solely on task completion, the dementia participants had mixed results. For example, pre-intervention, participant 8 only performed 2/11 sub-steps on the task they were trained on. At their immediate follow up assessment, they performed 8/11 sub-steps for the task they were

trained. However, pre-intervention, participant 7 performed 6/8 sub-steps on the task they were trained on, while at the immediate follow up assessment they performed 5/8 sub-steps. Given this mixed evidence, it is possible the findings may be consistent with results found by Foloppe and colleagues (2014), though future research is needed.

Based on the current results, future research on the current intervention may be most beneficial for individuals with MCI. This aligns with the broader literature that those with MCI can have moderate-to-large benefits from continued cognitive exercises (Gates, Sachdev, Singh, & Valenzuela, 2011). Further, this aligns with the theoretical standpoint and prior research showing that MCI marks a period sensitive to intervention to slow future decline and even potential reversion to normative cognition (Roberts & Knopman, 2013). Primary strengths of the current intervention platform (i.e. the virtual kitchen [VK]) is its relative ease of administration, general tolerability amongst participants, semi-automated scoring for some of the aforementioned error types, and that participants can independently and/or with a caregiver review their performance each they perform the task (Giovannetti et al., 2019). While interventions with objects in a similar fashion to the current intervention have shown some benefits, these interventions typically require the presence of a trained therapist (Giovannetti et al., 2019). While the VK boasts a number of advantages, it should be noted that there are a number of other modern approaches to functional interventions in similar populations that may serve to further refine intervention research with the VK. For example, more recent work in this area has found that continuous cueing via a SmartPhone application may be useful for individuals with MCI and dementia (Hackett et al., 2020). An additional promising approach involved having participants visualize and plan out how they will perform an everyday task before performing everyday tasks. Work by Faytell and colleagues (2017) found that

visualization increased performance in a naturalistic, everyday prospective memory-based task in sample of individuals with HIV. Given that prospective memory is often impaired in individuals with MCI and dementia (Thompson, Henry, Rendell, Withall, & Brodaty, 2010), and the strong relationship between prospective memory and everyday function (Faytell et al., 2017), incorporation of visualization before everyday task performance may be an important future direction for this area of research.

A second aim of the present study was to examine if participant characteristics, such as baseline age, depression, and global cognition were related to post intervention changes in outcomes. There was a relationship between global cognition and time to completion for both the immediate and one month follow up assessment on the trained task. This finding is consistent with broader literature, showing that global cognition is related to, though not the most sensitive measure of everyday functioning (Gross, Rebok, Unverzagt, Willis, & Brandt, 2011). There were not associations between age and depression and the post-intervention outcomes. This is inconsistent with the larger body of literature on age and depression and everyday functioning in older adults. In terms of age, numerous theories have arisen to explain this association, ranging from the tendency for caregivers to rate older adults as being more functionally dependent (Martyr et al., 2012) to evidence that older adults demonstrate increased "goal" decay when performing everyday tasks (Paxton, Barch, Racine, & Braver, 2008). Likewise, depression has also been consistently related to functional impairment in this population, either directly (Yen, Rebok, Gallo, Jones, & Tennstedt, 2011) or indirectly by increasing risk for cognitive decline and dementia development (Dotson, Beydoun, & Zonderman, 2010). Given the sample size, it is likely that there was not sufficient power to detect these effects.

Limitations

While the present study aimed to add to an important area of research using novel methods, important limitations should also be noted. The most apparent limitation of the present study is the small sample size. While the present study expands upon previous research using a single case study design (Foloppe et al., 2014), the small sample size limited the ability to detect expected effects and the ability to conduct group-based analyses. Further, upon conducting cognitive assessments, four participants fell in a normative cognitive range, causing them to have little room to improve from the intervention. Future work in this area should involve a baseline screening before enrollment in the study to ensure individuals are not already "at ceiling", while also ensuring that individuals are not so impaired as to not be able to fully comprehend the intervention. An additional limitation of the study was a focus on elaborate, error-based coding as outcomes. While error-based coding has been employed to functional tasks in the past and has been found to be sensitive to both measures of cognition and subtle measure of everyday dysfunction (Seligman et al., 2014), this approach eliminated potential broader post-intervention gains, such as simple level of task accomplishment (Giovannetti, Bettcher, Libon, Brennan, Sestito, & Kessler, 2007). Future work would benefit from an integrative approach for assessing post-intervention changes.

Despite increasing rates of dementia diagnoses every year, a dearth of interventions specifically aimed at improving everyday functioning still remains. This is particularly problematic given evidence that functional disability associated with dementia is a driving factor in association with both increased healthcare costs (Hill et al., 2006) and caregiver burden (Razani et al., 2007). The present study built on a previous case-study examining the benefit of rehabilitation conducted in a virtual environment. Specifically, the study aimed to identify which individuals may be most appropriate for an intervention like this, to incorporate a more detailed

examination of post-intervention changes, and to identify factors associated with change. Results indicated that individuals with MCI may receive the most benefit from an intervention of this kind in terms of improvement of errors, as older individuals with normative cognition or dementia may have too little room to improve or not be able to fully comprehend the current iteration of the intervention. In terms of specific scores, results indicated improvements in various error types for one individual, but also showed time to completion and micro-errors may increase for individuals with dementia. Results also indicated an association between global cognition and post-intervention time to completion. Future work in this area would benefit from collecting additional data, specifically on those with MCI, and incorporating an integrative approach to assessing potential post-intervention changes.

References

Arevalo-Rodriguez, I., Smailagic, N., Roqué-Figuls, M., Ciapponi, A., Sanchez-Perez, E., Giannakou, A., ... & Cullum, S. (2021). Mini-Mental State Examination (MMSE) for the early detection of dementia in people with mild cognitive impairment (MCI). *Cochrane Database of Systematic* Reviews, (7). epub ahead of print. https://doi.org/10.1002/14651858.CD010783.pub3

Clare, L., Wilson, B. A., Carter, G., Breen, K., Gosses, A., & Hodges, J. R. (2000). Intervening with everyday memory problems in dementia of Alzheimer type: an errorless learning approach. *Journal of Clinical and Experimental Neuropsychology*, *22*(1), 132-146.

Davis, K. L., Price, C. C., Kaplan, E., & Libon, D. J. (2002). Error analysis of the nine-word California Verbal Learning Test (CVLT-9) among older adults with and without dementia. *The Clinical Neuropsychologist, 16,* 81-89.

Divers, R., Ham, L., Matchanova, A., Hackett, K., Mis, R., Howard, K., ... & Giovannetti, T. (2021). When and how did you go wrong? Characterizing mild functional difficulties in older adults during an everyday task. *Aging, Neuropsychology, and Cognition*, *28*(2), 308-326.

Dotson, V. M., Beydoun, M. A., & Zonderman, A. B. (2010). Recurrent depressive symptoms and the incidence of dementia and mild cognitive impairment. *Neurology, 75*(1), 27-34.

El-Saifi, N., Moyle, W., Jones, C., & Tuffaha, H. (2018). Medication adherence in older patients with dementia: a systematic literature review. *Journal of Pharmacy Practice, 31*(3), 322-334.

Etters, L., Goodall, D., & Harrison, B. E. (2008). Caregiver burden among dementia patient caregivers: A review of the literature. *Journal of the American Association of Nurse Practitioners, 20,* 423-428.

Farias, S.T. & Giovannetti, T. (in press). Everyday Function in Older Adults. In R. Parks, R. Zec, M. Bondi & A. Jefferson (Eds). *Neuropsychology of Alzheimer's Disease and Other Dementias, Second Edition,* Oxford.

Farias, S. T., Lau, K., Harvey, D., Denny, K. G., Barba, C., & Mefford, A. N. (2017). Early functional limitations in cognitively normal older adults predict diagnostic conversion to mild cognitive impairment. *Journal of the American Geriatrics Society, 65*(6), 1152-1158.

Faytell, M. P., Doyle, K. L., Naar-King, S., Outlaw, A. Y., Nichols, S. L., Casaletto, K. B., & Woods, S. P. (2017). Visualisation of future task performance improves naturalistic prospective memory for some younger adults living with HIV disease. *Neuropsychological rehabilitation, 27*(8), 1142-1155.

Feldman, H., Gauthier, S., Hecker, J., Vellas, B., Emir, B., Mastey, V., & Subbiah, P. (2003). Efficacy of donepezil on maintenance of activities of daily living in patients with moderate to severe Alzheimer's disease and the effect on caregiver burden. *Journal of the American Geriatrics Society, 51*(6), 737-744.

Foloppe, D. A., Richard, P., Yamaguchi, T., Etcharry-Bouyx, F., & Allain, P. (2015). The potential of virtual reality-based training to enhance the functional autonomy of Alzheimer's disease patients in cooking activities: A single case study. *Neuropsychological Rehabilitation, 0*, 1-25.

Gates, N. J., Sachdev, P. S., Singh, M. A. F., & Valenzuela, M. (2011). Cognitive and memory training in adults at risk of dementia: a systematic review. *BMC geriatrics, 11*(1), 1-14.

Giovannetti, T., Bettcher, B. M., Brennan, L., Libron, D. J., Kessler, R. K., & Duey, K. (2008). Coffee with jelly or unbuttered toast: Commissions and omissions are dissociable aspects of everyday action impairment in Alzheimer's disease. *Neuropsychology, 22*(2), 235-245.

Giovannetti, T., Bettcher, B. M., Libon, D. J., Brennan, L., Sestito, N., & Kessler, R. K. (2007). Environmental adaptations improve everyday action performance in Alzheimer's disease: Empirical support from performance-based assessment. *Neuropsychology, 21*(4), 448-457.

Giovannetti T., Libon D.J., Buxbaum L.J., & Schwartz M.F. (2002). Naturalistic action impairment in dementia. *Neuropsychologia, 40*, 1220-1232.

Giovannetti, T., Yamaguchi, T., Roll, E., Harada, T., Rycroft, S. S., Divers, R., ... & Hackett, K. (2019). The Virtual Kitchen Challenge: preliminary data from a novel virtual reality test of mild difficulties in everyday functioning. *Aging, Neuropsychology, and Cognition, 26*(6), 823-841.

Gross, A. L., Rebok, G. W., Unverzagt, F. W., Willis, S. L., & Brandt, J. (2011). Cognitive predictors of everyday functioning in older adults: Results from the ACTIVE cognitive intervention trial. *Journals of Gerontology Series B: Psychological Sciences and Social Sciences, 66*(5), 557-566.

Hackett, K., Lehman, S., Divers, R., Ambrogi, M., Gomes, L., Tan, C. C., & Giovannetti, T. (2020). Remind Me To Remember: A pilot study of a novel smartphone reminder application for older adults with dementia and mild cognitive impairment. *Neuropsychological Rehabilitation,* advanced online publication: https://doi.org/10.1080/09602011.2020.1794909

Herrmann, N., Mittmann, N., Silver, I. L., Shulman, K. I., Busto, U. A., Shear, N. H., & Naranjo, C. A. (1996). A validation study of the Geriatric Depression Scale short form. *International Journal of Geriatric Psychiatry*, *11*(5), 457-460.

Hill, J., Fillit, H., Thomas, S. K., & Chang, S. (2006). Functional impairment, healthcare costs and the prevalence of institutionalisation in patients with Alzheimer's disease and other dementias. *Pharmacoeconomics, 24*(3), 265-280.

Lesher, E. L., & Berryhill, J. S. (1994). Validation of the geriatric depression scale-short form among inpatients. *Journal of Clinical Psychology, 50*(2), 256-260.

Martyr, A., Clare, L., Nelis, S. M., Marková, I. S., Roth, I., Woods, R. T., ... & Morris, R. G. (2012). Verbal fluency and awareness of functional deficits in early-stage dementia. *The Clinical Neuropsychologist, 26*(3), 501-519.

Mayeda, E. R., Glymour, M. M., Quesenberry, C. P., & Whitmer, R. A. (2016). Inequalities in dementia incidence between six racial and ethnic groups over 14 years. *Alzheimer's & Dementia, 12*(3), 216-224.

Paxton, J. L., Barch, D. M., Racine, C. A., & Braver, T. S. (2008). Cognitive control, goal maintenance, and prefrontal function in healthy aging. *Cerebral cortex, 18*(5), 1010-1028.

Payne, J. L., Lyketsos, C. G., Steele, C., Baker, L., Galik, E., Kopunek, S., ... & Warren, A. (1998). Relationship of cognitive and functional impairment to depressive features in Alzheimer's disease and other dementias. *The Journal of Neuropsychiatry and Clinical Neurosciences, 10*(4), 440-447.

Perneczky, R., Wagenpfeil, S., Komossa, K., Grimmer, T., Diehl, J., & Kurz, A. (2006). Mapping scores onto stages: Mini-mental state examination and clinical dementia rating. *The American Journal of Geriatric Psychiatry, 14*, 139-144.

Rasmusson, X. D., Zonderman, A. B., Kawas, C. & Resnick, S. M. (1998). Effects of Age and Dementia on the Trail Making Test. *The Clinical Neuropsychologist, 12,* 169-178.

Razani, J., Kakos, B., Orieta-Barbalace, C., Wong, J. T., Casas, R., Lu, P., ... & Josephson, K. (2007). Predicting caregiver burden from daily functional abilities of patients with mild dementia. *Journal of the American Geriatrics Society, 55*(9), 1415-1420.

Roberts, R., & Knopman, D. S. (2013). Classification and epidemiology of MCI. *Clinics in Geriatric Medicine, 29*(4), 753-772.

Rycroft, S. S., Giovannetti, T., Divers, R., & Hulswit, J. (2018). Sensitive performance-based assessment of everyday action in older and younger adults. *Aging, Neuropsychology, and Cognition, 25*(2), 259-276.

Schmitter-Edgecombe, M., Howard, J. T., Pavawalla, S. P., Howell, L., & Rueda, A. (2008). Multidyad memory notebook intervention for very mild dementia: A pilot study. *American Journal of Alzheimer's Disease & Other Dementias, 23*(5), 477-487.

Schwartz, M. F., Mayer, N. H., FitzpatrickDeSalme, E. J., & Montgomery, M. W. (1993). Cognitive theory and the study of everyday action disorders after brain damage. *The Journal of Head Trauma Rehabilitation, 8*(1), 59–72.

Schwartz, M., Segal, M., Veramonti, T., Ferraro, M., & Buxbaum, L. (2002). The Naturalistic Action Test: A standardized assessment for everyday action impairment. *Neuropsychological Rehabilitation, 12*(4), 311–339.

Seidel, G. A., Giovannetti, T., Price, C. C., Tanner, J., Mitchell, S., Eppig, J., & Libon, D. J. (2013). Neuroimaging correlates of everyday action in dementia. *Journal of Clinical and Experimental Neuropsychology, 35*(9), 993-1005.

Seligman, S. C., Giovannetti, T., Sestito, J., & Libon, D. J. (2014). A new approach to the characterization of subtle errors in everyday action: Implications for mild cognitive impairment. *The Clinical Neuropsychologist, 28*, 97-115.

Steinberg, M., Leoutsakos, J. S., Podewils, L. J., & Lyketsos, C. G. (2008). Evaluation of a home-based exercise program in the treatment of Alzheimer's disease: The Maximizing Independence in Dementia (MIND) study. *International Journal of Geriatric Psychiatry, 24*, 680-685.

Stringer, A. Y. (2017). Empirically Based Rehabilitation of Neurocognitive Disorde r. In Textbook of Clinical Neuropsychology (pp. 1078-1088). Taylor & Francis.

Teri, L., Logsdon, R. G., Uomoto, J., & McCurry, S. M. (1997). Behavioral treatment of Depression in dementia patients: A controlled clinical trial. *The Journals of Gerontology,*

Thompson, C., Henry, J. D., Rendell, P. G., Withall, A., & Brodaty, H. (2010). Prospective memory function in mild cognitive impairment and early dementia. *Journal of the International Neuropsychological Society*, *16*(2), 318-325.

Tombaugh, T. N., & McIntyre, N. J. (1992). The mini-mental state examination: a comprehensive review. *Journal of the American Geriatrics Society*, *40*(9), 922-935.

Tuokko, H., Hadjistavropoulos, T., Miller, J. A., & Beattie, B. L. (1992). The clock test: A sensitive measure to differentiate normal elderly from those with Alzheimer's disease. *Journal of the American Geriatrics Society, 40,* 579-584.

Vernooij-Dassen, M., Vasse, E., Zuidema, S., Cohen-Mansfield, J., & Moyle, W. (2010). Psychosocial interventions for dementia patients in long-term care. *International Psychogeriatrics, 22*(7), 1121-1128.

Wechsler, D. (1981). The psychometric tradition: Developing the wechsler adult intelligence scale. *Contemporary Educational Psychology, 6,* 82-85.

Wimo, A., Winblad, B., & Jönsson, L. (2010). The worldwide societal costs of dementia: Estimates for 2009. *Alzheimer's & Dementia*, *6*(2), 98-103.

Winson, R., Wilson, B. A., & Bateman, A. (Eds.). (2016). *The brain injury rehabilitation workbook*. Guilford Publications.

World Health Organization & Alzheimer's disease International. (2012). *2012 Dementia: a public health priority.* Retrieved from http://www.who.int/mental_health/publications/dementia_report_2012/en/

World Health Organization. (2017). Dementia: Fact sheet. Retrieved from Yen, Y. C., Rebok, G. W., Gallo, J. J., Jones, R. N., & Tennstedt, S. L. (2011). Depressive symptoms impair everyday problem-solving ability through cognitive abilities in late life. *The American Journal of Geriatric Psychiatry, 19*(2), 142-150.

Yesavage, J. A., Brink, T. L., Rose, T. L., Lum, O., Huang, V., Adey, M., & Leirer, V. O. (1982). Development and validation of a geriatric depression screening scale: A preliminary report. *Journal of Psychiatric Research*, *17*(1), 37–49

Vita

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