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# Analysis of Verbal Fluency Ability in Amnestic and Non-Amnestic Mild Cognitive Impairment

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**Abstract**

The purpose of this study was to investigate the pattern of performance on letter and category fluency tests of individuals with mild cognitive impairment (MCI). Previous research has suggested that organization strategies, including "clustering" (i.e., groups of related words) and "switching" (i.e., shift from one cluster to another), are important for efficient verbal fluency performance. Participants were 25 individuals with single-domain amnestic MCI (aMCI), 49 with multidomain aMCI, 16 with non-amnestic MCI (naMCI), and 90 cognitively healthy older adults. Fluency performances were analyzed across two 30-s intervals for total words produced, cluster size, and switching. Analyses of variance (ANOVAs) with follow-up tests revealed that the single-domain aMCI group performed comparably with healthy controls on each dependent measure across both fluency tasks. In contrast, the multidomain aMCI group showed performance decrements in total words and switching production compared with healthy controls on both fluency tasks, whereas the naMCI group produced fewer words and switches on letter fluency. Each group generated more words and switches during the first 30-s on both fluency tasks, with the exception of the naMCI group, whose switching on letter fluency did not decrease as the task progressed. As indicated by the single-domain aMCI group's unimpaired performance, our findings demonstrate that verbal fluency performance decreases as domains beyond memory become impaired in MCI. Reduced switching ability, which has been linked to prefrontal executive functioning, contributed the most to the poorer performance of individuals with multidomain MCI and naMCI.

*Keywords:* Mild cognitive impairment; Fluency; Language and language disorders; Executive functioning

## Introduction

Mild cognitive impairment (MCI) is characterized by cognitive deficit(s) that is greater than that considered to be "healthy aging" but fails to meet criteria for dementia (Petersen et al., 1999). Much MCI and dementia research have focused on changes in memory ability. However, non-memory abilities are impacted in the course of cognitive decline as well, including executive function, language ability, perceptual speed, attention, and visuospatial skills (Taler & Phillips, 2008). Of these, deficits in language ability (e.g., verbal fluency, word comprehension) appear to occur early in the course of cognitive decline (Henry, Crawford, & Phillips, 2004). Notably, verbal fluency has been observed to be impaired in individuals several years before they meet criteria for the diagnosis of MCI or dementia (Bäckman, Jones, Berger, Laukka, & Small, 2005). Furthermore, verbal fluency tasks have been found to distinguish between those with normal cognitive function and individuals in the early stages of cognitive decline (Clark et al., 2009). The purpose of the present study is to identify differences in verbal fluency performance between healthy older adults and individuals with multidomain amnestic MCI (aMCI), single-domain aMCI, and non-amnestic MCI (naMCI).

Verbal fluency tests are the most widely used measures of language processing in dementia (Taler & Phillips, 2008). These tasks evaluate an individual's ability to rapidly retrieve and generate words under specific constraints within a definite time period


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(e.g., 60 or 90 s). Subtests commonly used to test verbal fluency ability include category and letter fluency tests. Category fluency, also known as semantic fluency, requires a search through conceptual knowledge stores for semantic extensions derived from a target word (Taler & Phillips, 2008). For example, if the category "animals" was given an individual may say the word "horse," followed by "pig, cow, and sheep" in succession due to the close semantic associations with farm animals. Letter fluency, also referred to as phonemic fluency, relies on lexical (i.e., word) representation strategies (Rohrer, Salmon, Wixted, & Paulsen, 1999). Specifically, letter fluency requires an individual to select and retrieve words based on spelling and fund of word knowledge.

Both letter and category fluency tasks rely heavily on frontal lobe functioning (Lezak, Howieson, Loring, Hannay, & Fischer, 2004), including executive processes that require individuals to organize retrieval, initiate verbal responses, monitor responses previously recalled, and inhibit responses that do not fit within the criteria (Henry et al., 2004). Both measures also access semantic memory stores, a function of the temporal lobe; although letter fluency appears to tap this ability to a lesser extent than category fluency (Lezak et al., 2004). Functional brain imagining and lesion studies also support the involvement of the frontal and temporal lobes in fluency ability. Specifically, when examined with the functional magnetic resonance imaging technology, letter fluency is shown to be associated with increased activation in the frontal lobes, while both the temporal and frontal lobes are utilized during category fluency (Birn et al., 2010; Mummery, Patterson, Hodges, & Wise, 1996). In addition, frontal lobe lesion patients have been found to have impaired performance on letter (Owen, Downes, Sahakian, Polkey, & Robbins, 1990) and category (Troyer, Moscovitch, Winocur, Alexander, & Stuss, 1998) fluency compared with controls, whereas temporal-lobe atrophy patients exhibit mild impairment on letter fluency and significant impairment on category fluency tasks (Hodges, Patterson, Oxbury, & Funnell, 1992).

According to Troyer, Moscovitch, Winocur, Leach, and Freeman (1998), two verbal fluency strategies used to search, organize, and retrieve words are clustering and switching. A cluster is defined as a group of semantically (e.g., animals that are pets) or phonemically (e.g., words that rhyme) related words (Troyer, Moscovitch, & Winocur, 1997). Switching refers to the shift from one cluster of words that has been exhausted to the start of another cluster of words (Troyer et al., 1997). Although clustering relies heavily on verbal memory of words, word sounds, and word storage (Murphy, Rich, & Troyer, 2006), switching relies on the integrity of the frontal lobe to engage in strategic search processes and cognitive flexibility (Troyer et al., 1997). Because clustering and switching depend on different cognitive processes, they are often investigated to supply additional information about cognitive performance.

Within the aMCI verbal fluency literature, two types of contrasting results are typically reported: either a similar level of impairment on both letter and category fluency tasks (Nutter-Upham et al., 2008) or a selective impairment on the category fluency task (Adlam, Bozeat, Arnold, Watson, & Hodges, 2006; Murphy et al., 2006). The former suggests that deficits in both temporal and frontal lobe functioning, or the frontal lobe only, are impacting performance, whereas the later implies that participants have compromised semantic memory stores while their frontal lobe processes are comparatively intact. A differential verbal fluency pattern has also been observed within the Alzheimer's disease (AD) verbal fluency literature. Specifically, participants with AD, while impaired on both fluency measures, typically show greater impairment on category compared with letter fluency (Henry et al., 2004). When aMCI has been divided into single domain and multidomain, individuals with single-domain aMCI were found to perform similarly on both fluency tasks and comparably with controls (Brandt & Manning, 2009). In contrast, individuals with multidomain aMCI were found to exhibit greater impairment on category compared with letter fluency, with poorer overall performance relative to controls. These findings indicate that it may be important to separate aMCI into single and multidomains when exploring the effects of clustering and switching abilities on verbal fluency.

Only one study could be located that explored cluster and switching performance in aMCI participants. Murphy and colleagues (2006) found that both aMCI and normal control participants had greater average cluster sizes on category compared with letter fluency and made more switches on the letter fluency task. Of note, the aMCI group's average cluster size and the number of switches were comparable with the control group on both fluency tasks, despite overall poorer category fluency performance. To our knowledge, no research has been conducted exploring clustering and switching ability of individuals with single- and multidomain aMCI.

Despite the fact that aMCI and naMCI have different clinical presentations, verbal fluency performance of individuals with naMCI has largely been ignored. Brandt and Manning (2009) found that the naMCI participant's performance on category and letter fluency tasks was significantly lower than that of healthy older adults. In addition, the naMCI participants did not exhibit differential impairment on the two fluency tasks. Of interest, this pattern of verbal fluency performance is similar to those observed in verbal fluency studies involving individuals with frontotemporal (Rascovsky, Salmon, Hansen, Thal, & Galasko, 2007), Lewy body (Shimomura et al., 1998), and vascular dementia (Almkvist, 1994; Fahlander, Wahlin, Almkvist, & Bäckman, 2002); the three types of dementia naMCI have been hypothesized to progress into (Petersen, 2004). In addition, Jones, Laukka, and Bäckman (2006) found that frontotemporal and Lewy body dementia patients made significantly lower cluster sizes and number of switches on both tasks compared with healthy older adults, with the exception of Lewy body dementia participants who did not differ from controls in terms of cluster size on category fluency. Examination of clustering and switching ability of individuals with naMCI was not included in Brandt and Manning's study.

In addition, although research suggests that word generation is comprised of an initial semiautomatic retrieval phase, where many words are produced, followed by a later effortful retrieval phase (Fernaeus & Almkvist, 1998; Ober, Dronkers, Koss, Delis, & Friedland, 1986), the temporal characteristics of MCI participant's verbal fluency performance have not been widely investigated. According to Fernaeus and Almkvist (1998), looking at word generation in terms of two time frames rather than one global measure will lead to more detailed information about the functioning of word retrieval from memory. In a recent study with neurologically healthy adults, the mean cluster size and switching production, as well as the number of words generated, were found to decrease with time (Raboutet et al., 2010). Furthermore, consistent with the theory that greater executive resources are necessary to complete a demanding task over time (Fuster, 1997), participants with executive impairment (i.e., Parkinson's disease dementia, vascular dementia, dysexecutive MCI) showed impaired temporal gradients on total words produced on letter fluency compared with control participants and individuals with amnestic deficits (Eppig et al., 2011; Lamar, Price, Davis, Kaplan, & Libon, 2002). To better understand organization strategies and word retrieval, in this study, we examine word, cluster, and switch generation during two 30 s time frames to determine how temporal processing impacts the performance of MCI participants.

The aim of the present study was to (a) determine time-dependent patterns of verbal fluency responses, switches, and clusters for single- and multidomain aMCI and naMCI compared with neurologically normal older adults; and (b) investigate relationships between components of verbal fluency ability and neuropsychological factors thought to be important to verbal fluency ability (i.e., language ability and executive functioning; Taler & Phillips, 2008). To examine verbal fluency ability, letter and category fluency total responses, number of switches, and mean cluster sizes were measured across two 30 s intervals. We hypothesized that all groups would exhibit a pattern of rapid word retrieval followed by an effortful retrieval phase and that cluster and switch production would also decrease across the time interval. Based on the reviewed literature, we further hypothesized that individuals with single-domain aMCI would not differ significantly from controls in overall performance or in cluster size and the number of switches. Multidomain aMCI was expected to perform more poorly on category versus letter fluency and produce fewer words and clusters than controls. In contrast, naMCI was hypothesized to produce fewer words and switch less than controls on both category and letter fluency and show equivalent deficits on the two fluency tests.

## Method

### *Participants*

Participants were 25 persons with single-domain aMCI (14 women and 11 men), 49 with multidomain aMCI (26 women and 23 men), 16 with naMCI (10 women and 6 men), and 90 cognitively healthy older adults (61 women and 29 men; Table 1). Each MCI participant was closely matched with a healthy older adult participant in terms of age, gender, and education. All participants were age 50 or older and able to provide informed consent. Participants were volunteers tested as part of two larger studies investigating

**Table 1.** Table of demographic and test variables

| Variable or test | Single domain aMCI ($n = 25$) | | Multidomain aMCI ($n = 49$) | | naMCI ($n = 16$) | | Control ($n = 90$) | | $p$-value |
|---|---|---|---|---|---|---|---|---|---|
| | Mean | *SD* | Mean | *SD* | Mean | *SD* | Mean | *SD* | |
| Demographics | | | | | | | | | |
| Age (years) | 72.72 | 10.47 | 72.06 | 8.77 | 71.00 | 11.47 | 71.44 | 9.37 | .92 |
| Education (years) | 16.44 | 2.87 | 15.04 | 2.99 | 15.56 | 2.92 | 15.67 | 2.70 | .24 |
| Gender (% female) | 56 | — | 53 | — | 63 | — | 69 | — | .35 |
| CDR | 0.5 | — | 0.5 | — | 0.5 | — | 0 | — | — |
| TICS | 33.96 | 2.94 | 29.88[a,b] | 8.41 | 32.75 | 3.07 | 34.25 | 4.47 | <.001 |
| Neuropsychological correlates | | | | | | | | | |
| BNT total correct[c] | 56.21 | 4.25 | 51.88[a,b] | 8.43 | 54.13 | 3.22 | 56.61 | 2.56 | <.001 |
| Trails B (s)[c] | 101.25 | 49.25 | 142.15[a,b] | 65.11 | 109.2 | 35.19 | 82.62 | 27.04 | <.001 |
| DFswitch total score | 7.28 | 2.99 | 6.63[a] | 2.77 | 6.25[d] | 3.11 | 8.37 | 2.66 | .001 |

*Notes:* Unless otherwise indicated, mean scores are raw scores. Norm sources for the cognitive tests are in parentheses following the test. aMCI = amnestic Mild Cognitive Impairment; naMCI = non-amnestic Mild Cognitive Impairment; CDR = Clinical Dementia Rating Scale (Morris, 1993); TICS = Telephone Interview of Cognitive Status (Brandt & Folstein, 2003); BNT = Boston Naming Test (Ivnik et al., 1996); Trails B (Steinberg, Bieliauskas, Smith, & Ivnik, 2005); DFswitch = Switching subtest of Design Fluency (Delis et al., 2001).

[a]Multidomain aMCI differed significantly from controls.

[b]Multidomain aMCI differed significantly from single-domain aMCI.

[c]Data available for 177 of 180 participants.

[d]naMCI differed significantly from controls.

the relationship between cognition and everyday functional abilities of healthy older adults and individuals with MCI or AD at Washington State University (*see* Schmitter-Edgecombe, Parsey, & Cook, 2011; Schmitter-Edgecombe, Woo, & Greeley, 2009). Both studies were reviewed and approved by the Washington State University Institutional Review Board.

Participants were recruited through advertisements, community health and wellness fairs, physician referrals, referrals from local agencies working primarily with older adults, and from past studies in the Aging and Dementia laboratory at Washington State University. Initial screening of potential participants was conducted over the phone. Screening included a medical and cognitive interview to exclude participants who were significantly cognitively impaired or met exclusion criteria. Exclusion criteria included the history of significant head trauma, current or recent (past year) psychoactive substance abuse, history of cerebrovascular accidents, and known medical, neurological, or psychiatric causes of cognitive dysfunction (e.g., epilepsy, schizophrenia).

Participants who met initial screening criteria completed a 3-h battery of standardized and experimental neuropsychological tests including measures of memory, attention, executive functioning, language abilities, speeded processing, visuospatial skills, and general intellectual ability. Each participant appointed a knowledgeable informant (e.g., spouse, adult child) who was contacted to supply subjective information on functional and cognitive ability and completed the Clinical Dementia Rating Scale (CDR; Morris, 1993), which was administered by an examiner who had completed CDR certification. Participant medical information was also reviewed when available. All participants were given a report reviewing their performance on the neuropsychological tests as compensation for their time.

Inclusion criteria for participants in the aMCI group followed the criteria outlined by Petersen and colleagues (2001) and Albert and colleagues (2011). Reference to the individual's medical, education, and socioeconomic background was also made before carefully determining whether the individual met criteria for MCI. Individuals classified as aMCI met each of the following criteria: (a) subjective memory impairment with support from a knowledgeable informant as obtained from the CDR and knowledgeable informant interview; (b) objective memory impairment confirmed by a score falling 1.5 *SD* below the mean of age and education-matched peers on list learning, immediate recall, or delayed recall on the Rey Auditory Verbal Learning Test (Lezak et al., 2004) or the Memory Assessment Scales verbal list learning task (Williams, 1991) depending on the study sample; (c) non-fulfillment of the "Diagnostic and Statistical Manual of Mental Disorders" (DSM-IV) criteria for dementia (American Psychiatric Association, 2000); (d) preserved general cognitive functions as confirmed by a 27 or above on the telephone interview for cognitive status (TICS; Brandt & Folstein, 2003); (e) no significant impact of the memory deficit on the participant's daily activities, as confirmed by a total CDR score no greater than 0.5; and (f) the absence of severe depression as confirmed by a score less than 10 on the 15-item Geriatric Depression Scale (GDS; Yesavage et al., 1983). Similar criteria were used for classifying naMCI as for aMCI with the exception that there could be no objective memory impairment. Rather, participants in the naMCI group performed at least 1.5 *SD* below the mean on one or more non-memory measures.

Participants who met criteria for aMCI were further divided into the single- or multidomain aMCI group. Those classified as single-domain aMCI met all of the above criteria and had no performances on a non-memory measure of speeded processing (i.e., Trails A, Symbol Digit Modality Test), language (i.e., Boston Naming Task), or executive function (i.e., Trails B, Design Fluency) that fell 1.3 *SD* below the mean of age and education-matched peers. Those classified as multidomain aMCI had at least one performance on a non-memory measure that was 1.3 *SD* below the mean of age and education-matched peers. The naMCI participants were not further classified into either single-($n = 10$) or multidomain ($n = 6$) MCI for the analysis due to small sample size. A more liberal performance criterion of 1.3 *SD* below the mean was used to specify the second domain of impairment to better capture those MCI individuals who were experiencing difficulties in more than one cognitive domain.

Participants classified as cognitively healthy older adults met the following criteria: (a) no self or informant reported history of cognitive changes; (b) performance within 1.5 *SD* of the mean on neuropsychological measures; (c) a CDR of zero; (d) score on the TICS within normal limits; and (e) no severe depression as documented by a score less than 10 on the 15-item GDS.

### *Procedure*

All participants were administered the Delis–Kaplin Executive Functioning System (D-KEFS) letter and category verbal fluency subtests (Delis, Kaplan, & Kramer, 2001) along with a battery of other neuropsychological measures. The letter fluency subtest, which is a component of the D-KEFS verbal fluency subtest, required that participants name as many words as possible starting with the letter F, A, and S for a total of 60 s each. Participants were instructed to refrain from providing names of persons, places, and numbers, as well as words with different suffixes (e.g., run, runs, running). Participants were also administered a category fluency subtest which required them to name as many animals as possible. Participants were asked to stop the task after a total of 60 s.

Three raw scores were obtained for the letter (F, A, and S) and category (animal) verbal fluency subtests: total responses, average cluster size, and total switches. Scores were calculated for two intervals: 1–30 and 31–60 s, referred to as Interval 1 and Interval 2, respectively. Total responses were scored by tallying all of the words recited excluding set-loss errors (e.g.,

names of people, places) and repetitions. Clustering and switching scores were coded in consonance with the scoring method derived by Troyer and colleagues (1997). Minimal modifications to the Troyer (2000) scoring categories were made to include items specific to the Pacific Northwest region (e.g., coyote). All protocols were scored blind to the participant diagnostic category by the first author followed by a second scoring conducted by an independent rater to limit scoring errors. If incongruent scores were obtained, both raters discussed the disparity and came to a consensus based on Troyer and colleagues scoring scheme.

### *Analysis*

Prior to running analyses, frequencies were investigated for the following letter and category fluency scores: Total responses, mean cluster size, and total number of switches. All verbal fluency scores were raw scores. Participants who performed three standard deviations above or below the mean performance for a given measure were removed from all fluency analyses for that fluency subtest.

The dependent measures (i.e., total responses, average cluster size, number of switches in both letter and category fluency) were analyzed using a group (i.e., single-domain aMCI, multidomain aMCI, naMCI, and neurologically healthy older adults) by interval (i.e., 0–30 and 31–60 s) mixed model ANOVA with repeated measures on the second factor. Pairwise comparisons were computed using Tukey's honestly significant difference post hoc when appropriate. The significance level was set at .05 for the ANOVA and post hoc tests. Eta-squared was used as the measure of effect size. Paired samples *t*-tests were also calculated on the dependent measures for each participant group to determine if differences existed between participant groups' 0–30 s response, cluster, or switch total scores and their 31–60 s scores. In order to examine differences between total words, switches, and cluster sizes produced on each fluency task, *z*-scores were calculated using the means and standard deviations of the control group. Paired samples *t*-tests were then performed to compare participant groups' letter to category word production. Finally, correlations were performed between the fluency tasks and a neuropsychological test of language (i.e., Boston Naming Test [BNT]; Ivnik, Malec, Smith, Tangalos, & Petersen, 1996) and executive functioning (i.e., Trails B; Reitan, 1958; switching subtest of Design Fluency; Delis et al., 2001) that research suggests play a role in verbal fluency performance (Taler & Phillips, 2008). A significance level of $p < .05$ was used for the Pearson correlations.

## Results

### *Letter Fluency*

Six participants (one aMCI single domain, three aMCI multidomain, one naMCI, and one control) performed 3 *SD* above or below the mean on one or more of the dependent measures and were removed as outliers. Mean scores and standard deviations for each dependent measure can be found in Table 2.

**Table 2.** Performances on the Letter Fluency Task by group and time interval

| | Total responses | Mean cluster size | Total switches |
|---|---|---|---|
| Single-domain aMCI | | | |
| Interval 1 | 22.79 (5.50) | 0.44 (0.22) | 14.79 (4.11) |
| Interval 2 | 13.33 (5.47) | 0.41 (0.31) | 10.71 (4.16) |
| Total time | 36.13 (9.55) | 0.35 (0.16) | 25.50 (7.08) |
| Multidomain aMCI | | | |
| Interval 1 | 21.07 (7.63)[a] | 0.36 (0.26) | 13.83 (5.48)[a] |
| Interval 2 | 11.54 (6.51)[a] | 0.39 (0.35) | 10.24 (4.99) |
| Total time | 32.61 (13.33)[a] | 0.33 (0.21)[a] | 24.07 (9.62)[a] |
| naMCI | | | |
| Interval 1 | 18.13 (5.67)[b] | 0.53 (0.30) | 10.67 (4.17)[b] |
| Interval 2 | 12.73 (7.59) | 0.37 (0.30) | 9.67 (3.98) |
| Total time | 30.87 (11.62)[b] | 0.38 (0.19) | 20.33 (7.50)[b] |
| Control | | | |
| Interval 1 | 26.52 (6.58) | 0.51 (0.32) | 16.82 (5.72) |
| Interval 2 | 16.17 (5.76) | 0.49 (0.38) | 12.17 (3.79) |
| Total time | 38.10 (12.54) | 0.38 (0.21) | 26.45 (8.91) |

*Notes:* aMCI = amnestic Mild Cognitive Impairment; naMCI = non-amnestic Mild Cognitive Impairment. Mean scores are raw scores and standard deviations are in parentheses; Interval 1 = 0–30 s; Interval 2 = 31–60 s.

[a]Multidomain aMCI differed significantly from controls.

[b]The naMCI group differed significantly from controls.

*Total Words Produced.* A 4 (group) × 2 (interval) mixed model ANOVA conducted on total words revealed a significant main effect for interval, $F(1, 170) = 305.43, MSE = 13.98, p < .001, \eta^2 = 0.64$. Post hoc tests indicated that more responses were generated at Interval 1 ($M = 22.13$) than at Interval 2 ($M = 13.45$). The main effect of group, $F(1, 170) = 3.78, MSE = 13.98, p = .01, \eta^2 = 0.06$, was modified by a significant two-way interaction, $F(3, 170) = 3.78, MSE = 13.98, p = .01, \eta^2 = 0.06$. Breakdown of the interaction revealed that at Interval 1 the control group produced significantly more responses than the multidomain aMCI and naMCI groups, $p$'s $< .001$ (Table 2). At Interval 2, the control group only significantly differed in total responses from the multidomain aMCI group, $p < .001$. Paired-samples $t$-tests revealed a significant decrease in word production from Interval 1 to Interval 2 for each of the groups ($t$'s $> 3.14$; $p$'s $< .007$).

*Cluster Size.* A mixed model ANOVA revealed a main effect for group, $F(1, 170) = 2.79, MSE = 0.35, p = .04, \eta^2 = 0.05$. Post hoc tests indicated that only the multidomain aMCI group had a significantly smaller mean cluster size than the control group, $p = .03$. The main effect for interval ($F = 1.04$) and interval by group interaction ($F = 0.69$) were not significant. Paired-samples $t$-tests indicated that differences in the size of cluster were not observed between Interval 1 and Interval 2 for any of the groups, $t$'s $> -0.54$, suggesting that participants' cluster size did not notably change over time despite total responses significantly decreasing across the 60-s task.

*Switching.* The ANOVA conducted on total switching revealed a significant main effect for interval, $F(1, 170) = 6.50, MSE = 36.34, p < .001, \eta^2 = 0.10$, with more switches made at Interval 1 ($M = 14.03$) compared with Interval 2 ($M = 10.70$). The main effect of group, $F(1, 170) = 6.97, MSE = 35.02, p < .001, \eta^2 = 0.11$, was modified by a significant two-way interaction, $F(3, 170) = 3.04, MSE = 9.90, p = .03\ \eta^2 = 0.05$. Breakdown of the interaction revealed that at Interval 1 the control group switched more than the multidomain aMCI ($p = .01$) and naMCI ($p < .001$) groups (Table 2). At Interval 2, the control group did not significantly differ in total switches from any group; however, the control group trended toward significantly more switches than the multidomain aMCI group, $p = .06$. Paired-samples $t$-tests revealed a significant decrease in switch production from Interval 1 to Interval 2 for the control, $t(88) = 9.15, p < .001$, single-domain aMCI, $t(23) = 4.67, p < .001$, and multidomain aMCI, $t(45) = 5.85, p < .001$, groups (Table 2). The naMCI group's total switches at Interval 1 did not significantly differ from Interval 2, $t(14) = 1.22, p > .05$.

### *Category Fluency*

Three participants (one single-domain aMCI and two controls) performed 3 *SD* above or below the mean performance and one participant (control) who did not complete the category fluency task were removed from the category fluency analyses. Mean scores and standard deviations of each dependent measure can be found in Table 3.

**Table 3.** Performances on the Category Fluency Test by group and time interval

| | Total responses | Mean cluster size | Total switches |
|---|---|---|---|
| Single-domain aMCI | | | |
| Interval 1 | 13.33 (4.02) | 1.51 (0.87) | 5.58 (2.19) |
| Interval 2 | 6.00 (2.48) | 0.90 (0.68) | 4.00 (1.64) |
| Total time | 19.33 (5.76) | 1.21 (0.52) | 9.58 (3.05) |
| Multidomain aMCI | | | |
| Interval 1 | 11.42 (3.39) | 1.07 (0.51) | 5.55 (2.13) |
| Interval 2 | 5.80 (2.81) | 1.00 (0.87) | 3.51 (1.60) |
| Total time | 17.22 (5.25)[a] | 1.03 (0.44) | 9.06 (3.12)[a] |
| naMCI | | | |
| Interval 1 | 12.38 (2.33) | 1.31 (0.83) | 5.38 (1.86) |
| Interval 2 | 6.63 (2.87) | 1.09 (0.90) | 3.56 (1.63) |
| Total time | 19.00 (4.41) | 1.19 (0.64) | 8.94 (2.82) |
| Control | | | |
| Interval 1 | 14.02 (3.36) | 1.17 (0.60) | 5.95 (2.12) |
| Interval 2 | 7.36 (3.23) | 1.13 (82) | 3.87 (1.67) |
| Total time | 21.36 (5.45) | 1.13 (0.44) | 10.47 (3.04) |

*Notes:* aMCI = amnestic Mild Cognitive Impairment; naMCI = non-amnestic Mild Cognitive Impairment. Mean scores are raw scores and standard deviations are in parentheses; Interval 1 = 0–30 s; Interval 2 = 31–60 s.

[a]Multidomain aMCI differed significantly from controls.

*Total Responses.* A group by interval mixed model ANOVA conducted using total responses on category fluency revealed a main effect for group, $F(3, 173) = 6.63$, $MSE = 14.12$, $p < .001$, $\eta^2 = 0.10$. Post hoc tests indicated that only the multidomain aMCI group made significantly fewer responses than the control group, $p < .001$ (Table 3). A main effect for interval, $F(1, 173) = 372.22$, $MSE = 6.36$, $p < .001$, $\eta^2 = 0.68$, revealed that participants made more responses at Interval 1 ($M = 12.79$) than at Interval 2 ($M = 6.45$). There was no significant group by interval interaction, $F = 1.63$. The paired-samples $t$-test revealed a significant decrease in word production from Interval 1 to Interval 2 for all four groups ($t$'s $> 8.17$; $p < .001$).

*Cluster Size.* There was no significant main effect for group ($F = 0.90$) or group by interval interaction ($F = 1.98$). A significant main effect for interval, $F(1, 173) = 5.94$, $MSE = 0.55$, $p = .02$, $\eta^2 = 0.03$, revealed that participants' average cluster size decreased as the category fluency task progressed (Interval 1, $M = 1.27$; Interval 2, $M = 1.03$). Paired-samples $t$-tests revealed that this decrease in average cluster size from Interval 1 to Interval 2, $t(23) = 2.54$, $p = .02$, reached statistical significance for the single-domain aMCI group only (Table 3).

*Switching.* An ANOVA conducted using total switches on category fluency revealed a main effect for group, $F(3, 173) = 2.84$, $MSE = 4.62$, $p = .04$, $\eta^2 = 0.05$. Post hoc tests indicated that only the multidomain aMCI group made significantly fewer switches than the control group, $p = .05$ (Table 3). However, the naMCI group ($M = 8.94$) made numerically fewer total switches than the multidomain aMCI group ($M = 9.06$) despite producing numerically greater total responses ($M = 19.00$ vs. 17.22), suggesting that sample size and reduced power may have contributed to the finding of no statistically significant difference between the naMCI and controls in total switches. A main effect for interval, $F(1, 173) = 87.39$, $MSE = 2.51$, $p < .001$, $\eta^2 = 0.34$, revealed that more switches were made at Interval 1 ($M = 5.72$) than at Interval 2 ($M = 3.79$). The group by time interaction was not significant, $F = 0.72$. Paired-samples $t$-tests revealed a significant decrease in switching ability on category fluency from Interval 1 to Interval 2 for all four groups ($t$'s $> 3.27$; $p$'s $< .003$; Table 3).

### *Performance Differences Between Tasks*

$z$-scores were created using the means and standard deviations of the control group's total word, switch, and mean cluster size scores for each of the fluency tasks. Paired-samples $t$-tests revealed that each groups' total word, switches, and mean cluster size scores did not significantly differ by fluency task ($t$'s between $-1.87$ and 0.30).

### *Correlations with Neuropsychological Variables*

Correlations were computed to examine the relationship between fluency task scores and language (i.e., BNT) and executive functioning (i.e., Trails B; switching subtest of D-KEFS Design Fluency) abilities. As can be seen in Table 4, the BNT total correct score did not correlate with any of the letter fluency task scores. In contrast, BNT performance significantly correlated with the single- and multidomain aMCI and the control groups' total responses ($r$'s $> .34$) and total number of switches ($r$'s $> .39$) on category fluency. Time on Trails B was significantly correlated with total responses and switches on letter fluency and total responses on category fluency for the naMCI and control groups ($r$'s $> -.60$). Trails B was also significantly correlated with total switches on category fluency for the single- and multidomain amnestic MCI and control groups ($r$'s $> -.33$). Like Trails B, total score on the Design Fluency switching subtest was related to total responses and switches on letter fluency for the control group ($r$'s $> .25$), and total responses on category fluency for both the single-domain aMCI and naMCI groups ($r$'s $> .52$). Design Fluency switching performance was also significantly correlated with the single-domain aMCI group's total category switches ($r = .55$). Unlike Trails B, although the correlation between Design Fluency switching performance and total words and switches on letter fluency did not reach significance for the naMCI group, the observed correlation values for the naMCI group were similar to those of the control group which reached significance at $p \leq .01$. These correlations suggest that higher BNT scores were associated with better category fluency, but not better letter fluency. Longer Trails B time and lower Design Fluency switching subtest score were related to poorer word response and switching on both tasks.

## Discussion

Although tests of verbal fluency are sensitive to cognitive decline, research concerning the verbal fluency performance of individuals with MCI is limited. The purpose of this study was to investigate the time-dependent pattern of verbal fluency performance in individuals with MCI. We also sought to identify cognitive correlates (i.e., language ability, executive functioning) of performance on the verbal fluency tasks.

**Table 4.** Correlations between neuropsychological tests and fluency task performances by group

| | Letter fluency | | | Category fluency | | |
|---|---|---|---|---|---|---|
| | BNT | Trails B | DFswitch | BNT | Trails B | DFswitch |
| Single-domain aMCI | | | | | | |
| Total words | −.09 | −.27 | .32 | .49** | −.38 | .52** |
| Mean cluster size | .17 | −.35 | .23 | −.20 | .12 | −.14 |
| Total switches | −.32 | −.05 | .19 | .50*** | −.46* | .55** |
| Multidomain aMCI | | | | | | |
| Total words | .18 | −.01 | .02 | .51** | −.27 | .28 |
| Mean cluster size | .27 | .01 | −.11 | .08 | −.01 | .13 |
| Total switches | −.07 | .08 | −.02 | .53** | −.39** | .18 |
| naMCI | | | | | | |
| Total words | .17 | −.55* | .23 | .24 | −.60* | .54* |
| Mean cluster size | −.14 | −.26 | −.08 | −.16 | −.19 | .07 |
| Total switches | .29 | −.56* | .34 | .16 | −.25 | .38 |
| Control | | | | | | |
| Total words | .16 | −.22* | .26** | .34*** | −.28** | .21 |
| Mean cluster size | .40 | .15 | −.01 | −.02 | .04 | .05 |
| Total switches | .12 | −.25* | .31** | .39*** | −.33** | .08 |

*Notes:* aMCI = amnestic Mild Cognitive Impairment; naMCI = non-amnestic Mild Cognitive Impairment; BNT = Boston Naming Test; Dfswitch = Switching subtest of Design Fluency. Scores are correlation values represented by *r*.
*$p < .05$.
**$p < .01$.
***$p < .001$.

For the letter fluency task, similar to Brandt and Manning (2009), we found that the single-domain aMCI group's performance did not significantly differ from that of the control group. The control group did, however, produce more responses and switched more frequently than the multidomain aMCI and naMCI groups during the first 30 s interval of the letter fluency task. During the second and final 30 s interval, the control group was only found to produce significantly more words, and trended toward significantly more switches, than the multidomain aMCI group. These findings may suggest that the neurological changes of the frontal lobe (if any) in the single-domain aMCI participants were not significant enough to be detected using the letter fluency task. However, these anterior regions are likely compromised in naMCI and become impaired as further decline occurs in aMCI, contributing to the poorer letter fluency performance of individuals with multidomain MCI. Deficient letter fluency performance is also commonly seen in individuals with AD (Henry et al., 2004).

Consistent with time-dependent attentional process (e.g., Fernaeus & Almkvist, 1998) and temporal organization (e.g., Fuster, 1997) theories, the single- and multidomain aMCI groups and the control group generated significantly more words and switches during the first 30 s interval of the letter fluency task compared with the second 30 s interval. Fernaeus and Almkvist (1998) hypothesized that initial fluency ability begins with a semi-automatic and rapid retrieval of words accompanied by adequate flexibility in moving between subcategories. As the task progresses, word and switching production diminish, resulting in a change to a more effortful retrieval and search process. Although the naMCI group produced more words on the letter fluency task during the first 30 s than the final 30 s, the total number of switches produced did not notably decrease across the time interval. Furthermore, compared with the other participant groups, the naMCI group generated the fewest words and switches on the letter fluency task in the first 30 s, suggesting that the naMCI participants did not begin the task with the same rapid retrieval of words and flexibility in switching between subcategories as the other participant groups. Since switching ability and word retrieval on the letter fluency task are thought to rely heavily on strategic search processes and cognitive flexibility (Troyer et al., 1998), difficulties with these processes may have impacted the performance of the naMCI group on the letter fluency task. Consistent with this explanation, naMCI participants who performed better on Trails B also switched more and produced a greater number of responses on the letter fluency test.

On the category fluency task, each participant groups' word and switch generation significantly decreased during the second 30 s interval. Although each MCI group made fewer responses and switched less than the control group, the single-domain aMCI and naMCI groups' performance did not differ significantly from controls. The multidomain aMCI group, in contrast, generated significantly fewer words and switched less between semantic subcategories than controls. Of note, the naMCI group also produced numerically fewer switches (but not total responses) than the multidomain MCI group, suggesting that reduced power and sample size may have contributed to the lack of significant findings between the control and naMCI groups on category switches. The MCI groups did not differ from controls in terms of cluster size. These findings are consistent with data from a

study by Raoux and colleagues (2008). They found that at 2 and 5 years before the onset of dementia, participants generated less words and had a significantly lower switching index on the category (animal) fluency task compared with cognitively healthy older adults. Furthermore, the pre-dementia group's switching and word production were found to be measurably diminished at each testing session compared with the previous session. Similar to our findings, their pre-dementia group's mean cluster size was not significantly different from normal controls at any time, including the visit where the diagnosis of dementia was made.

Overall, the study findings revealed that the single-domain aMCI group did not differ from controls on either fluency task. In contrast, participants with multidomain aMCI exhibited performance deficits in switching and word generation on both fluency tasks compared with controls. These findings suggest that verbal fluency performance decreases as domains beyond memory become impaired. Unlike Brandt and Manning's (2009) findings, our multidomain aMCI group performed as poorly on the letter fluency task as they did on the category fluency task. Consistent with Troyer and colleagues (1998) finding that participant's with frontal lobe lesions produced fewer words and switched less on both fluency tasks compared with controls and participants with temporal lobe lesions, these findings suggest that executive functioning difficulties are likely contributing to the multidomain aMCI groups poorer verbal fluency performances. This explanation is also consistent with the finding of poorer switching by the multidomain MCI group compared with controls but no difference in cluster size.

Although the naMCI group did not show a distinct difference in performance between the fluency tasks they did perform significantly poorer than controls on the letter fluency task in terms of both word and switch generation. On the category fluency task, while not differing significantly from controls in either total responses or switch generation, the naMCI group produced fewer switches than the multidomain group which did exhibit a significant difference from controls. These findings suggest that the naMCI group's switching ability was compromised on both fluency tasks. Given the larger cluster sizes for the category fluency test, the letter fluency task appeared to rely on switching ability to a greater extent than the category fluency task, which may account for the naMCI group's poorer performance on letter fluency compared with controls. As the current study was limited in the number of naMCI participants, further research should be conducted to determine if a distinct pattern of fluency performance does in fact accurately represent this population.

Results from this study suggest that the requirement to efficiently switch between categories contributed most to the poorer performance of individuals with multidomain MCI and naMCI likely due to compromised executive functioning. However, past research with AD populations has found that average cluster size can negatively influence the word generation of individuals with AD (Troyer et al., 1998). This suggests that at the multidomain MCI stage, individuals may be experiencing more difficulty with cognitive flexibility and that difficulty accessing semantic networks may become more prominent as cognitive decline progresses to AD.

In the present study, for the naMCI and control groups, letter and category fluency total responses and letter fluency switches were negatively correlated with Trails B. Similarly, the control groups' letter fluency total responses and switches were positively related to Design Fluency switching, as was the naMCI's groups total responses on category fluency. The control and aMCI groups' category fluency switches were also negatively related to Trails B and the single-domain aMCI's total category responses and switches were positively related to Design Fluency switching. These relationships further suggest that executive abilities are involved in word generation and switching ability for both fluency tasks. In contrast, BNT performance was found to be positively related to total words and switches on solely the category fluency task for all groups, with the exception of naMCI. The multidomain aMCI group also showed a significantly reduced total correct score on the BNT compared with the control group (Table 1). These results may indicate that the multidomain aMCI group had reduced ability to retrieve information from intact semantic stores, a depletion of semantic stores, a combination of the two, or an unknown impairment. This relationship is, however, in contrast with the lack of impairment on category clustering, a task that is thought to rely heavily on access to, and the integrity of, semantic memory stores (Troyer et al., 1998). It may be that significant impairment is necessary in order for category clustering abilities to become notably impaired, as is seen with individuals with AD (for a review, *see* Henry et al., 2004). Future research should focus on identifying the stage of impairment where difficulties forming clusters on category fluency tasks become apparent. Furthermore, additional studies should be conducted to determine whether access to semantic stores, the integrity of the semantic stores themselves, or a combination therein is impacted at the prodromal stage of impairment.

Limitations to this study include the small sample size of the naMCI group, which impacted the power of our findings. In addition, due to sample size, we were unable to divide the naMCI group into single- and multidomain groups, an endeavor that may be of interest to researchers in the future. Another important limitation is the homogeneity of participants in regard to level of education and ethnicity. Specifically, our study sample was composed largely of well-educated, Caucasian individuals, which limits our ability to generalize the results and conclusions to other populations with MCI. The neuropsychological correlates that were used in this study were also limited by the battery of tests that were given to participants. Future studies may be interested in exploring how performance on verbal fluency measures is related to other tests that require frontal lobe and language ability. Furthermore, examining performance in total word responses across 4, 15-s epochs, as has recently been explored by Eppig and colleagues (2011), may have provided additional insights in regard to group differences in temporal gradients. Finally, the

data used to complete this study were derived from two separate studies collected by the same laboratory at Washington State University. It is possible that differences in study administration and testing battery could have impacted the present results, although no systematic errors were evident.

Results from the present study revealed that individuals with multidomain aMCI performed deficiently on both fluency tasks, primarily due to difficulties in switching ability. Although the naMCI group had a compromised performance compared with controls on the letter fluency task only, switching ability on both tasks appeared to be diminished. Although the performances of the single-domain aMCI group did not differ significantly from controls, their performances generally fell between the scores of the normal controls and the multidomain aMCI group. The relatively intact performances of the single-domain aMCI group suggests that impairment on verbal fluency tests occurs as cognitive domains beyond memory become impaired. Reduced switching capacity, which has been linked to prefrontal executive abilities, appears to be contributing most to the poorer performance of individuals with multidomain MCI and naMCI. Based on the observed differences between groups, future studies examining MCI participants performances on verbal fluency tasks should take into account subtypes and domains of MCI as these differences may explain the variance in performance outcomes of studies that looked at aMCI as a single entity.

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## Conflict of Interest

None declared.

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## References

Adlam, A. R., Bozeat, S., Arnold, R., Watson, P., & Hodges, J. R. (2006). Semantic knowledge in mild cognitive impairment and mild Alzheimer's disease. *Cortex*, *42*, 675–684.

Albert, M. S., DeKosky, S. T., Dickson, D., Dubois, B., Feldman, H. H., Fox, N. C., et al. (2011). The diagnosis of mild cognitive impairment due to Alzheimer's disease: Recommendations from the National Institute on Aging Alzheimer's Association workgroups on diagnostic guidelines for Alzheimer's disease. *Alzheimer's and Dementia: The Journal of the Alzheimer's Association*, *7*, 270–279.

Almkvist, O. (1994). Neuropsychological deficits in vascular dementia in relation to Alzheimer's disease: Reviewing evidence for functional similarity or divergence. *Dementia*, *5*, 203–209.

American Psychiatric Association. (2000). *Diagnostic and statistical manual of mental disorders, 4th edition, Text Revision*. Washington, DC: American Psychiatric Press.

Bäckman, L., Jones, S., Berger, A. K., Laukka, E. J., & Small, B. J. (2005). Cognitive impairment in preclinical Alzheimer's disease: A meta-analysis. *Neuropsychology*, *19*, 520–531.

Birn, R. M., Kenworthy, L., Case, L., Caravella, R., Jones, T. B., Bandettini, P. A., et al. (2010). Neural systems supporting lexical search guided by letter and semantic category cues: A self-paced overt response fMRI study of verbal fluency. *Neuroimage*, *49*, 1099–1107.

Brandt, J., & Folstein, M. (2003). *Telephone interview for cognitive status*. Lutz, FL: Psychological Assessment Resources.

Brandt, J., & Manning, K. J. (2009). Patterns of word-list generation in mild cognitive impairment and Alzheimer's disease. *The Clinical Neuropsychologist*, *23*, 870–879.

Clark, L. J., Gatz, M., Zheng, L., Chen, Y. L., McCleary, C., & Mack, W. J. (2009). Longitudinal verbal fluency in normal aging, preclinical, and prevalent Alzheimer's disease. *American Journal of Alzheimer's Disease and Other Dementias*, *24*, 461–468.

Delis, D. C., Kaplan, E., & Kramer, J. H. (2001). *Delis-Kaplan Executive Function System (D-KEFS)*. San Antonio, TX: The Psychological Corporation.

Eppig, J., Wambach, D., Nieves, C., Price, C. C., Lamar, M., Delano-Wood, L., et al. (2011). Dysexecutive functioning in mild cognitive impairment: Derailment in temporal gradients. *Journal of the International Neuropsychological Society*, *18*, 20–28.

Fahlander, K., Wahlin, A., Almkvist, O., & Bäckman, L. (2002). Cognitive functioning in Alzheimer's disease and vascular dementia: Further evidence for similar patterns of deficits. *Journal of Clinical Experimental Neuropsychology*, *24*, 733–734.

Fernaeus, S. E., & Almkvist, O. (1998). Word production: Dissociation of two retrieval modes of semantic memory across time. *Journal of Clinical and Experimental Neuropsychology*, *20*, 137–143.

Fuster, J. M. (1997). *The prefrontal cortex: Anatomy, physiology, and neuropsychology of the executive lobe* (2nd ed.). New York: Lippincott-Raven Press.

Henry, J. D., Crawford, J. R., & Phillips, L. H. (2004). Verbal fluency performance in dementia of the Alzheimer's type: A meta-analysis. *Neuropsychologia*, *42*, 1212–1222.

Hodges, J. R., Patterson, K., Oxbury, S., & Funnell, E. (1992). Semantic dementia: Progressive fluent aphasia with temporal lobe atrophy. *Brain*, *115*, 1783–1806.

Ivnik, R. J., Malec, J. F., Smith, G. E., Tangalos, E. G., & Petersen, R. C. (1996). Neuropsychological testing norms above age 55: COWAT, BNT, MAE TOKEN, WRAT-R Reading, AMNART, Stroop, TMT, and JLO. *The Clinical Neuropsychologist*, *10*, 262–278.

Jones, S., Laukka, E. J., & Bäckman, L. (2006). Differential verbal fluency deficits in the preclinical stages of Alzheimer's disease and vascular dementia. *Cortex*, *42*, 347–355.

Lamar, M., Price, C. C., Davis, K. L., Kaplan, E., & Libon, D. J. (2002). Capacity to maintain mental set in dementia. *Neuropsychologia*, *40*, 435–445.

Lezak, M. D., Howieson, D. B., Loring, D. W., Hannay, H. J., & Fischer, J. S. (2004). *Neuropsychological assessment* (4th ed.). New York: Oxford University Press.

Morris, J. C. (1993). The Clinical Dementia Rating (CDR): Current version and scoring rules. *Neurology*, *43*, 2412–2414.

Mummery, C. J., Patterson, K., Hodges, J. R., & Wise, R. J. (1996). Nonlinear regression in parametric activation studies. *Neuroimage*, *4*, 60–66.

Murphy, K. J., Rich, J. B., & Troyer, A. K. (2006). Verbal fluency patterns in amnestic mild cognitive impairment are characteristic of Alzheimer's type dementia. *Journal of the International Neuropsychological Society*, *12*, 570–574.

Nutter-Upham, K. E., Saykin, A. J., Rabin, L. A., Roth, R. M., Wishart, H. A., Pare, N., et al. (2008). Verbal fluency performance in aMCI and older adults with cognitive complaints. *Archives of Clinical Neuropsychology*, *23*, 229–241.

Ober, B. A., Dronkers, N. F., Koss, E., Delis, D. C., & Friedland, R. P. (1986). Retrieval from semantic memory in Alzheimer-type dementia. *Journal of Clinical and Experimental Neuropsychology*, *8*, 75–92.

Owen, A. M., Downes, J. J., Sahakian, B. J., Polkey, C. E., & Robbins, T. W. (1990). Planning and spatial working memory following frontal lobe lesions in man. *Neuropsychologia*, *28*, 1021–1034.

Petersen, R. C. (2004). Challenges of epidemiological studies of mild cognitive impairment. *Alzheimer Disease and Associated Disorders*, *18*, 1–2.

Petersen, R. C., Doody, R., Kurz, A., Mohs, R. C., Morris, J. C., Rabins, P. V., et al. (2001). Current concepts in mild cognitive impairment. *Archives of Neurology*, *58*, 1985–1992.

Petersen, R. C., Smith, G. E., Waring, S. C., Ivnik, R. J., Tangalos, E. G., & Kokmen, E. (1999). Mild cognitive impairment: Clinical characterization and outcome. *Archives of Neurology*, *56*, 303–308.

Raboutet, C., Sauzéon, H., Corsini, M., Rodrigues, J., Langevin, S., & N'Kaoua, B. (2010). Performance on a semantic verbal fluency task across time: Dissociation between clustering, switching, and categorical exploitation processes. *Journal of Clinical and Experimental Neuropsychology*, *32*, 268–280.

Raoux, N., Amieva, H., Le Goff, M., Auriacombe, S., Carcaillon, L., Letenneur, L., et al. (2008). Clustering and switching processes in semantic verbal fluency in the course of Alzheimer's disease subjects: Results from the PAQUID longitudinal study. *Cortex*, *44*, 1188–1196.

Rascovsky, K., Salmon, D. P., Hansen, L. A., Thal, L. J., & Galasko, D. (2007). Disparate letter and semantic category fluency deficits in autopsy-confirmed frontotemporal dementia and Alzheimer's disease. *Neuropsychology*, *21*, 20–30.

Reitan, R. M. (1958). The relation of the Trail Making Test to organic brain damage. *Journal of Consulting Psychology*, *19*, 393–394.

Rohrer, D., Salmon, D. P., Wixted, J. T., & Paulsen, J. S. (1999). The disparate effects of Alzheimer's disease and Huntington's disease on semantic memory. *Neuropsychology*, *13*, 381–388.

Schmitter-Edgecombe, M., Parsey, C., & Cook, D. (2011). Cognitive correlates of functional performance in older adults: Comparison of self-report, direct observation and performance-based measures. *Journal of the International Neuropsychological Society*, *17*, 853–864.

Schmitter-Edgecombe, M., Woo, E., & Greeley, D. (2009). Characterizing multiple memory deficits and their relation to everyday functioning in individuals with mild cognitive impairment. *Neuropsychology*, *23*, 168–177.

Shimomura, T., Mori, E., Yamashita, H., Imamura, T., Hirono, N., Hashimoto, M., et al. (1998). Cognitive loss in dementia with Lewy bodies and Alzheimer disease. *Archives of Neurology*, *55*, 1547–1552.

Steinberg, B. A., Bieliauskas, L. A., Smith, G. E., & Ivnik, R. J. (2005). Mayo's Older Americans Normative Studies: Age- and IQ-adjusted norms for the Trail-Making Test, the Stroop Test, and MAE Controlled Oral Word Association Test. *Clinical Neuropsychology*, *19*, 329–377.

Taler, V., & Phillips, N. A. (2008). Language performance in Alzheimer's disease and mild cognitive impairment: A comparative review. *Journal of Clinical and Experimental Neuropsychology*, *30*, 501–556.

Troyer, A. K. (2000). Normative data for clustering and switching on verbal fluency tasks. *Journal of Clinical and Experimental Neuropsychology*, *22*, 370–378.

Troyer, A. K., Moscovitch, M., & Winocur, G. (1997). Clustering and switching as two components of verbal fluency: Evidence from younger and older healthy adults. *Neuropsychology*, *11*, 138–146.

Troyer, A. K., Moscovitch, M., Winocur, G., Alexander, M. P., & Stuss, D. (1998). Cluster and switching on verbal fluency: The effects of frontal- and temporal-lobe lesions. *Neuropsychologia*, *36*, 499–504.

Troyer, A. K., Moscovitch, M., Winocur, G., Leach, L., & Freedman, M. (1998). Clustering and switching on verbal fluency tests in Alzheimer's and Parkinson's disease. *Journal of the International Neuropsychological Society*, *4*, 137–143.

Williams, J. M. (1991). *Memory Assessment Scales professional manual*. Odessa: Psychological Assessment Resources.

Yesavage, J. A., Brink, T. L., Rose, T. L., Lum, O., Huang, V., Adey, M., et al. (1983). Development and validation of a geriatric depression screening scale: A preliminary report. *Journal of Psychiatric Research*, *17*, 37–49.