INDIVIDUAL DIFFERENCES IN VERBAL FLUENCY

BY

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Abstract

Young adults, healthy older adults, adults with Parkinson's disease and adults with Alzheimer's disease were given a battery of cognitive tests and a series of verbal fluency tasks including tests of phonetic fluency, semantic fluency and action fluency in both traditional and alternating conditions. Different scoring techniques were compared including counts of correct responses, perseverations, intrusions, and clustering. As expected, young adults produced the most correct responses and the fewest perseverations, while the older adults with Alzheimer's disease produced the fewest correct responses and most perseverations. Cluster size was similar across all groups. The cognitive tests addressed individual differences in processing speed, working memory, inhibition, and verbal ability. Speed and inhibition were the best predictors of performance on verbal fluency measures for the three older groups of adults.

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Individual Differences in Verbal Fluency

Aging impacts cognitive function in all adults, healthy as well as those with neurodegenerative diseases like Alzheimer's disease and Parkinson's disease. Cognitive deficits are tied to the loss of functional status and independence (Beatty, et al., 2002). One commonly used test to assess older adults' cognitive function is the verbal fluency test, a word generation task. Verbal fluency has been assessed since 1938 when Thurstone identified it as one of components of intelligence (Thurstone, 1938). Verbal fluency is tested by giving participants a specific rule to prompt the generation of words such as "words beginning with f" or "animals" and allowing them 60s to 90s to respond. The traditional administration of the test includes three letter prompts or phonemic category prompts (F/A/S) and a semantic category such as animals. The number of correct responses is usually taken as the measure of cognitive status**.** On the typical 60s F/A/S test, a young adult might generate 14 correct responses, a healthy older adults might generate 14 correct responses, and an impaired older adult with dementia might produce 10 correct responses (Murphy, Rich, & Troyer, 2006; Troyer, Moscovitch, & Winocur, 1997).

Verbal fluency requires multiple cognitive functions such as verbal ability, sustained attention, both working memory and semantic memory, and inhibition (Beatty, Salmon, Troster, & Tivis, 2002; March & Pattison, 2006; Troyer, Moscovitch, & Winocur, 1997). These cognitive processes can vary across individuals; therefore verbal fluency is a useful tool for assessing individual differences in overall intelligence (Raskin & Rearick, 1996). Some general factors have been shown to influence verbal fluency performance including age and education level. March, Wales, and Pattison (2003) found that education level significantly impacts both phonetic and semantic fluency, while age impacts only semantic fluency. Troyer (2000) also found age and education to be predictors of phonetic and semantic fluency, but not gender. Older adults tend to produced fewer correct responses than young adults on verbal fluency. People with higher education tend to have better scored on verbal fluency, but men and women perform equally well. Verbal fluency is a potentially powerful tool for assessing neurodegenerative disorders in clinical settings (Fernaus, et al., 2008). Performance on verbal fluency tests predicts the rate of cognitive decline and the progression of diseases such as Alzheimer's and Parkinson's (Cosentino, Scarmeas, Albert, & Stern, 2006). Cosentino and colleagues (2006) have found that verbal fluency can predict mortality in community based sample of individuals with incident Alzheimer's disease.

Troyer, Moscovitch, and Winocur (1997) specifically suggest that verbal fluency has two components: semantic retrieval and executive function. Semantic retrieval is the ability of the individual to access their mental word store following a prompt and find candidate words consistent with that prompt. This aspect of verbal fluency is considered to be a relatively automatic (Rende, Ramsberger, & Miyake, 2002) and is not typically thought to be impacted by age unless affected by disease (Mayr & Kliegl, 2000). However, individuals with Alzheimer's disease (Troyer, Moscovitch, Winocur, Leach, & Freedman, 1998) and Parkinson's disease (Raskin, Sliwinski, & Borod, 1992) have decreased verbal fluency. Verbal fluency progressively worsens as these diseases progress (Beatty, Salmon, Testa, Hanisch, & Troster, 2000; Murphy, Rich & Troyer, 2006). Fernaus and colleagues (2008) believe that semantic fluency is the best test for assessing the differences between healthy and Alzheimer's disease patients.

The second component of verbal fluency identified by Troyer, Moscovitch, and Winocur (1997) is executive function (EF). EF is a critical aspect of cognition and functional status that is generally defined as "those capacities that enable a person to engage successfully in independent, purposive, self-serving behavior" (Lezak, Howieson, & Loring, 2004, p. 35). However, there is disagreement about the measures that best assess EF. Typically, EF is decomposed into major component processes such as inhibition, planning, time-sharing, updating, and switching, all of which can influence individual performance on verbal fluency measures (Zhang, 2007). Executive function is typically assessed by performance on neuropsychological tests such as Wisconsin Card Sort Task and measures of verbal fluency (Aron, 2008). Executive function plays a role in the number of errors an individual produces on verbal fluency tasks.

Unlike semantic processing, there are age differences in executive functioning (Mayr, 2002). Executive function is often localized to the frontal lobe of the brain and dysfunction within this lobe is related to changes in aspects of executive function. For example, individuals with frontal lobe impairments perform worse on phonetic fluency than normal healthy controls (March & Pattison, 2006). Selective deficits on tests of semantic fluency such as impaired use of semantic clustering have been found in individuals with Parkinson's disease (Raskin, et al., 1992). Frontal lobe dysfunction interferes with verbal fluency performance in patients with frontotemporal dementia who produce significantly fewer responses on both phonetic and semantic fluency measures (Rascovsky, et al., 2007). Those with frontal lobe lesions or Huntington's disease also have impaired phonetic fluency (Rich, Troyer, Bylsma, & Brandt, 1999). In order to assess impairment on verbal fluency, the total number of correct responses is commonly used to measure the level of performance by individuals.

Traditionally, fluency is assessed by counting the number of correct responses, excluding perseverations (repeating a correct response: fraud, friend, fake, *fraud*) and intrusions (using a word that does not fit the category: fraud, friend, *phlegm*). When compared with healthy controls, the most common manifestation of verbal fluency impairment due to multiple types of dementia, Parkinson's disease, and mild traumatic brain injury is a decrease in the number of correct responses (Troster, et al., 1998; Raskin, et al., 1992; Troyer, Moscovitch, Winocur, Leach, et al., 1998). Fernaus and colleagues (2008) were able to predict membership of AD and mild cognitive impairment patients with 80% accuracy using the number of correct responses to letter and semantic fluency tests. However the number of correct responses can not always differentiate between disorders, for example, Parkinson's dementia and Alzheimer's dementia (Troyer, Moscovitch, Winocur, Leach, et al., 1998). In an attempt to assess individual differences are impacted by various disorders, researchers have developed a variety of scoring procedures and verbal fluency formats thought to be more sensitive to impairment than correct responses alone.

Researchers have examined a number of other measures that may be more sensitive to individual and group differences on verbal fluency including: perseverations, intrusions, phonetic or semantic clusters and cluster switching, as well as by using alternative measures such as the time course of responding (March & Pattison, 2006). Perseverations are common for adults with Alzheimer's disease, but relatively infrequent for healthy adults. Different types of perseverations (i.e. recurring perseverations: fan, fried, friend, *fan;* continuous perseverations: fan, *fan, fan;* stuck-in-set: continues to name f words after a new letter has been presented) were more prevalent in different stages of the disease (Pekkala, Albert, Spiro, & Erkinjuntti, 2008). Perseverations on semantic tasks have been used to distinguish between mild and moderate Alzheimer's and healthy older adults. Recurrent perseveration occurred in all groups; mild Alzheimer's disease patients made more continuous perseverations and few stuck-in-set errors; moderate Alzheimer's disease patients made many of all types of perseverations (Pekkala, et al., 2008). However, many studies use the total of all perseverations types because the number of perseverations is relatively low even in impaired groups.

Cluster and switching scoring has also been used on both phonetic and semantic fluency measures. These scoring methods may be more sensitive to the type of the neurological impairment than traditional scoring methods because they focus on the ability to use semantic search processes to access lexical knowledge. Over extended periods of time, words tend to be produced in spurts on verbal fluency measures, e.g., a cluster of words produced, followed by a pause before another spurt or cluster of words. Words within a cluster will tend to share common phonetic or semantic features (Troyer, Moscovitch, Winocur, Leach, et al., 1998). Cluster size is related to temporal lobe functioning (Troyer, Moscovitch, Winocur, Leach, et al., 1998). Switching to a new subcategory requires search processes, and switching is a frontal lobe function (Troyer, Moscovitch, Winocur, Leach, et al., 1998). Clustering and switching are highly correlated with the number of correct responses generated (Troyer Moscovitch, Winocur, Alexander, & Stuss, 1998).

Phonetic clusters (i.e., fie, foe, fee or shoe, shirt, shawl) tend to be produced in responses to the phonetic fluency prompts, while semantic clusters (i.e., fist, fight, foe or t-shirt, sweater, button-down shirt) are produced in response to semantic fluency prompts (Raskin, Sliwinski, & Borod, 1992; Troster, et al., 1998). Older adults switch less often than the young adults. However, healthy older adults produce larger clusters than the young adults on the phonetic fluency measures which may reflect large vocabularies (Troyer, et al., 1997). Individuals with Alzheimer's dementia produce small clusters and have reduced switching (March & Pattison, 2006). In other studies, cluster size on semantic fluency tests was impaired in adults with Alzheimer's disease, while the phonetic clustering was impaired for adults with Parkinson's disease dementia (Troyer, Moscovitch, Winocur, Leach, et al., 1998; Troyer Moscovitch, Winocur, Alexander, et al., 1998). However cluster size may not distinguish between groups such as Alzheimer's dementia and Parkinson's dementia.

Beatty and colleagues (2000) were unable to distinguish between stable and declining individuals with Alzheimer's disease in a multiple session study. Clustering measures have been challenged because the number of clusters or switches between clusters relies not only on the difficulty of moving between clusters but on the difficulty of generating words within clusters (Mayr, 2002).

In the past, verbal fluency has been assessed using tests of letter or phonetic fluency and tests of semantic or category fluency. Recently, novel fluency tests have been developed and novel approaches to scoring verbal fluency have been proposed. Action fluency tests have recently been developed to capture specific dissociations between verb and noun retrieval (Piatt, Fields, Paoloa, & Troster, 1999). Action fluency is thought to be a more sensitive measure of frontal lobe dysfunction than traditional fluency measures, especially for those with Parkinson's disease (Woods, Scott, Sires, Grant, Heaton, & Troster, et al., 2005; Piatt, et al., 1999). Verb retrieval may more closely depend on the frontal cortex while noun retrieval may depend more closely on temporal cortex (Piatt, Fields, Paoloa, & Troster, 2004). Hence, action fluency may be affected by Parkinson's disease since this disease affects frontal, striate cortex (Piatt et al., 2004).

A common approach to investigating how executive function affects verbal fluency is through the use of dual tasking which increases cognitive demands on the individual. Researchers have use a verbal fluency task in conjunction with another task such as finger tapping (Troyer, Moscovitch, & Winocur, 1997), arithmetic tasks, articulatory suppression, or cube comparisons (Rende, Ramsberger, & Miyake, 2002).

When finger tapping is used to divide attention, fewer words are generated, switching decreases, but clustering is unaffected. The results suggest that some components of working memory disrupted by the tapping task contribute to verbal fluency performance. Rende and colleagues (2002) suggests that finger tapping interferes with the phonological loop component of working memory (Baddeley, Gathercole, & Papagno, 1998).

Instead of using a different task, some research uses an alternating format of verbal fluency which requires the participant to respond to two distinct fluency prompts, first to one prompt then the next in an alternating fashion. Mayr and Kliegl (2000) used an alternating fluency task to assess the costs associated with switching between response categories. The alternating condition was more difficult for the older adults than the young adults as evidenced by a consistently higher number of within category perseverations. This pattern suggests that the alternating fluency tests is impaired in those with lower executive function, i.e., older adults, and are therefore unable to keep track of prior responses or inhibit them.

This review suggests that a number of factors affect verbal fluency performance including group and individual differences, test format, and scoring method. There were five goals for the current study. First, compare the performance of the four groups, young adults, healthy older adults, older adults with Alzheimer's disease, and older adults with Parkinson's disease, on verbal fluency tests. Second: evaluate alternate scoring approaches such as traditional scoring (correct, perseverations, intrusions) and the clustering and switching methods based on their ability to differentiate between groups. Third: assess the consistently of performance on various fluency tests including tests of the letter fluency, easy category fluency, hard category fluency, and action fluency. Fourth: contrast performance on traditional and alternating fluency tests. Fifth: compare how individual differences in speed of processing, working memory, verbal ability, and inhibition affect performance on verbal fluency tests.

Methods

Participants

All participants were native English speakers and paid $10 per hour for their time. The thirty-six young adults (18-30 years old, M_{YA} = 21.5, *SD* = 3.1) were enrolled at a Midwestern university. Data from one additional participant was lost due to a technical failure. All young adults were recruited using flyers posted on campus. The healthy community-dwelling older adults (n=30, 65-90 years old, M_{HA} = 72.0, *SD* = 5.4) were recruited from databases of past recruited participants maintained by the Grayhawk Laboratory at the University of Kansas Medical Center and the Language Across the Lifespan Laboratory at the University of Kansas. Data from three older adults were lost due to technical problems.

Twenty-three community-dwelling older adults (65-90 years old, M_{AD} = 73.8, *SD* = 7.2) with Alzheimer’s disease were recruited from the participant registry maintained by the Brain Aging Center at the University of Kansas Medical Center. All had mild (1.0) or very mild (0.5) dementia on the Clinical Dementia Rating Scale (CDR scale; Hughes, 1982). They were tested primarily at the Landon Center on

Aging at University of Kansas Medical Center or at a testing site in Lawrence, KS. Data from one participant with AD was lost due to technical problems, another withdrew from testing.

The 30 independent-living individuals with Parkinson's Disease (65-90 years old, M_{PD} = 71.9, *SD* = 6.0) were recruited from the University of Kansas Medical Center's Parkinson's Disease Center of Excellence and tested primarily at the Landon Center. The participants had idiopathic PD; individuals with other forms of PD were excluded from the study. Individuals did not have other chronic conditions such as a history of stroke, use of anxiolytics, antidepressants, neuroleptics, sedatives, alcohol abuse, pulmonary disease, and other conditions that may affect speech articulation and speech rate nor did they show any signs of dementia.

Cognitive Tests

All participants were given a battery of tests of cognitive abilities administered by a trained research assistant. The test battery included tests of cognitive status and depression as well as tests of verbal ability, processing speed, working memory, and inhibition. All testing was audio recorded to facilitate later analysis. A digital ink software utility developed by the Digital Electronic Core of the Biobehavioral Neurosciences of Communication Disorders Research Center at the University of Kansas was used to administer the tests and record their responses. Table 1 summarizes the results of the cognitive tests.

Table 1.

Means and standard deviations for cognitive tests for young adults, healthy older adults, older adults with Alzheimer's disease, older adults with Parkinson's disease.

	Young Adults		Healthy Older Adults		Older Adults with AD		Older Adults with PD	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
MMSE	29.4_{a}	1.2	$28.5_{a,b}$	1.2	25.2_{c}	4.98	27.9_{b}	2.1
GDS	1.2_{a}	1.2	1.1_{a}	1.0	1.5_{a}	1.5	2.8	2.9
Boston Naming	56.0_{a}	3.7	55.8_{a}	5.2	38.1	13.5	54.2_{a}	4.6
Digit Symbol	34.8_{a}	5.3	24.2_{b}	4.8	15.0_{c}	5.2	20.0_{d}	6.8
Stroop XXXs	91.5_{a}	14.2	69.5_{b}	14.1	43.9_{c}	13.4	64.2_{b}	16.5
Stroop Words	65.8_{a}	12.2	40.2_{b}	8.9	19.2_{c}	10.0	35.1_{b}	12.0
Stroop Interference	0.3_{a}	0.1	0.4_{b}	0.1	0.6_{c}	0.2	0.4_{b}	0.1
Trail A Time	46.6_{a}	14.1	77.7_{b}	30.0	123.6_{c}	44.1	96.0_{d}	31.2
Trails B Time	55.3_{a}	16.4	107.4_{b}	59.1	199.9_{c}	98.1	158.5_{d}	87.8
Trails Interference	-0.2_{a}	0.4	$-0.4_{a,b}$	0.7	-0.7_{b}	0.5	-0.6_{b}	0.5
Forward Digits	9.8_{a}	2.3	$9.0_{a,b}$	3.0	7.1_{c}	4.6	$7.5_{b,c}$	2.4
Backward Digits	8.2_{a}	3.0	6.9_{b}	2.5	5.3_{c}	1.7	$6.0_{b,c}$	1.2
Operation Span	3.3_{a}	1.1	2.2_{b}	0.8	0.5_{d}	.8	1.6_{c}	1.1
Letter Comparison Time	84.9_{a}	14.2	122.5_{b}	38.3	195.3_{d}	63.0	165.2_{c}	58.4
Letter Comparison Rate	2.9_{a}	0.5	4.2_{b}	1.3	7.7_{d}	3.6	6.2_{c}	3.0
Letter Comparison Correct	29.7_{a}	0.8	$28.9_{a,b}$	1.1	25.8_{c}	6.7	27.7_{b}	3.6

Note. Table entries that have common subscripts do not differ at $p < 0.05$.

Basic demographic information that was collected included years of formal education completed. The four groups differed significantly in years of education completed, F(3, 114) = 5.152, p = 0.002. Healthy older adults had significantly more formal education than the other groups (M_{YA} = 14.77, *SD* = 1.90; M_{HA} = 17.00, *SD* = 2.64; M_{AD} = 15.26, *SD* = 2.91; M_{PD} = 14.90, *SD*=2.71). For this and all the comparisons, least significant difference tests were used to compare the groups with alpha = 0.05.

The Mini-Mental Status Examination (MMSE; Folstein, Folstein, & McHugh, 1975) provides general assessment of cognitive status including tests of orientation, attention, memory, and language. The four groups differed significantly on the MMSE, F(3, 114) = 12.72, p < .001. The young adults and healthy older adults had similar scores (M_{YA} =29.37 SD = 1.21, M_{HA} = 28.5 SD = 1.22); the older adults with PD (M_{PD} = 27.93 SD = 2.12) and healthy older adults had similar scores, and the older adults with AD (M_{AD} = 25.2 SD = 4.90) had significantly lower scores than the other participants.

All participants were given the Geriatric Depression Scale (GDS; Sheikh & Yesavage, 1986) which is a widely used depression measure. The four groups differed significantly on this test, F(3,114) = 5.548, p = 0.001; however, the young adults, healthy older adults, and older adults with AD had similar scores (M_{YA} = 1.23 SD = 1.22, M_{HA} = 1.07 SD = 1.02, M_{AD} = 1.52 SD = 1.47). The older adults with PD (M_{PD} = 2.77 SD = 2.90) had significantly lower scores than the other participants.

The Boston Naming Test (Kaplan, Goodglass, & Weintraub, 1983) is used to assess verbal ability. Sixty black and white line drawings are presented to the participants to name. Semantic and phonetic cues are provided if the participant is unable to spontaneously name the object. The four groups differed significantly on this test, $F(3,114) = 35.88$, $p < 0.001$; however, the young adults, healthy older adults, and older adults with PD had similar scores ($M_{YA} = 55.97$, $SD = 3.71$; $M_{HA} = 55.77$, $SD = 5.19$; $M_{PD} = 54.20$; $SD = 4.62$); the older adults with AD ($M_{AD} = 38.13$, $SD = 13.50$) had significantly lower scores than the other participants.

The digit symbol task (Wechsler, 1958) is used to test speed of processing. Participants matched symbols to numbers from a key for 45 seconds. The number of correct responses was totaled. The four groups differed significantly on this test, $F(3,112) = 66.86$, $p < 0.001$. However, the young adults ($M_{YA} = 34.77$ SD = 5.28) performed better than the healthy older adults ($M_{HA} = 24.17$ SD = 4.7), whose performance was better than older adults with PD ($M_{PD} = 19.97$ SD = 6.78), who performed better than the older adults with AD ($M_{AD} = 14.95$ SD = 5.20).

The Stroop task was used to assess processing speed. Participants identify the color of blocks of colored XXX’s (blue, green, red) as quickly as they can for 45 seconds. The number of correct responses is counted. In Stroop color words, the color words (BLUE, GREEN, and RED) are printed in different colors of ink e.g., “BLUE” printed in green ink. Participants identify the color of the ink, ignoring the words, for 45 seconds, and the number of correct responses is counted. Inhibition is measured by calculating an interference score with equation 1:

Interference = (blocks of XXX – color names) / blocks of XXX (1)

The four groups differed significantly on the Stroop XXX's, F(3,110) = 49.75, $p <$ 0.001; the young adults had faster processing speeds (M_{YA} = 91.46, SD = 14.22) than the three groups of older adults. Healthy older adults and older adults with PD had similar scores (M_{HA} = 69.5 SD = 14.12, M_{PD} = 64.24 SD = 16.51), while the older adults with AD had significantly slower speeds than the other participants (M_{AD} = 43.91, SD = 13.35). This same pattern was seen in the Stroop words and the Stroop interference score. The four groups were significantly different on their performance on Stroop words, F(3,110) = 89.5, $p < 0.001$ and the Stroop interference calculation, F(3,110) = 20.79, $p < 0.001$. The young adults exhibited less interference (M_{YA} = 0.277 SD = .10) than all the older participants. The healthy older adults and the adults with PD both experienced less interference from the color words (M_{HA} = 0.41 SD = 0.11, M_{PD} = 0.44 SD = 0.15) than the older adults with AD (M_{AD} = 0.56 SD = 0.20).

The Trail Making test has two components. The Trail A is given to measure processing speed as participants connected labeled dots in numerical order while, Trail B requires the participant to alternate between letters and numbers. An interference score assessing the participant's inhibition was calculated using equation 2:

Interference = (time in seconds on Trail A – time in seconds on Trail B) / time in seconds on Trail A (2)

The four groups differed significantly on Trail A, F (3,111) = 31.34, $p < 0.001$. The four groups also differed significantly on Trail B, F (3,108) = 21.25, $p < 0.001$. Both tasks had the same pattern; older adults with AD took more time to complete the task than older adults with PD, who were slower than healthy older adults, who were slower than the healthy young adults. The interference scores were significantly different among the groups, F(3, 104) = 4.13, $p = 0.008$; the healthy older adults (M_{HA} = -0.41, SD = 0.65) were statistically similar to all other groups. Young adults experienced significantly less interference (M_{YA} = -0.22 SD =0.38) than either disordered groups (M_{AD} = -0.69 SD = 0.52, M_{PD} = -0.61 SD = 0.50).

To assess working memory, the Digits Forward and Digits Backward tests were administered (Wechsler, 1958). The tests present participants with a string of numbers between 2-10 digits in length which they are to repeat in the same order (Digits Forward) or in reverse order (Digits Backwards). The four groups differed significantly on Digits Forward, F(3,114) = 5.11, $p = 0.002$. The young adults and healthy older adults were statistically similar (M_{YA} = 9.83, *SD* = 2.35; M_{HA} = 9.00, *SD* = 3.04) and had higher scores than the older adults with AD (M_{AD} = 7.13, *SD* = 4.56). However, the older adults with PD (M_{PD} = 7.47, *SD* = 2.36) only differed significantly from the young adults. On Digits Backward, there was an overall group effect, F(3,114) = 9.34, $p < 0.001$; young adults (M_{YA} = 8.2, *SD* = 3.0) were better than healthy older adults (M_{HA} = 6.90, *SD* = 2.5); healthy older adults were statistically similar to older adults with PD (M_{PD} = 6.0, *SD* = 1.2); older adults with AD (M_{AD} = 5.3, *SD* = 1.7)had statistically lower scores than all other groups.

The Operation Span was given as a measure of working memory. For this task, the participant reads a math equation out loud, responds whether the equation is correct or not, then reads the word printed on the page. The participant repeats this for a set of 2 - 5 equations; at the end of each set of equations, the participant must verbally recall each of the words from the set. All four groups differed significantly on this test, $F(3,114) = 42.12$, $p < 0.001$. Participants with AD in particular had a great deal of difficulty on this measure, most failing to complete the practice items ($M_{AD} = 0.48$, $SD = 0.79$).

The Letter Comparison Task was used to measure processing speed. Participants compare pairs of lists of randomly ordered letters and determine if the pairs are the same or different. The pairs are different if any of the letters are in a different order or if there are different letters. Participants were asked to make 30 comparisons as rapidly as possible. The time required to complete the task was collected, as well as the number correct. The letter comparison rate was calculated using equation 3:

$$\text{Letter Comparison Rate} = \text{time in seconds} / \text{number correct} \quad (3)$$

The four groups were significantly different on the time taken to complete this task, $F(3,111) = 31.9$, $p < 0.01$ and had significantly different letter comparison rates, $F(3,111)$ 23.7, $p < 0.01$. The four groups had similar patterns for time and comparison rates, young adults outperformed healthy older adults, who were better than older adults with PD, who were better than the older adults with AD. The four groups performed significantly different on the number correct, $F(3,113) = 6.2$, $p < 0.01$.

The young adults (M_{YA} = 29.69, *SD* = 0.80) and older adults (M_{OA} = 28.90, *SD* = 1.06) rarely made errors. Older adults and older adults with PD (M_{PD} = 27.73 SD = 3.60) performed similarly and all groups had more correct responses than the older adults with AD (M_{AD} = 25.77 *SD* = 6.71).

Wisconsin Card Sort Task (WCST) is a classic measure of inhibition and executive function. For this battery, the WCST was administered on using a 64 – card computerized test on a Toshiba Tablet PC. Means and standard deviations are listed in Table 2. A series of cards with squares, crosses, stars, or circles that vary in number or color is displayed on the screen and the participant sorts each card based on a rule. The rule is not given explicitly by the tester, instead each response is acknowledged as correct or incorrect. During the test, a new rule is introduced and the participant must adapt to the change without being told. In addition to correct responses, the total numbers of perseverative and nonperseverative errors were collected. Perseverative errors are repeated failures to switch to the new rule. Nonperseverative errors occur when an individual fails to follow the current rule correctly. The number of correct responses was statistically different for each group; F (3,114) = 33.28, $p < 0.01$. Young adults were statistically more likely to be correct than the healthy older adults, who were performed better than the older adults with PD, who were better than the older adults with AD. The four groups were significantly different for both perseverative errors, F(3,114) = 15.1, $p < 0.01$, and nonperseverative errors, F(3,114) = 16.5, $p < 0.01$. Young adults had fewer perseverative errors and fewer nonperseverative errors than any of the older groups.

Healthy older adults committed fewer perseverative errors than both disordered groups, who performed similarly. The healthy older adults and older adults with PD had similar numbers of nonperseverative errors but both made fewer nonperseverative errors than the older adults with AD.

Verbal Fluency

The verbal fluency portion of the test battery took approximately 48 minutes to administer. Verbal fluency tests were interspersed among the other cognitive tasks. Three types of verbal fluency tests were administered; letter (phonetic) fluency (S/L/M/P), semantic fluency – (Easy categories – birds, clothes, body parts, colors; Hard categories – insects, fabrics, fluids, writing utensils), and action fluency (things people do; ways you can move; ways you can talk; things you can do to an egg). Letter prompts were selected based on pilot testing with a group of 10 young adults and 10 healthy older adults. Each was given a list of 12 consonants and asked to generate words beginning with each letter, excluding proper names. Participants were allowed 15 minutes to complete the task. The final set of letter prompts was selected such that each participant generated 40 to 50 exemplars of each letter (mean = 43) by both young and older adults. Rejected letter prompts resulted in 25 or fewer exemplars by each group. The category prompts were selected from a wider set of potential prompts based initially on piloted testing with the group of 10 young and 10 older adults; the participants were allowed 15 minutes to generate exemplars of 30 different category prompts. Four prompts that resulted in 50 to 60 exemplars (mean = 56) from each group of participants were selected as easy categories; hard categories elicited 15 to 30 (mean = 26) from each group of participants. This distinction was then validated against two sets of word association norms. Category norms provided by Van Overschelde, Rawson, and Dunlosky (2004) provide category norms including a measure of “category potency” of the average number of responses given for each category by participants within 30 s. Easy categories resulted in six or more responses, on average (mean = 8.6); hard categories resulted in six or fewer responses (mean = 4.3).

In addition, easy and hard categories differed in terms of the number of exemplars listed for each prompt in the South Florida word association norms (Nelson, McEvoy, & Schreiber, 1998). Easy categories had 50 or more exemplars (mean = 83); hard categories had 30 or fewer (mean = 29). Action fluency prompts were developed following Piatt, Fields, Paolo, & Troster (1999) who used a single item “things that people do.” Like the letter and category prompts, the action prompts were chosen from a wider set of potential actions based on pilot testing with the group of 10 young and 10 healthy older adults. Each was given a list of 30 actions and asked to generate exemplars. Participants were allowed 15 minutes to complete the task. The final set of action prompts was selected such that each participant generated 20 - 30 exemplars of each action (mean = 28). Rejected action prompts resulted in 15 or fewer exemplars. For the traditional test format, one prompt is provided and the participant is given three minutes to respond. In the alternating format, participants are given both the prompts and are instructed to alternate their responses between the two prompts. The categories were counterbalanced across the traditional and alternating forms between participants.

Each traditional fluency test took three minutes, while the alternating tests took six minutes. On each test, the participants were shown the prompt, e.g. words that begin with S, and asked to generate as many words as they could think of that would matched the prompt. For the alternating tests, the participants were shown both prompts and were instructed to respond to prompt, then the second prompt, and continue back and forth. The page with the prompt remained available for the participant to look at the entire time. Two traditional fluency tests were administered and one alternating fluency test was administered for each type of fluency, e.g., letter, easy, hard, and action. Targets were counterbalanced across participants, e.g., one participant responded to S and L prompts in the traditional format and M and P prompts in the alternating fluency; while the next participant responded to M and P prompts in the traditional format and S and L prompts in the alternating format.

All responses were digitally recorded for later transcription. The transcripts were coded for four types of responses: correct responses, perseverations, intrusions, and clusters. In addition, cluster size and cluster switches were calculated. Meta-comments were counted as well, but were not included in the analyses. The meta-comments are comments made by the participant about their own performance or attempting to avoid responding such as “I am not doing so well,” “This is really difficult,” “Are these responses ok?” or “I don’t know.” Tables 3-6 show the means and standard deviations of the verbal fluency measures. Correct responses were required to meet the target rule. In the traditional condition, the correct responses from both categories were summed for comparison with the alternating condition. The younger adults produced significantly more correct answers than the other groups. The healthy older adults produced more answers than the two disordered groups for both the traditional and alternating format. Perseverations are correct responses that are repeated; e.g., if the participant responds, “robin, bluebird, cardinal, robin,” the second occurrence of “robin” would be a perseveration. Intrusions are incorrect responses that are not members of the category; if the participant responds, “hand, foot, shirt, head,” shirt is an intrusion.

Clusters were a group of words generated successively that formed a subgroup of the category. For the letter fluency, clusters were identified as words that rhymed (mint, meant), differed by vowel (mat, mitt), shared the first two letters (straight, stop), or were homonyms (pair, pear, pare) (Troyer, Moscovitch, and Winocur, 1997). Clusters for the semantic and action categories were defined for each category (see Appendix A). For example, subcategories of colors included rainbow colors, pastels, colors preceded by descriptive words, and shades of the same color. For the action category, subcategories for “Things You Can Do To An Egg” include ways to cook an egg, ways to destroy an egg, and ways you can decorate an egg. Cluster size was the total number of responses within a cluster minus one. Cluster switching was the number of transitions that occurred between clusters. On the alternating version, clusters and cluster switching were counted each prompt separately and the totals for each prompt were summed for a single score. (See Tables 3, 4, 5, 6 for the results of the verbal fluency measures.)

Reliability

All audio recorded responses were transcribed and scored by a single coder; 15% (5 per group) of the transcripts were randomly selected and verified by a second coder. Agreement was quite high for the number of correct responses and for identification of perseverations and intrusions (all Cronbach's alpha > .95). Agreement was also high for the identification of clusters and the measure of cluster size (Cronbach's alpha > .90).

Table 2.

Means and Standard Deviations of the Wisconsin Card Sorting Task for the young adults, healthy older adults, older adults with Alzheimer's disease, older adults with Parkinson's disease.

	Young Adults		Healthy Older Adults		Older Adults with AD		Older Adults with PD	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Correct	52.9_a	4.4	44.4_b	10.1	30.0_d	9.4	38.2_c	11.2
Errors	11.1_a	4.4	19.6_b	10.0	31.0_d	7.4	25.6_c	11.0
Perseverative Errors	5.5_a	1.4	8.7_b	4.8	14.4_c	6.0	13.7_c	9.4
Nonperseverative Errors	5.6_a	3.8	10.9_b	6.1	16.6_c	7.2	11.9_b	6.7

Note. When entries have the same subscript, the scores are not significantly different at $p < 0.05$.

Table 3.

Means and standard deviations for letter fluency for the young adults, healthy older adults, older adults with Alzheimer's disease, older adults with Parkinson's disease.

	Young Adults		Healthy Older Adults		Older Adults with AD		Older Adults with PD	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Traditional								
Correct	76.8_a	23.2	67.0_b	23.0	40.0_c	16.7	45.2_c	12.3
Perseveration	1.7_a	2.2	5.0_b	4.6	6.0_b	5.0	5.1_b	4.2
Intrusions	1.2_a	2.1	2.0_a	2.8	2.0_a	1.8	2.1_a	2.6
Avg. Cluster Size	2.9_a	0.7	$2.8_{a,b}$	0.6	2.0_c	0.9	2.4_b	0.4
Total Clusters	15.4_a	8.5	$14.6_{a,b}$	8.0	7.0_c	5.8	$10.3_{b,c}$	12.4
Cluster Switching	54.7_a	12.2	51.1_a	15.5	36.9_b	13.8	40.9_b	11.0
Alternating								
Correct	65.3_a	17.8	59.0_a	18.3	32.3_c	14.8	41.2_b	12.1
Perseveration	1.4_a	1.3	5.4_b	4.4	8.2_c	6.7	4.9_b	4.5
Intrusions	0.9_a	1.5	0.9_a	1.0	1.4_a	2.5	1.2_a	1.8
Avg. Cluster Size	1.2_a	0.4	1.2_a	0.4	1.2_a	0.4	1.1_a	0.3
Total Clusters	7.1_a	4.5	7.8_a	4.1	4.0_b	2.9	4.0_b	3.2
Cluster Switching	56.2_a	13.6	54.9_a	17.0	38.1_b	15.7	43.0_b	11.9

Note: Row entries showing the same subscript do not differ at $p < 0.05$.

Table 4.

Means and standard deviations of the easy category fluency for the young adults, healthy older adults, older adults with Alzheimer's disease, older adults with Parkinson's disease.

	Young Adults		Healthy Older Adults		Older Adults with AD		Older Adults with PD	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Traditional								
Correct	68.1_a	21.1	64.2_a	17.6	35.0_c	12.3	51.8_b	14.1
Perseveration	1.7_a	2.1	3.7_b	4.3	8.0_c	5.6	5.5_b	3.1
Intrusions	1.3_a	1.6	$2.1_{a,b}$	3.0	3.4_b	5.8	1.6_a	2.0
Avg. Cluster Size	4.1_a	1.3	4.0_a	0.8	4.5_a	4.0	3.7_a	0.9
Total Clusters	16.7_a	4.7	16.7_a	5.2	10.9_c	4.9	14.1_b	4.5
Cluster Switching	68.1_a	21.1	64.2_a	17.6	35.0_c	12.3	51.8_b	14.1
Alternating								
Correct	47.5_a	11.0	44.9_a	11.6	23.9_c	8.5	35.2_b	9.0
Perseveration	1.3_a	1.3	$2.8_{a,b}$	2.6	8.0_c	8.4	5.1_b	5.1
Intrusions	1.1_a	1.8	1.2_a	1.5	1.0_a	1.2	1.5_a	2.3
Avg. Cluster Size	1.6_a	0.5	1.9_a	0.6	$1.5_{a,b}$	0.6	$1.6_{a,b}$	0.4
Total Clusters	9.8_a	3.9	10.2_a	3.0	5.3_c	3.3	7.8_b	2.8
Cluster Switching	31.9_a	7.9	$29.2_{a,b}$	8.8	25.0_b	10.2	$28.3_{a,b}$	6.8

Note: Row entries showing the same subscript do not differ at $p < 0.05$.

Table 5.

Means and standard deviations of the hard category fluency for the young adults, healthy older adults, older adults with Alzheimer's disease, older adults with Parkinson's disease.

	Young Adults		Healthy Older Adults		Older Adults with AD		Older Adults with PD	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Traditional								
Correct	38.1_{a}	15.4	34.3_{a}	12.5	19.6_{c}	10.4	27.6_{b}	9.1
Perseveration	0.7_{a}	1.4	$1.5_{a,b}$	1.7	2.7_{c}	2.8	$1.9_{b,c}$	2.1
Intrusions	2.6_{a}	7.1	1.9_{a}	2.7	4.3_{a}	8.2	1.4_{a}	2.1
Avg. Cluster Size	8.5_{a}	3.7	$7.7_{a,b}$	3.3	4.8_{c}	3.6	$6.2_{b,c}$	2.4
Total Clusters	8.5_{a}	3.7	$7.7_{a,b}$	3.3	4.8_{c}	3.6	$6.2_{b,c}$	2.4
Cluster Switching	21.0_{a}	12.2	21.7_{a}	6.6	13.1_{b}	6.2	$17.4_{a,b}$	7.4
Alternating								
Correct	27.0_{a}	8.9	25.8_{a}	6.6	12.0_{c}	5.7	19.3_{b}	7.0
Perseveration	0.8_{a}	1.4	0.9_{a}	1.3	2.7_{b}	3.2	1.2_{a}	1.4
Intrusions	$0.9_{a,b,c}$	1.0	$0.7_{a,b}$	1.2	$1.6_{a,c}$	2.3	$0.9_{a,b,c}$	1.2
Avg. Cluster Size	1.5_{a}	0.7	1.6_{a}	0.5	1.4_{a}	1.1	1.8_{a}	1.1
Total Clusters	5.9_{a}	2.5	5.5_{a}	2.0	2.1_{c}	1.7	3.7_{b}	1.9
Cluster Switching	18.0_{a}	6.6	$17.6_{a,b}$	5.7	12.6_{c}	6.7	$14.6_{b,c}$	5.6

Note: Row entries showing the same subscript do not differ at $p < 0.05$.

Table 6.

Means and standard deviations of the action fluency for the young adults, healthy older adults, older adults with Alzheimer's disease, older adults with Parkinson's disease.

	Young Adults		Healthy Older Adults		Older Adults with AD		Older Adults with PD	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Traditional								
Correct	69.0_{a}	25.7	60.2_{a}	23.1	33.3_{c}	14.9	47.2_{b}	17.0
Perseveration	1.1_{a}	1.4	$1.8_{a,b}$	1.8	5.0_{c}	3.7	3.1_{b}	3.0
Intrusions	0.9_{a}	1.4	1.5_{a}	2.3	$2.8_{a,b}$	3.3	3.5_{b}	7.1
Avg. Cluster Size	3.4_{a}	0.8	3.7_{a}	1.1	3.6_{a}	2.0	5.0_{c}	3.1
Total Clusters	16.6_{a}	7.2	14.5_{a}	9.1	8.8_{b}	5.4	10.9_{b}	6.1
Cluster Switching	41.6_{a}	14.9	$35.7_{a,b}$	12.9	24.0_{c}	11.5	$30.0_{b,c}$	15.1
Alternating								
Correct	43.8_{a}	15.3	33.3_{b}	9.5	22.0_{c}	12.2	26.6_{c}	11.4
Perseveration	0.9_{a}	1.2	$1.5_{a,b}$	1.5	4.6_{c}	4.2	2.3_{b}	3.4
Intrusions	0.6_{a}	0.9	0.3_{a}	0.5	0.9_{a}	1.6	0.8_{a}	1.0
Avg. Cluster Size	1.4_{a}	0.4	$1.7_{a,b}$	0.7	$1.8_{a,b}$	1.1	2.0_{b}	1.4
Total Clusters	8.0_{a}	4.0	6.1_{b}	2.8	4.2_{c}	3.2	4.4_{c}	2.2
Cluster Switching	32.6_{a}	12.6	24.0_{b}	9.6	22.0_{b}	11.8	21.0_{b}	10.7

Note: Row entries showing the same subscript do not differ at $p < 0.05$.

Results

Participants' verbal fluency performance was assessed using a variety of measures including Correct Responses, Perseverations, Intrusions, and two measures of clustering, the Total Number of Clusters and Average Cluster Size. Each measure will be discussed separately. Repeated measures ANOVAs were used to compare the four groups (Young Adults, Healthy Older Adults, Adults with Parkinson's disease, and Adults with Alzheimer's dementia) on each fluency test (Letters, Easy, Hard, Actions). Format (traditional versus alternating) was considered to be a within-subject factor.

Young adults and healthy older adults tended to produce more correct responses than the older adults with Alzheimer's dementia or Parkinson's disease. Perseverations tended to be rare among all groups, although increasing somewhat with task difficulty (easy versus hard, traditional format versus alternating format). Although intrusions were also relatively rare among all of the groups, intrusions were relatively more common on some tasks (i.e., action fluency) than on others (i.e. letters). Average cluster size did not tend to differ between the four groups.

Correct Responses

Letter fluency.

All groups performed better on the traditional tests, F (1, 113) = 51.32, η^2 = .31, p < .001 (M = 57.25, SD = 1.85) than the alternating versions (M = 49.5, SD = 1.5). There was a significant main effect of group, F (3, 113) = 26.18, η^2 = .41, p < .001. Young adults (M = 71.0, SD = 2.9) produced the most correct responses regardless of format. The healthy older adults (*M* = 62.9, *SD* = 3.1) performed better than the adults with Parkinson's disease (*M* = 43.5, *SD* = 3.2). All three groups produced more correct responses than the Alzheimer's dementia participants (*M* = 36.2, *SD* = 3.6). There was a non-significant interaction between task and group, *F* (3, 113) = 2.62, $\eta^2 = .07$, *p* = .55.

Easy category fluency.

All groups performed better on the traditional format, *F* (1, 114) = 122.80, $\eta^2 = .52$, $p < .001$ (*M* = 54.8, *SD* = 1.6) than the alternating format (*M* = 37.9, *SD* = 1.0). There was a significant main effect of group, *F* (3, 114) = 33.54, $\eta^2 = .47$, $p < .001$. Young adults (*M* = 57.8, *SD* = 1.9) produced the most correct responses regardless of format. Healthy older adults produced nearly as many correct responses (*M* = 54.5, *SD* = 2.1) as young adults. The adults with Parkinson's disease (*M* = 43.5, *SD* = 2.1) did not perform as well as the young adults and older adults. All three groups produced more correct responses than the Alzheimer's dementia participants (*M* = 29.4, *SD* = 2.4). There was no significant interaction between format and group, *F* (3, 114) = 1.75, $\eta^2 = .44$, *p* = .16.

Hard category fluency.

All groups performed better on the traditional format, *F* (1, 113) = 65.24, $\eta^2 = .37$, $p < .001$ (*M* = 30.0, *SD* = 1.2) than the alternating format (*M* = 21.0, *SD* = 0.7). There was a significant main effect of group, *F* (3, 113) = 22.29, $\eta^2 = 0.37$, p < .001. Young adults (*M* = 32.5, *SD* = 1.4) produced the most correct responses regardless of format and were similar to the healthy older adults (*M* = 30.1, *SD* = 1.5). The adults with Parkinson's disease (*M* = 23.6, *SD* = 1.5) produced fewer correct responses than the young adults and healthy older adults. All three groups produced more correct responses than the Alzheimer's dementia participants (*M* = 15.8, *SD* = 1.7). There was no significant interaction between format and group, F (3, 113) = .51, η^2 = .01, p = .673.

Action category fluency.

All groups performed better on the traditional format, F (1, 114) = 130.60, η^2 = .53, $p < .001$ (*M* = 52.4, *SD* = 2.0) than the alternating format (*M* = 31.4, *SD* = 1.2). There was a significant main effect of group, F (3, 114) = 21.65, η^2 = .36, $p < .001$. Young adults (*M* = 56.4, *SD* = 2.4) produced the most correct responses regardless of format. The healthy older adults (*M* = 46.8, *SD* = 2.6) produced more correct responses than adults with Parkinson's disease (*M* = 36.9, *SD* = 2.6). All three groups produced more correct response than the Alzheimer's dementia participants (*M* = 27.6, *SD* = 3.0). There was a significant interaction between format and group, F (3, 114) = 3.24, η^2 = .78, p = .025. The deficit on the alternating fluency was greater than the traditional format for the Alzheimer's dementia participants (difference = 11 responses) and the Parkinson's disease, (difference = 20.6 responses) than for the young adults or healthy older adults (difference = 26.1).

Perseverative Responses

Letter fluency.

Perseverative errors were no more common with the traditional format (*M* = 4.5, *SD* = 0.4) than with the alternating format, F (1, 113) = 2.80, η^2 = .02, p = .097, (*M* = 5.0, *SD* = 0.4). There was a significant main effect of group, F (3, 113) = 327.67, $\eta^2 = .61$, $p < .001$. Young adults (*M* = 1.5, *SD* = 0.7) produced few perseverative responses regardless of format. The healthy older adults (*M* = 5.2, *SD* = 0.7) and the adults with Parkinson's disease (*M* = 5.0, *SD* = 0.7) produced more perseverative errors than the young adults; older adults with Alzheimer's dementia participants produced many perseverative errors (*M* = 7.1, *SD* = 0.8). The interaction between format and group was marginally significant, F (3, 113) = 2.56, $\eta^2 = .06$, p = .059. There were reduced deficits on the traditional over the alternating fluency format was similar for the young adults and healthy older adults, there were more deficits for the adults with impairments.

Easy category fluency.

Perseverative errors were equally infrequent with the traditional format (*M* = 4.7, *SD* = 0.4) and the alternating format (*M* = 4.3, *SD* = 0.4), regardless of group, F (1, 114) = .59, $\eta^2 = .01$, $p = .44$. There was a significant main effect of group, F (3, 114) = 431.83, $\eta^2 = .34$, $p < .001$. Young adults (*M* = 1.5, *SD* = 0.6) produced few perseverative responses regardless of format. The healthy older adults (*M* = 3.2, *SD* = 0.6) committed fewer perseverative errors than the adults with Parkinson's disease (*M* = 5.3, *SD* = 0.6) and older adults with Alzheimer's dementia produced the most perseverative errors (*M* = 8.0, *SD* = 0.7). The interaction between format and group was non-significant, F (3, 114) = 0.11, $\eta^2 = .01$, $p = 0.95$.

Hard category fluency.

Perseverative errors on the traditional format (*M* = 1.7, *SD* = 0.2) and the alternating format (*M* = 1.4, *SD* = 0.2) were equally rare, regardless of group, *F* (1, 113) = 1.89, η^2 = .02, *p* = 0.17. There was a significant main effect of group, *F* (3, 113) = 6.69, η^2 = .15, *p* < .001. Young adults (*M* = 0.8, *SD* = 0.3), healthy older adults (*M* = 1.2, *SD* = 0.3), and adults with Parkinson's disease (*M* = 1.5, *SD* = 0.3) produced few perseverative responses. Alzheimer's dementia participants produced more perseverative errors (*M* = 2.7, *SD* = 0.3) than the other three groups. The interaction between format and group was non-significant, *F* (3, 113) = 1.12, η^2 = .03, *p* = .35.

Action category fluency.

Perseverative errors on the traditional format (*M* = 2.8, *SD* = 0.2) and the alternating format (*M* = 2.3, *SD* = 0.3) were infrequent, regardless of group, *F* (1, 114) = 2.32, η^2 = .02, *p* = .131. There was a significant main effect of group, *F* (3, 114) =15.36, η^2 = 0.29, *p* < .001. Young adults (*M* =1.0, *SD* = 0.4) produced few perseverative responses regardless of format. The healthy older adults (*M* = 1.7, *SD* = 0.4) and the adults with Parkinson's disease (*M* = 2.7, *SD* = 0.4) also produced few perseverative errors. Alzheimer's dementia participants produced more perseverative errors (*M* = 4.8, *SD* = 0.5) than the other 3 groups. The interaction between format and group was non-significant, *F* (3, 114) = 0.26, η^2 = .01, *p* = .851.

Intrusions

Letter fluency.

Intrusions were more common with the traditional format (*M* = 1.8, *SD* = 0.2) than with the alternating format (*M* = 1.1, *SD* = 0.2), regardless of group, F (1, 113) = 10.91, η^2 = .10, *p* = .001. The main effect of group was not significant, F (3, 113) = 0.88, η^2 = 20.02, *p* = .456. The four groups produced similar numbers of intrusions (M_{YA} = 1.1, *SD* = 0.3; M_{OA} = 1.5, *SD* = 0.3; M_{PD} = 1.7, *SD*=0.3; M_{AD}=1.7, *SD*=0.4). The interaction between format and group was non-significant, F (3, 113) = 0.78, η^2 = .02, *p* = .51.

Easy category fluency.

More intrusions occurred with the traditional format (*M* = 2.1, *SD* = 0.3) than with the alternating format (*M* = 1.2, *SD* = 0.2), regardless of group, F (1, 114) = 7.31, η^2 = .06, *p* = .01. The main effect of group was not significant, F (3, 114) = 8.72, η^2 = .03, *p* = .335 (M_{YA} = 1.2, *SD* = 0.3; M_{OA} = 1.7, *SD* = 0.4; M_{PD} = 1.6, *SD* = 0.4; M_{AD} = 2.2, *SD* = 0.4). The interaction between format and group was non-significant, F (3, 114) = 2.34, η^2 = .06, *p* = .078.

Hard category fluency.

More intrusions occurred with the traditional format (*M* = 2.6, *SD* = 0.5) than with the alternating format (*M* = 1.0, *SD* = 0.1), F (1, 113) = 9.13, η^2 = .08, *p* = .003. The main effect of group was not significant, F (3, 113) = 1.92, η^2 = .05, *p* = .13 (M_{YA} = 1.8, *SD* = 0.5; M_{OA}= 1.3, *SD* = 0.5; M_{PD} = 1.2, *SD* = 0.6; M_{AD} = 3.0, *SD* = 0.6). The interaction between format and group was non-significant, F (3, 113) = .69, η^2 = .02, *p* = .56.

Action category fluency.

Intrusions were more common with the traditional format (*M* = 2.2, *SD* = 0.4) than with the alternating format (*M* = 0.7, *SD* = 1.0), *F* (1, 114) = 14.51, η^2 = .11, *p* < .001. There was a significant main effect of group, *F* (3, 114) = 3.25, η^2 = .79, *p* = .025. Young adults (*M* = 0.7, *SD* = 0.4) and healthy older adults (*M* = 0.9, *SD* = 0.4) produced few intrusions regardless of format. The adults with Parkinson's disease (*M* = 2.1, *SD* = 0.4) and those with the Alzheimer's dementia (*M* = 1.9, *SD* = 0.4) produced more intrusions than the healthy older adults and the young adults. The interaction between format and group was non-significant, *F* (3, 114) =1.83, η^2 = .05, *p* = .145.

Number of Clusters

Letter fluency.

All of the groups produced more clusters on the traditional format (*M* = 11.8, *SD* = 0.9) than the alternating format (*M* = 5.8, *SD* = 0.4), *F* (1, 113) = 75.61, η^2 = .40, *p* < .001. There was a significant main effect of group, *F* (3, 113) = 6.65, η^2 = .15, *p* < .001. Young adults (*M* = 11.3, *SD* = 1.0) and the healthy older adults (*M* = 11.2, *SD* = 1.1) produced the most clusters. The adults with Parkinson's disease (*M* = 7.2, *SD* = 1.1) produced more clusters than the Alzheimer's dementia participants (*M* = 5.5, *SD* = 1.2). The interaction of format and group was non-significant, *F* (3, 113) = 2.39, η^2 = .06, *p* = .072.

Easy category fluency.

The groups produced more clusters on the traditional format (*M* = 14.6, *SD* = 0.5) than the alternating format (*M* = 8.3, *SD* = 0.3), *F* (1, 114) = 181.80, η^2 = .62, *p* < .001. There was a significant main effect of group, *F* (3, 114) = 15.10, η^2 = .28, *p* < .001. Young adults (*M* = 13.3, *SD* = 0.6) and the healthy older adults (*M* = 13.5, *SD* = 0.6) produced more clusters than the adults with Parkinson's disease (*M* = 11.0, *SD* = 0.6) who produced more than the Alzheimer's dementia participants (*M* = 8.1, *SD* = 0.7). The interaction between format and group was non-significant, *F* (3, 114) = 0.35, η^2 = .01, *p* = .79.

Hard category fluency.

All of the groups produced more clusters on the traditional format (*M* = 6.8, *SD* = 0.3) than the alternating format (*M* = 4.3, *SD* = 0.2), *F* (1, 111) = 63.41, η^2 = .36, *p* < .001. There was a significant main effect of group, *F* (3, 111) = 16.51, η^2 = .31, *p* < .001. Young adults (*M* = 7.2, *SD* = 0.4) and the healthy older adults (*M* = 6.5, *SD* = 0.4) produced more clusters than the other groups. The adults with Parkinson's disease (*M* = 5.1, *SD* = 0.4) produced few clusters, but significantly more clusters than the Alzheimer's dementia participants (*M* = 3.4, *SD* = 0.5). The interaction between format and group was non-significant, *F* (3, 111) = 0.05, η^2 = .00, *p* = .98.

Action category fluency.

All groups produced more clusters on the traditional format (*M* = 12.7, *SD* = 0.6) than the alternating format (*M* = 5.7, *SD* = 0.3), *F* (1, 114) = 142.40, η^2 = 0.56, *p*

< .001. There was a significant main effect of group, *F* (3, 114) = 11.96, η^2 = .24, *p* < .001. Young adults (*M* = 12.3, *SD* = 0.7) and the healthy older adults (*M* = 10.3, *SD* = 0.8) produced more clusters than the adults with Parkinson's disease (*M* = 7.7, *SD* = 0.8) and Alzheimer's dementia participants (*M* = 6.5, *SD* = 0.9). The interaction between format and group was non-significant, *F* (3, 114) = 2.31, η^2 = 0.06, *p* = 0.08.

Average Cluster Size

Letter fluency.

Participants produced larger clusters with the traditional format (*M* = 2.5, *SD* = 0.1) than with the alternating format (*M* = 1.2, *SD* = 0.04), *F* (1, 113) = 399.10, η^2 = .78, *p* < .001. There was a significant main effect of group, *F* (3, 113) = 7.38, η^2 = .16, *p* < .001. Cluster size was similar for young adults (*M* = 2.1, *SD* = 0.1) and healthy older adults (*M* = 2.0, *SD* = 0.1). The adults with Parkinson's disease (*M* = 1.8, *SD* = 0.1) and Alzheimer's dementia participants (*M* = 1.6, *SD* = 0.1) produced smaller clusters than the other two groups. There was a significant interaction found between format and group, *F* (3, 113) = 6.24, η^2 = .14, *p* = .001. The advantage of the traditional format over the alternating versions was less than one word for the older adults with Alzheimer's dementia (difference = 0.83) than the three other groups (difference = 1.50).

Easy category fluency.

The groups produced larger average clusters on the traditional format (*M* = 4.1, *SD* = 0.2) than the alternating format (*M* = 1.7, *SD* = 0.1), *F* (1, 114) = 162.30, η^2 = .59, *p* < .001. There was no main effect of group, *F* (3, 114) = 0.61, η^2 = .02, *p* =

.61. All four groups produced similarly sized clusters (*M* = 2.9, *SD* = 0.1). There was no significant interaction found between format and group, F (3, 114) = 0.91, η^2 = .23, p = .440.

Hard category fluency.

All of the groups produced larger clusters with the traditional format (*M* = 6.8, *SD* = 0.3) than the alternating format (*M* = 1.6, *SD* = 0.1), F (1, 111) = 255.80, η^2 = .67, $p < .001$. There was a significant main effect of group, F (3, 111) = 6.85, η^2 = .16, $p < .001$. Cluster size was similar for young adults (*M* = 5.0, *SD* = 0.3) and the healthy older adults (*M* = 4.6, *SD* = 0.3). The adults with Parkinson's disease (*M* = 4.1, *SD* = 0.3) produced smaller clusters while the Alzheimer's dementia participants (*M* = 3.1, *SD* = 0.3) produced the smallest cluster size. There was a significant interaction found between format and group, F (3, 111) = 5.83, η^2 = .14, p = .001. The advantage of the traditional format over the alternating versions was larger for young adults (difference = 7.0) and healthy older adults (difference = 6.2) than the older adults with Parkinson's disease (difference = 4.6) and smallest for the older adults with Alzheimer's dementia (difference = 3.4).

Action category fluency.

All of the groups produced larger clusters on average with the traditional format (*M* = 3.9, *SD* = 2.0) than with the alternating format (*M* = 1.7, *SD* = 0.1), F (1, 114) = 118.40, η^2 = .51, $p < .001$. There was a significant main effect of group, F (3, 114) = 5.42, η^2 = .13, p = .002. Cluster size was similar for young adults (*M* = 2.4, *SD* = 0.2) and the healthy older adults (*M* = 2.7, *SD* = 0.2), and the Alzheimer's dementia participants (*M* = 2.7, *SD* = 0.2). The adults with Parkinson's disease (*M* = 3.5, *SD* = 0.2) produced larger cluster than the other groups. The interaction between format and group was non-significant, *F* (3, 114) = 1.80, $\eta^2 = .05$, *p* = 0.15.

Cluster Switching

Letter fluency.

All of the groups made fewer switches between clusters on the traditional format (*M* = 46.9, *SD* = 14.9) than the alternating format (*M* = 49.0, *SD* = 16.3), *F* (1, 113) = 4.90, $\eta^2 = .04$, *p* = .029. There was a significant main effect of group, *F* (3, 113) = 12.516, $\eta^2 = .25$, *p* < .000. Cluster switching was similar for young adults (*M* = 55.5, *SD* = 2.2) and the healthy older adults (*M* = 53.0, *SD* = 2.4). The adults with Parkinson's disease (*M* = 41.9, *SD* = 2.4) and the adults with Alzheimer's disease (*M* = 37.5, *SD* = 2.7) made similar numbers of switches between clusters. The interaction between format and group was non-significant, *F* (3, 113) = 0.36, $\eta^2 = .01$, *p* = 0.779.

Easy category fluency.

All of the groups made more switches between clusters on the traditional format (*M* = 56.5, *SD* = 20.9) than the alternating format (*M* = 29.0, *SD* = 8.6), *F* (1, 114) = 280.09, $\eta^2 = .71$, *p* < .001. There was a significant main effect of group, *F* (3, 114) = 19.02, $\eta^2 = .33$, *p* < .001. Cluster switching was similar for young adults (*M* = 50.0, *SD* = 1.8) and the healthy older adults (*M* = 46.7, *SD* = 1.9). The adults with Parkinson's disease (*M* = 40.0, *SD* = 1.9) switched less than the healthy young and old adults but more than the adults with Alzheimer's disease (*M* = 30.0, *SD* = 2.2) made similar numbers of switches between clusters. There is an interaction between format and group, *F* (3, 114) = 14.00, $\eta^2 = .27$, $p < 0.001$.

Hard category fluency.

All of the groups made more switches between clusters on the traditional format (*M* = 18.9, *SD* = 9.3) than the alternating format (*M* = 16.0, *SD* = 6.5), *F* (1, 113) = 12.33, $\eta^2 = .10$, $p = .001$. There was a significant main effect of group, *F* (3, 113) = 6.66, $\eta^2 = .15$, $p < .001$. Cluster switching was similar for young adults (*M* = 19.5, *SD* = 1.1) and the healthy older adults (*M* = 19.7, *SD* = 1.2) made similar numbers of switches between clusters. The adults with Parkinson's disease (*M* = 15.9, *SD* = 1.2) and the adults with Alzheimer's disease (*M* = 12.8, *SD* = 1.4) made similar numbers of switches between clusters. The interaction between format and group was non-significant, *F* (3, 113) = 0.90, $\eta^2 = .02$, $p = 0.441$.

Action category fluency.

All of the groups made more switches between clusters on the traditional format (*M* = 33.7, *SD* = 15.1) than the alternating format (*M* = 25.4, *SD* = 12.1), *F* (1, 114) = 28.60, $\eta^2 = .20$, $p < .001$. There was a significant main effect of group, *F* (3, 114) = 12.02, $\eta^2 = .24$, $p < .001$. Young adults (*M* = 37.1, *SD* = 1.6) switched between clusters more than any other group; the healthy older adults (*M* = 29.9, *SD* = 1.8) and the adults with Parkinson's disease (*M* = 25.5, *SD* = 1.8) made similar numbers of switches between clusters. The adults with Parkinson's disease also made a similar number of switches as the adults with Alzheimer's disease (*M* = 23.0, *SD* =

2.0). The interaction between format and group was non-significant, F (3, 114) = 1.69, $\eta^2 = .04$, $p = 0.174$.

Consistency

A series of correlations was computed to examine the consistency of verbal fluency performance across tasks. Since the number of clusters is confounded with cluster size and switches (Mayr, 2002), only the number of clusters produced was used in the remaining analyses. To avoid spurious correlations caused by the large group mean differences on these measures, separate correlations were computed for the young adults and the older groups, combining all three groups of older adults (Hofer, Flaherty, & Hoffman, 2006). These results are summarized in Table 7 thru 14.

Fluency in letter, easy, hard and action tests was highly correlated (see Table 7 and 8). The young adults who generated many correct responses on the letter fluency also generated many correct responses on easy and action categories with the traditional fluency. For the alternating format, young adults who had many responses on one tests were likely to have many responses on the other fluency measures. Young adults produced few perseverations and intrusions and their performance across tasks was more variable. However, young adults who produced more intrusions on one alternating fluency task were more likely to do so on the other alternating fluency tasks. Those who tend to produce many clusters on one test tend to produce many clusters on the others tests.

Table 7.

Consistency in Verbal Fluency across Tasks for the Young Adults. Results for the Traditional Fluency Tests are Presented in the Lower Half-Matrix for each Type of Response; Those for the Alternating Fluency Tests are Presented in the Upper Half-Matrix.

		Letter	Easy Category	Hard Category	Action
Correct Responses	Letter	---	.425*	.489**	.435**
	Easy Category	.510**	--	.743**	.245
	Hard Category	.272	.834**	--	.361*
	Action	.523**	.297	.321	--
Perseverations	Letter	---	-.382*	-.188	.130
	Easy Category	.488**	--	.134	.111
	Hard Category	.322	.342**	--	.299
	Action	.303	.278	.127	--
Intrusions	Letter	---	.447**	.491**	.386*
	Easy Category	-.032	--	.373*	.492**
	Hard Category	.363*	.290	--	.342*
	Action	-.192	.201	-.009	--
Number of Clusters	Letter	--	.202	.298	.348*
	Easy Category	.290	--	.487**	.438**
	Hard Category	.202	.718**	--	.386*
	Action	.362*	.348**	.349*	--

* $p < .05$; ** $p < .01$

Table 8.

Consistency in Verbal Fluency across Tasks for the Older Adults. Results for the Traditional Fluency Tests are Presented in the Lower Half-Matrix for each Type of Response; Those for the Alternating Fluency Tests are Presented in the Upper Half-Matrix.

		Letter	Easy Category	Hard Category	Action
Correct Responses	Letter	--	.757**	.661**	.691**
	Easy Category	.645**	--	.717**	.595**
	Hard Category	.513**	.787**	--	.603**
	Action	.635**	.519**	.482**	--
Perseverations	Letter	--	.436**	.425**	.626**
	Easy Category	.400**	--	.543**	.559**
	Hard Category	.377**	.631**	--	.390**
	Action	.477**	.369**	.275*	--
Intrusions	Letter	---	-.005	.073	-.089
	Easy Category	.032	--	.086	.024
	Hard Category	.147	.555**	--	.182
	Action	.330**	.183	.187	--
Number of Clusters	Letter	--	.497**	.347**	.394**
	Easy Category	.454**	--	.578**	.302**
	Hard Category	.416**	.706**	--	.469**
	Action	.341**	.280*	.337**	--

* $p < .05$; ** $p < .01$

Older adults' performance was also highly correlated across tests. Those who produce many correct responses or perseverations on one fluency test tend to produce many correct responses or perseverations on the other fluency tests, whether alternating or not. Because there were few intrusions, performance was more variable across the tests. Older adults who generated more clusters on one test tended to generate more clusters on the other verbal fluency tests.

Factor Analysis

The cognitive battery was designed to assess four individual differences that have been assumed to contribute to performance on verbal fluency tests: verbal ability, working memory, inhibition, and processing speed. A principal components factor analysis with varimax rotation was used to extract four factors for each participant. Table 9 summarizes the results; Table 10 reports factor scores for the four groups. Individual factor scores were then correlated with correct responses, perseverations, instructions, and the number of clusters on each traditional and alternating fluency test.

Correlation with Factors.

Correlations between the various fluency measures and the four factor scores are summarized in Tables 11 thru 14. For young adults, these factor scores were not consistently correlated with fluency performance on the either the traditional or the alternating tests. For older adults, correct responses and cluster size were correlated with processing speed, working memory, inhibition, and verbal ability for both the traditional and alternating tests. Faster individuals, those with more verbal ability, those with better inhibition, and those with larger working memory spans tended to produce more correct responses and more clusters. Perseverations tended to be negatively correlated with verbal ability and working memory and processing speed. Intrusions were infrequent and did not tend to be correlated with the individual differences factors.

To more closely examine how these individual differences in processing speed, verbal ability, working memory, and inhibition affected performance on the verbal fluency tests, a series of stepwise regressions models was compared using forward selection to control the order of entry of the factor scores in the models. The results are summarized in Tables 15 through 18. For young adults, few of these models were significant for either traditional or alternating fluency tests, reflected the limited range of scores among the young adults on these tests of processing speed, working memory, inhibition, and verbal ability. For older adults, processing speed was the best predictor in Step 1 of the number of correct responses on the traditional letter, category, and action fluency tests. Inhibition also contributed to traditional verbal fluency accounting for additional variance in Step 2 for letter, easy categories, and action fluency.

Processing speed was the best predictor of the number of clusters on the letter, easy categories, and action fluency tests and low verbal ability was the best predictor of perseverations on easy and hard categories and action fluency. On the alternating fluency tests, processing speed and inhibition again were independent predictors of correct responses by older adults on the letter and category fluency tests although processing speed was the sole predictor of correct responses on the alternating action fluency test. Processing speed and inhibition were independent predictors of the number of clusters on both alternating category fluency test whereas processing speed and, somewhat surprisingly, working memory were the only significant predictors of the number of clusters on alternating letter and action fluency, respectively. Low verbal ability also predicted perseverations on the alternating easy category and action fluency tests as well as intrusions on the alternating hard category test.

Table 9.

Results of the Principal Components Factor Analysis of the Cognitive Battery.

	% of Variance	Loadings
Verbal Ability	58.66	
Education		.776
Boston Naming		.776
Working Memory	62.69	
Forward Digit Span		.735
Backward Digit Span		.793
Operation Span		.843
Inhibition	55.88	
Stroop Interference		.780
Trails Interference		.583
WCST Correct		.853
Speed	81.58	
Digit Symbol		.934
Letter Comparison Time		.902
Trails A Time		.895
Stroop XXX's		.882

Table 10.

Group Differences in Verbal Ability, Working Memory, Inhibition, and Processing Speed.

	Verbal Ability		Working Memory		Inhibition		Speed	
	X	*SD*	*X*	*SD*	*X*	*SD*	*X*	*SD*
Young Adults	.09	.57	.82	.97	.94	.46	1.05	.37
Older Adults	.62	.67	.14	.77	.09	.60	.07	.56
Parkinson's Disease	.01	.79	-.39	.58	-.37	.82.	.45	.79
Alzheimer's Dementia	-.97	1.36	-.92	.67	-1.06	.91	-1.10	.76

Table 11.

Correlations between the Factor Scores for Verbal Ability, Working Memory, Inhibition, and Processing Speed and Performance on the Traditional Verbal Fluency Tests for Young Adults.

		Verbal Ability	Working Memory	Inhibition	Speed
Letter	Correct Responses	.269	.414*	.290	.224
	Perseverations	.213	.155	.099	-.002
	Intrusions	.335*	-.166	-.056	-.125
	Clusters	.227	.380*	.314	.143
Easy	Correct Responses	.290	.288	.270	.163
	Perseverations	-.007	-.249	-.140	-.208
	Intrusions	-.236	-.507**	-.464**	-.100
	Clusters	.315	.130	.289	.071
Hard	Correct Responses	.237	.016	.073	-.002
	Perseverations	.037	-.348*	-.369*	.046
	Intrusions	-.151	-.038	.011	-.093
	Clusters	.351*	.234	.116	.181
Action	Correct Responses	.154	.043	.117	-.046
	Perseverations	-.014	-.113	-.043	-.284
	Intrusions	-.108	-.216	-.415*	-.163
	Clusters	.055	.076	.151	-.010

* $p < .05$; ** $p < .01$

Table 12.

Correlations between the Factor Scores for Verbal Ability, Working Memory, Inhibition, and Processing Speed and Performance on the Alternating Verbal Fluency Tests for Young Adults.

		Verbal Ability	Working Memory	Inhibition	Speed
Letter	Correct Responses	.328	.307	.301	.160
	Perseverations	.205	.002	.308	.028
	Intrusions	-.177	-.339*	-.331	-.017
	Clusters	.166	.139	.126	-.096
Easy	Correct Responses	.298	.103	.177	-.144
	Perseverations	-.054	-.147	-.149	-.035
	Intrusions	-.108	.014	-.009	-.114
	Clusters	.246	.234	.099	.188
Hard	Correct Responses	.305	.031	.027	-.044
	Perseverations	.054	-.337*	-.104	-.068
	Intrusions	.178	-.116	-.216	-.182
	Clusters	-.024	-.022	-.136	.031
Action	Correct Responses	.268	-.001	.088	.114
	Perseverations	.074	-.338*	-.012	.054
	Intrusions	-.094	-.086	.035	.039
	Clusters	.230	.176	.171	.050

* $p < .05$; ** $p < .01$

Table 13.

Correlations between the Factor Scores for Verbal Ability, Working Memory, Inhibition, and Processing Speed and Performance on the Traditional Verbal Fluency Tests for Older Adults.

		Verbal Ability	Working Memory	Inhibition	Speed
Letter	Correct Responses	.328**	.427**	.419**	.515**
	Perseverations	-.049	-.099	.057	-.016
	Intrusions	-.046	-.192	.024	.004
	Clusters	.242*	.265*	.231	.355**
Easy	Correct Responses	.430**	.485**	.447**	.617**
	Perseverations	-.376**	-.314**	-.198	-.367**
	Intrusions	-.099	-.137	.149	-.105
	Clusters	.287**	.409**	.270**	.443**
Hard	Correct Responses	.390**	.425**	.344**	.475**
	Perseverations	-.318**	-.274*	-.032	-.189
	Intrusions	-.214	-.166	.015	-.218
	Clusters	.250*	.336**	.320**	.323**
Action	Correct Responses	.369**	.405**	.397**	.528**
	Perseverations	-.351**	-.175	-.122	-.340**
	Intrusions	-.205	-.234*	-.152	-.094
	Clusters	.225*	.356**	.298*	.373**

* $p < .05$; ** $p < .01$

Table 14.

Correlations between the Factor Scores for Verbal Ability, Working Memory, Inhibition, and Processing Speed and Performance on the Alternating Verbal Fluency Tests for Older Adults.

		Verbal Ability	Working Memory	Inhibition	Speed
Letter	Correct Responses	.383**	.499**	.459**	.655**
	Perseverations	-.230*	-.031	.033	-.087
	Intrusions	-.004	-.182	-.043	-.135
	Clusters	.307**	.410**	.295*	.450**
Easy	Correct Responses	.444**	.571**	.506**	.679**
	Perseverations	-.300**	-.110	-.095	-.212
	Intrusions	.050	.016	.140	-.031
	Clusters	.327**	.528**	.462**	.528**
Hard	Correct Responses	.383**	.457**	.523**	.522**
	Perseverations	-.318**	-.292**	-.147	-.358**
	Intrusions	-.271*	-.232*	-.226	-.228*
	Clusters	.302**	.511**	.521**	.457**
Action	Correct Responses	.350**	.454**	.379**	.546**
	Perseverations	-.316**	-.101	.009	-.169
	Intrusions	-.080	-.209	-.031	-.043
	Clusters	.347**	.464**	.386**	.356**

* $p < .05$; ** $p < .01$

Table 15.

Results of the Stepwise Regression Analyses for Traditional Verbal Fluency for Young Adults. Only significant results are reported based on the probability of *F*-to enter ≤ .05.

		Step 1 (df = 1,70)		
		Factor	R^2	*F*-to-enter
Letter	Correct Responses	WM	.171	5.98
	Perseverations	-	-	-
	Intrusions	-	-	-
	Clusters	WM	.144	4.887
Easy Category	Correct Responses	-	-	-
	Perseverations	-	-	-
	Intrusions	WM	.257	10.056
	Clusters	-	-	-
Hard Category	Correct Responses	-	-	-
	Perseverations	INHB	.136	4.561
	Intrusions	-	-	-
	Clusters	-	-	-
Action Category	Correct Responses	-	-	-
	Perseverations	-	-	-
	Intrusions	INHB	.172	6.019
	Clusters	-	-	-

Note: VRL = Verbal Ability, WM = Working Memory, INHB = Inhibition, SPD = Speed

Table 16.

Results of the Stepwise Regression Analyses for Alternating Verbal Fluency for Young Adults. Only significant results are reported based on the probability of *F*-to enter ≤ .05.

		Step 1 (df = 1,70)		
		Factor	R^2	*F*-to-enter
Letter	Correct Responses	-	-	-
	Perseverations	-	-	-
	Intrusions	-	-	-
	Clusters	-	-	-
Easy Category	Correct Responses	-	-	-
	Perseverations	-	-	-
	Intrusions	-	-	-
	Clusters	-	-	-
Hard Category	Correct Responses	-	-	-
	Perseverations	-	-	-
	Intrusions	-	-	-
	Clusters	-	-	-
Action	Correct Responses	-	-	-
	Perseverations	-	-	-
	Intrusions	-	-	-
	Clusters	-	-	-

Note: VRL = Verbal Ability, WM = Working Memory, INHB = Inhibition, SPD = Speed

Table 17.

Results of the Stepwise Regression Analyses for Traditional Verbal Fluency for Older Adults. Only significant results are reported based on the probability of *F*-to enter ≤ .05.

		Step 1 (df = 1,70)			Step 2 (df = 1,69)		
		Factor	R^2	*F*-to-enter	Factor	R^2	*F*-to-enter
Letter	Correct Responses	SPD	.266	25.304	INHB	.325	6.065
	Perseverations	-	-	-			
	Intrusions	-	-	-			
	Clusters	SPD	.126	10.105			
Easy Category	Correct Responses	SPD	.381	43.003	INHB	.435	6.612
	Perseverations	VRL	.142	11.556			
	Intrusions	-	-	-			
	Clusters	SPD	.196	17.112			
Hard Category	Correct Responses	SPD	.226	20.428			
	Perseverations	VRL	.101	7.892			
	Intrusions	-	-	-			
	Clusters	WM	.113	8.779			
Action	Correct Responses	SPD	.279	27.083	INHB	.325	4.733
	Perseverations	VRL	.123	9.808			
	Intrusions	WM	.055	4.046			
	Clusters	SPD	.139	11.280			

Note: VRL = Verbal Ability, WM = Working Memory, INHB = Inhibition, SPD = Speed

Table 18.

Results of the Stepwise Regression Analyses for Alternating Verbal Fluency for Older Adults. Only significant results are reported based on the probability of *F*-to enter ≤ .05.

		Step 1 (df = 1,70)			Step 2 (df = 1,69)		
		Factor	R^2	*F*-to-enter	Factor	R^2	*F*-to-enter
Letter	Correct Responses	SPD	.429	52.694	INHB	.483	7.131
	Perseverations	-	-	-			
	Intrusions	-	-	-			
	Clusters	SPD	.203	17.822			
Easy Category	Correct Responses	SPD	.461	59.859	INHB	.535	10.915
	Perseverations	VRL	.090	6.903			
	Intrusions	-	-	-			
	Clusters	SPD	.279	27.053	INHB	.360	8.765
Hard Category	Correct Responses	INHB	.273	26.313	SPD	.397	14.146
	Perseverations	SPD	.128	10.274			
	Intrusions	VRL	.073	5.553			
	Clusters	INHB	.271	26.041	SPD	.351	8.504
Action	Correct Responses	SPD	.298	29.694			
	Perseverations	VRL	.100	7.748			
	Intrusions	-	-	-			
	Clusters	WM	.215	19.210			

Note: VRL = Verbal Ability, WM = Working Memory, INHB = Inhibition, SPD = Speed

Discussion

The goals of this study were to determine how verbal fluency performance is affected by group, scoring, task, format, and individual differences in cognition. To these ends, young adults, healthy older adults, older adults with Alzheimer's disease, and older adults with Parkinson's disease were scored with both traditional and alternate measures scoring including correct responses, perseverations, intrusions, and various measures of clustering. Each individual was tested on four different verbal fluency tasks: letters, easy semantic categorys, hard semantic categorys and action categorys using both traditional and alternating formats of each task. Along with the fluency tests, participants were given a battery of cognitive tests including tests of processing speed, working memory, verbal ability, and inhibition to measure the individual differences among the groups.

The first goal was to investigate how verbal fluency performance varies with group. As expected based on prior research (Murphy, Rich, & Troyer, 2006; Troyer, Moscovitch, & Winocur, 1997), young adults had superior verbal fluency performance. They produce the most correct responses, fewest perseverations, least intrusions, and the most clusters. Healthy older adults tended to have excellent verbal fluency as well, matching the young adults' performance with regard to correct responses, perseverations, intrusions, and clusters. As expected, verbal fluency performance was compromised for the two adult clinical groups. The older adults with Alzheimer's disease show the greatest deficits on the verbal fluency tasks, producing the fewest correct responses, the most perseverations, the most intrusions, and the least clusters on all tasks.

The second goal was to evaluate methods for scoring verbal fluency. Verbal fluency is traditionally scored by counting the number of correct responses. Alternative scoring methods include counting perseverations and intrusions, as well as identifying clusters of responses, measuring the size of clusters, and the number of switches between clusters. There were relatively few perseverations and intrusions produced by participants in the present study but these measures did differentiate between the groups. Consistent with the findings by Pekkala, Albert, Spiro, and Erkinjuntti (2008), older adults with Alzheimer's disease produced more perseverations than the other groups on all four verbal fluency tests. Perseverations may result from the inability to remember previous responses or from the inability to inhibit previous responses. Older adults with Alzheimer's disease also produced more intrusions than the other groups of participants suggesting they were unable to keep track of the prompts, had difficulty selecting responses on the basis of the prompts, or difficulty inhibiting incorrect responses. One exception to this pattern was that older adults with Parkinson's disease produced many intrusions on the action fluency tests, consistent with the findings of Piatt and colleagues (1999). This may suggest that the individuals with Parkinson's disease have more difficulty with verb retrieval than with noun retrieval as assessed by the letter and category fluency.

The cluster and switching scores yielded similar patterns across groups: young adults produced more clusters, larger clusters, and more switches than healthy older adults, and older adults with Alzheimer's disease produced few clusters, smaller clusters, and fewer switches than the other groups, consistent with the findings by Troyer, Moscovitch, Winocur, Leach, et al., (1998). In contrast to the findings of Troyer and colleagues, (1997) this study did not find that the older adults produced larger clusters than young adults. As noted by Mayr (2002) and Mayr and Kliegl (2000) switching between clusters is confounded by the number of clusters produced and the size of the clusters. The general pattern suggests that young adults were able to respond rapidly within the time limits, generating both many clusters and many switches between clusters as compared to older adults.

The third goal was to compare performance on four different fluency tasks: letters, easy semantic categories, hard semantic categories, and actions. Overall, the pattern of performance between tasks was similar for the four groups such that the young adults produced more correct responses than the healthy older adults and older adults with Alzheimer's disease produced the fewest correct responses. Verbal fluency performance was also highly consistent across task. Individuals who produced many correct responses on one task tended to produce many correct responses on the other tasks. So too, older adults who produced many preservations on one task tended to produce many preservations on the other tasks and older adults who produced many clusters on one task tended to do so on the other tasks. Consistency was somewhat more variable for intrusions, perhaps reflecting how few intrusions were produced by the participants.

The fourth goal was to compare traditional and alternating fluency formats. In order to perform well on the traditional fluency tests, participants must have the ability to utilize cognitive functions such as verbal ability, sustained attention, both working memory and semantic memory, and inhibition (Beatty, Salmon, Troster, & Tivis, 2002; March & Pattison, 2006; Troyer, Moscovitch, & Winocur, 1997). Alternating fluency requires all of the same cognitive resources as traditional fluency with the additional executive function abilities of keeping track of two prompts, and remembering to alternate between them. (Troyer, Moscovitch, & Winocur, 1997, Rende, Ramsberger, & Miyake, 2002). All participants produced fewer correct responses on the alternating fluency tasks than on the traditional fluency tasks, which is not surprising given the increased processing demands required by the alternating task. The alternating format resulted in fewer intrusions than the traditional format although no more preservations; alternating fluency also had fewer clusters, smaller clusters, and fewer switches between clusters than the traditional format.

The difference between traditional and alternating fluency performance appears to reflect the differences in processing speed rather than executive function. The alternating format results in slower lexical retrieval - reducing the number of correct responses and the number of clusters, rather than impairing executive functioning which would be expected to result in more perseverations and intrusions. In fact, the slowing induced by the alternating format actually reduced their intrusions suggesting that individuals may more carefully monitor responses on alternating fluency tests. This output monitoring might be considered to be an executive function.

The fifth goal investigated how individual differences in cognition affect performance on verbal fluency performance. Four factors, verbal ability, working memory, inhibition, and speed of processing, were based on the principal components factor analysis of the cognitive test battery. For young adults, none of these individual differences was consistently correlated with verbal fluency performance on any of the tasks. For older adults, speed of processing and inhibition appeared to be primary determinates of verbal fluency performance. Previous research has not investigated the role of speed of processing in performance on verbal fluency. If speed had not been considered in this study, inhibition would have been the factor driving individual's performance on verbal fluency which is consistent with claims of executive functioning's role in verbal fluency. Faster individuals produced more correct responses and more clusters and those with better inhibition produced more correct responses and more clusters on both the traditional fluency tests and on the alternating fluency tests. The results of the individual differences analysis suggest that speed and inhibition are consistent explanations for the group differences on the verbal fluency tasks, those with Alzheimer's disease and Parkinson's disease are slower and have reduced inhibition.

Each of the goals of the study confirmed previous findings regarding verbal fluency as a measure of cognitive function and provided new information relevant to the interpretations of these findings. The comparison of the four groups indicated that there is a general pattern of performance for the groups: the young adults perform at the highest level, the healthy older adults performed somewhat worse the young adults, the older adults with Parkinson's disease performed more poorly than the healthy older adults, and the older adults with Alzheimer's disease have the poorest level of performance on the verbal fluency tasks. Traditional scoring of correct responses was sensitive to group differences as suggested in the verbal fluency literature. Other methods of scoring, cluster and switching indicated the same relative order of the groups. All of the groups performed better on the letter and easy category fluency tests than the hard category and action fluency tests. The difference between the traditional and alternating fluency formats was similar for all four groups and all four fluency tests. Individual differences in speed of processing, working memory, verbal ability, and inhibition appear to affect performance on all verbal fluency tests at least for older adults, in particular the speed of processing represents the strongest predictor of performance. The verbal fluency tests and alternative scoring methods, individual patterns of performance and group differences are highly stable and characteristic across task and scoring methods. Thus, the conclusion to be drawn from this study is that despite the extensive verbal fluency literature, verbal fluency is a test of processing speed, not a test of executive function as it is widely believed.

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Appendix A.

Fluency Prompts with Correct Response Examples.

Category	Prompt	Examples
Letter	M	month, man, myth, marvelous, merchant
	P	prune, pursue, parcel, pail, pear, pillbox
	S	scant, shawl, smashing, standby, sell, star
	L	lasso, limited, look, luxurious, lantern
Easy	Birds	flamingo, duck, raven, parrot, penguin
	Clothes	shirt, shoes, pants, dress, tie, skirt, coat
	Body Parts	head, arm, leg, nose, stomach, lungs, brain
	Colors	red, violet, lemon, cream, gold, turquoise
Hard	Insects	dragonfly, beetle, grasshopper, spider
	Fabrics	satin, cotton, linen, cashmere, velvet
	Writing Utensils	pen, pencil, marker, stick, paintbrush
	Fluids	water, soda, soap, blood, gasoline, wine
Action	Ways You Can Move	fast, slow, up, down, jerky, smoothly
	Things People Do	sing, marry, run, pray, play, ride, smile
	Things You Can Do To An Egg	boil, devil, paint, dye, refrigerate, throw
	Ways You Can Talk	gruff, cheerfully, fast, loudly, whisper

Appendix B.

Easy fluency cluster types and example clusters.

Category	Cluster	Examples
Birds	common birds	robin, sparrow, blue jay
	color birds	bluebird, blackbird, cardinal
	tropical birds	toucan, parrot, macaw
	birds that don't fly	penguin, dodo, emu
	farm birds	goose, chicken, turkey
	pet birds	parrot, canary, songbird
	birds of prey	eagle, hawk, kestrel
	water birds	ducks, pelican, seagull
	tall birds	flamingo, heron, emu
	forest birds	woodpecker, sparrow, owl

Category	Cluster	Examples
Clothes	underwear	panties, boxers, briefs
	formalwear	ball gown, tuxedo, suit
	footwear	tennis shoes, heels, slippers
	tank tops	tube top, halter top, camisole
	workout clothes	sweatpants, yoga pants, gym shorts
	business clothes	suit, tie, workpants
	shirt type	polo, turtleneck, t-shirt
	outerwear	raincoat, gloves, scarf, cape
	types of coats	overcoat, suit coat, windbreaker
	pieces of man's business suit	trousers, blazer, vest, tie
	culturally specific clothes	sombrero, poncho, sari, kilt
	sports wear	jersey, sports bra, running shoes
	women's dress clothes	dress, skirt, blouse, stockings, slip
	hats	ball cap, top hat, stocking cap
	brands	Gap, J-Crew, Kohls, Oshgosh-B'gosh

Category	Cluster	Examples
Body Parts	arm parts	hand, wrist, forearm, shoulder
	leg parts	foot, shin, thigh, calf, knee
	face/head parts	eyes, ears, scalp, chin, nose, jaw
	specifics of eye/ear/mouth	pupil, iris, ear canal, earlobe, teeth, tongue
	hand parts	fingers, palm, thumb, nails
	foot parts	toes, heel, sole, nails
	trunk	abdomen, back, chest, shoulders
	organs	heart, lungs, spleen, appendix, intestines
	digestive organs	throat, stomach, intestines, colon
	reproductive organs	uterus, penis, vagina, testicles, breasts
	facial hair	beard, mustache, eyebrows
	bones	hipbone, tibia, funny bone, scapula
	muscles	heart, triceps, bicep, hamstring
	chest parts	breasts, lungs, heart, collarbone
	back parts	spine, shoulder blades, lower back

Category	Cluster	Examples
Colors	rainbow colors	red, orange, yellow, green, blue, violet
	metal colors	bronze, gold, silver, platinum
	combination colors	yellow-green, blue-green, red-orange
	shades of colors	dark blue, light green
	neutral tones	cream, white, khaki, gray, black
	adjective modified colors	fire engine red, sky blue, macaroni yellow
	variations on a color	(example: greens) turquoise, teal, chartreuse, olive, mint

Appendix C.

Hard fluency cluster types and example clusters.

Category	Cluster	Examples
Insects	types of bees	bumblebee, honeybee, killer bee, wasp
	spiders	tarantula, brown recluse, daddy long legs
	flies	horsefly, housefly, dragonfly
	grasshopper/cricket types	grasshopper, cricket, locust, cicada
	ants	carpenter ants, fire ants, black ants, leafcutter ant
	parasites	louse, tick, leech, tapeworm
	blood sucking insects	leech, mosquito
	butterflies/moths	monarch, gypsy moth, swallowtail

Category	Cluster	Examples
Fabrics	natural fabrics	cotton, linen, flax, wool
	designs on fabrics	plaid, stripes, tie-dye
	dress fabrics	satin, silk, cashmere
	warm cloth	flannel, wool
	synthetics	nylon, polyester, rayon

Category	Cluster	Examples
Writing Utensils	classic	pen, pencil
	technology	computer, typewriter, cell phone
	types of pens	ballpoint, feather, fountain, felt tip
	natural utensils	rocks, sticks, fingers
	art utensils	markers, charcoal, graphite, paintbrush, colored pencils
	color of pens	red pen, blue pen, black pen
	types of markers	permanent, dry erase, washable
	types of pencils	mechanical pencil, #2 pencil
	body parts	finger, foot, nose

Category	Cluster	Examples
Fluids	juice	apple, orange, grapefruit
	soda	cola, orange, root beer
	body fluids	saliva, semen, urine, blood
	soup	tomato, chicken noodle, cream of mushroom
	food	broth, soy sauce, gravy
	car fluids	antifreeze, gasoline, brake fluid
	alcohol	wine, beer, whiskey
	types of water	salt, tap, fresh, bottled
	cleaning fluids	bleach, Windex, dish soap, detergent
	drinkable (edible)	soda, juice, foods, soup

Appendix D.

Sample transcript of verbal fluency responses including coding.

Coding Key

(P) = Perseverations

(I) = Intrusions

(M) = Meta-comments

(#) = Cluster size

[= Clusters are contained in the brackets along the left column. In the case of alternating fluency, the brackets contain words from both prompts, but cluster size is indicated only for the first prompt.

	Traditional Letter 1: M
(1)	Mouse
	Mice
	Macaroni
	Music
	Millionaire
	Magnifier
	Man
(P)	A um...music
(I)	Margery
	Mule
(M)	Mixer, you can mixer
	Mark
(M)	(mumbling)
(1)	Muscle
	And then musclemen
	And....moccasin
	Motel
	Machine

	Traditional Letter 2: P
(1)	Pea
	Peanut

(I) Fetal
Position
(1) Pencil
Pen
(2) Pity and
Petty, a i and an e
(1) Postal
Post
Pistachio
(1) Pi p-i
Pie p-i-e
Pigpen
(M) That's a word right?
Problem
(M) See what is coming out?
Pulmonary
(1) Prophylaxis
(P) Problem
(I) Phoenix bird

Alternating Letter: S/L
Sinus
(1) Lung
System
Long
Subway
Little
(1) Show
Lose
Shopper
Longer
(2) Sea s-e-a
Lank
Seascape
Landscape
Seaboard
Language
Stout
Loud
Soft
(M) Did I say little?
(M) I don't know
(I) Ok, let's see, slam dunk
Lost

(P) Silly
(M) (mumbling)
And a symposium
Longitude
(NS) Like
(NS) Well now...layer l-a-y-e-r
Sex
Loose
Systolic
Lonely
Short
(NS)(1)Um...song
Lyrics
Sing
(R) Loud
(NS) Lure
Scissors
Loess l-o-e-s-s
Ship
Limner
Sandbar

Traditional Easy Category 1: Body Parts
(2) Arm
Hand
(1) Fingers
Toes
Neck
Ankle
(5) Intestines
Lungs
Stomach
Pancreas
Liver
(1) Heart
Blood vessels
(M) Can I use bones?
Metatarsals
Nerves
(3) Tongue
Teeth
Epiglottis
Throat

(3) Ear
Inner canal
(P) Ear
Earlobe
Scalp
(M) Where were we here?
(2) Rotator cuff
Elbow
Wrist
(P) Esophagus

Traditional Easy Category 2: Colors
(4) Red
(P) Red
Green
Purple
Orange
(1) Black
White
Pink
Turquoise
And….gee…fuchsia
Beige
Rose
(M) I don't know if that is a color I did
Emerald
(1) Navy
Azure
Tan
(M) I don't know if I said tan

Traditional Hard Category 1: Writing Utensils
(1) Pen
Pencil
(1) Stick
A stone
(P) Ball point pen
Automatic pencil
(1) Typewriter
Computer keyboard
(M) I don't know what you call that
Finger, you can write in the sand with your finger
(P) A ball point pen

(I) Um…a pheasant has an end on it
Printing press
(M) I don't know, that's probably not right
Magic marker
Chalk

Traditional Hard Category 2: Fluids
(2) Water
And milk
And orange juice
And blood
And river
(M) Can you say beer?
(6) Beer
And soft drinks
(P) Beer
And whiskey
And soda
Juice
(2) Urine
Semen
Saliva
(M) That is worse that writing utensils

Alternating Easy Category: Birds/Clothes
(1) Robin
(2) Pants
Sparrow
Shorts
Eagle
Jeans
Cardinal
(1) Shoes
Hummingbird
Socks
Hawk
Blouse
A wren
(2) And a underwear
Falcon
And uh….hosiery
Meadow lark

And bra
Overalls
Pheasant
(1) Gloves
And um…flea bird
Mittens
Nuthatch
Anklets
Bluebird
(3) Clothes…heavy coat
(M) I don't know
(NS) Winter coat
(M) Birds birds birds
Seagull
Raincoat
Blue jay
Windbreaker jacket
Owl
(M) I think I said overalls
(P) But overalls

Alternating Hard Category 2: Fabrics/Insects
Cotton
Bull weevil
(1) Satin
Silk worm
Silk
Mosquito
Nylon
Water bug, well, a water bug, one of those black ones
(1) Denim
(1) Gnat
(P) Cotton
(M) No I said cotton
(M) I don't know many fabrics
(NS)(1)Ramee
(P) Mosquito
Linen
Butterfly
(M) Is that an insect?
Polyester
Lice
(M) I don't know

Tulle
(M) I guess that is another kind of fabric t-u-l-l-e
Fly
Fur
(1) A flea
Orlon which is another
Little mite, m-i-t-e
Leather
(M) I don't know anymore
(M) I wanted to come out even, but I can't think of any more
Lightning bug
Traditional Action Category 1: Ways You Can Talk
(1) With your mouth
With you hands
You can pantomime
Whisper
Sing
You can write and print
(M) I can't think of anymore
(I) You can advertise
(M) But that's not really ways you can talk
(M) How much more time?
-25 more seconds
(M) When you get done you tell me some?

Traditional Action Category 2: Things You Can Do To An Egg
Dye it
(2) Fry it
Poach it
Scramble it
Paint it
You can sit on it
(3) You can mix it in a cake
You can hard boil it
You can soft boil first then hard boil
Over easy
Throw it
(P) Sit on
(M) That's an old term
Make egg salad

Alternating Action: Ways You Can Move/Things People Do

Sideways
And sing
And forward
And things people do, talk
You can drive a car
And look out
And take the escalator up
(NS)(2) And ways you can move…scoot
(M) Is that ok?
-mhm
(NS) And you can walk
(NS) And you can crawl
You can move backwards
Things people do, people worry
(NS) People marry
(NS) And they ride in a car
(NS) They shop
And you ride in a train
And they worship
(1) And ways you can move, ski
(NS) You can swim
(NS) You can um…subway
Things people do, date
(P) You can walk
(M) I guess I said that
Grow Christmas trees
Be carried
Things people do, think up tests