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Influence of Cognitive Aging on Intraindividual Variability and Time of Day Effects in Verbal Fluency Performance

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by

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ABSTRACT

A new wave of cognitive aging research is demonstrating that variability in performance on cognitive tasks is an indicator of both aging and neurological disturbance, providing information beyond that garnered from the average level of performance on such tasks. In this study, my focus was on intradindividual variability and time of day effects on verbal fluency and on the relationship of these short-term fluctuations to cognitive aging. Younger and older adults were equally consistent across four testing sessions in terms of total words produced, number of errors, mean cluster size, and number of switches. They also showed comparable dispersion of performance within the task across eight 15-second intervals. An age related shift in time of day in self-reported preference was found, and it was associated with performance on category fluency (older adults performed better in the morning, whereas younger adults performed better in the evening) but not letter fluency. The results of this study suggest that it is important to note time of day when testing clients or research participants in different age groups, because age differences in verbal fluency are likely to be exaggerated when individuals from different age groups are tested during their non-optimal time of day.

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CHAPTER I

INTRODUCTION

Most research in the area of aging and cognition has involved making comparisons between older and younger subjects across various cognitive domains. This type of research involves comparing the mean level of performance of various age groups using cross sectional designs, or the mean level of change in performance in longitudinal studies. Such research assumes that the changes that occur over time are stable at the time of testing. Thus, these studies overlook the possibility of variability in performance within groups and within persons (Hultsch, Strauss, Hunter, & MacDonald, 2008). Performance variability may refer to both interindividual and intraindividual variability. Interindividual variability is referred to as diversity in performance, and intraindividual variability involves dispersion and consistency of performance (subsequently defined). There is now a body of research demonstrating that performance variability is associated with cognitive aging and neurological disturbance, and thus offers information beyond that garnered from group averages (Hultsch, MacDonald, & Dixon, 2002; Murphy, West, Armilio, Craik, & Stuss, 2007; Shammi, Bosman, & Stuss,, 1998; West, Murphy, Armilio, Craik, & Stuss,., 2002b). However, much of the research on performance variability has involved reaction time tasks that are not typically used in neuropsychological testing. It is important to consider how this phenomenon manifests on more commonly used neuropsychological measures such as verbal fluency. In addition, several studies have shown that older adults' performance on some cognitive tasks is more vulnerable to time of day effects than younger adults' (Intons-Peterson, Rocchi, West, McLellan, & Hackney., 1998; May & Hasher, 1998; West, Murphy, Armilio, Craik, & Stuss, 2002a).

In this study, my focus was on intraindividual variability and time of day on verbal fluency and the relationship of these short-term fluctuations to cognitive aging. This study is part of a large research project at Baycrest Centre on performance variability, aging, and executive function. To date, three studies from this project have been published. Two of these studies have focused on experimental tasks (West et al., 2002a, b), and one has focused on the executive aspects of a common neuropsychological verbal memory test (Murphy et al., 2007). West et al. (2002b) examined the variability in performance on four RT tasks varying from low to high demands on executive control processes. They found significant age-related changes in consistency and dispersion (subsequently defined) that were robust after controlling for mean response time. West et al. (2002a) compared the level of performance on different but similar RT tasks also varying from low to high demands on executive control. They found that older adults tend to perform better in the morning than the evening, whereas younger adults tended to perform equally during both times of day. Murphy et al. (2007) found that older adults performed less consistently than younger adults on the executive aspects of a word list learning task, such as false memory, but not on the number of words recalled correctly.

CHAPTER II

REVIEW OF LITERATURE

Conceptualization of performance variability

There are three types of performance variability, each providing a unique dimension of information: (1) *diversity* or inter-individual variability, which is the difference between subjects in a group and is usually measured on a single task on a single occasion; (2) *dispersion*, which is the variability associated with a single person's performance within a single continuous task; and (3) *consistency*, which is the variability associated with the instability of a single person's performance of the same task on multiple occasions, (Stuss, Murphy, Binns, & Alexander, 2003; West et al., 2002b). Other researchers use different terminology for these three types of variability (e.g., Hilborn, Strauss, Hultsch, & Hunter, 2009). However, in the present study I will adhere to the definitions provided by Stuss et al. (2003). Diversity is usually thought of as noise, and can be controlled with methodological designs that use very large groups, homogeneous groups, or more extremely in single case studies. Dispersion and consistency (the focus of this study) are both types of intraindividual variability and may provide substantial additional information.

Interindividual variability and cognitive aging. It has been established in the literature that older adults tend to exhibit greater interindividual variability as a group than younger adults (Morse, 1993; Shammie al.,1998). For example, in a meta-analytic study, Morse (1993) found that older adults exhibited greater variability than younger adults for response time, memory, and fluid intelligence, whereas no significant difference in variability between older and younger adults was found for crystallized intelligence. Morse (1993) suggested that older adults show more variability in performance as a group than younger adults due to several factors including the effects of unique experiences over a longer life course, a greater amount of time for genetically based differences to be expressed, and reduced social constraints allowing for more freedom later in life.

Dispersion and cognitive aging. Findings from studies examining dispersion and aging are not as clear cut. Salthouse (1993) and Shammi et al. (1998) both found significant effects of age on dispersion using reaction time tasks. Salthouse examined performance of older and younger adults on different blocks of timed measures of motor speed, perceptual speed, working memory in older adults. Shammi compared the performance of older and younger female adults on different blocks of choice RT, finger tapping, and time estimation tasks. However, in both of these studies, the age related differences in dispersion were no longer statistically significant after controlling for mean RT (i.e. because mean RT was typically higher for older adults, this resulted in more variability for statistical reasons). On the other hand, West et al. (2002b) compared performance on four RT tasks varying from low to high demands on executive control processes. They found significant age-related increases in dispersion that were robust after controlling for mean response time. Lindenberger and Baltes (1997) examined dispersion in psychometric measures of intelligence, and found that dispersion remains stable and may even decrease in older adults depending on the ability level of the individual. Using nine paper and pencil tasks including three measures of perceptual speed, one measure of fluid reasoning, three measures of episodic memory, and two measures of category memory, Hilborn and her colleagues (2009) found that dispersion was higher amongst old-old adults (i.e., over 75 years old), and old adults experiencing cognitive decline. Taken together, results of these studies suggest that dispersion levels in older adults vary according to the nature of the tasks used. Additionally, it appears that dispersion levels are greater in older adults when the tasks examined place varying demands on executive control processes (e.g., low towards the beginning and high towards the end).

Consistency and cognitive aging. Studies on intraindividual variability have typically involved using RT tasks to assess dispersion rather than consistency (Anstey, 1999; Hultsch et al., 2002; Nesselroade & Salthouse, 2004). Consistency of performance has received less attention. Shammi et al. (1998) found an age-related decrease in consistency over two days of testing for a time estimation task with more cognitively demanding *filled* intervals (i.e., participants were required to perform a task then asked to estimate time elapsed), but not with less cognitively demanding *blank* intervals (i.e., participants looked at a blank screen and were then asked to estimate time elapsed). West and his colleagues (2002b) reported an age-related decrease in consistency over four days of testing for conditions of a RT task that placed a high demand on executive control processes, but not for conditions that placed few demands on executive processes. Additionally, Murphy et al. (2007) also found an age-related decrease in consistency in the executive aspects of a word list learning task (the number of false memory errors), but not in other aspects of the test (e.g., number of words recalled, percent of words retained following a delay). In fact, the ability to sustain a consistent performance level in itself is considered an "executive" cognitive ability.

The Frontal Lobe Hypothesis of Cognitive Aging in Relation to Executive Control

One model of cognitive aging that has been applied to intraindividual variability studies states that prefrontal cortex circuits are more vulnerable to the effects of normal aging than circuits in other cortical regions (Dempster, 1992; Moscovitch & Winokur, 1992; West, 1996, 2000). This model is often referred to as the *frontal lobe hypothesis of cognitive aging*. Several neuroimaging studies have provided general support for this model by documenting that frontal lobe atrophy occurs at a rate of .9% to 1.5% per year, whereas the brain as a whole declines at a rate of .35% per year after middle age (Dennis & Cabeza, 2008). Additionally, Head, Rodrigue, Kennedy, and Raz (2008) found that performance declines on a neuropsychological test of planning with prefrontal cortex shrinkage measured through volumetric MRI.

Neuropsychologically, frontal lobe integrity is generally assessed by tasks of executive function. Executive functions are the cognitive abilities involved in performing actions that requires the effortful control of more routine automatic processes. Executive functions typically involve planning and complex problem solving. These abilities are tested in one of more of these situations: (1) when the level of complexity of a task requires more than automatic processing, (2) when old information must be thought about in new ways, or (3) when the information to be processed is novel (Stuss & Alexander, 2000).

Variations on the frontal lobe hypothesis. There is no consensus in the literature on any one model of cognitive aging. In fact, the frontal lobe hypothesis of cognitive aging has been criticized as being too broad (MacPherson, Phillips, & Della Sala, 2002) and too narrow (Greenwood, 2000). MacPherson et al. argued that it is important to separately consider the two prefrontal subdivisions of the frontal lobes: the dorsolateral and ventromedial regions. The dorsolateral prefrontal region is thought to be responsible for cognitive processes such as executive functioning and working memory, whereas the ventromedial prefrontal region is thought to be responsible for emotional judgment and social decision making. MacPherson and her colleagues found that older adults did poorly on tasks dependent on dorsolateral regions but not ventromedial regions and argued for a specific dorsolateral prefrontal theory of cognitive aging. However, more recent research suggests that older adults respond with greater social inappropriateness than do younger adults in a provocative laboratory situation (Henry, von Hippel, & Bynes, 2009). This study, therefore, suggests that ventromedial prefrontal regions also are vulnerable to accelerated negative changes with normal aging.

On the other hand, Greenwood (2000) argued that behavioural and neurobiological changes in aging are not limited to the prefrontal regions or the frontal lobes. Greenwood stated that the frontal lobe theory of cognitive aging relies too heavily on localization. In the most recent variations of the frontal lobe hypothesis, however, it is acknowledged that the frontal lobe system is closely connected with nonfrontal areas of the brain such as the medial temporal lobes (Friedman, Nessler, Johnson, Ritter, & Bersick, 2008; Murphy et al., 2007; West & Travers, 2008). The most recent studies generally emphasize the importance of distributed neural networks underlying brain functions, including executive functions.

The frontal lobe hypothesis and performance variability. Frontal lobe lesions are associated with increased intraindividual variability. It has been shown that patients with focal frontal lesions and frontal lobe dementia show more dispersion and less consistency than controls on RT tasks (Murtha, Cismaru, Waechter, and Chertkow, 2002; Stuss, Murphy, Binns, & Alexander, 2003). Similarly, older adults show less consistency and more dispersion than younger adults on RT tasks that place high demands on executive control, thought to be supported by frontal systems, but the association of age with consistency is not seen on simple RT tasks (West et al., 2002b). Furthermore, older adults show less consistency than younger adults on the executive aspects of word list memory (e.g. false memory errors), but not in the number of words recalled, thought to be associated more strongly with posterior than with frontal areas. (Murphy et al., 2007). Finally, time of day studies have shown that older adults showed a greater decrement in performance than younger adults when tested during their nonoptimal time of day on tasks requiring executive control. Put together, these findings suggest that intraindividual variability is associated with frontal lobe dysfunction; and therefore, according to the frontal systems hypothesis, increased intraindividual variability is expected as a part of the changes that occur in frontal areas in normal cognitive aging

Intraindividual variability as an indicator of neurological disturbance. Hultsch and his colleagues (2008) suggest that a change in consistency has been known to be a part of neurological disturbance as long ago as Harlow's description of Phineas Gage, who became "capricious and vacillating" after his famous brain injury (p. 510). However, only recently have researchers begun to empirically investigate the proposal that intraindividual variability is indicatory of neurological disturbance. Stuss, Pogue, Buckle, & Bondar et al. (1994) began this trend by examining intraindividual variability in patients with traumatic brain injury (TBI). They found that TBI patients were less consistent than controls on RT tasks. Additionally, the more recently the patients were injured, the more variability they showed.

Higher intraindividual variability has also been observed in chronic fatigue syndrome, schizophrenia, depression, and borderline personality disorder (Fuentes, Hunter, Strauss, & Hultsch, 2001; Kaiser et al., 2008). Additionally, intraindividual variability on complex RT tasks was found to predict mild cognitive impairment and Alzheimer's disease (Gorus, De Raedt, Lambert, Lemper, & Mets, 2008). Two longitudinal studies also showed that performance variability was related to cognitive decline (Lovden, Li, Shing, & Lindenberger, 2007; MacDonald, Hultsch, & Dixon, 2003). Using longitudinal data from the Berlin Aging Study, Lovden et al. asserted that not only does intraindividual variability predict cognitive decline as measured through neuropsychological tests, it precedes it. Dixon and colleagues (2007) have also shown that intraindividual variability is a differential contributor to emerging cognitive impairment, more so than level of performance on a test of cognitive speed. That is, performance consistency distinguished between nonimpaired, mildly impaired, and moderately impaired groups better than level of performance on the task.

Intraindividual variability is especially salient after neurological disturbance to the prefrontal cortex. Murtha et al. (2002) studied variability in patients with frontal lobe dementia. They found that frontal lobe dementia patients showed more intraindividual variability on the Stroop task than two matched groups of Alzheimer's disease patients and healthy older adults. De Frias, Dixon, Fisher, and Camicioli (2007) found that Parkinson's patients had poorer executive functioning than normal healthy adults, and performed less consistently than controls on the most complex RT task, but not on less complex RT tasks. In this study, consistency was not correlated with tasks that placed fewer demands on executive control such as tapping speed and gait speed.

Intraindividual Variability as a Neurobiological Sequela of Cognitive Aging

Given the findings that neurologically-normal older adults and neurological patients perform less consistently on only selected cognitive functions, it seems reasonable to assert that these fluctuations cannot be explained merely by variations in affect, stress level, or energy level. Rather, these changes appear to be due to instability in network pathways and neurotransmitter systems, particularly those in the prefrontal cortex. Williams, Hultsch, Strauss, Hunter, and Tannock (2005) investigated intraindividual variability in choice RT performance in participants from 6 to 81 years old. They found that the lowest levels of consistency were for children and older adults, with younger adults performing most consistently.

As previously noted, West et al. (2002b) found that intraindividual variability (both consistency and dispersion) on tasks requiring executive control processes such as inhibition, set switching, and working memory (but not on simpler RT tasks) is greater in older than younger adults. In a more recent similar study, Dixon, Garrett, Lentz, MacDonald, Strauss, and Hultsch (2007) found significant age differences in consistency on all RT tasks given, and the largest effects were shown on the 1-back RT task, which places high demands on executive control processes. In addition, Murphy et al. (2007) found that older adults performed less consistently than younger adults on executive aspects of word list learning, such as false memory, but not on the number of words recalled correctly. However, a study using working memory measures different from those used by West et al. and Dixon et al. failed to show less consistency in older adults (Robertson, Myerson, and Hale, 2006). Therefore more research is needed to further investigate the frontal system hypothesis as it relates to intraindividual variability and cognitive aging. In addition, it is important to determine whether or not useful intraindividual variability data can be obtained from other neuropsychological tests, especially those in widespread clinical use. Use of a verbal fluency measure thought to recruit prefrontal cortex circuits allows one to evaluate further the predictions of the frontal system model of intraindividual variability in normal cognitive aging.

Intraindividual Variability and Time of Day

An issue deserving of more attention in the intra-individual variability literature is whether fluctuations in cognitive performance occur randomly or follow a systematic pattern. One pattern of cognitive change that occurs with aging is a shift in self-reported time of peak arousal, with older adults reporting mornings as their optimum time of day and younger adults reporting evenings as their optimum time of day (May, Hasher, & Stoltzfus, 1993). The self-report measure used in such studies is the Morningness-Eveningness Questionnaire (MEQ; Horne & Östberg, 1976).

On several neuropsychological tasks, it has been found that when both older adults and younger adults are tested during their respective nonoptimal times of day, older adults show a bigger performance decrement relative to performance at their optimal time of day on several tasks (May & Hasher, 1998; Intons-Peterson et al., 1998; West et al., 2002b). May and Hasher found that performance on two frontally-mediated neuropsychological tests, Trails and Stroop, was more vulnerable to circadian variations in older adults than in younger adults. Intons-Peterson et al. found that using the negative priming paradigm, a task requiring inhibition of a previous response pattern, older adults performed as well as younger adults during their optimal time of day, but not during their nonoptimal time of day.

West et al. (2002b) provided more evidence for the hypothesis that older adults, as compared to younger adults, have particular difficulty maintaining performance of executive control tasks that are highly demanding of frontal lobe systems at nonoptimal times of day. There was no evidence of a time of day effect for either age group in various conditions in which the participant had to identify whether a given stimulus was the one that had just been presented. In contrast two of three error measures revealed an interaction between time of day and age group for conditions in which the participant had to identify the next to the last target presented while keeping the last target in mind (1-back conditions).The 1-back conditions are thought to require a high level of executive ability. All these studies found time of day effects in tasks or conditions that were more difficult and presumably more demanding of executive ability.

Verbal Fluency: Components, Neurobiology, and Relation to Cognitive Aging

Components of verbal fluency. Verbal fluency measures are an essential tool in the field of neuropsychology. They typically involve asking the subject to produce as many words as they can that begin with a certain letter (letter or phonemic fluency) or belong to a certain category (category or semantic fluency) within a set time limit (Lezak, Howieson, & Loring, 2004). Different components of this task tap such cognitive processes as response generation/self-initiation, working memory, processing speed, semantic memory, and set shifting (Strauss, Sherman, & Spreen, 2006). This task is used as a measure of executive functioning because subjects are required to retrieve words in an atypical manner, while tracking prior responses and inhibiting habitual responses from other semantic or phonemic categories (Kemper & McDowd, 2008; Ross, Calhoun, Cox, Wenner, Kono, & Pleasant, 2007).

During verbal fluency tasks, two types of errors can be made: repetitions (i.e., saying the same word more than once per trial) and intrusions (i.e., words not from the target letter or category and nonwords). Both error types rarely occur in normal individuals, and studies usually combine the two types as one error score for analysis, because the number within each error type is limited even in people with neurological damage (e.g., Stuss et al., 1998).

Verbal fluency performance also provides a window into the way people organize their thinking into clusters of related words (Estes, 1974; Lezak et al., 2004). In particular, we can evaluate storage and retrieval from semantic memory by assessing *clustering*, the average size of groups of related words produced over the course of the task. We can observe mental flexibility by assessing *switching*, the number of times the person successfully moves to a new cluster after exhausting the current one (Troyer, Moscovitch, & Winocur, 1997). When combined with measures of the total number of correct words produced and the number of errors, clustering and switching scores also allow us to determine how well a person keeps track of which clusters have been exhausted (Troyer et al., 1997).

Troyer and her colleagues (1997) developed a scoring system to measure clustering and switching on verbal fluency tasks. Clusters sharing the initial sound group or initial sound are called phonological clusters (e.g., clothes, clock, clown) whereas clusters sharing meaning or whose meanings are associated with each other are called semantic clusters (e.g., cow, pig, chicken) as explained by Laine & Neimi (1988). This scoring system has been shown to have near perfect interrater reliability, but poor to modest test-retest reliability due to practice effects (Ross, 2003).

The neurobiology of verbal fluency performance. The association between the frontal lobes and verbal fluency is one of the earliest findings in neuropsychology (Tow, 1955). Individuals with frontal lobe damage have been shown to perform worse on verbal fluency than those with damage to other lobes, independently of the side of the lesion (Miceli, 1981). Both letter and category fluency are associated with the integrity of frontal structures, but category fluency also makes a demand on temporal lobe structures (Henry & Crawford, 2004). Using Positron Emission Tomography (PET) scans, Parks, Loewenstein, Dodrill, and Barker (1988) studied brain activation during letter fluency performance in healthy adults. They found that performing this task produces bilateral activation of the temporal and frontal lobes. Interestingly, participants who performed more proficiently showed less metabolic activation than poor performers, suggesting that more efficient strategies require less metabolic activation. In a more recent PET study examining both letter and category fluency performance in healthy adults, Guorovithch, Krikby, Goldberg, and Weinberger (2000) found that both tasks activated the anterior cingulate, left prefrontal regions, thalamus, and cerebellum. However, letter fluency produced relatively greater activation of the left frontal cortex.

Letter fluency performance is especially poor following left frontal lesions, because lesions in the left hemisphere generally impair verbal abilities, and frontal lesions generally impair adaptation of behaviour to unusual situations (Perret, 1974). In a study measuring regional cerebral blood flow (rCBF), in which frontal dementia patients were compared with normal controls, patients with frontal dementia performed worse than controls on letter fluency, and showed less activation in the frontal lobes (Warkentin & Passant, 1993). In terms of clustering and switching, it was shown that patients with frontal lesions were impaired on switching but produced normal sized clusters on both letter and category fluency (Troyer, Moscovitch, Winocur, Alexander, & Stuss, 1998).

Clustering is thought to be dependent on intact temporal lobe functions such as verbal memory and word storage, which are thought to be more automatic. In fact, clustering is compromised in patients with temporal lobe neuropathology (Troyer & Moscovitch, 2006). On the other hand, switching is thought to be dependent on intact frontal lobe functions such as strategic search processes and the ability to shift from one category to another. These functions are more effortful, and are compromised in patients with frontal lobe neuropathology (Troyer & Moscovitch).

Clustering and switching analysis has been shown to be important in characterizing several neuropsychological disorders. For example, in a study that compared older adults with Alzheimer's dementia, Parkinson's dementia, Parkinson's disease with no dementia, and demographically matched controls, it was found that whereas the total numbers of words generated did not discriminate amongst the Parkinson's dementia and Alzheimer's dementia groups, measures of switching and clustering did (Troyer, Moscovitch, Winocur, Leach, & Freedman, 1998). Patients with Alzheimer's dementia produced smaller clusters on both letter and category fluency, and made fewer switches on category fluency than controls. On the other hand, patients with Parkinson's dementia produced smaller clusters on letter fluency, and made fewer switches on both letter and category fluency than controls. The authors suggested that this indicates that clustering is more dependent on temporal lobe functioning whereas switching is more dependent on frontal lobe functioning. This is because neuropathological changes in Alzheimer's disease occur mainly in temporal and parietal regions, whereas in Parkinson's disease, neuropathology occurs mainly in frontal-neostriatal systems.

Patients with Huntington's disease, who typically have frontal atrophy, show a pattern similar to that that of Parkinson's patients of reduced switching and intact clustering (Rich, Troyer, Bylsma, & Brandt, 1999). In addition, in disorders that do not clearly affect one brain system more than the other, clustering and switching performance tend to be equally impaired. For example, patients with schizophrenia show impairments in both clustering and switching relative to normal controls (Zakzanis, Troyer, Rich, & Heinrichs, 2000).

Finally, error scores have also been correlated with damage involving the left frontal area. Stuss et al. (1998) found that the ratio of total errors to total correct words was greatest in patients with left frontal lesions compared to patients with different lesions and to normal controls. These errors were not differentiated according to type because of the small number of errors made. Within those with left frontal lesions, patients with left dorsolateral lesions performed the worst.

Verbal fluency and normal aging. The effect of age on verbal fluency performance is controversial with some studies reporting significant changes on both letter and category fluency (Auriacombe et al., 2001), some reporting a decline on only category fluency (Kozora & Cullum, 1995; Tomer & Levine, 1993; Troyer et al., 1997), some reporting no significant change on either letter or category fluency (Treitz, Heyder, & Daum, 2007), and some claiming an age by gender interaction in word fluency (Capitani, Laiacona, & Basso, 1998). That is, when it comes to level of performance, age-related changes in verbal fluency appear to be subtle at best, and when do they occur category fluency appears to be more vulnerable to change. Not surprisingly, on tasks of alternating fluency, which require subjects to switch back and forth between two semantic categories, older adults tend to perform worse than younger adults (Henry & Phillips, 2006). In terms of clustering and switching, increasing age is associated with slightly larger cluster sizes, and with a reduced number of switches (Troyer et al., 1997; Troyer, 2000).

Verbal Fluency and Intraindividual Variability

Little is known about consistency and dispersion in verbal fluency tasks, because previous research in the area of intraindividual variability has not yet examined the effect of cognitive aging on verbal fluency. Further information is needed on the effects of age on verbal fluency by examining intraindividual variability in older and younger adults in performing different aspects of this task (e.g. total number of words produced, number of errors). Additionally, potential changes in switching and clustering strategies with age should be studied by examining intraindividual variability in the use of these strategies.

In terms of verbal fluency and time of day effects, studies suggest that a relationship between time of day and age may exist, but there is no definitive work. Allen, Grabbe, McCarthy, Wallace, and Bush (2008) found that young adults tested on a variety on neuropsychological tests across three different times of day performed significantly better on letter fluency in the afternoon and evening testing sessions compared to morning testing. They also found that time of day influenced a processing speed measure but did not affect tasks measuring category or episodic memory. On the other hand, Martin, Buffington, Welsh-Bohmer, and Brandt (2008) found that older adults' category verbal fluency performance was not related to time of day, whereas their episodic memory performance was. In order to clarify the relationship between aging, verbal fluency, and variability related to time of day, groups of older and younger adults should be included in the same study. Additionally, studies should examine the clustering and switching subcomponents of verbal fluency, which are thought to be influenced by temporal and frontal systems respectively.

The Present Study

In this study, I examined data from a verbal fluency task, a common neuropsychological test of language and executive function. This task was selected because it allowed for the study of both aspects of intraindividual variability: dispersion and consistency (subsequently defined). I was able to investigate both consistency, measured across sessions on four consecutive days, and dispersion, measured across eight 15-secondintervals on each testing occasion. Finally, I appraised the influence of time of day (TOD) on verbal fluency performance in older and younger adults.

Using data collected at Baycrest as part of a larger battery, I examined differences in dispersion and consistency in letter and category fluency tests. I also examined time of day effects. I expected to find greater intraindividual variability in verbal fluency performance of older adults compared to that of younger adults, as measured by both dispersion and consistency, as well as greater vulnerability to time of day effects. This study built on the work previously published in the areas of intraindividual variability (West et al., 2004a, Murphy et al., 2007), including time of day effects (West et al., 2002a). I evaluated five specific hypotheses:

Hypothesis 1. Older adults were expected to show less consistency across the four days of testing than younger adults on letter and category fluency performance in terms of the number of correct responses and total number of errors made. This is because verbal fluency is a task that taps frontal lobe systems, which are thought to be more vulnerable to cognitive aging and consequently more likely to fluctuate. I expected this effect to be stronger for letter than category fluency, because although both types of fluency are affected after frontal lobe injury, category fluency is also heavily dependent on posterior regions that are less affected by normal aging (Stuss et al., 1998). Additionally, letter fluency is thought to require greater non-habitual strategic capabilities, and therefore more executive control processes (Riva, Nichelli, & Devoti, 2000).

Hypothesis 2. For similar reasons, older adults were expected to show more dispersion across the two minutes of each task than younger adults on the number of words generated for both category and letter fluency performance.

Hypothesis 3. Older adults were expected to be less consistent across the four days of testing than younger adults on number of switches but not averagecluster size, in letter and category fluency performance. This is because switching has been shown to be more vulnerable to frontal lobe dysfunction than cluster size (Troyer et al., 1998).

Hypothesis 4. Older adults were expected to be more vulnerable than younger adults to time of day effects on the level of performance, measured by number of words generated in both letter and category fluency. This is because research has indicated that older adults are more likely to perform worse at nonoptimal times of day than younger adults (May et al., 1993; West et al., 2002b).

Hypothesis 5. For similar reasons, greater dispersion was expected in older adults than younger during sessions in which they were tested at their nonoptimal time of day.

CHAPTER III

DESIGN AND METHODOLOGY

Participants

Archival data from 40 participants were used for this study, including 20 older adults (10 women and 10 men 65 to 83years old), and 20 younger adults (10 women and 10 men; 19 to 29 years old). The participants were recruited from the Baycrest-Rotman research volunteer pool and through newspaper advertisements. Screening ensured that these participants did not have neurological or psychiatric disorders, and were in good physical health according to self-report. Additionally, participants with low education (i.e., <10 years) or with self-reported depression outside the range of normal on the Beck Depression Inventory (BDI; Beck, 1987) were excluded. This was done because not unlike many other cognitive tasks, verbal fluency performance is related to education, intelligence, and depressive symptoms (Auriacombe et al., 2001; Phillips, 1999). Therefore studies evaluating verbal fluency must also control for or assess the influence of these variables. Participants completed the Beck Depression Inventory, the National Adult Reading Test-Revised (NART-R; Blair & Spreen, 1989), and a split-half version of the vocabulary subtest of the Wechsler Adult Intelligence Scale-Revised (WAIS-R; Wechsler, 1981) at the end of the first session.

For a comparison of the demographic variables between groups, refer to Table 1. The older adult and younger adult groups were comparable in terms of years of education and BDI scores. The older adults group had significantly higher scores on the NART-R $F(1,39) = 11.32$, $p < .05$, and on the vocabulary subtest of the WAIS-R $F(1,39) = 4.57$, $p < .05$.

Participants also completed the Morningness-Eveningness Questionnaire (MEQ)(Horne & Ostberg, 1976) at the end of the first session in order to assess their optimal time of day. The MEQ classifies individuals into “definitely morning type,” “moderately morning type,”“neither type,”“moderately evening type,” and “definitely evening type” (higher scores indicating morningness). According to this classification system, the mean score for older adults corresponds to the moderately morning type (M = 58.85, SD = 8.46), and the mean score for younger adults corresponds to the neither type (M = 5.00, SD = 10.23). As expected, the two groups were significantly different on this measure $F(1, 39) = 21.76$, $p < .001$.

Materials and Procedure

Participants performed verbal fluency tasks as part of a larger battery of tests. They were tested on four consecutive days, with two morning sessions (i.e., 9:00 am) and two evening sessions (i.e., 5:00 pm) each. On each testing occasion half the subjects were first tested in the morning and half were first tested in the evening. After the first session, participants alternated between morning and evening sessions across the four days of testing. An equal number of male and female participants in each age group were assigned to a morning or evening session on the first day of testing (see Table 2). This design allowed for measuring intraindividual variability within sessions (dispersion) and across four testing sessions (consistency) and for examination of interactions between age, task conditions, and time of day effects.

On each test day, one letter fluency and one category fluency test was administered. Participants were asked to give as many exemplars as possible for each letter for 2 minutes. Similarly participants were asked to give as many exemplars of each semantic category as possible for 2 minutes (see Table 2). The letters and categories used for each session were: “M” and “Countries”, “P” and “Food”, “C” and “Canadian Cities and Towns”, “B” and “Animals”. The order in which these pairs were given across the four days was randomly assigned. As shown in Table 2, the same letter was administered with the same category across participants, and each participant completed all four letter/category forms.

The instructions, based on Benton (1968), were as follows for letter fluency:

“I would like to find out how many words you know that begin with certain letters. I will give you a letter of the alphabet, and I’d like you to tell me as many different words as you can that begin with that letter. There are some rules to keep in mind, however. (1) You cannot use the names of people or places – no proper names please. (2) You must use different words. For example, if the letter was “R” and you said the word “run” you would not be allowed to make up different versions of the word “run” by adding different endings to it like “runs, running, or runner” – these different versions would not count, they must be different words. (3) Finally, you cannot use numbers; for example, if the letter was “T” and you said “thirty, thirty-one, thirty-two, etc.”, those words would not count. Otherwise, any word will do, as long as it begins with the letter that is given to you. Any questions? The letter is “_”. Tell me as many words as you can think of that begin with the letter “_” in two minutes. If you draw a blank during the two minutes, don’t worry just continue to try and think up words beginning with the letter “_”. Go ahead”.

For category fluency, the instructions, based on Newcombe (1969), were as follows:

“Now we are going to change things a little. This time, please think of words that belong to a certain category. The category is “___”. Tell me as many different kinds of “___” as you can. It doesn't matter what letter of the alphabet the "___" begins with, as long as it's a "____". Again, if you draw a blank during the two minute time period, don't worry just continue to try and think up words that are "___". Any questions? Go ahead."

The examiner recorded the words verbatim, and all answers were taped and reviewed later. Responses were written on a response sheet separated into 15 second intervals. They were scored by a research assistant, and I re-scored them in order to ensure that the data had acceptable inter-rater reliability. Protocols were scored as shown in Appendices A and B..

Interrater reliabilities for clustering and switching were within acceptable ranges. For letter fluency, the Pearson correlation coefficient was .994 for cluster size and .995 for switching. For category fluency, the interrater reliability was calculated separately for each form because unlike letter fluency, there are separate subcategories for each semantic category. The Pearson correlation coefficient for animal fluency was .903 for cluster size, and .974 for switching; country fluency was .913 for cluster size, and .915 for switching; Canadian cities and towns fluency was .986 for clustering and .983 for switching; and food fluency was .986 for clustering and .984 for switching. The reliability values were similar to those found by Troyer et al. (1997).The letters used were chosen to be as comparable as possible in terms of frequency in the English language. Similarly, the categories were chosen to be comparable in terms of the semantic knowledge of Canadian participants. Pilot data collected by Angela Troyer showed that the four letters, as well as the four categories, were roughly equivalent in terms of number of exemplars produced (personal communication). These findings were generally confirmed by this study (see Appendix D).

As shown in Appendix D, form effects were found on mean cluster size and number of switches for letter fluency. That is, participants had a larger mean cluster for the letter C than the letters M and P. They also made less switches for the letter C than the letters B and P. Form effects also were found for total number of correct words produced and total number of errors for category fluency. That is, participants came up with more exemplars of countries than Canadian cities and towns. They also made more errors on countries than animals. No effect of age or interaction between age and forms was found. Additionally, all letter and category fluency forms were strongly correlated with each other respectively (see Appendix D).

As described subsequently some data analyses were modified to correct for differences among forms.

A chi-square test indicated that forms were given in random order across days and groups, as intended. The chi-square values for the distribution of the four forms across the different testing occasions were .17, 1.6, 1.84, and 1.13 respectively. Finally, practice effects were examined to ensure that differences in consistency or time of day effects were separable from interactions between age and practice effects.

Statistical Analysis Plan

When form effects were pertinent to a given analysis , the relevant analysis above was conducted using z-scores instead of the raw total words generated for that condition. For example, a statistically significant form effect was found for the total number of words generated in the category fluency condition, so in analyses of level of performance in category fluency I calculated the mean and standard deviation of the distribution of all 40 participants’ total words produced in the category fluency condition for each form. The z-scores of a particular participant’s number of words produced with respect to each form given was used instead of the raw total words produced in the category fluency condition on that occasion.

Effect size (eta squared) was calculated for all significant interactions. In keeping with recent recommendations for psychology research, a squared association index (e.g., eta squared) lower than .04 will not be interpreted for effects that have not been predicted, because effects of this size are not thought to represent "practically" significant effects for social science data (Ferguson, 2009).

Hypothesis 1: Older adults were expected to be less consistent across the four days of testing than younger adults on letter and category fluency performance in terms of the number of correct responses and total number of errors made. This effect was expected to be stronger for letter than category fluency. To evaluate this hypothesis in terms, a mixed-design ANOVA was used with age as the between subjects variable, and condition (letter or category) as the within-subjects variable. The dependent variable was the consistency ISD (individual standard deviation), which is the standard deviation of the total words produced across the four test sessions for the letter condition or for the category condition (see Appendix C for an example of how this was calculated). A smaller ISD score indicates more consistent performance.

The same mixed ANOVA was then conducted using the total number of errors in the letter condition on each testing occasion and the total number of errors in the category condition on each occasion as the basis for calculation of the consistency ISD for each fluency condition.

Hypothesis 2: Older adults were expected to show more dispersion across the two minutes of each task than younger adults on the number of words generated for both category and letter fluency performance. To evaluate this hypothesis, a mixed-design

ANOVA was used with age as the between subjects variable, and condition (letter or category) as the within-subjects variable. The dependent variable was the dispersion ISD (see Appendix C for an example of how this was calculated). Dispersion ISDs were calculated averaging across four test days the number of words produced for each of eight 15-second intervals.

Hypothesis 3: Older adults were expected to be less consistent across the four days of testing than younger adults on switching, but not average cluster size, in letter and category fluency performance. To evaluate this hypothesis, two mixed-design ANOVAs was conducted with age as the between subjects variable, and condition (letter or category) as the within-subjects variable. The dependent variable for the first ANOVA was the clustering ISD, and the dependent variable for the second ANOVA was the switching ISD. Clustering ISD was calculated by finding the standard deviation of the average cluster size of letter and category fluency, respectively, across the four days of testing. Switching ISD was based on the standard deviation of the mean number of switches of letter and category fluency, respectively, across the four test sessions.

Hypothesis 4. Older adults were expected to be more vulnerable than younger adults to time of day effects on the level of performance, measured by number of words generated in both letter and category fluency. To evaluate this hypothesis, two repeated measures ANOVAs were conducted, one for letter fluency and one for category fluency. Age was the between subjects variable, and time of day (morning or evening) was the repeated measure. The dependent variable was the total number of words for each condition averaged across the two testing sessions for that time of day. An interaction between age and time of day would support the hypothesis. Because form effects were found for level of performance for the category condition in the preliminary condition, form-specific z scores were used as the dependent variable for that condition rather than raw scores as described above in the planned preliminary analyses for practice effects and time of day effects.

Hypothesis 5. Greater dispersion was expected in older adults than younger during session in which they were tested at their nonoptimal time of day. To evaluate this hypothesis, two repeated measures ANOVAs were conducted, one for letter fluency and one for category fluency. Age was the between subjects variable, and time of day (morning or evening) was the repeated measure. The dependent variable was the dispersion ISD for each condition averaged across the two testing sessions for that time of day. An interaction between age and time of day would support the hypothesis.

CHAPTER IV

ANALYSIS OF RESULTS

Preliminary Analyses

Level of performance. Older adults and younger adults performed similarly on letter fluency total word scores, clustering, and switching (see Table 3). Older adults made more errors than younger adults on letter fluency. This was observed on all four occasions of testing. On category fluency, older and younger adults performed similarly on all measured aspects (see Table 4). Older adults tended to make more errors than younger adults on category fluency, but this was not statistically significant. Unlike the findings of Troyer et al. (1997, 2000) there was no significant difference between older and younger adults on cluster size or number of switches, likely due to the smaller sample size in this study. The similarity in the level of performance between groups on these tasks suggests that any difference in consistency or dispersion was not due to or influenced by a difference in the mean level of performance.

Practice effects. In order to assess for these effects two repeated measures ANOVAs were used: one for letter fluency and one for category fluency. This was done through a 2 Age (younger, older) X 2 Order of Test Days (first 2 days, last 2 days) design, with age group as the between-subject factor and order of test days as a repeated measures factor. The dependent variables were total words generated on letter fluency for the first ANOVA and total words generated on category fluency for the second ANOVA.

A practice effect was found for letter fluency F (1, 38) = 13.29, p = .001, η^2 = .24 (see Figure 1). However, there was no main effect of age, or interaction between age and practice effects. Because both groups benefited equally from practice, no adjustments were necessary in examining the variability of performance as part of the main analyses. There was no practice effect for category fluency F (1, 38) = .26, p = .614, η^2 =.01 (see Figure 2). Similarly, there was no main effect of age or an age by practice interaction. Because form effects for category were found, this analysis was repeated using Z-scores instead of raw scores, as described in the Methods section. This analysis yielded similar results F (1, 38) = 1.24, p = .272, η^2 = .03.

Main Findings

Hypothesis 1: Older adults will be less consistent across the four days of testing than younger adults on letter and category fluency performance in terms of the number of correct responses and total number of errors made. Because of the form effects that were found for category fluency total and errors, ISDs were calculated using Z-scores based on each form as opposed to raw scores. For total words produced, there was no main effect of age F (1, 38) = .39, p = .54, η^2 = .01, condition F (1, 38) = 3.56, p = .067, η^2 = .09 or an age by condition interaction F (1, 38) = .30, p = .587, η^2 = .01 (see Figure 3). Similarly, there was no main effect of age F (1, 38) = .91, p = .347, η^2 =.02, condition F (1, 38) = .91, p = .347, η^2 = .02, or an age by condition interaction F (1, 38) = 1.76, p = .193, η^2 = .04 for number of errors produced (see Figure 4). These results suggest that healthy adults do not in fact become less consistent on verbal fluency measures with age.

Hypothesis 2: Older adults are expected to show more dispersion across the two minutes of each task than younger adults on the number of words generated for both category and letter fluency performance. Contrary to expectations, older adults did not differ from younger adults in terms of dispersion. Contrary to expectations, there was no main effect of age F (1, 38) = 1.22, p = .276, η^2 = .03 or an age by condition interaction F (1,38) = 3.56, p = .067, η^2 = .09 (see Figure 5). There was a main effect of condition F (1,

38) = 39.00, $p < .001$, $\eta^2 = .51$. This is likely because participants on average provided 10 more words for category than letter fluency, resulting in higher variation.

Hypothesis 3: Older adults are expected to be less consistent across the four days of testing than younger adults on switching, but not average cluster size, in letter and category fluency performance. Because form effects were found on letter clustering and switching, ISDs were calculated using Z-scores based on each form as opposed to raw scores. As expected, consistency of average cluster size did not differ between older and younger adults (see Figure 6). For consistency of average cluster size, there was no main effect of age, F (1, 38) = .34, p = .566, η^2 = .01, condition F (1, 38) = .32, p = .574, η^2 = .00, or an age by condition interaction, F (1, 38) = .11, p = .743, η^2 = .003. Unexpectedly, younger adults were less consistent than older adults on switching (i.e., they showed more intraindividual variability, see Figure 7). For switching, there was a main effect of age F (1, 38) = 6.09, p = .018, η^2 = .013 but no main effect of condition F (1, 38) = .17, p = .686, η^2 = .004, or age by condition interaction F (1, 38) = .07, p = .800, η^2 = .002. However, the effect size of this finding (<.04) renders it inconsequential.

Hypothesis 4. Older adults are expected to be more vulnerable than younger adults to time of day effects on the level of performance, measured by number of words generated in both letter and category fluency. This hypothesis was supported by the data for category fluency, but not letter fluency. For letter fluency there was no main effect of time of day F (1, 38) = 2.63, p = .113, η^2 = .07, age F (1, 38) = .14, p = .708, η^2 = .004 or a time of day by age interaction F (1, 38) = .20, p = .658, η2 = .01 (see Figure 8

For category fluency, there was no main effect of time of day F (1, 38) = .63, p = .431, η^2 = .02 or age F (1, 38) = .01, p = .924, η^2 = .00. However, there was a clear age by time of day interaction *F* (1, 38) = 4.32, $p = .044$, $\eta^2 = .10$ supporting the hypothesis (see Figure 9).

Because there were form differences on category fluency, the forementioned analysis was repeated using each person's form-based z-score instead of their raw scores. Similarly, the results of that analysis also showed no main effect of time of day *F* (1, 38) = .32, $p = .575$, $\eta^2 = .01$ or age *F* (1, 38) = .08, $p = .777$, $\eta^2 = .002$. The age by time of day interaction remained *F* (1, 38) = 4.21, $p = .047$, $\eta^2 = .10$ (see Figure 10).

One limitation of the randomized design was that 15 older adults but only 11 younger adults received the "countries" category in the morning (see Table 2). As can be seen in Table 4, participants tended to perform better in this category. However, the Z-score correction should account for this potential confound by reducing raw scores into standard scores for each form. In addition, I re-ran the analysis covarying for MEQ scores to see whether the time of day by age interaction diminished once time of day preference was accounted for, and it did, *F* (1, 37) = 1.76, $p = .193$, $\eta^2 = .05$. Additionally, to account for the fact that the older adults in this sample had significantly higher vocabulary scaled scores on a split-half form, I covaried for the vocabulary score in order to see whether the time of day effect became stronger. Doing so did in fact result in a higher effect size for the time of day by age interaction *F* (1, 37) = 5.69, $p = .022$, $\eta^2 = .13$.

Additional analyses were conducted to discern the effects of time of day and age on mean cluster size and number of switches. For letter fluency, older adults tended to have a similar average cluster size in the morning (*M* = .87, *SD* = .67) as in the evening (*M* = .95, *SD* = .58, Cohen's *d* = .17). They also produced the same number of switches in both the morning (*M* = 12.13, *SD* = 3.53) and the evening (*M* = 12.62, *SD* = 4.25, Cohen's *d* = .13). Similarly, younger adults tended to have a similar mean cluster size in the morning (*M* = .82, *SD* = .37) as in the evening (*M* = .77, *SD* = .66, Cohen's *d* = .09). They tended to switch less in the morning (*M* = 12.13, *SD* = 3.53) than in the evening (*M* = 13.70, *SD* = 4.44, Cohen's *d* = .39).

For category fluency, older adults tended to have a bigger mean cluster size in the morning (*M* = 1.78, *SD* = .72) than in the evening (*M* = 1.64, *SD* = .63, Cohen's *d* = .21). They produced the same number of switches in the morning (*M* = 12.18, *SD* = 3.14) and in the evening (*M* = 11.73, *SD* = 2.73, Cohen's *d* = .15). Younger adults tended to have a similar mean cluster size in the morning (*M* = 1.62, *SD* = 1.09) and in the evening (*M* = 1.78, *SD* = 1.49, Cohen's *d* = .12). However, they tended to switch less in the morning (*M* = 12.35, *SD* = 3.03) than in the evening (*M* = 13.40, *SD* = 3.62, Cohen's *d* = .31).

These results followed the general pattern of older adults performing best in the morning and younger adults performing best in the evening. Troyer (2000) reported a pattern in which older adults show a slightly larger mean cluster size but a reduced number of switches compared to younger adults. In fact, it appears that this pattern emerges more clearly when older adults are tested in the evening and younger adults are tested in the morning.

Hypothesis 5. Greater dispersion is expected in older adults than younger during session in which they were tested at their nonoptimal time of day. Contrary to expectations, older adults did not differ from younger adults in terms of dispersion in the morning or evening sessions. For letter fluency, there was no main effect of age *F* (1, 38) = .003, *p* = .960, η^2 = .000, time of day *F* (1, 38) = .17, *p* = .686, η^2 = .004, or an age by time of day interaction *F* (1,38) = 2.03, *p* = .163, η^2 = .05 (see Figure 11). For category fluency, there was no main effect of age *F* (1, 38) = 3.16, *p* = .084, η^2 = .07, time of day *F*

$(1, 38) = 2.91$, $p = .096$, $\eta^2 = .07$, or an age by time of day interaction $F(1,38) = 3.62$, $p = .065$, $\eta^2 = .09$ (see Figure 12).

CHAPTER V

DISCUSSION

In this study, an age related shift in time of day in self-reported preference was associated with level of performance on a category but not letter fluency. Contrary to expectations, there was no overall difference between age group in consistency of performance across days or in dispersion of performance within a verbal fluency task on a given occasion. This study showed that (1) older adults were as consistent as younger adults on verbal fluency measures including total number of correct words produced and total number of errors; (2) older and younger adults exhibited no difference in the dispersion of scores within each verbal fluency measure; (3) for both fluency measures, no difference between younger and older adults was found in the consistency of mean cluster size, whereas younger adults were less consistent in the number of switches; (4) on category but not letter fluency older adults produced more correct words in the morning than in the evening while younger adults showed the opposite pattern, and (5) neither older adults or younger adults showed greater dispersion of performance when tested at the nonpreferred time of day. Despite the similar performance of younger and older adults on the majority of analyses in this study, there was a clear interaction between time of day and level of performance for category fluency as predicted by the fourth hypothesis.

These results are significant because unlike most other studies showing time of day effects with aging (e.g., Li et al., 1998; May & Hasher, 1998), participants were not selected based on the morningness-eveningness preference. Therefore, these results parallel changes that are more representative of naturally occurring changes in the population. In examining Figures 9 and 10, it can be observed that younger adults tend to be slightly less influenced by time of day effects than older adults on category fluency. Regardless, older adults appear to perform best in the morning, whereas younger adults appear to perform best in the evening on category fluency. Although it was thought that younger adults' performance was less dependent on time of day than older adults, more recent research has also shown that younger adults perform better in the afternoon and evening than in the morning on a variety of neuropsychological tasks (Allen et al., 2008). Allen and colleagues also showed that younger adults performed better in the evening regardless of their self-reported preference. This appears to hold true in this study as well, because although younger adults reported being neither morning nor evening types on the MEQ, their category fluency performance tended to improve in the evening. Older adults, on the other hand, report morning as their optimal time of day and do in fact perform better in the morning on category fluency.

It is somewhat surprising that the time of day by age interaction occurred in category fluency but not in letter fluency (see Figure 8), given that letter fluency is more closely associated with frontal lobe functioning, and executive functions associated with the frontal lobe show more pronounced changes in normal aging than those associated with other cortical areas. However, studies examining level of performance have shown that older adults perform worse than younger adults on category fluency but not letter fluency (Tomer & Levin, 1993; Troyer et al., 1997). This finding is subtle and was not replicated in this study or in other studies (e.g. Treitz et al., 2007). Nonetheless, this study suggests that category fluency may in fact be more sensitive to cognitive aging than letter fluency, but only if the participant is tested during non-optimal times of day. In addition, it is likely that whereas letter fluency is impaired by localized lesions of the frontal lobes, changes in category fluency (and those observed as part of cognitive aging) represent more global effects in frontal networks and their connections to other areas of the brain. For example, Stuss et al. (1998) found that letter fluency was affected by lesions in the superior medial frontal regions, left dorsolateral and striatal regions, and left parietal regions, but not in right dorsolateral cortical or connecting striatal regions, right posterior regions, or medial inferior frontal regions. Category fluency, on the other hand, was affected by lesions if any of these regions.

This study also provides data on the clustering and switching patterns of three semantic categories that have not previously been studied: “food”, “Canadian cities and towns”, and “countries”. Although this study does not speak directly to the validity of these categories, the scores from these categories were strongly correlated with the already validated “animals” category. Additionally, interrater reliability was above .90 for clustering and switching scores on all four of the categories used in this study.

An important finding reported here is that older adults are in fact no less consistent across days in the number of words produced (see Figure 3), errors made (see Figure 4), cluster size (see Figure 6), or number of switches on tasks of verbal fluency than younger adults (see Figure 7). Their within task performance on single testing occasions was also as stable as that of younger adults on both letter and category fluency (see Figure 5); and this did not change during their nonoptimal time of day for either letter or category fluency (see Figures 11 and 12). These findings were not expected based on the frontal lobe hypothesis given that verbal fluency is often regarded as a frontal lobe task. A possible explanation for this is that healthy older adults are not challenged by these tasks because they were highly educated, with above average vocabulary and estimated verbal IQ. It is also possible that the older adult group in this study was not old enough to show increased levels of dispersion on verbal fluency. For example, Hilborn et al. (2009) found that dispersion scores on various neuropsychological tasks (not including verbal fluency) were higher amongst the old-old (aged 75-94 years) than the young-old (aged 64-74 years).

A final possibility is that although verbal fluency has been shown to involve the frontal lobes, the task does not in fact place a high enough demand on executive control. There is no doubt that there are some demands placed on the participants' executive control in that they are required to inhibit (words that they have already said or that do not comply with the rules of the task), switch (between clusters of items), and use working memory (to keep track of the words said so far and the rules of the task). However, with a rich enough vocabulary, these executive constraints may not pose a challenge for the average well-educated older adult. Phillips (1999) has suggested that letter fluency tasks are not novel enough, because individuals who regularly play scrabble or crossword puzzles may have a pre-existing cognitive response set that would help them perform the task.

A potential strength of this study is the attempt to evaluate variability on a task in which mean performance between younger and older adults is not different. To my knowledge, no other study on performance variability has compared older and younger adults on tasks in which their level of performance is comparable. All studies in this field have focused on examining tasks in which older adults already perform worse than younger adults and then analyzed the variability in this performance. In order to do this, however, they have had to correct for mean levels of performance by computing the Individual Coefficient of Variance (e.g. Stuss et al., 2003) or using the index of residual ISD (e.g. Dixon et al., 2007). These methods do not provide a perfect correction, and a study where changes in dispersion and consistency are present despite no difference in mean performance would provide a more convincing account of the importance of considering intraindividual variability in clinical situations. Additionally, it may in fact be the case that changes in intraindividual variability only occur when changes in level of performance are also observed. A potential challenge in this area of research is to use a task that elicits age-related changes in intraindividual variability in which there is no pre-existing change in level of performance.

Limitations of this study include a relatively small sample size, and small unequal numbers of older and younger adults (within and across age groups) receiving a particular form at any one testing occasion and time of day. Another potential weakness of this study is that despite pilot data showing that all four letter and category fluency forms were equivalent; this was not the case for category fluency forms in this study.

This study is important because it showed that some aspects of letter fluency performance may not be as affected by normal cognitive aging as category fluency. Not only did older participants perform as well as younger adults on this task in terms of the total number of correct words produced, their performance was also unaffected by time of day influences and was stable within session and across sessions. Therefore, in clinical practice, psychologists can be more confident that a lower than expected performance on number of correct words produced on letter fluency is due to an abnormal change rather than an effect of normal cognitive aging. In fact, Troyer et al. (1997) showed that older adults performed well as younger adults on letter fluency, and produced larger clusters.

However, despite producing an equal number of correct words, older adults made significantly more errors than younger adults on letter fluency and showed a tendency to make more errors on category fluency. This suggests that older adults have more trouble in self-monitoring than younger adults. This finding is in line with the finding that aging affects aspect of working memory (West et al., 2002a). According to the working memory model developed by Hasher and Zacks (1988), efficient working memory depends on inhibitory processes that (a) limit the access of irrelevant information into working memory (access), (b) delete no longer relevant information (deletion), and (c) inhibiting incorrect responses (restraint; for review of current applications of this model, see Hasher, Lustig, & Zacks, 2007). Given this model, errors on verbal fluency represent problems in deletion (repetition errors) and inhibition (intrusion errors).

As predicted, on a category fluency task, while older and younger adults overall produced a similar number of correct words, each group on average performed better when testing was conducted at the time of day preferred by that age stratum. On this task, younger adults tended to do better in the evening than the morning, whereas older adults tended to do better in the morning. This effect was found despite the fact that participants were not selected based on their time of day preference. It also occurred despite equal overall level of performance between older and younger adults. It is difficult to ascertain whether this difference is due to normal shifts in circadian preference or to reduced stamina at later times of day in old age.

Complicating this finding is that the older adults in this study had a larger vocabulary than younger adults. When vocabulary scores were covaried, the effect age by time of day interaction became even clearer (the effect size increased from .100 to .133). This suggests that a superior vocabulary in older adults may mask or guard against the effect of time of day on verbal fluency performance in that group when compared to younger adults. These findings are encouraging in that they suggest that not only does vocabulary continue to improve with age, this improvement may also lead to more stable performance throughout the day.

The WAIS-R vocabulary score is often used along with years of education and NART scores to calculate an index of *cognitive reserve* (Stern, 2009). The theory of cognitive reserve aims to explain the difference between brain changes that occur as a function of age or brain injury and its clinical manifestation (i.e., why different individuals display varying levels of functioning despite undergoing similar brain changes). Although not directly explored in this study, older adults who have underlying subtle neurological disorder but a superior vocabulary may have more cognitive reserve, which may help them perform at close to normal levels even during non-optimal times of day.

Conclusions

Based on the findings of this study, it can be asserted that older adults are no more variable than younger adults in their performance on all measurable aspects of verbal fluency. It can also be concluded that time of day preference changes with age. Older adults reported morning as their optimal time of day and younger adults reported no time of day preference. In terms of the frontal lobe hypothesis of cognitive aging, this study provides mixed evidence. On the one hand, category fluency performance, which requires the involvement of both frontal and temporal areas of the brain, varied by age in relation to time of day. On the other hand, letter fluency performance, which is closely associated with specific areas of the frontal lobes, was unaffected by age or time of day.

This suggests that performance on tasks involving broad regions of the frontal lobe network and its connections to temporal areas of the brain may be more likely to change with age than performance on tasks involving more distinct regions within the frontal lobes. The results from this study do not support the assertion by MacPherson et al. (2002) that cognitive aging is best explained by dorsolateral prefrontal dysfunction. To my knowledge, no other study has investigated the effects of time of day, consistency, and dispersion simultaneously on a clinical neuropsychological measure.

In this study, it was shown that younger adults performed best on category fluency during the evening, whereas older adults performed best during the morning. This effect was stronger when the older adults' higher vocabulary scores were taken into account, suggesting that cognitive reserve may improve older adults' performance at nonoptimal times of day. An older adult's performance on category fluency in the evening was on average.321 z-scores lower than their performance in the morning. This standard score can easily tip a client's standard score from the low average range to the borderline impaired range. That is, age differences in verbal fluency are likely to be exaggerated when clients or research participants in different age groups are tested during their non-optimal time of day. This study adds to a body of research suggesting that it may be useful to ask older clients (about their time of day preference, and to use morning test times when appropriate (Hasher et al., 2007; May et al., 1993; Yoon et al., 2000).

Table 1

Participant Characteristics

Measure	Older Adults *M*	Older Adults *SD*	Younger Adults *M*	Younger Adults *SD*	*F* (1, 39)	*p*	Cohen's *d*
Age	72.75	4.63	24.20	3.49			
Education (yrs,)	16.00	2.75	15.55	1.93	.36	.55	.19
NART-R	115.44	7.02	106.82	9.05	11.32	.002*	1.06
Vocabulary (Scaled Score)	16.00	3.43	13.60	3.66	4.57	.04*	.68
BDI	4.58	2.84	5.50	4.80	.53	.47	.23

Note. NART-R = estimated Verbal IQ from the National Reading Test-Revised; Vocabulary = age scaled score on a split ½ version of the WAIS-R Vocabulary subtest; and BDI = Beck Depression Inventory

Table 2.

Order of Letters and Categories Given.

Subject #	M/F	Day 1	Day 2	Day 3	Day 4
Older adults (n = 20)					
1*	F	1	3	2	4
2*	M	3	1	4	2
3*	F	3	4	2	1
4*	F	2	3	4	1
5*	M	3	1	2	4
6*	F	2	4	1	3
7*	F	2	1	4	3
8*	M	2	1	3	4
9*	M	2	3	1	4
10*	M	4	3	2	1
11**	F	2	4	3	1
12**	M	4	2	1	3
13**	F	4	1	3	2
14**	M	1	2	4	3
15**	F	1	3	2	4
16**	M	3	2	1	4
17**	M	4	2	3	1
18**	F	4	1	2	3
19**	F	1	2	3	4
20**	M	1	4	2	3
Younger adults (n = 20)					
21*	F	4	2	3	1
22*	M	3	2	4	1
23*	F	2	1	3	4
24*	M	4	3	2	1
25*	M	1	4	2	3
26*	M	2	3	4	1
27*	F	3	4	1	2
28*	F	2	4	3	1
29*	M	1	4	3	2
30*	F	2	1	4	3
31**	F	3	1	2	4
32**	M	2	4	1	3
33**	F	1	2	3	4

34**	F	3	4	1	2
35**	M	1	3	2	4
36**	F	3	1	4	2
37**	F	1	2	3	4
38**	M	3	4	2	1
39**	M	4	1	3	2
40**	M	4	3	2	1

Note. Subjects alternated between morning and evening test times each day, with half beginning in the morning and half beginning in the evening. The order presented corresponds to:
1 = B, animals
2 = M, countries
3 = C, Canadian towns and cities
4 = P, food
*First session in the evening.

**First session in the morning.

Table 3

Letter Fluency Average Level of Performance

	Older Adults		Younger Adults				
Measure	*M*	*SD*	*M*	*SD*	*F* (1, 39)	*p*	Cohen's *d*
Total Words	22.00	6.67	22.79	6.74	.142	.71	.12
Total Errors	1.64	1.42	.63	.46	9.17	.004*	.96
Mean Cluster Size	.91	.54	.78	.41	.67	.42	.27
Number of Switches	12.40	3.50	13.06	3.14	.40	.53	.20

Note. * Older adults made more errors than younger adults on letter fluency.

Table 4

Category Fluency: Average Level of Performance

	Older Adults		Younger Adults				
Measure	*M*	*SD*	*M*	*SD*	*F*(1,39)	*p*	Cohen's *d*
Total Words	33.79	10.32	33.44	12.62	.01	.92	.03
Total Errors	1.21	1.12	.66	.67	3.54	.07	.60
Mean Cluster Size	1.74	.63	1.70	1.15	.014	.91	.04
Number of Switches	12.20	2.85	12.88	3.04	.524	.47	.23

Note. Older and younger adults performed similarly on category fluency. Older adults tended to make more errors.

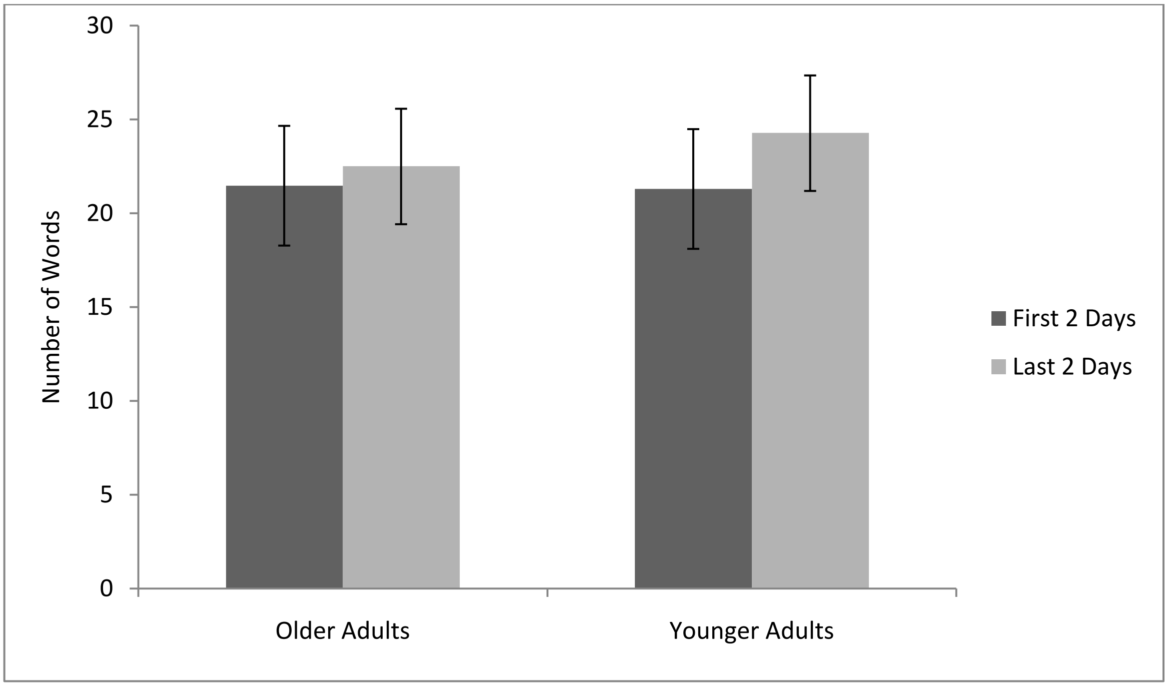

Figure 1. Average total number of words produced on the first two and last two occasions for letter fluency (with error bars representing 95% confidence intervals).

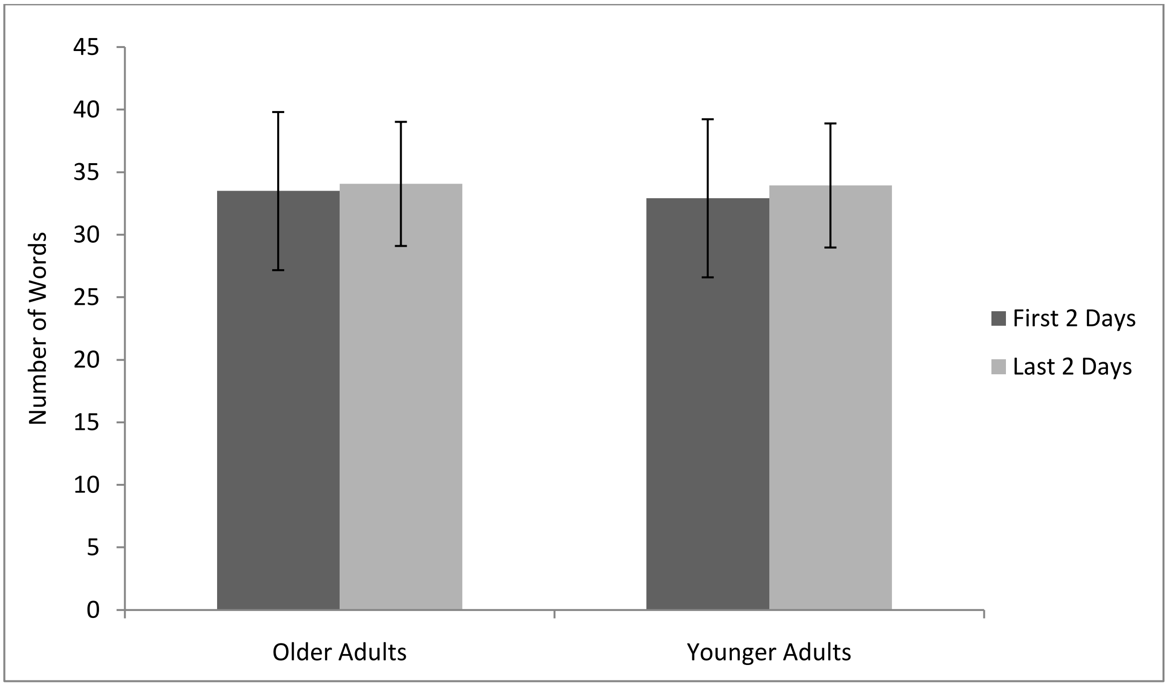

Figure 2. Average total number of words produced on the first two and last two occasions for category fluency (with error bars representing 95% confidence intervals).

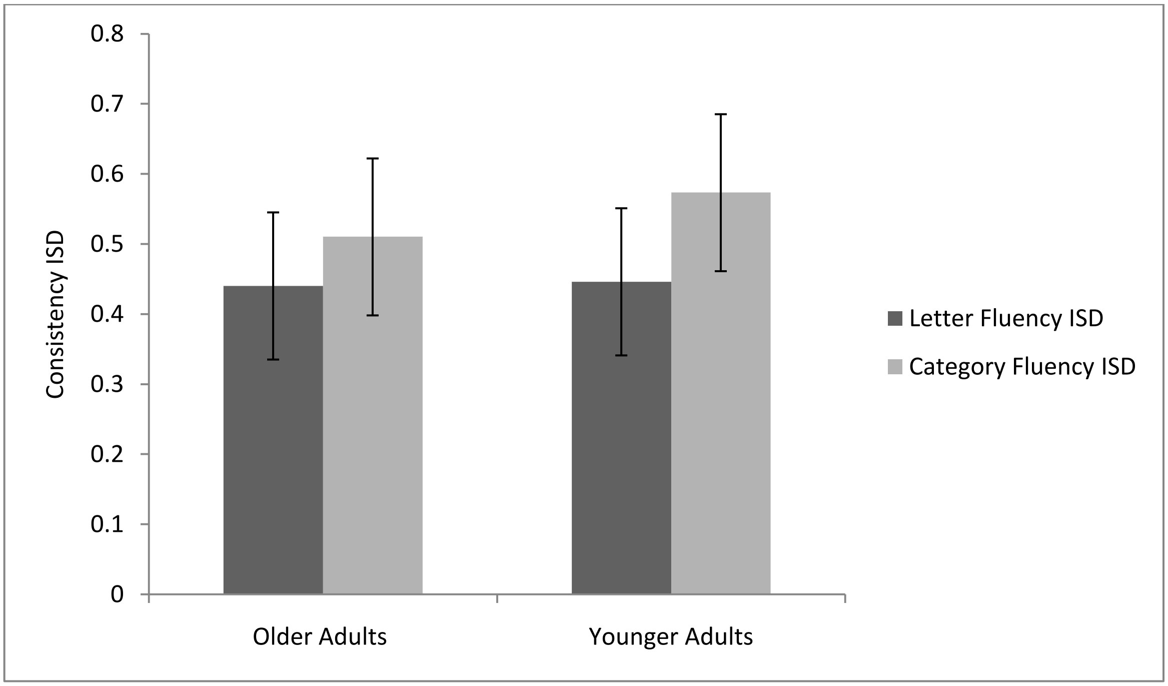

Figure 3. Average consistency ISD of total number of words produced *across* testing occasions for letter and category fluency (with error bars representing 95% confidence intervals).

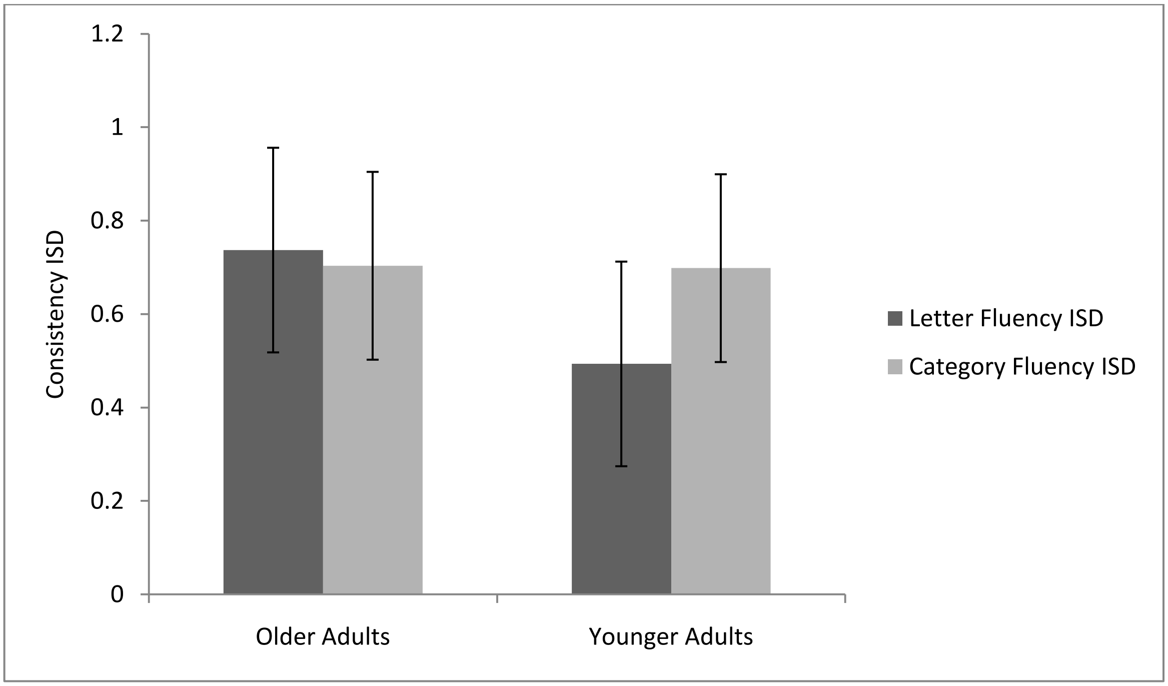

Figure 4. Average consistency ISD of number of errors produced *across* testing occasions for letter and category fluency (with error bars representing 95% confidence intervals).

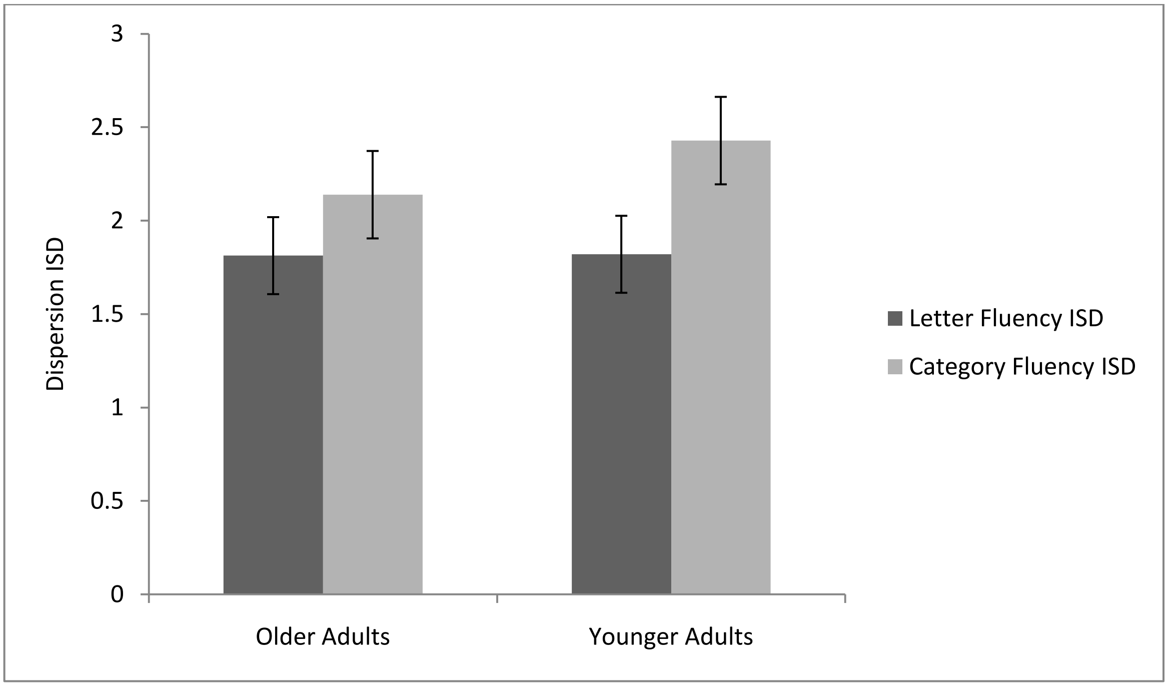

Figure 5. Average dispersion ISD of total number of words produced *within* testing occasions for letter and category fluency (with error bars representing 95% confidence intervals).

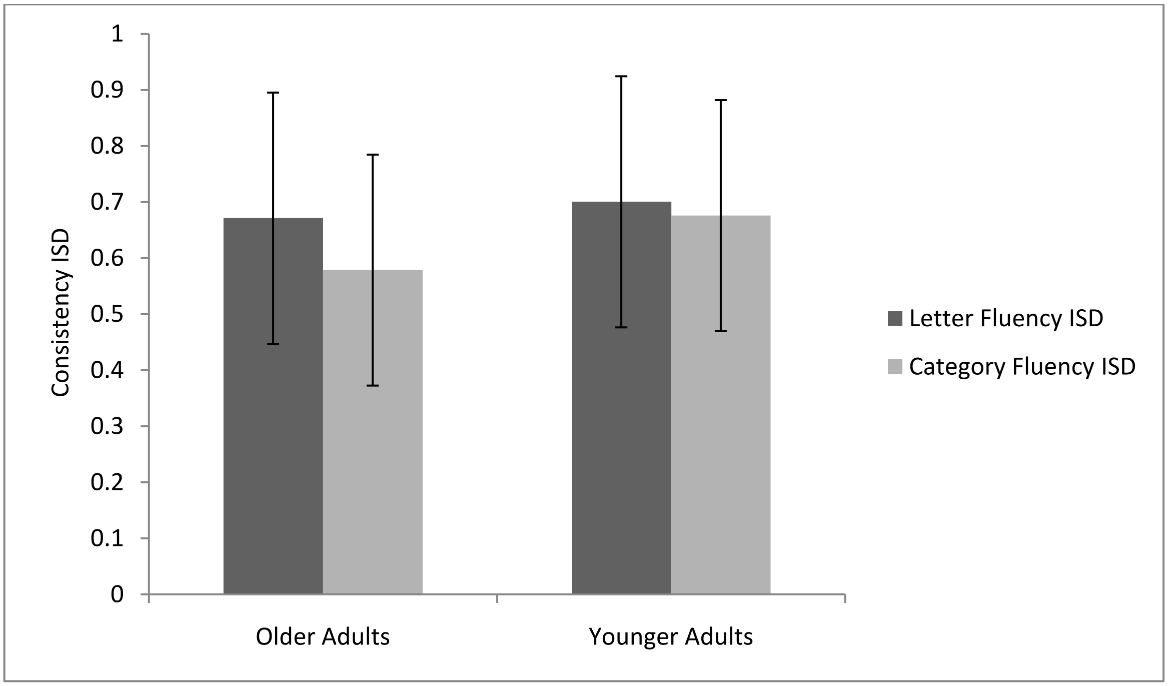

Figure 6. Average consistency ISD of mean cluster size *across* testing occasions for letter and category fluency (with error bars representing 95% confidence intervals).

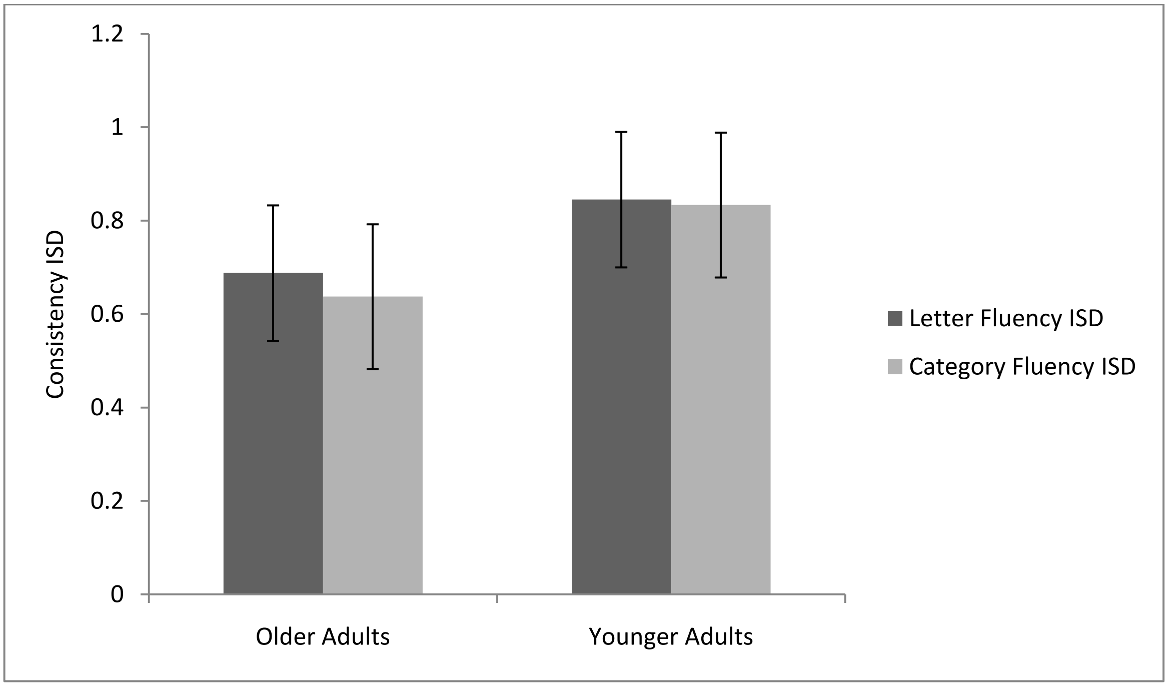

Figure 7. Average consistency ISD of number of switches *across* testing occasions for letter and category fluency (with error bars representing 95% confidence intervals).

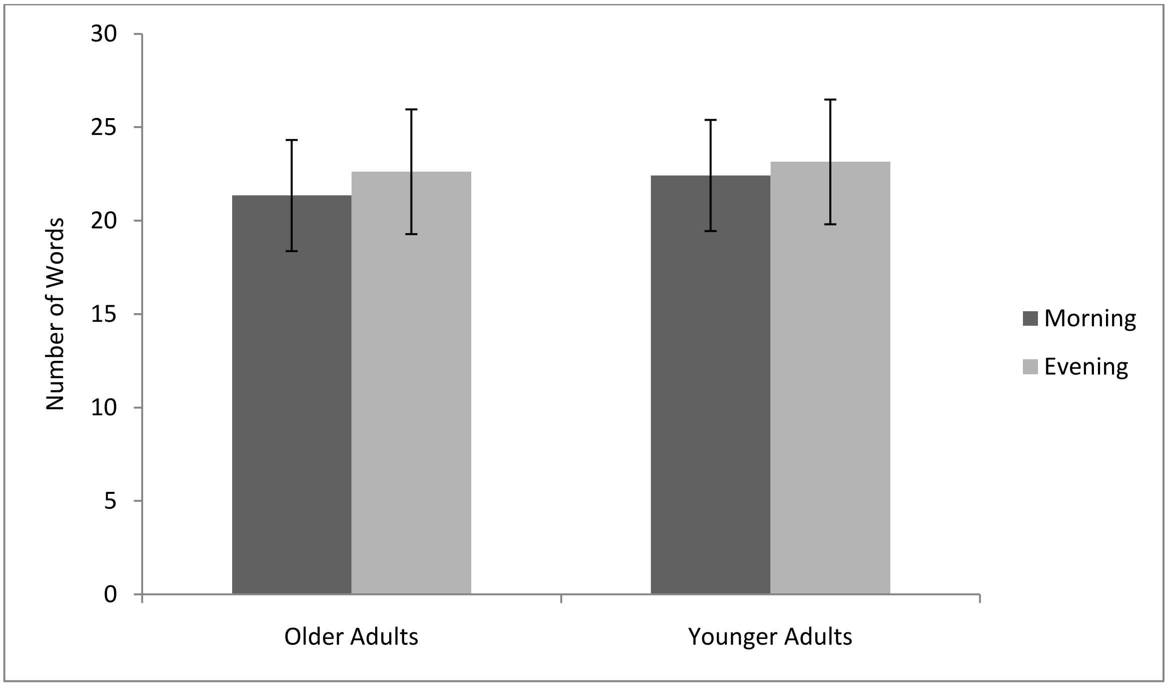

Figure 8. Average total number of words produced in the morning and evening sessions on letter fluency (with error bars representing 95% confidence intervals).

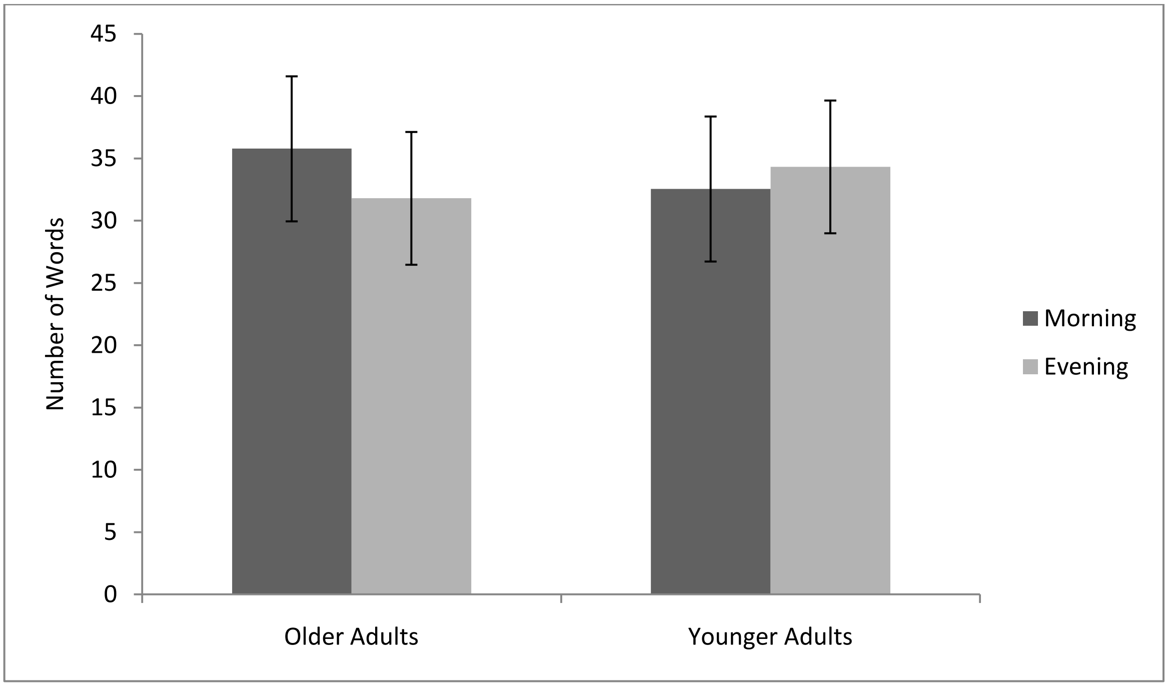

Figure 9. Average total number of words produced in the morning and evening sessions on category fluency (with error bars representing 95% confidence intervals).

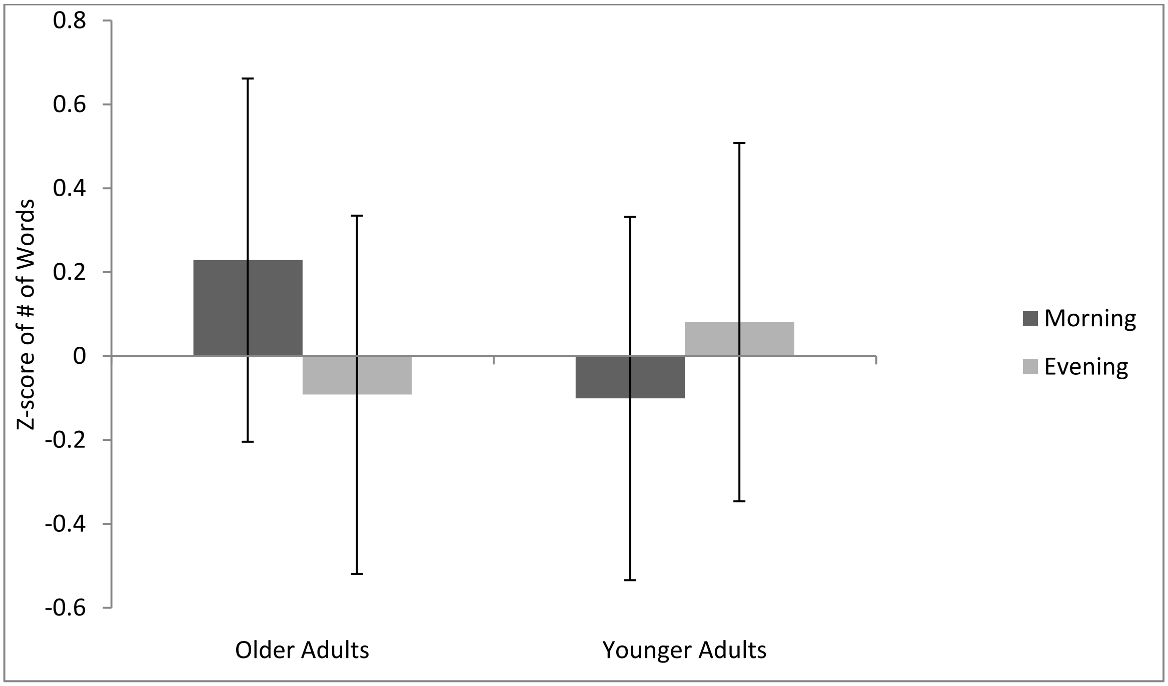

Figure 10. Average of z-scores based on the total number of words produced in the morning and evening sessions on category fluency (with error bars representing 95% confidence intervals).

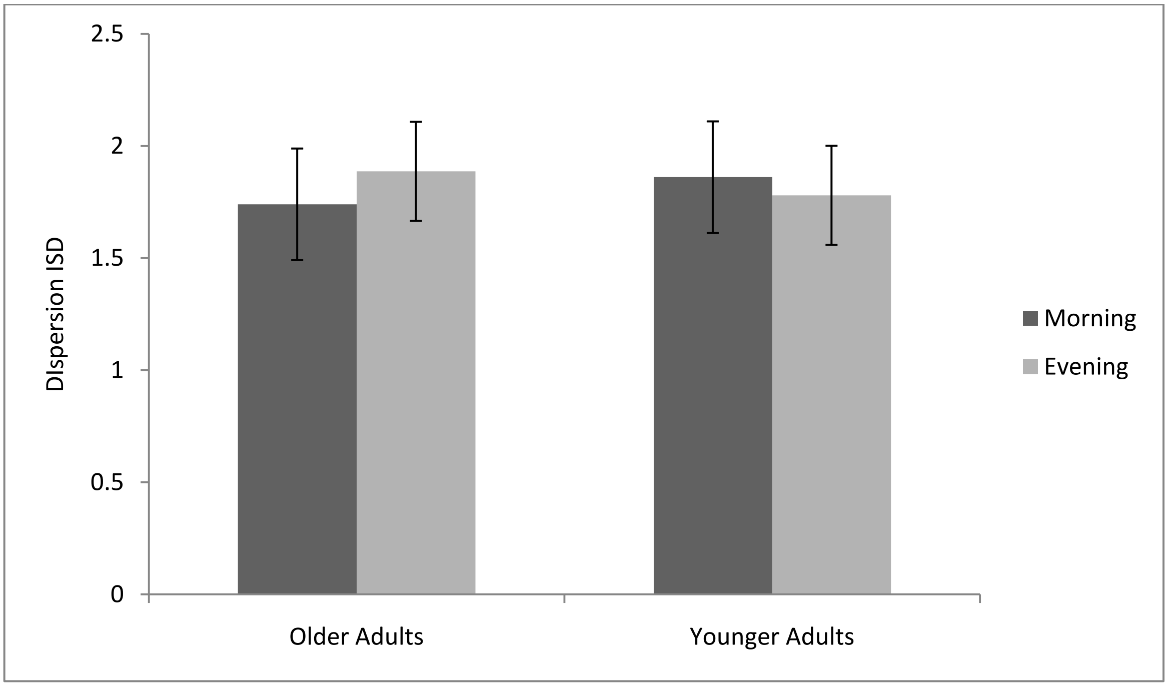

Figure 11. Average dispersion ISD of total number of words produced *within* morning and evening testing occasions for letter fluency (with error bars representing 95% confidence intervals).

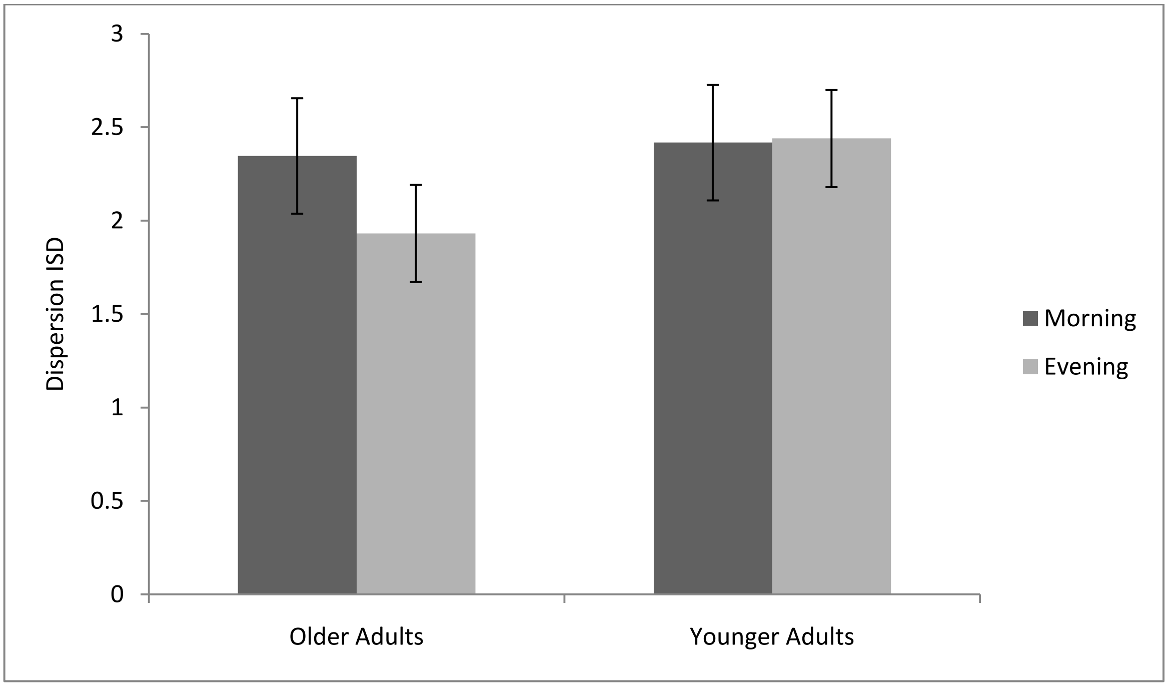

Figure 12. Average dispersion ISD of total number of words produced *within* morning and evening testing occasions for category fluency (with error bars representing 95% confidence intervals).

APPENDICES

Appendix A: Letter Fluency Clustering and Switching Sample Scoring Protocol

0-15''	Cluster		Cluster Size
buy	1	buy, but	1
but	2	botanical, bone, bore, bottom	3
botanical	3	Bloom	0
bone	4	Brother	0
bore	5	Buouy	0
bottom	6	battery, batter	1
16-30''	7	blossom, bloom, blow	2
bloom	8	Button	0
brother	9	Bows	0
31-45''	10	Buckle	0
buouy	11	Belt	0
battery	12	Butter	0
batter	13	Bottle	0
blossom	Mean Cluster Size = 0.076923		
46-60''	# of switches = 12		
bloom*			
blow	Total Words Correct = 20		
button	1 Repetition Error		
bows			
61-75''			
buckle			
belt			
76-90''			
butter			
91-105''			
106-120''			
bottle			

Appendix B: Semantic Fluency Clustering and Switching Sample Scoring Protocol

0-15''
monkey
ape
lion
tiger
gorilla

16-30''
giraffe
elephant

31-45''
mongoose
snake
alligator
zebra

46-60''
hippopotamus

61-75''
cat
dog
pig
horse

76-90''
sheep
kangaroo

91-105''

106-120''
lynx
cheetah

Cluster		Cluster Size
1	monkey to mongoose	7
2	snake, alligator	1
3	zebra, hippopotamus	1
4	cat, dog	1
5	pig, horse, sheep	2
6	kangaroo	0
7	lynx, cheetah	1

Mean Cluster Size = 1.142857
# of switches = 6

Total Words Correct = 20
Total Errors = 0

Appendix C: An Example of Calculating Dispersion and Consistency ISDs

Day 1	Day 2	Day 3	Day 4
more	boy	pearl	car
many	buy	pretty	call
mast	but	polite	come
morning gl	botanical	party	compact
	bottom	pause	collar
	bloom	poem	caller
meant	brother	poet	celery
mother	buouy	prison	cover
mommy	battery	picture	conjurer
moment	batter	poppy	coat
minutes	blossom	poinsettia	cloak
mammal	bloom	propper	cape
monkey	button	prim	chair
margiold fl	bows	prince	carpet
maze	buckle	princess	cushion
myst	belt	poetry	comforter
	butter	pallbearer	case
		probe	
	bottle	prompt	
		purse	
		parka	
		park	

	Day 1	Day 2	Day 3	Day 4		
15"	4	5	5	6		
30"	0	2	3	1		
45"	0	4	3	2		
60"	2	3	3	3		
75"	1	2	2	1		
90"	3	1	2	2		
105"	2	0	2	1		
120"	2	1	2	1		
Total	14	18	22	17	3.304038	Consistency ISD
Dispersion ISDs	1.38873	1.669046	1.035098	1.726888		

Appendix D: Form Effects

Form Effects for Letter Fluency

Measure	Form B	Form M	Form C	Form P
Total Words	21.95 (6.92)	20.40 (6.75)	22.95 (7.46)	22.65 (8.15)
Total Errors	1.43 (2.11)	1.00 (1.24)	.88 (1.34)	.65 (.93)
Mean Cluster Size*	.74 (.63)	.697 (.45)	1.21 (1.00)	.715 (.50)
No. switches**	14.13 (5.52)	12.30 (3.52)	10.83 (4.75)	13.45 (4.83)
Dispersion	1.88 (.57)	1.78 (.65)	1.74 (.65)	1.87 (.68)

Note. Means and standard deviations.
 * Participants produced larger clusters for the letter C than the letter M and P.
** Participants switched less often for the letter C than for letters B and P.

Correlations of Letter Fluency Forms

Measure	Form B	Form M	Form C	Form P
Form B		.72**	.80**	.75**
Form M			.74**	.78**
Form C				.70**

Note. Pearson correlation coefficients
** $p<.001$.

Form Effects for Category Fluency

Measure	Animals	Countries	Canadian Cities and Towns	Food
Total Words*	31.33 (10.69)	38.63 (17.40)	30.55 (15.06)	33.95 (9.60)
Total Errors**	.58 (.81)	1.48 (2.46)	1.03 (1.12)	.675 (1.02)
Cluster Size	1.70 (1.29)	2.00 (1.26)	1.52 (2.09)	1.75 (1.05)
Switching	12.90 (2.83)	12.33 (4.20)	13.10 (4.43)	12.58 (4.40)
Dispersion	2.19 (.75)	2.43 (.79)	2.28 (.79)	2.28 (.76)

Note. Means and standard deviations.
* Participants produced more exemplars of countries than Canadian cities and towns
** Participants made more errors on countries than animals.

Correlations of Category Fluency Forms

Measure	Animals	Countries	Canadian Cities and Towns	Food
Animals		.64**	.63**	.55**
Countries			.775**	.56**
Canadian Cities and Towns				.69**

Note. Pearson correlation coefficients
** p<.001.

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