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The effect of age and sex on clustering and switching during speeded verbal fluency tasks

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Abstract

Past research has been inconsistent with regard to the effects of normal aging and sex on strategy use during verbal fluency performance. In the present study, both Troyer et al.'s (1997) and Abwender et al.'s (2001) scoring methods were used to measure switching and clustering strategies in 60 young and 72 older adults, equated on verbal ability. Young adults produced more words overall and switched more often during both phonemic and semantic fluency tasks, but performed similarly to older adults on measures of clustering. Although there were no sex differences in total words produced on either fluency task, males produced larger clusters on both tasks, and females switched more frequently than males on the semantic but not on the phonemic fluency task. Although clustering strategies appear to be relatively age-insensitive, age-related changes in switching strategies resulted in fewer overall words produced by older adults. This study provides evidence of age and sex differences in strategy use during verbal fluency tests, and illustrates the utility of combining Troyer's and Abwender's scoring procedures with in-depth categorization of clustering to understand interactions between age and sex during semantic fluency tasks. (*JINS*, 2009, *15*, 196–204.)

Keywords: Verbal fluency, Normal aging, Sex differences, Clustering, Switching, Language

INTRODUCTION

Verbal fluency is typically operationalized as the speeded generation of words that begin with a specific letter (phonemic fluency) or belong to a particular category, such as animals or vegetables (semantic fluency). These are commonly used experimental and clinical measures of access to lexical (phonemic) and semantic information, which are differentially sensitive to frontal and temporal lobe dysfunction, respectively (e.g., Crossley et al., 1997; Crowe 1992; Gomez & White, 2006; Henry et al., 2004; Monsch et al., 1994; Troster et al., 1998; Troyer et al., 1998a; 1998b), although this pattern is not always observed (e.g., Henry & Crawford, 2004; Suhr & Jones, 1998). Clinical and neuroimaging data suggest that phonemic and semantic fluency tasks rely on distinct cognitive processes and underlying brain correlates (e.g., Curtis et al., 1998; Mummery et al., 1996; Weiss et al., 2003b).

A consistent pattern of age-related decline on total words produced has been established for semantic fluency (e.g., Crossley et al., 1997; Kozora & Cullum, 1995; Tomer & Levin, 1993; Troyer, 2000; Troyer et al., 1997); however, investigations of age-related effects in performance on phonemic verbal fluency tasks have yielded inconsistent findings. For example, some researchers have shown that total output on phonemic fluency is age-stable (e.g., Bolla et al., 1990; Crossley et al., 1997; Kozora & Cullum, 1995; Tomer & Levin, 1993; Troyer et al., 1997) or that age has a minimal effect size (Troyer, 2000), whereas other studies report significant age-related decline (Bolla et al., 1998; Brickman et al., 2005; Rodriguez-Aranda & Martinussen, 2006).

The literature is inconsistent regarding sex differences in verbal fluency performance. Some studies report a female advantage for total words produced on semantic fluency tasks (Bolla et al., 1998; Weiss et al., 2003a) and on phonemic fluency tasks (Bolla et al., 1990; Capitani et al., 1998; Cohen & Stanczak, 2000; Crossley et al., 1997; Weiss et al., 2003a; 2006), and other studies report no sex differences regardless of task type (Brickman et al., 2005; Brucki & Rocha, 2004; Kempler et al., 1998; Kozora & Cullum, 1995; Tombaugh et al., 1999; Troyer et al., 1997).

Troyer and colleagues (1997) were among the first to examine strategy use during the performance of verbal fluency tasks to elucidate the underlying cognitive processes involved. The authors postulated that efficient fluency performance

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requires both the generation of words within a subcategory (clustering) and the ability to shift to a new category when a subcategory is exhausted (switching). Clustering is proposed to depend on verbal memory and retrieval from verbal storage and is related to temporal lobe functioning (Troyer et al., 1997). Reduced cluster size is seen in individuals with dementia of the Alzheimer's type and in individuals with temporal lobe lesions (e.g., Troyer et al., 1998a; 1998b). Conversely, Troyer et al. (1997) proposed that switching requires the ability to engage in strategic search processes such as cognitive flexibility and mental set shifting and is related to executive or prefrontal lobe functioning. Impaired performance in switching relative to clustering is seen in Parkinson's disease, Huntington's disease, schizophrenia, and in individuals with discrete prefrontal lobe lesions (e.g., Moelter et al., 2001; Rich et al., 1999; Robert et al., 1998; Troster et al., 1998; Troyer et al., 1998a; 1998b). Recently, this two-component model of verbal fluency has received support from functional neuroimaging studies that show different brain regions are involved in switching and clustering processes (e.g., Hirschorn & Thompson-Schill, 2006).

Although clustering and switching has been investigated in clinical populations, few studies have addressed normal aging and sex differences in these component processes. Troyer et al. (1997) found that younger participants switched more frequently on semantic fluency measures, leading to more overall words produced when compared to older adults. In contrast, during phonemic fluency, older participants produced larger clusters than younger adults, with equivalent overall word production.

Initial research on switching and clustering strategies did not find sex differences for either semantic or phonemic verbal fluency tasks (Brucki & Rocha, 2004; Troyer, 2000; Troyer et al. 1997). More recently, in a study with young adults, females were found to switch more frequently between categories on a phonemic fluency test, whereas males showed a trend toward a larger cluster size and produced fewer total words (Weiss et al., 2006). Weiss et al.'s (2006) study was the first to suggest that males and females are using different processing strategies for verbal output on speeded word generation tasks.

Conceptualization of and scoring procedures for clustering and switching as proposed by Troyer and colleagues (1997) have been contested by other researchers (Abwender et al., 2001; Mayr, 2002; Ross et al., 2007). Abwender and colleagues (2001) proposed alternate scoring methods that included hard switches (i.e., shifting between a group of clustered words and a single word, or between two single words) and cluster switches (i.e., shifting between two groups of clustered words). Cluster switching is theorized to require greater mental flexibility and is a more strategic process, whereas hard switching results from the speeded nature of the task, rather than an overt strategy.

In the current study, we sought to clarify the effects of age and sex on total number of words produced and strategy use during semantic and phonemic fluency in healthy young and older adults. Scores were calculated using the criteria for clustering and switching proposed by Troyer and colleagues (1997), and criteria for hard and cluster switching proposed by Abwender and colleagues (2001). In addition, to address perceived scoring limitations associated with including single words as clusters, we recorded the number of novel and repeated clusters (calculated both with single words included and excluded), and the percentage of single and clustered words produced.

For Troyer's scoring methods, based on previous findings we hypothesized that younger adults would generate significantly more words and switch more often than older adults for both phonemic and semantic fluency measures, but that there would be no age differences in cluster size. On the basis of recent literature showing sex differences in strategy use, we hypothesized that females would switch more often than males, and that males would have larger cluster sizes than females for both tasks. Because switching is more highly correlated than cluster size with total words produced on phonemic fluency tasks (Troyer et al., 2007), we hypothesized that females would produce more overall words than males on the phonemic fluency task.

For Abwender et al.'s (2001) hard and cluster switching scoring procedure, we predicted that older age groups would produce fewer hard switches but equivalent cluster switches for phonemic and semantic fluency, because Abwender and colleagues (2001) reported that hard switches correlated more strongly with overall words produced. In terms of sex differences, females were hypothesized to produce more hard switches and cluster switches than males because of their predicted greater reliance on a switching strategy.

Using the new variables to address limitations in the conceptualization of clustering as a strategy, we proposed that older adults would produce fewer novel clusters but equivalent repeated clusters (both with single words included and excluded). These age effects were predicted based on the theory of executive functioning decline with aging, with relatively preserved semantic memory stores (Daigneault et al., 1992; Henry & Phillips, 2006; Moscovitch & Winocur, 1992; Raz et al., 1998). Additionally, older adults were predicted to have a lower percentage of single words, reflecting their reduced switching ability. We hypothesized that males would produce more novel clusters and repeated clusters (with single words included or excluded) than females. We hypothesized that females would produce a higher percentage of single words as compared to males because of their proposed greater reliance on a switching strategy, whereas males were predicted to produce a higher percentage of clustered words because of a greater reliance on a clustering strategy.

METHODS

Participants

Participants were recruited for a larger neuropsychological investigation of normal aging and were screened; participants were excluded from the study if neuropsychological test performance was below the age-appropriate range or if health status included conditions that could significantly impact higher cognitive functions. The data included in this article were obtained in compliance with the regulations of the authors' institution. Participants included 60 younger adults between the ages of 18–40 years (29 males; 31 females). The average age of participants in this group was 28.8 years (*SD* = 6.2) and the average years of education were 16.1 years (*SD* = 2.7). The young group had an average Peabody Picture Vocabulary Test-Revised (PPVT-R; Dunn & Dunn, 1981) raw score of 161.9 (*SD* = 9.6), which corresponds to the 61st percentile. This group was compared to 72 older adults between the ages of 65–91 (29 males; 43 females). The older adult group had an average age of 74.7 years (*SD* = 5.8) and an average of 13.2 years of education (*SD* = 3.7). For the older group the average PPVT-R raw score was 163.1 (*SD* = 11.0), which corresponds to the 66th percentile. There were no significant main effects or interactions for age group or sex on the PPVT-R ($p > .05$ for all analyses).

Materials

As part of a comprehensive neuropsychological research battery, participants completed the Controlled Oral Word Association Test (COWAT; Benton & Hamsher, 1976) as a measure of phonemic fluency, and the Animal Naming test (AN; Spreen & Strauss, 1991) as a measure of semantic fluency.

Procedure and Scoring

The COWAT consists of three one-minute trials. During each trial the participants were required to produce as many words as possible beginning with either the letter "C," "F," or "L." For the AN test, participants were given one minute to produce as many different animal names as possible.

Eleven scores were obtained for each verbal fluency measure: total words produced, average cluster size, number of switches, number of hard switches, number of cluster switches, number of novel clusters, number of repeated clusters (calculated both with single words included and excluded), percentage of single words, and percentage of clustered words. A score of total words was calculated as all words produced on a trial, minus errors and perseverations. The three phonemic trials were added together to calculate total words produced on the phonemic task. Detailed scoring procedures for the calculation of average cluster size and number of switches have been previously documented (Troyer et al., 1997; 2000) and will not be described here. For each phonemic trial and for the semantic trial a score of average cluster size was calculated for each participant. On the phonemic task, the cluster size scores were averaged across the three trials. Consistent with the procedure of Troyer and colleagues (1997), errors and perseverations were included when calculating mean cluster size scores. The total number of switches for the phonemic and the semantic tests was calculated for each participant by adding the number of switches between clusters, including single words. The three phonemic trials were combined to form a total score for number of switches on the phonemic task.

In addition, numbers of hard switches and cluster switches as defined by Abwender and colleagues (2001) were obtained. Hard switches occur between two single words or between a cluster of two or more words and a single word. Cluster switches occur between two groups of clustered words (with two or more words per cluster).

Both the phonemic and semantic fluency tasks were scored for the number of novel clusters and the number of repeated clusters per trial. For the calculation of novel and repeated clusters, clusters were defined by the criteria of Troyer and colleagues (1997). For example, if an individual begins with a cluster of African animals on semantic fluency, then switches to a cluster of farm animals, then back to African animals this would be scored as two novel clusters (African and farm) and one repeated cluster (African). For the phonemic trials, clusters were defined using the criteria of having the same first two letters (Troyer et al., 1997). For the semantic trial, in situations where a cluster could be categorized into two clustering strategies, the superordinate category of living environments described by Troyer and colleagues (1997) was used. Novel and repeated clusters were calculated, both by including single words as clusters, as conceptualized by Troyer and colleagues (1997), and by excluding single words from the calculation. Finally, the percentage of single and clustered words per trial was calculated.

RESULTS

For semantic and phonemic fluency tasks, separate 2 (Age Group) x 2 (Sex) analyses of variance (ANOVAs) were performed on the variables included in Troyer et al.'s scoring procedure (i.e., total words produced, mean cluster size, and number of switches.), Abwender et al.'s (2001) scoring procedures (i.e., number of hard and cluster switches), and the additional proposed variables for examining clustering. The Troyer et al. and Abwender et al. variables for phonemic and semantic fluency are presented by age group and by sex in Table 1. The additional fluency scores are presented by age group and by sex in Table 2. Effect sizes based on correlation ratios (partial eta-squared) were calculated for each analysis.

Age-related Effects

Phonemic fluency scoring method (Troyer et al., 1997)

As shown in Table 1, there was a significant main effect of age category on phonemic fluency total words, $F(1, 128) = 8.308$, $p = .005$, η^2 ($p = .061$). Younger adults produced more words, overall, than older adults. There was also a significant main effect of age category on number of switches, $F(1, 128) = 4.426$, $p = .037$, η^2 ($p = .033$) The younger age group produced more switches than the older age group. There was no significant

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Table 1. Vocabulary and Troyer et al. (1997) and Abwender et al. (2001) fluency ccores.

	Young			Old			Total	
	Female	Male	Total	Female	Male	Total	Female	Male
	M (SD)	*M (SD)*	*M (SD)*	*M (SD)*	*M (SD)*	*M (SD)*	*M (SD)*	*M (SD)*
Peabody Picture Vocabulary Test	161.0 (10.8)	162.9 (8.2)	161.9 (9.6)	162.4 (10.7)	164.1 (11.6)	163.1 (11.0)	161.8 (10.6)	163.5 (10.0)
Phonemic Fluency								
Total Words Produced	45.3 (10.1)	45.3 (11.8)	45.2 (10.8)	41.5 (11.4)	37.7 (10.3)	40.0 (11.1)**	43.0 (10.9)	41.5 (11.6)
Number of Switches	31.3 (8.8)	30.0 (9.2)	30.5 (8.9)	29.1 (9.4)	25.3 (8.1)	27.6 (9.0)*	29.9 (9.1)	27.6 (8.9)
Average Cluster Size	0.45 (0.18)	0.65 (0.51)	0.55 (0.38)	0.47 (0.32)	0.55 (0.39)	0.50 (0.35)	0.46 (0.27)	0.60 (0.45)*
Number of Hard Switches	27.9 (8.1)	25.7 (9.1)	26.9 (8.6)	26.1 (9.3)	22.6 (8.0)	24.7 (8.89)	28.9 (8.8)	24.1 (8.6)
Number of Cluster Switches	2.6 (2.2)	3.3 (3.3)	3.0 (2.8)	2.6 (2.5)	2.5 (2.5)	2.6 (2.5)	2.6 (2.4)	2.9 (2.9)
Semantic Fluency								
Total Words Produced	26.8 (6.4)	25.5 (4.3)	26.2 (5.5)	19.4 (4.5)	19.9 (5.8)	19.6 (5.0)***	22.5 (6.5)	22.7 (5.8)
Number of Switches	12.2 (2.8)	11.1 (3.6)	11.6 (3.2)	8.6 (3.4)	7.0 (2.7)	8.0 (3.3)***	10.1 (3.6)	9.1 (3.8)*
Average Cluster Size	1.19 (0.51)	1.45 (1.00)	1.31 (0.79)	1.30 (0.69)	1.93 (1.12)	1.55 (0.93)*	1.26 (0.62)	1.69 (1.09)*
Number of Hard Switches	7.2 (3.4)	7.6 (4.5)	7.4 (3.9)	5.9 (3.9)	3.9 (3.0)	5.1 (3.7)***	6.5 (3.7)	5.8 (4.2)
Number of Cluster Switches	4.5 (2.2)	3.4 (1.9)	4.0 (2.1)	2.7 (1.5)	3.3 (2.0)	2.9 (1.8)**	3.5 (1.8)	3.3 (1.9)*

Note. $^{*}p < .05$, $^{**}p < .01$, $^{***}p < .001$.

main effect of age category on phonemic fluency average cluster size, $F(1, 128) = 0.462$, $p = .498$.

Phonemic fluency scoring method (Abwender et al., 2001)

As shown in Table 1, there were no significant differences between younger and older adults on number of hard, $F(1,127) = 2.497$, $p = .117$, or cluster switches, $F(1,127) = .741$, $p = .391$.

Phonemic fluency additional scoring variables

As shown in Table 2, there were no significant differences between younger and older adults on number of novel, $F(1, 127) = 3.056$, $p = .083$, or repeated clusters, $F(1, 127) = 2.394$, $p = .124$. Similarly, there were no main effects of age for either multiple word novel clusters, $F(1, 127) = 3.067$, $p = .082$, or multiple word repeated clusters, $F(1, 127) = .000$, $p = .999$. For percentage of single words, there was no main effect of age, $F(1, 127) = 1.873$, $p = .174$. Similarly, there was no main effect of age for percentage of clustered words, $F(1, 127) = .000$, $p = .986$.

Semantic fluency scoring method (Troyer et al., 1997)

For total words produced, there was a significant main effect of age category, $F(1, 128) = 49.799$, $p < .001$, η^2 (p = .280). As shown through Table 1, the younger age group produced more words than the older age group. There was a significant main effect of age category on semantic fluency number of switches, $F(1, 128) = 45.265$, $p < .001$, η^2 ($p = .261$). The younger age group produced more switches than the older age group. In terms of cluster size, older adults had a significantly higher average cluster size than younger adults, $F(1, 128) = 3.919$, $p = .004$, η^2 ($p = .064$).

Semantic fluency scoring method (Abwender et al., 2001)

As shown in Table 1, there was a main effect of age for number of hard switches, with younger adults producing more hard switches than older adults, $F(1, 128) = 14.365$, $p <.001$, η^2 ($p = .101$). This main effect was qualified by an Age Group x Sex interaction that approached significance, $F(1, 128) = 3.362$, $p = .069$, and indicated that the age effect was related to an age-related decline for males on this variable ($M = 7.62$, $SD = 4.46$ for young males and $M = 3.90$, $SD = 3.02$ for older males), compared to age-stable performance in females ($M = 7.23$, $SD = 3.42$ for younger females and $M = 5.93$, $SD = 3.91$ for older females). In contrast, the observed main effect of age for clustered switches, $F(1, 128) = 7.804$, $p = .006$, η^2 ($p = .057$), was qualified by a significant Age Group x Sex interaction, $F(1, 128) = 6.169$, $p = .014$, η^2 ($p = .046$), that revealed that the age effect was almost entirely a result of the age-related

Table 2. Additional fluency scores

	Young			Old			Total	
	Female	Male	Total	Female	Male	Total	Female	Male
	M (SD)	*M (SD)*	*M (SD)*	*M (SD)*	*M (SD)*	*M (SD)*	*M (SD)*	*M (SD)*
Phonemic Fluency								
Number of Novel Clusters (NC)	14.9 (2.2)	14.3 (2.3)	14.6 (2.3)	14.3 (2.3)	13.4 (2.4)	13.9 (2.4)	14.5 (2.3)	13.9 (2.4)
Number of Repeated Clusters (RC)	19.3 (7.8)	17.9 (7.3)	18.6 (7.6)	18.1 (8.5)	15.0 (6.6)	16.8 (7.9)	18.6 (8.2)	16.5 (7.1)
Number of Multiple Word NC	6.7 (2.0)	7.1 (2.3)	6.9 (2.2)	6.3 (2.7)	6.0 (1.9)	6.2 (2.4)	6.5 (2.4)	6.5 (2.2)
Number of Multiple Word RC	2.2 (1.7)	2.3 (1.6)	2.3 (1.7)	2.2 (1.9)	2.3 (2.1)	2.3 (1.9)	2.3 (1.8)	2.3 (1.9)
Percentage of Single Words	53.2 (11.2)	48.5 (14.5)	50.9 (13.0)	55.6 (16.2)	53.3 (16.2)	54.7 (16.1)	54.6 (14.3)	50.9 (15.4)
Percentage of Clustered Words	49.9 (11.8)	57.8 (14.3)	53.8 (13.6)	52.3 (15.9)	55.6 (16.0)	53.6 (15.9)	51.3 (14.4)	56.7 (15.1)*
Semantic Fluency								
Number of Novel Clusters (NC)	8.3 (1.7)	7.5 (2.2)	7.9 (2.0)	6.6 (1.8)	6.0 (1.9)	6.4 (1.9)***	7.3 (2.0)	6.7 (2.2)*
Number of Repeated Clusters (RC)	4.4 (1.8)	4.3 (2.6)	4.3 (2.2)	2.9 (2.0)	2.1 (1.7)	2.6 (1.9)***	3.5 (2.1)	3.2 (2.4)
Number of Multiple Word NC	6.0 (1.6)	5.4 (1.5)	5.7 (1.6)	4.6 (1.2)	4.8 (1.7)	4.7 (1.4)***	5.2 (1.6)	5.1 (1.6)
Number of Multiple Word RC	1.5 (1.0)	1.1 (1.0)	1.3 (1.0)	0.8 (0.8)	0.8 (0.8)	0.8 (0.8)**	1.1 (1.0)	0.9 (0.9)
Percentage of Single Words	24.1 (20.2)	22.5 (17.5)	23.3 (18.8)	23.9 (20.2)	13.3 (10.2)	19.6 (17.6)	24.0 (20.1)	17.9 (14.9)
Percentage of Clustered Words	78.9 (20.8)	81.8 (20.0)	80.3 (20.3)	80.7 (19.5)	93.9 (12.2)	86.0 (18.0)*	80.0 (19.9)	87.8 (17.5)*

Note. $*p < .05$, $**p < .01$, $***p < .001$.

decline for females ($M = 4.48$, $SD = 2.20$ for young females *vs.* $M = 2.72$, $SD = 1.55$ for older females) but not for males ($M = 3.38$, $SD = 1.90$ for young males *vs.* $M = 3.28$, $SD = 2.02$ for older males).

Semantic fluency additional scoring variables

As shown in Table 2, there were significant age differences in favor of young adults on number of novel clusters, $F(1, 128) = 23.061$, $p < .001$, η^2 ($p = .153$), repeated clusters, $F(1, 128) = 25.579$, $p < .001$, η^2 ($p = .167$), multiple-word novel clusters, $F(1, 128) = 14.165$, $p < .001$, and multiple-word repeated clusters, $F(1, 128) = 9.586$, $p = .002$. The percentage of clustered words was higher for older than for younger adults, $F(1, 128) = 4.510$, $p = .035$, η^2 ($p = .034$). For percentage of single words, there was no main effect of age, $F(1, 128) = 2.234$, $p = .137$.

Sex Differences

Phonemic fluency scoring method (Troyer et al., 1997)

As shown in Table 1, for phonemic fluency total words produced, there was no significant main effect of sex, $F(1, 128) = 0.898$, $p = .345$. There was also no significant difference between males and females on number of switches, $F(1, 128) = 2.402$, $p = .124$. There was a significant main effect of sex for phonemic average cluster size, $F(1, 126) = 4.845$, $p = .030$, η^2 ($p = .036$), with males producing larger average cluster sizes than females on this task.

Phonemic fluency scoring method (Abwender et al., 2001).

There was a trend toward a significant main effect for sex on number of hard switches, $F(1, 127) = 3.59$, $p = .060$, η^2 ($p = .027$), with females tending to produce a higher number of hard switches than males. There was no sex difference on number of cluster switches, $F(1, 127) = .288$, $p = .593$.

Phonemic fluency additional scoring variables

As shown in Table 2, there were no significant differences between males and females for number of novel clusters, $F(1, 127) = 3.287$, $p = .072$, number of repeated clusters, $F(1, 127) = 2.718$, $p = .102$, multiple word novel clusters, $F(1, 127) = .015$, $p = .903$, multiple word repeated clusters, $F(1, 127) = .017$, $p = .895$, or percentage of single words, $F(1, 127) = .1.817$, $p = .180$. For percentage of clustered words, there was a main effect of sex, $F(1, 127) = 4.65$, $p = .033$, η^2 ($p = .035$), indicating that males produced a higher percentage of clustered words.

Semantic fluency scoring method (Troyer et al., 1997)

As shown by Table 1, there was no difference between males and females in total words produced, $F(1, 128) = 0.224$, $p = .637$. For number of switches, there was a significant main effect of sex, $F(1, 128) = 5.407$, $p = .022$, η^2 ($p = .043$), with females producing more switches than males. There was also a significant main effect of sex for average cluster size, $F(1, 128) = 8.471$, $p = .004$, η^2 ($p = .062$), with males producing larger average clusters than females.

Semantic fluency scoring method (Abwender et al., 2001).

Although there were no main effects of sex for number of hard switches, $F(1, 128) = 1.531$, $p = .218$, or for cluster switches, $F(1, 128) = .677$, $p = .412$, as reported above, there were Age Group x Sex interactions for these variables.

Semantic fluency additional scoring variables

As shown in Table 2, there were significant sex differences in favor of females on number of novel clusters, $F(1, 128) = 4.600$, $p = .034$, η^2 ($p = .035$), and for percentage of single words produced, $F(1, 128) = 3.758$, $p = .055$, η^2 ($p = .029$). There was a significant main effect of sex in favor of males for percentage of clustered words, $F(1, 128) = 5.995$, $p = .016$, η^2 ($p = .045$). There were no main effects of sex for number of repeated clusters, $F(1, 128) = 1.514$, $p = .221$, for multiple word novel clusters, $F(1, 128) = .444$, $p = .506$, or for multiple word repeated clusters, $F(1, 128) = 1.902$, $p = .170$, and no significant interactions with age on any of these variables.

DISCUSSION

As predicted, younger adults produced more overall words and switched more often on both phonemic and semantic fluency tasks. The largest effect size was produced for semantic fluency total words and number of switches, supporting previous research indicating that the effect of normal aging is particularly significant on the semantic fluency task. Switching, as a processing strategy, appears to be particularly vulnerable to the effects of normal aging during fluency performance, and results in fewer overall words produced by older adults. Contrary to our hypotheses, the older adults in our study had larger average cluster sizes than younger adults on the semantic fluency tasks. This is consistent with previous findings of larger cluster sizes in older adults, although found on the phonemic fluency task (Troyer, 2000; Troyer et al., 1997). Troyer and colleagues (1997) postulated that larger clusters reflect increases in vocabulary size over the lifespan. Our finding of larger semantic fluency cluster sizes and a higher percentage of clustered words in older adults might be related to an age-related increase in semantic knowledge; however, younger adults produced more novel and repeated clusters. Examining clustering strategies using the additional scoring methods provides a clearer understanding of age-related changes in clustering processes.

The differential effect of aging on switching ability when compared to clustering, for both semantic and phonemic fluency tasks, and the large effect size for age in switching during semantic fluency is consistent with the hypothesis of executive function decline in aging. Contrary to previous research showing age-stability on phonemic fluency performance, the current study demonstrated a significant age-related difference in total words generated, although the effect size was smaller than for semantic fluency.

Abwender et al.'s (2001) scoring criteria for hard switches and cluster switches revealed informative and contrasting interactions between age and sex effects during the semantic fluency tasks. These interactions shed some additional light on the source of sex differences during verbal fluency tasks, and indicate that males appear to be particularly vulnerable to normal aging effects during hard switching, and females are relatively vulnerable to age-related declines on cluster switching. In addition, hard switches appear to be related to overall proficiency on semantic fluency tasks.

For the additional variables, which described the number of unique *versus* repeated clusters, there were no age differences on any of the variables for phonemic fluency. For semantic fluency, younger adults produced more overall and multiple-word novel clusters and returned to previous clusters more often than older adults, suggesting that returning to clusters is a beneficial strategy.

Regarding sex differences, it was hypothesized that females would produce more switches, and males would produce larger cluster sizes on both fluency tasks. Based on past research, we also expected a female advantage for total words on phonemic fluency. However, there was no main effect of sex for total words produced on either fluency task. The expected effect of sex was produced for phonemic and semantic cluster size; males produced significantly larger clusters for both fluency tasks. The results only partially supported the hypotheses regarding sex differences on switching tasks. On the semantic fluency tasks, females switched more frequently than males; however, there was no significant difference in switching performance between males and females on phonemic fluency. Although the female advantage for switching during verbal fluency tests was not found for phonemic fluency in the current study, these results provide preliminary support for differences in strategy use between males and females on verbal fluency tests. Males rely more heavily on a clustering strategy whereas females rely more on a switching strategy, at least on semantic fluency tasks. Given that there was no sex difference in overall words produced during either task, it appears that males and females

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use these strategies differentially in order to optimize their performance on verbal fluency tasks. The effect sizes of the sex differences found were relatively small, which may account for previous findings of no differences between males and females on either total words produced or use of switching and clustering.

Although there were no significant sex differences for hard switching and cluster switching on the phonemic fluency task, interactions between sex and age on semantic fluency were evident. As expected, and consistent with the overall sex difference on average cluster size, males and females differed significantly on the percentage of clustered words for both the phonemic and semantic fluency tasks. For semantic fluency, females generated more new clusters overall, but there were no differences for multiple-word novel or repeated clusters. Compared to males, females had a higher percentage of single words and a lower percentage of clustered words. This appears to be a reflection of females' relative reliance on switching as an optimal verbal fluency strategy.

In summary, Abwender et al.'s (2001) qualitative scoring procedure for hard switches and cluster switches appears particularly useful for understanding age and sex differences in switching on semantic fluency. Similarly, the additional variables employed to further understand sex and age differences in clustering as a cognitive process were most informative for the semantic fluency task. The number of new clusters generated overall appears to be related to switching ability, as both females and younger adults produced more novel clusters. The finding that younger adults returned to previous clusters more often than older adults suggests that this is an effective strategy that is associated with higher overall word production.

The current study extends Weiss et al.'s (2006) finding of sex differences in strategy use for younger participants to an older participant group; however, in contrast to Weiss et al. (2006), sex differences were evident for both clustering and switching on the semantic fluency task, but were found for only clustering on the phonemic task. Additionally, in the Weiss et al. study, males, who produced larger clusters, generated fewer words, leading the authors to conclude that females employed a more successful strategy of balancing clustering and switching on phonemic fluency. The current study does not show sex differences in overall words produced and it does not appear that sex differences in strategy use are contributing to differing levels of overall performance. Rather, while males and females differ in the strategy typically favored, both strategies appear successful in generating total words for both tasks. The underlying mechanism for sex differences remains unclear. Females may possess a more efficient organizational processing ability, leading to a higher number of switches, or rapid switching might be a successful compensatory strategy for smaller cluster size.

The current study provides support for the two-component model of verbal fluency production. The older compared to the younger age group had lower total word output and lower overall switching rates. According to the model of Troyer and colleagues (1997), switching is a prefrontal executive function, and executive functions are believed to show age-related decline (Henry & Phillips, 2006). A lower switching rate with intact cluster sizes in older age groups is consistent with the two-component model of verbal fluency production. As well, the current study showed that males and females tend to rely on different strategies when producing output on verbal fluency tasks, with males relying more on a clustering strategy and females relying more on a switching strategy.

This study is the first to examine age and sex differences using Abwender et al.'s (2001) scoring procedure for examining qualitative differences in switching. This study also addressed limitations in Troyer et al.'s (1997) scoring of clusters by examining number of unique and repeated clusters and percentage of single words *versus* clustered words. These additional scoring measures were employed to further analyze the process of clustering during verbal fluency tasks. Hard and cluster switching scores contribute to our understanding of the cognitive processes that underlie semantic fluency changes with age and between males and females.

Although the current study is consistent with previous research on verbal fluency and with the theoretical two-component model of clustering and switching, there are limitations to this study, which will be addressed in future research. One limitation is that the full age spectrum was not included (i.e., middle-aged adults are not represented). Participants included individuals in young (20–40) and older (66–90) age categories, which is consistent with previous aging research on verbal fluency and clustering and switching strategies (Troyer, 2000; Troyer et al., 1997). Future work will extend the use of these informative measures of verbal fluency performance to clinical groups and will further elucidate the strategies and underlying mechanisms associated with both normal aging and common age-associated conditions (e.g., mild cognitive impairment, dementias).

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