ORIGINAL RESEARCH

Age and Verbal Fluency: The Mediating Effect of Speed of Processing

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ABSTRACT

Background and Purpose

Cognitive decline is a function of normal aging; however, the effect of age on various domains is differential. This study examined the effect of age on verbal fluency and showed how speed of processing modifies fluency performance in healthy older adults compared to younger individuals.

Methods

Three age groups, 62 young (17–40 years), 30 middle-aged (41–59 years), and 38 older adults (60–78 years), were studied using the Controlled Oral Word Association Test, National Adult Reading Test, and speed-of-processing composite score. The study examined the effect of age on fluency before and after controlling for processing speed and intelligence quotient.

Results

The young group performed better than the older group on category fluency as measured by animal category ($p < .001$) and on processing speed composite score ($p < .001$). However, the older group performed better than the young group on the National Adult Reading Test ($p < .05$) and on letter fluency after controlling for the decline in processing speed ($p < .05$). Processing speed had a significant effect on both category and letter fluency ($p < .01$) in older adults.

Conclusions

This study suggests that aging adversely affects some but not all cognitive domains and that age-related decline in processing speed contributes to age-related changes in fluency.

Key words: aging, cognitive function, premorbid IQ, verbal fluency, speed of processing, verbal knowledge

INTRODUCTION

Discriminating Alzheimer's dementia from normal age-related cognitive decline in the early stages of the disease remains a challenging process, but familiarity with the normal age-related cognitive changes may guide decisions regarding when further evaluation is required of an older person with cognitive complaints. Nonetheless, general patterns of age-related cognitive changes have emerged in the literature: younger adults perform better than older adults on verbal memory and speed-of-processing measures. However, studies examining verbal fluency showed variable results. Clark and colleagues[(1)] suggested that decline in letter and category verbal fluency occurs but, generally, performance on letter fluency is higher than on category fluency. Some studies reported that category fluency, but not letter fluency, declines with aging.[(2,3)] Others confirmed that the effect of age is small and is equivalent for both letter and categorical fluency performance.[(4)] However, an earlier study reported that age did not contribute to fluency performance.[(5)] A recent meta-analysis showed that patients with Alzheimer's disease are relatively more impaired on category fluency than on letter fluency and that category fluency decline is expressed at an earlier age.[(6)]

Turning to speed of processing, studies generally agreed that processing speed declines with age[(7,8)] and that it is associated with progressive age-related structural brain changes,[(9)] which makes it an inevitable consequence of the aging process. Studies supporting the speed-of-processing hypothesis suggest that processing speed is the core component that mediates the relation between aging and decline in other cognitive domains such as fluid intelligence,[(10,11)] letter and exclude-letter fluency,[(12)] verbal memory,[(11,13)] and working memory.[(14)] However, others[(8)] reported that the influence of processing speed on age-related decline could not be generalized. Whether the change in processing speed accounts for the range of cognitive decline attributable to age remains contentious.

In this study, we hypothesized that processing speed contributes significantly to the relation between aging and verbal fluency. The study had three aims: to examine the effect of age on the letter and category fluency, verbal knowledge, and speed of processing in a group of highly educated individuals; to explore how speed of processing affects performance on the letter and category fluency differentially; and to show the pattern of age-related performance on verbal fluency, speed of processing, and verbal knowledge across a wide age range.

METHODS

Participants

We recruited 130 healthy adults from a community in Southern Ontario by local advertisement (age 17–78 years). Participants were divided into three groups: a young group aged 40 years and under, a middle group aged over 40 and under 60 years, and an older group aged 60 years and over. Participants were excluded if their mother tongue was not English or if they had less than 10 years of education, a neurological disorder, a history of mental illness, a cognitive concern or head injury, an uncontrolled medical condition, or drug or alcohol dependence as determined by interviewing the participant. Approval of the local research ethics board was obtained and all participants signed an informed consent prior to participation. The study was conducted in accordance with the Tri-Council Policy Statement and the Good Clinical Practice guidelines.

Measures

Demographic variables assessed were age, sex, and education. Neuropsychological measures included the following. The National Adult Reading Test[15] (NART) is a valid estimate of the premorbid full-scale intelligence quotient[16] (IQ) and is a measure of prior verbal knowledge; it requires reading 50 irregular words that do not follow the phonemic rules of the English language, in a rising order of difficulty. The Trail Making[17] tests A (TMT-A) and B (TMT-B) are paper-and-pencil timed tests of visuomotor speed and working memory, with TMT-B also being a valid[18,19] test of executive function. Both parts have a speed-of-processing component.[20,21] TMT-B correlated highly with finger tapping and peg board test[22] and with the Digit Symbol Substitution Test (DSST).[23] Speed-of-processing variables (finger tapping and grooved pegboard) accounted for 29% of the variance in TMT-B.[22] In part A, the participant must draw lines to connect consecutively numbered circles. In part B, the participant must draw lines to connect alternating numbered and lettered circles. We used the time of completion of the tasks in the analysis. The DSST[24] is a valid test for coding, visuomotor speed, and working memory. The subjects are presented with a series of rows that pair digits with nonsense symbols; participants are asked to draw a corresponding symbol under ordered digits. The number of symbols completed in 90 seconds was used in the analysis. The category fluency is a timed task in which participants are asked to recall as many animals as they can in 60 seconds. Number recalled was used in the analysis. For letter fluency (Controlled Oral Word Association Test), participants are asked to generate as many words as possible that begin with each of the letters F, A, and S in 60 seconds.[25] The sum of scores for the words generated from the three letters was used in the analysis.

Statistical Analysis

Descriptive statistics were used to show mean ± SD for age, education, and IQ, and proportions of males and females. Pairwise deletion was selected in all correlational analyses.

Three speed-of-processing measures were used in this study (TMT-A, TMT-B, and DSST). Since all these measures were highly correlated with age and with each other (Table 1),

TABLE 1.
Pearson's correlation between age and cognitive variables (n = 130)

		Age	*NART*	*TMT-A*	*TMT-B*	*DSST*	*Processing speed**	*Letter fluency*	*Category fluency*
1	Age	1.00	0.29†	0.53†	0.51†	–0.65†	–0.63†	0.05	–0.3†
2	NART		1.00	–0.09	–0.1	0.01	0.09	0.28†	0.18
3	TMT-A			1.00	0.64†	–0.66†	–0.87†	–0.14	–0.31†
4	TMT-B				1.00	–0.7†	–0.88†	–0.33†	–0.4†
5	DSST					1.00	0.89†	0.25†	0.42†
6	Processing speed*						1.00	0.29†	0.43†
7	Letter fluency							1.00	0.71†
8	Category fluency								1.00

DSST = Digit Symbol Substitution Test; NART = National Adult Reading Test; TMT-A = Trail Making Test A; TMT-B = Trail Making Test B.
*Composite score created by sum of z scores of TMT-A, TMT-B, and DSST; †significant at $p < .05$.

we developed a single composite speed-of-processing score relative to the entire sample. Performance on each processing speed measure was expressed as the *z* score for each participant. The *z* scores for the three variables were summed to create a single composite score for processing speed. Reversed scores for TMT-A and TMT-B were taken into consideration. Normality of the following variables was confirmed using the Kolmogorov-Smirnov test: letter and category fluency, processing speed composite score, and IQ.

Then, participants were divided into three age groups (young, middle age, and old). The groups were compared on demographic variables using one-way analysis of variance (ANOVA) for the continuous variable (education) and chi-square statistic for the categorical variable (sex). The effect of age on the neuropsychological measures was examined in several ways. First, age was treated as a categorical variable, and a series of one-way ANOVAs compared the three groups on the neuropsychological measures separately; post hoc analysis was done using Fisher's least significant difference method. To control for the inflation of type I error, we reexamined the effect of age on all measures in single multivariate ANOVA. In the second analysis, age was treated as a continuous variable, and the relation between age and the neuropsychological variables was examined using Pearson's correlation.

The next analyses aimed at examining how processing speed and full-scale IQ influence the effect of age and involved analysis of covariance (ANCOVA). The first was univariate ANCOVA, which examined the effect of age group on each measure of verbal fluency separately while controlling for processing speed composite score and full-scale IQ. The second analysis involved a multivariate ANCOVA (MANCOVA), which included both verbal fluency measures as dependent variables to control for type I error.

The final analysis involved curve estimation for both fluency measures, verbal knowledge, and processing speed variables to determine the pattern of performance on the cognitive variables across the age range that was included in this study. Curve estimation can show whether the relation between age (independent variable) and performance on the various cognitive measures (dependent variables) is linear or nonlinear, and identify the onset of decline in cognitive performance. All significance levels were set at $p < .05$ (two tailed).

RESULTS

Forty five men and 85 women completed the study (mean age: 42.9±19.8 years; mean education: 15.7±3.2 years; and mean IQ: 114.7±6.0). Correlation between the processing speed variables (TMT-A, TMT-B, and DSST) showed a significantly high correlation coefficient at $p < .001$ (Table 1). This implies that there is sharing of variance among the three variables and that constructing a global composite score for processing speed is justifiable.

Assessment of normality of data showed that IQ, fluency variables, and composite score for processing speed were normally distributed; Kolmogorov-Smirnov statistics ranged between 0.05 and 0.08 with *p* values >.05. Examination of demographic variables for the three age groups showed that they did not differ on sex or education (Table 2).

The results of group comparisons using one-way ANOVA showed that the groups differed significantly on IQ, processing speed, and category fluency subtest, but not on letter fluency. Post hoc analysis showed that both old and middle-aged groups had significantly higher scores on IQ than the young group; however, processing speed for the older group was lower than for the other two groups, and performance of the middle-aged group was lower than in the younger group. On category fluency, both young and middle-aged groups performed significantly better than the older group (Table 3 shows mean ± SD, *p* values, and post hoc analyses).

A multivariate analysis, which included both fluency variables, verbal knowledge (full-scale IQ), and processing speed composite score as dependent variables, showed that the between-group effect using Wilks' lambda is significant ($F_{2,105} = 17.8$, $p < 0.001$). That is, controlling for type I error did not change the between-group differences in the results.

Age as a continuous variable was negatively correlated with processing speed and category fluency and positively correlated with IQ, but not correlated with letter fluency (Table 1), confirming the results of the ANOVA. However, further analysis that examined letter fluency showed that there were significant between-group differences when we controlled for effect of processing speed and IQ using the ANCOVA model. These differences were not shown initially when we computed ANOVA. The model that examined the category fluency confirmed that the differences between the groups remained significant even after controlling for processing speed and IQ.

TABLE 2.
Demographic variables for the three age groups compared by one-way analysis of variance* and chi-square statistics†

	Young adults (mean ± SD, n *= 62)*	*Middle age (mean ± SD,* n *= 30)*	*Older adults (mean ± SD,* n *= 38)*	*df*	F	p *Value*
Age (years)*	24.4±6.6	49.8±6.2	67.8±4.4	2, 127	663.6	<.001
Education (years)*	15.5±2.9	15.3±2.2	16.5±4.2	2, 127	1.5	.22
Sex† (male/female)	22/40	9/21	14/24	2	0.2	.95

The two models showed that processing speed had a significant effect on both fluency measures; however, the effect of IQ was not significant (Table 4). The MANCOVA model, which included both letter and categorical fluency as dependent variables, and processing speed and IQ as covariates, showed that the model was significant ($p < .001$), the between-group effects for each of the fluency measures were significant ($p = .04$ for letter fluency and $p < .01$ for category fluency), and the effect of speed was significant ($p = .001$). However, the effect of IQ was consistently insignificant ($p = .24$).

Plotting the data using curve estimation showed that processing speed remains unchanged until about the age of 30 years, after which it declines linearly. However, the changes in category fluency and in IQ are nonlinear and best represented by a quadratic curve. Category fluency improves until about the age of 35 years, after which it declines continuously into the later years, while IQ continues to improve until about age 50 years, after which it declines gradually. Plotting the data for the letter fluency did not show any change with age (Figure 1).

DISCUSSION

In this study, we compared the performance of the three age groups on fluency, processing speed, and full-scale IQ as measured by the NART to understand the effect of aging on these domains and the relation of these domains to one another. The younger group performed better than the middle-aged group and the older group on processing speed, supporting earlier studies.[8] However, on IQ, the two older groups performed better than the young group, confirming another study[26] that suggested that the NART increases by 4.5 points across the adult life span. Our study showed a difference of 2.9 points on the NART between the young and the old groups. Our study also suggested that the significant increase in IQ from young adulthood to middle age starts to decrease slowly thereafter.

The current study revealed that the apparent effect of age on fluency depends on the task used and on processing speed, but not on verbal knowledge as measured by the NART. First, on semantic category fluency, our results showed that there is significant impairment in performance as a function of age, which confirms the results of prior studies.[1,4] This decline starts after the age of 35 years and remains significant even after eliminating the effect of decline in processing speed. That is, the older adults' decline in generating words from semantic categories after middle age is partially dependent on processing speed, but not on verbal knowledge. In fact, the older adults have a higher estimated verbal IQ in the face of a lower category fluency score. The decline in category fluency with age then likely reflects some decline in the size of the pool of semantic knowledge or the time or speed with which this information can be accessed. Interestingly, even

TABLE 3.
Comparison of the three age groups on neuropsychological variables: results of analysis of variance and post hoc analysis using Fisher's least significant difference method

	Young adults (mean ± SD, n = *62)*	*Middle age (mean ± SD,* n = *30)*	*Older adults (mean ± SD,* n = *38)*	*df*	F	p *Value*	*Young versus middle*	*Young versus old*	*Old versus middle*
NART	112.9±5.6	117.9±6.5	115.3±5.2	2, 127	7.9	.001	<.001	.04	.07
Speed of processing	1.8±1.7	–0.6±1.7	–2.0±2.7	2,105	33.9	<.001	<.001	<.001	.01
Letter fluency	42.6±10.7	44.9±11.9	44±12.6	2, 106	0.34	.72	.5	.6	.8
Category fluency	26.5±6.3	28.3±7.2	21.4±5.6	2, 106	10.3	<.001	.29	<.001	<.001

NART = National Adult Reading Test.

TABLE 4.
Group differences on verbal fluency and the effect of processing speed and full-scale intelligence quotient: results of univariate analysis, controlling for the effect of NART and speed of processing

	Young adults (mean ± SD)	*Middle age (mean ± SD)*	*Older adults (mean ± SD)*	*df*	p *Value*	*Effect size*	p *Value*	
							Effect of NART	*Effect of speed*
Letter	42.8±10.7	44.9±11.9	44.0±12.6	2, 103	.04	0.06	.09	<.001
Category	26.6±6.3	28.3±7.2	21.4±5.6	2,103	.01	0.08	.25	.002

NART = National Adult Reading Test.

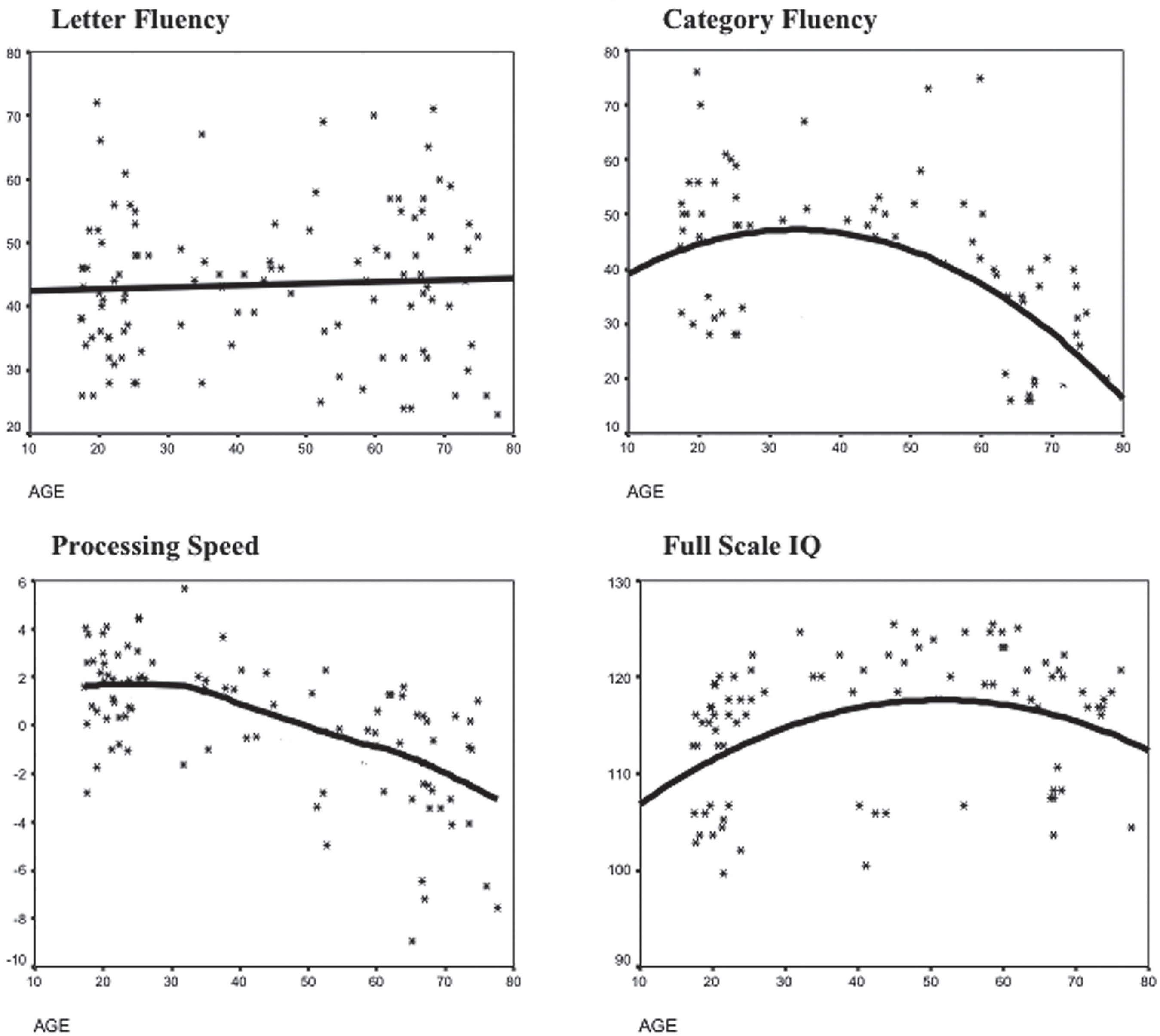

FIGURE 1. Best-fit line for performance on cognitive variables across the age groups. Letter fluency and speed of processing are best represented by linear graph (decline occurs after age of 30 years for processing speed), but category fluency and full scale intelligence quotient (IQ) (National Adult Reading Test) are best represented by quadratic graph. AGE: age in years

though older adults exhibited slower processing speed on our composite measure, this measure does not appear to completely envisage the speed of accessing semantic knowledge.

Initially age had no effect on letter fluency. The change in letter fluency as a function of age appeared only after accounting for processing speed. This emergence of an age effect after controlling for the confounding factors is very unusual. It suggests that once the effect of processing speed is factored out, the advantage for the older adults in this fluency task emerges as significant, and they perform slightly better than younger adults. The decline in processing speed influences the rate of generation of words and therefore masks the advantageous effect of age on letter fluency. In this case, however, the older adults appeared to have a disadvantage solely due to the decline in processing speed. In fact, older adults would be able to generate more words in the specified time period if they were not slower than younger adults. Possibly this advantage on letter fluency task arises in part from an advantage the older adults enjoy in some other cognitive domain. One explanation could be their knowledge of the phonemic characteristics of words in a different manner from that reflected by the NART. Although the older adults performed better than the younger adults on the NART in this study, this difference did not contribute to performance on the letter fluency task, either before or after controlling for processing speed. Since letter fluency requires accessing words based on an aspect of their phonemic quality, we may infer that the older adults' superior knowledge of the phonemic characteristics of words could confer an advantage to them in this type of fluency task.

This study also examined the nature of the relation between aging and the cognitive domains of interest using curve estimation. Interestingly, curve plotting showed different patterns of change in performances for various cognitive domains. The study suggests that the relation between age and processing speed is linear; however, the relation between age and category fluency, as well as full-scale IQ, is nonlinear.

The findings in this study suggest that processing speed differentially modifies performance on letter and category fluency. This supports the results of another study that examined the contribution of reading and writing speed to the age-related changes in phonemic and semantic category fluency.[27] However, the latter did not employ the conventional measures of processing speed, but rather used reading and writing speed, which may share some verbal components with fluency measures, and therefore mediate a portion of the variance in fluency apart from the effect of processing speed. The current study included speed-of-processing tasks that do not employ language abilities to avoid the overlap in these cognitive domains. The study revealed a complex relationship between processing speed and verbal fluency that was not proposed by previous studies. Moreover, other studies on cognitive performance consistently focused on the detrimental effect of aging and did not consider any favorable effect of getting old. This study shows that not all cognitive domains decline with aging; nevertheless, some domains show variable degrees of enhancement. The study also suggests that the decline in one domain may contribute to the apparent decline in another domain that may otherwise remain stationary or even improve with aging. While processing speed partially contributes to the decline in category fluency that occurs as a function of age, it masks the improvement in letter fluency that older adults attain. Another study that examined the effect of processing speed, verbal ability, and executive function on fluency in healthy aging, Alzheimer's disease, and Parkinson's disease reported that processing speed is the best predictor for fluency[28] in these populations.

It is important to note that there is no demarcating line between age-associated cognitive decline and impairment due to dementia, especially in the early stages of Alzheimer's disease. The cognitive change is a continuum that starts at an earlier age, before the appearance of symptoms, and progresses slowly until it reveals itself as age-related cognitive decline; further decline results in mild cognitive impairment that, if it progresses, can lead to dementia. Decline in some cognitive domains such as verbal memory and processing speed is a variant of normal aging and should not substantially impair an individual's capacity to function. Performance on letter fluency should not be adversely affected by age. If this domain declines significantly, further evaluation to exclude neurological or mental disorder should be initiated. On the other hand, categorical fluency declines significantly with age, mainly because of the contribution of processing speed and possibly other domains to performance on category tasks.

It is notable that the effect of aging on various cognitive constructs depends on the task used, which suggests that various tasks that researchers select to measure the same cognitive construct could be employing different brain processes, and therefore the results cannot be generalized. It is imperative to appreciate the psychological properties of the tasks used in order to avoid misinterpreting the results. This necessitates that, when interpreting the results of similarly timed cognitive tasks, controlling for processing speed should be considered essential, especially when the between-group variable suggests a possible effect for speed of performance.

CONCLUSION

This study suggests that the effect of processing speed on fluency is multifarious. The first age-related decline in category fluency is in part influenced by the slowing of information processing; however, a significant portion of the decline is still independent of the decline in processing speed. The influence of processing speed on letter fluency is, however, different. The slow processing masks the enhancement on letter fluency that occurs during the transition from young to middle age. In both conditions, the age-related change is independent of IQ. This study shows that the effect of aging on cognitive function is differential; aging is associated with decline in some domains, yet with appreciation in other domains.

Limitations

This study has limitations because we employed a cross-sectional design, which implies that the results may be confounded by a cohort effect across generations. The study recruited more younger adults than middle-aged and older adults as a result of an imbalance in the response to the advertisement. Moreover, the overall population of participants in this study had a relatively high level of health and no history of mental illness which may not represent the true population.

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CONFLICT OF INTEREST DISCLOSURES

None of the authors have any conflicts of interest.

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