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Verbal ability in postmenopausal women in relation to age, cognitive and reproductive factors

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ABSTRACT

Word-finding difficulties have been associated with age and, in women, lowered sex hormone levels following menopause. However, there is limited understanding of the ways that specific aspects of word-finding are shaped by women's age, reproductive histories, and background factors such as education. The current study investigated the effects of age, cognitive and reproductive factors on word-finding abilities in 53 healthy postmenopausal women aged 48–79. A questionnaire was used to gather demographic information and reproductive history. A battery of verbal fluency, continuous series, and naming tasks was designed to assess word-finding across different sensory modalities and cognitive demands. Category and letter fluency were quantified as total number of correct words produced on each task. For continuous series, switch rates and switch costs were computed. For the naming tasks, accuracy and latency measures were used. There were three key findings. Firstly, there was a consistent positive association between education and all word-finding measures, i.e., verbal fluency, continuous series, and naming. Secondly, age-related declines were seen on tasks heavily dependent on working memory such as the continuous series task. Thirdly, reproductive factors across the lifespan such as age at menarche and reproductive years showed subtle effects on naming abilities, but not on verbal fluency or continuous series. The results highlight that word-finding abilities in healthy postmenopausal women are shaped by factors associated with their early years (education, age at menarche) and later adult life (age, reproductive years). The study also distinguished between the more global effects of education, and the more task-specific associations with age and reproductive variables, on verbal task performance after menopause.

1. Introduction

In a span of only three decades (1990 to 2019), the global life expectancy at birth has increased by 8.4 years, i.e., from 64.2 years in 1990 to 72.6 years in 2019 (United Nations, Department of Economic and Social Affairs, Population Division, 2019). As a result, the number of older adults across nations is increasing with time and it is estimated that 9.1 % of the global population consists of people aged 65 and above (United Nations, Department of Economic and Social Affairs, Population Division, 2019). As part of this demographic trend, women comprise 55 % of people over 65 years and 61 % of those aged 80 years and older (United Nations, Department of Economic and Social Affairs, Population Division, 2019). Associated with increasing age is the risk of decline in cognitive functions, and specifically, word-finding (as measured by verbal fluency) was found to be associated with caregiver reports on instrumental activities of daily living (Cahn-Weiner et al., 2002).

Research into how language changes with cognitive ageing indicates a decline in word-finding ability as measured by verbal fluency and naming tasks. Declines in verbal fluency are detected from the age of 60 and further accelerate in the 80s (Rodriguez-Aranda & Martinussen, 2006); declines in naming are seen from the age of 70 (Zec et al., 2005). Some report age-related declines in verbal fluency (Brickman et al., 2005; Rodriguez-Aranda & Martinussen, 2006; Singh-Manoux et al., 2012) and naming (Connor et al., 2004; Goral et al., 2007) beginning as early as the 40s and 50s. However, others have found no significant decline in verbal fluency (Sauzéon et al., 2011) or naming (Cruice et al., 2000). A few studies also showed differential effects of age on verbal fluency, with letter fluency remaining more stable with age than category fluency (Elgamal et al., 2011; Mathuranath et al., 2003; Troyer et al., 1997).

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Sex differences in ageing of verbal abilities are reported in healthy adults with mixed results (see Gurvich et al., 2018 for review). Some studies have shown no sex difference (Brickman et al., 2005), or differences with men scoring higher than women (Welch et al., 1996). Additionally observed in the literature are sex differences in older adults' verbal task performance that favour women, but which are not necessarily reflected in rate of decline with age. McCarrey et al. (2016), in a cohort study of adults aged 50–96, showed that women had higher verbal abilities than men as measured by verbal learning and fluency, together with parallel longitudinal trends of age-related decline across the sexes on these measures. de Frias et al. (2006) also showed stable sex differences over a 10-year period in adults aged 35–90 years with women outperforming men on episodic memory tasks requiring verbal processing. In an earlier cross-sectional study of adults aged 18–81, Capitani et al. (1998) showed comparable scores on letter-based fluency in younger men and women, with a greater sensitivity to age-related decline in men compared to women for letter-based verbal fluency from 50 years. At first glance these results (Capitani et al., 1998) appear at odds with more recent studies (de Frias et al., 2006; McCarrey et al., 2016), however, they all reflect consistent patterns of stable sex differences from age 60 onward for measures of verbal ability that favour women. Similarly, in twins, Finkel et al. (2006) showed some baseline sex differences related to verbal functions, but few sex differences in the trajectories of cognitive decline with age, and only one verbal task with differential patterns of heritability in men and women. They make the important point that, "Men and women may exhibit the same mean level of cognitive performance and the same pattern of decline but for different reasons. More specifically, their performance may arise from different combinations of biological and social factors." (Finkel et al., 2006, p. 353).

In healthy ageing, menopause status is one factor hypothesized to contribute to inconsistencies in findings regarding the presence and direction of sex differences in verbal tasks (Nebel et al., 2018; Rentz et al., 2017). Associations between sex hormone levels and word-finding abilities in women at midlife are unclear, with reports of decline (Fuh et al., 2006), no change (Fuh et al., 2003; Weber et al., 2013), or mixed findings (Berent-Spillson et al., 2012; Weber et al., 2014) in postmenopause performance.

The variable results across studies may be due in part to differences in the reproductive and hormonal status in female participant samples and the specific nature of the verbal tasks examined. The current study investigates the complex intersections among demographic and neuropsychoendocrinological factors. We examined effects of age on word-finding abilities, controlling for menopause-related changes in word-finding, in healthy postmenopausal women aged 48–79 years. The study was designed to support detailed analysis of the combined impact of hormonal (e.g., menopause status, reproductive history), cognitive, and salient background variables (e.g., vocabulary, years of education) on verbal abilities in relation to advancing age.

2. Method

2.1. Participants

Participants were 53 postmenopausal women aged 48–79 years. Women were classified as postmenopausal if they reported a permanent cessation of menstruation for at least 12 consecutive months (WHO Scientific Group on Research on the Menopause in the 1990s [1994: Geneva, Switzerland] & World Health Organization, 1996). The study sample included women from 1 to 34 years postmenopause; according to the STRAW 10+ criteria, there were women in early (8 years or less $n = 24$) and late (9 years or more $n = 29$) stages of menopause (Harlow et al., 2012). All women had attained natural menopause (those with hysterectomy alone or hysterectomy with unilateral/bilateral oophorectomy were excluded) after the age of 40 (premature menopause is defined as occurring earlier than age 40 years (Jewelewicz & Schwartz, 1986)).

None of the volunteers had a history of major illnesses that could affect their cognitive functioning. Neither were they pregnant or lactating in the past year, or taking antidepressants, thyroxin medication or hormone-based medications (oral contraceptives, hormonally based contraceptive implants, patches, estrogen or hormone replacement therapy) at the time of the study. However, participants who had previously taken hormone therapy, but had not received medication in the year prior to the study were included. The current study sample therefore consisted of women who reported never taking hormone-replacement therapy (HRT) ($n = 45$) and women who reported taking HRT at some point earlier than the 12 months before their study participation ($n = 8$).

All women gave informed written consent to participate. No financial compensation was provided to the participants. The research protocol was approved by the University of Sheffield Research Ethics Review Panel.

2.2. Materials and procedure

Questionnaire based interviews were used to gather information on age, years of education, hormonal, and reproductive history. To estimate hormonal exposure across the life span, details were obtained on age at menarche, menstrual cycle length, age at first pregnancy, number of children, age at menopause (defined as the age at final menstrual period), number of years since menopause (calculated as the age on the day of testing minus the age at menopause), and number of reproductive years (calculated as the age at menopause minus the age at menarche). See Table 1 for descriptive statistics relating to the above-mentioned reproductive factors.

Handedness was measured using the Edinburgh Handedness Inventory (Oldfield, 1971). In total, there were 47 right-handers ($M = 92.77$; $SE = 1.71$), three left-handers ($M = -80.00$; $SE = 11.55$) and three ambidextrous ($M = 3.33$; $SE = 20.28$) participants. This confirmed that the sample profile consisted of approximately 90 % right handers which is consistent with the larger population norms (Lezak, 1995, p. 301) and salient given the relationship between handedness and

Table 1
Means (±*SE*) for background demographics, reproductive factors, and word-finding measures for postmenopausal women aged 48–79 (N = 53, unless otherwise specified).

Variable	*M*	*SE*
Background demographics		
Age (in years)	63.49	1.20
Education (in years)	16.43	0.34
Full scale IQ	121.70	0.98
WASI-vocab (T score)	62.40	0.57
Matrix reasoning (T score)	62.06	0.77
Reproductive factors		
Age at menarche (in years)	12.98	0.18
Menstrual cycle length (in days)	27.99	0.27
Age at first pregnancy (in years) ($n = 47$)	27.81	0.77
Number of children	2.11	0.17
Age at menopause (in years)	51.40	0.45
Years since menopause (in years)	12.09	1.34
Reproductive years (in years)	38.42	0.49
Word-finding measures		
Category fluency (total words)	18.25	0.58
Letter fluency (total words)	16.84	0.63
2-Series switch rate (words/s)	0.89	0.03
3-Series switch rate (words/s)	0.60	0.02
4-Series switch rate (words/s)	0.50	0.02
2-Series switch cost (in %)	59.46	2.38
3-Series switch cost (in %)	68.77	1.64
4-Series switch cost (in %)	71.95	1.13
Picture naming accuracy	56.06	0.49
Picture naming latency (in ms)	1349.59	43.40
Auditory naming accuracy ($n = 51$)	50.43	0.59
Auditory naming latency (in ms) ($n = 51$)	1631.11	71.69

neurocognitive language organisation (Pujol et al., 1999), including verbal fluency in women (Gurd et al., 2013; Gurd & Cowell, 2015).

Two subtests from the Wechsler's Abbreviated Scale of Intelligence (WASI) (WASI; Wechsler, 1999) were administered to estimate verbal (vocabulary) and non-verbal IQ (matrix reasoning).

A battery of verbal tasks was designed to measure performance on word retrieval and fluency. Participants completed three verbal fluency tasks (category, letter, continuous series (C-series)) and two naming tasks (picture naming and auditory naming to definition). Five- to fifteen-minute breaks were provided between tasks as required.

The choice of the tasks was shaped by their sensitivity to age (category fluency, picture naming) and hormone-related (letter fluency) effects. To enable comparison of the current study's results with findings in the existing literature, the test battery contained frequently used neuropsychological tasks (verbal fluency, picture naming). Additionally, the C-series and the naming to auditory definitions tasks were incorporated to investigate higher-order cognitive functions underlying word-retrieval.

Although all the tasks measure word-finding ability, there are differences in their underlying neurocognitive systems. Letter fluency relies on selection and retrieval of orthographic or phonemic information; corresponding neuroimaging studies have shown selective activation of frontal cortex in early work (Mummery et al., 1996), and more recently, to left premotor and inferior frontal regions (Birn et al., 2010). In comparison, category fluency which requires access to conceptual stores, showed activation of temporal cortex, left fusiform gyrus, hippocampus (Birn et al., 2010; Gourovitch et al., 2000; Mummery et al., 1996), and regions of frontal cortex anatomically distinct from those observed with letter/phonemic fluency (Birn et al., 2010; Costafreda et al., 2006). Verbal fluency tasks involving a continuous switching between multiple item types, such as the continuous series task, involve more working memory and executive function compared to single item tasks. As such, they have been shown to activate premotor, posterior temporal (Birn et al., 2010) and parietal cortices (Gurd et al., 2002). Auditory (i.e., naming to auditory definition) and picture naming differ in their mode of word access. Accordingly, lesion studies indicate anterior temporal lobe involvement in auditory but not picture naming (Hamberger et al., 2001).

For the category and letter fluency tasks, participants generated as many words as possible in one-minute for each of three categories (animals, fruits, vehicles) or beginning with a letter (F, A, S), respectively (Lezak et al., 2004). The total number of correct words produced for each category/letter was counted; errors and repetitions were excluded from the total. Proper names and inflectional forms of the same word (e.g., eat, eats, eating) were not considered in the final count as participants were instructed not to produce these types of words. Homophones such as 'sent, scent' were counted as two different words if indicated by the participant in the recording.

For the C-series task, a baseline was taken whereby participants produced as many words as possible in one-minute from each of four overlearned serial categories in canonical order (numbers, letters of the alphabet, months, days of the week). The baseline rate was calculated as the number of words produced per second. The subsequent C-series task (adapted from Gurd, 1995) consisted of three conditions which involved alternate switching between 2 (numbers, letters), 3 (numbers, letters, months) and 4 (number, letters, months, days) categories for one-minute. For example, for letters of the alphabet and numbers, the expected response would be A, 1, B, 2, …, Z, 26, A, 27, B, 28 and so on. For finite categories (letters, months, days), participants repeated the series once all the items from that category had been produced. For the C-series task, switch rates and switch costs were computed. Switch rate was the number of words per second for each of the series. The switch cost was defined as the difference between the mean baseline rate (for those two, three, or four categories) and the switch rate of the series, expressed as a percentage of the total mean baseline rate across all categories (adapted from Gurd & Cowell, 2015). For example, switch cost for the 2-series condition (letters, numbers) was calculated as follows:

$$\text{Switch Cost} = \left\{\frac{\text{Mean baseline rate of letters and numbers} - \text{2series switch rate}}{\text{Mean baseline rate for letters, numbers, months, days}}\right\} \times 100$$

Fluency tasks were administered in the following fixed order: category, letter, C-series. The responses were audio recorded for later scoring and analysis.

The naming tasks were administered after the fluency tasks in the following fixed order: auditory naming, picture naming. Auditory naming was assessed with a task developed in our laboratory that used a set of 60 target stimuli and their associated definitions taken from the list developed by Harley and Bown (1998) which we adapted for administration via headphones using DMDX (Forster & Forster, 2003). The participant heard the definition and then named the item. For example, an item on the list was "A spherical or nearly spherical object, especially one used in games" (expected response: ball) (Harley & Bown, 1998, p. 171). The 60 items were administered in a fixed order. Picture naming (accuracy and latency) was examined using the Boston Naming Test (BNT) (Kaplan et al., 1983). Statistical analyses were conducted using SPSS Statistics (Version 28) (IBM Corp, 2021) with the exception of power analysis (see below).

2.3. Power analysis

Power calculations for repeated measures ANOVA designs estimated that for medium and large effect sizes, a sample of $n = 53$ would provide 80 % statistical power ($\alpha = 0.05$) for models with one group, 2 or 3 repeated measures, and repeated measures correlations from 0.4 to 0.7. Calculations for bivariate correlations estimated that for effect sizes >0.4, a sample of $n = 53$ would provide 80 % statistical power ($\alpha = 0.05$, two-tailed). These two aspects of power provided the basis for statistical model development and implementation which are described in the results. Power calculations were performed using G*Power software (Faul et al., 2007; Faul et al., 2009).

3. Results

Descriptive statistics (means, standard errors) for background demographic, reproductive factors, and word-finding measures are presented in Table 1.

Fluency and naming performance were evaluated using five task-specific ANCOVAs to investigate the cognitive, background demographic, and reproductive factors associated with the profiles of word-finding ability in this postmenopausal sample of healthy women.

To determine the most salient covariates for inclusion in the ANCOVAs described below, correlations between word-finding measures, demographic, and reproductive characteristics were analysed (Table 2). Age, WASI-vocab, and years of education were the most

Table 2
Correlations between word-finding, background demographics, and reproductive factors for postmenopausal women aged 48–79 (N = 53, unless otherwise specified).

Word-finding measure	Background demographics			Reproductive factors						
	Age	Vocab T score	Education	Age at menarche	Menstrual cycle length	Age at first pregnancy[a]	Number of children	Age at menopause	Years since menopause	Number of reproductive years
Category fluency	−0.36**	0.52**	0.41**	−0.35*	−0.18	0.06	−0.08	0.24	−0.40**	0.34*
Letter fluency	−0.20	0.38**	0.49**	−0.10	0.04	0.13	−0.09	0.14	−0.22	0.16
2-Series switch rate (words/s)	−0.19	0.38**	0.36**	−0.22	−0.12	0.03	−0.17	0.05	−0.19	0.13
3-Series switch rate (words/s)	−0.46**	0.29*	0.30*	−0.23	−0.12	0.06	−0.29*	0.07	−0.44**	0.15
4-Series switch rate (words/s)	−0.31*	0.38**	0.31*	−0.25	0.04	0.17	−0.18	0.10	−0.31*	0.18
2-Series switch cost (%)	0.01	−0.07	−0.06	−0.06	0.11	0.27	−0.04	−0.13	0.05	−0.09
3-Series switch cost (%)	0.22	0.01	−0.02	−0.01	0.11	0.23	−0.08	−0.13	0.24	−0.11
4-Series switch cost (%)	0.13	−0.09	−0.12	−0.05	−0.06	0.07	−0.02	−0.18	0.18	−0.15
Picture naming accuracy	−0.42**	0.44**	0.49**	−0.23	−0.04	0.17	−0.13	0.30*	−0.47**	0.36**
Picture naming latency (ms)	0.54**	−0.19	−0.38**	0.30*	0.16	−0.10	−0.01	−0.26	0.57**	−0.35**
Auditory naming accuracy[b]	−0.31*	0.38**	0.48**	−0.31*	0.30*	0.02	0.06	0.26	−0.36**	0.35*
Auditory naming latency (ms)[b]	0.10	0.01	−0.12	0.29*	−0.05	0.07	0.10	0.07	0.07	−0.04

[a] $n = 47$.
[b] Due to technical reasons, data were missing from two participants for the auditory naming task and therefore, $n = 51$ for all variables and $n = 45$ for auditory naming correlations with age at first pregnancy.
* $p < .05$.
** $p < .01$.

consistent correlates with word-finding measures. As age increased, category fluency, 3- and 4-series switch rates, picture naming and auditory naming accuracies decreased, and picture naming latency increased. Higher WASI-vocab scores were associated with better performance in category and letter fluency, continuous series switch rates, picture and auditory naming accuracy. More years of education were consistently associated with better performance on category and letter fluency, continuous series switch rates, picture and auditory naming accuracy, and faster picture naming latencies. Sporadic associations were seen between reproductive and word-finding measures; instances where reproductive measures were associated with more than one word-finding measure are summarised here. Higher age at menarche was associated with lower word generation on category fluency, and slower picture and auditory naming latencies. Number of reproductive years was positively associated with better performance on category fluency, picture naming and auditory naming accuracy, and shorter picture naming latency. Years since menopause was associated with the same word-finding measures as age. The magnitude of the correlations among various word-finding tasks ranged from moderate to strong across most measures. An exception to this pattern was observed for switch cost

Table 3
Correlations among word-finding measures (verbal fluency, switch rate, switch cost, and naming) for postmenopausal women aged 48–79 years (N = 53, unless otherwise specified).

Variable	1	2	3	4	5	6	7	8	9	10	11[a]	12[a]
1. Category fluency	–	0.57**	0.49**	0.50**	0.42**	−0.06	−0.13	−0.07	0.54**	−0.54**	0.51**	−0.25
2. Letter fluency		–	0.71**	0.42**	0.62**	−0.01	0.10	−0.11	0.39**	−0.38**	0.39**	−0.24
3. 2-Series switch rate			–	0.73**	0.68**	−0.11	−0.06	−0.05	0.32*	−0.50**	0.41**	−0.31*
4. 3-Series switch rate				–	0.74**	−0.10	−0.43**	−0.25	0.24	−0.49**	0.45**	−0.32*
5. 4-Series switch rate					–	−0.09	−0.22	−0.47**	0.18	−0.32*	0.34*	−0.34*
6. 2-Series switch cost						–	0.81**	0.76**	−0.09	0.06	0.06	−0.03
7. 3-Series switch cost							–	0.79**	0.01	0.11	−0.03	0.00
8. 4-Series switch cost								–	0.01	−0.00	−0.01	0.05
9. Picture naming accuracy									–	−0.59**	0.48**	−0.03
10. Picture naming latency										–	−0.56**	0.40**
11. Auditory naming accuracy[a]											–	−0.33*
12. Auditory naming latency[a]												–

[a] Due to technical reasons, data were missing from two participants for the auditory naming task and therefore, $n = 51$.
* $p < .05$.
** $p < .01$.

measures, which showed zero to low magnitude correlations with fluency, naming, and some switch rate measures (Table 3).

Separate repeated-measures ANCOVAs were used to investigate the effects of background and reproductive variables on verbal fluency (semantic, letter), verbal fluency continuous series switch rate and switch cost (2-, 3- and 4-series), naming (auditory, picture) accuracy and latency. This allowed a systematic comparison of effects in relation to the tasks. For the ANCOVAs, the internal-to-task variables were entered as the repeated measures, and the performance outcome measures on the verbal tasks served as the dependent variables (Verbal fluency model: Category and Letter fluency total number of words; C-series model 1: 2-, 3-, 4-series switch rates; C-series model 2: 2-, 3-, 4-series switch costs; Naming model 1: picture and auditory naming accuracy; Naming model 2: picture and auditory naming latency). As described above, covariates were chosen based on associations between word-finding, demographic, and reproductive measures (Table 2) where there was a pattern of more than one correlation between demographic background or reproductive factors and the corresponding word-finding measures. Correlations between demographic and reproductive characteristics (Table 4) were used to detect and address multicollinearity among covariate measures prior to entering them into the final models. If two variables were strongly correlated ($r \geq 0.80$), only one was retained in the ANCOVA. This occurred in relation to age and years since menopause ($r = 0.94$); age was retained given its salience to the study design. Age, years of education, WASI-vocab, age at menarche and reproductive years were considered as covariates.

Results from the ANCOVAs are described below: For semantic and letter verbal fluency, there was a significant interaction between Task × Education, $F(1, 47) = 6.72$, $p = .013$, $\eta_p^2 = 0.13$. As evident from the correlations, years of education had a stronger positive association with letter fluency than category fluency (Table 2). Given the correlations between years of education with age and WASI-vocab (Table 4), partial correlations were conducted to further explore the influence of these variables on letter fluency: the association between letter fluency and education remained significant after controlling for age and vocabulary, $r(49) = 0.37$, $p = .008$. The covariate vocabulary was significant, $F(1, 47) = 4.87$, $p = .032$, $\eta_p^2 = 0.09$, and years of education marginally so $F(1, 47) = 3.46$, $p = .069$, $\eta_p^2 = 0.07$. Marginal effects of Task × Age $F(1, 47) = 3.43$, $p = .070$, $\eta_p^2 = 0.07$, reflected trends for age to be more strongly correlated with the category fluency task (Table 2).

For the C-series task, analyses conducted with 2-, 3-, and 4-series switch rates showed significant interactions of Switch Rate series × Age, $F(1.71, 80.17) = 5.03$, $p = .012$, $\eta_p^2 = 0.10$ (Greenhouse-Geisser adjusted for sphericity). As observed from the correlations, increased age was associated with lower switch rate to a greater extent for 3-series compared to 2- and 4-series conditions. Given the correlations between age with years of education and WASI-vocab (Table 4), partial correlations were conducted to further explore the influence of these variables on switch rate: the association between 3-series switch rate and age remained significant after controlling for education and WASI-vocab, $r(49) = -0.39$, $p = .005$. Marginal effects included Switch Rate series × Education, $F(1.71, 80.17) = 2.64$, $p = .086$, $\eta_p^2 = 0.05$, which reflected the relatively stronger association between education and 2-series switch rate (vs 3- and 4-series); and the covariate WASI-vocab, $F(1, 47) = 2.99$, $p = .091$, $\eta_p^2 = 0.06$, which was moderately correlated with switch rate averaged across the 3 conditions.

Results from the ANCOVAs with 2-, 3-, and 4-series switch cost showed no significant main effects or interactions. Only Switch Cost series × Age was marginally significant, $F(1.47, 69.26) = 2.99$, $p = .072$, $\eta_p^2 = 0.06$ (Greenhouse-Geisser adjusted for sphericity), reflecting age trends similar to those seen with switch rate above.

Two participants lacked complete data for naming due to technical issues with response recordings for the auditory task. Thus, the repeated measures ANCOVAs for naming accuracy and latency were conducted for the $n = 51$ women with complete data for auditory and picture naming tasks.

For naming accuracy, there was a significant main effect of education, $F(1, 45) = 4.31$, $p = .044$, $\eta_p^2 = 0.09$. Given the correlations between years of education with age and WASI-vocab (Table 4), partial correlations were conducted to further explore the influence of these variables on average naming across the auditory and picture tasks (the average naming measure was computed using the mean of picture naming and auditory naming accuracy scores). The association between naming accuracy and education remained significant after controlling for age and WASI-vocab, $r(47) = 0.30$, $p = .034$. There was also a marginal effect of reproductive years, $F(1, 45) = 3.15$, $p = .083$, $\eta_p^2 = 0.07$, reflecting associations between greater accuracy and more reproductive years (Table 2).

No significant main effects or interactions were observed for naming latencies. There was a marginal effect of age at menarche, $F(1, 45) = 3.82$, $p = .057$, $\eta_p^2 = 0.08$, reflecting associations between shorter latency and earlier age at menarche (Table 2).

The complete set of ANCOVA results corresponding to the effects reported above are presented in Appendix Table 5.

ANCOVAs were performed with the 45 women who had reported never taking HRT and results were parallel to those above with no major differences in the patterns of significant results (see Appendix Table 6).

4. Discussion

Difficulty in retrieving words during everyday conversation is a primary concern in older adults and therefore, the effects of age on word-finding abilities is a central topic of research in cognitive ageing. Further, it is not clearly understood whether rate of decline in this ability varies across sexes. As noted in the introduction, a key factor that needs consideration in studies examining age-related effects in women is menopause status in relation to cognition. The present study investigated the effects of age, demographic, and reproductive factors on word-

Table 4

Correlations among background and reproductive measures for postmenopausal women aged 48–79 years (N = 53, unless otherwise specified).

Variable	2	3	4	5	6 [a]	7	8	9	10
1. Age	−0.27	−0.56**	0.19	0.20	−0.47**	0.25	−0.15	0.94**	−0.21
2. WASI-Vocab (T score)		0.51**	−0.24	0.03	0.05	−0.10	0.17	−0.29*	0.24
3. Education			−0.23	−0.01	0.14	0.02	0.18	−0.56**	0.25
4. Age at menarche				0.17	0.04	0.16	−0.03	0.18	−0.39**
5. Menstrual cycle length					−0.12	0.02	0.07	0.15	0.00
6. Age at first pregnancy[a]						−0.42**	0.23	−0.51**	0.20
7. Number of children							0.03	0.22	−0.03
8. Age at menopause								−0.47**	0.93**
9. Years since menopause									−0.50**
10. Number of reproductive years									–

[a] $n = 47$.
[*] $p < .05$.
[**] $p < .01$.

finding ability in postmenopausal women aged 48–79 years, controlling for the effects of menopause status.

There were three key findings. First, significant age-related effects were seen on tasks heavily dependent on working memory such as the continuous series task, and to less of an extent on the category verbal fluency task. Second, associations between education and word-finding measures were observed for the letter verbal fluency task and naming accuracy. Third, reproductive factors across the lifespan such as age at menarche and reproductive years showed subtle effects on naming abilities, but not on verbal fluency or continuous series.

The current study found a nuanced and task-specific pattern of ageing on word-finding abilities, with more robust ageing effects from the ANCOVA models detected for the continuous series switch rate measures, compared to verbal fluency and naming. These findings are in consonance with studies that have reported weak or no significant associations between age and word-finding abilities as measured on verbal fluency and picture naming tasks (Cruice et al., 2000; Nicholas et al., 1989; Parkin & Java, 1999; Sauzéon et al., 2011; Troyer et al., 1997). However, some studies do report moderate age-related decline in verbal fluency and picture naming (Brickman et al., 2005; Connor et al., 2004; Gordon & Kindred, 2011; Kave et al., 2010; Parkin & Java, 1999; Rodriguez-Aranda & Martinussen, 2006; Singh-Manoux et al., 2012; Troyer et al., 1997; Welch et al., 1996; Zec et al., 2005). Methodological factors that have contributed to such inconsistencies include differences in target population, study designs, age range considered, test materials, statistical models, or a combination of these factors. For example, age effects on verbal fluency in the current study were task-specific, showing moderate decline with age for category but not letter fluency – an effect also reported by Elgamal et al. (2011). However, other sources of variability in relation to word-finding at menopause may be more complex, multifaceted, and reflect the inherent interactions between age, education, verbal IQ, and indicators of reproductive status and history.

Inconsistencies and the nature of complex interaction effects in results across studies have given rise to key research questions about the source of individual and group differences in age-related cognitive decline. To better understand this phenomenon, age-related cognitive decline in healthy adults has been discussed in the context of cognitive reserve (Stern, 2009). An increase in cognitive reserve is associated with an increase in baseline cognitive performance or slower rate of cognitive decline (Opdebeeck et al., 2015; see review by Stern, 2009). Educational attainment is one of the most frequently explored proxy measures of cognitive reserve (Singh-Manoux et al., 2011; Turcotte et al., 2022). More years of education are reported to be associated with better word-finding abilities in late life and slower rate of cognitive decline (Foverskov et al., 2018; Zahodne et al., 2015). The present results in postmenopausal women are in line with previous research and suggest that subtle effects of age on word-finding measures such as verbal fluency and naming might have been mediated in part by higher average level of education of the current sample which was 3 years above the 13.4 mean years of schooling for females in the UK (UNDP, 2022), and may have conferred an overall protective effect compared to the general population. Within the current sample, education levels were associated with age, with older postmenopausal women having fewer years of education than younger postmenopausal women. Our study enabled a closer look at word-finding in this context, where we were able to model the contributions of age and education to demonstrate their respective associations with specific word-finding tasks. In the wider cognitive domain, a recent large-scale cohort study showed that despite higher baseline levels of global cognition, executive function, and memory, women showed faster rates of decline with age than men for global cognition and executive function (Levine et al., 2021). In line with our study, this indicates a highly complex picture for applications of the cognitive reserve hypothesis that should be sex- (Subramaniapillai et al., 2021) and task-specific, incorporate social and educational background (Nichols et al., 2021; Wolfova et al., 2021), and address possible disjunctions between starting baseline, verbal performance (Turcotte et al., 2022), and rate of decline measures.

Further to cognitive reserve, the neuroscience literature suggests that an increase in the number of years of education is associated with an increase in gray matter tissue volume of the temporal lobe (Ho et al., 2011), right superior temporal gyrus, left insula, bilateral anterior cingulate cortex (Arenaza-Urquijo et al., 2013), temporoparietal regions, bilateral frontal and limbic lobes and right occipital lobe (Foubert-Samier et al., 2012; Liu et al., 2012). Foubert-Samier et al. (2012) also reported an increase in white matter volume in the anterior region of the corona radiata on the right and in regions of internal capsule, fronto-occipital fasciculus, and cerebellar peduncles in the left hemisphere. Increased cortical thickness in temporal pole and transverse temporal gyrus (Liu et al., 2012), decreased mean diffusivity in the hippocampus (Piras et al., 2011), and increased metabolic activity in the anterior cingulate cortex (Arenaza-Urquijo et al., 2013) were also found to be associated with high levels of education in older adults. Thus, along with structural modifications, education has also been related to functional connectivity in the brain. Increased connectivity between the anterior cingulate cortex and right hippocampus, left inferior frontal lobe, right posterior cingulate cortex and left angular gyrus are found to be associated with higher levels of education (Arenaza-Urquijo et al., 2013). Arenaza-Urquijo et al. (2013) also found that this increased connectivity between the anterior cingulate and other regions was associated with greater word production on verbal fluency tasks, indicating that high levels of education might strengthen the connections between brain areas and thereby, improve behavioural performance on such cognitive tasks. Many of the above-mentioned brain regions, such as the inferior frontal cortex, anterior cingulate and temporal cortex are recruited during word-finding tasks. Taken together, the above findings suggest that additional structural and functional changes in the brain that are associated with high levels of education may be neuroprotective and delay age related cognitive decline. For women in the current study, having a higher-than-average level of education may have contributed to structural and functional modification in the brain areas supporting word-finding performance, and thereby provided protection against age-related declines in word-finding abilities overall. Moreover, it was evident that women with the highest within-sample levels of education had better performance on tasks shown to covary significantly with respect to this variable, such as letter fluency and naming accuracy.

Lower switch rates with increasing age on the continuous series verbal fluency task may have resulted from an overall slowing of underlying cognitive processing (Salthouse, 1996). Consistent with the current study's verbal fluency results, Henry and Phillips (2006) found that fluency tasks with category-alternating components revealed more prominent age-related performance decreases than single category fluency tasks. The continuous-series task relies on working memory to a great extent because it requires the individual to store in real time the target categories, the items that have been retrieved within each category, the sequence of retrieval, and to avoid repetitions and errors. Decrements in measures of working memory during menopause have been linked to women's subjective experience of changes in verbal memory (Weber et al., 2012). Effects have also been documented in related cognitive abilities, such as attention which was linked to menopausal changes at midlife (Schaafsma et al., 2010), and executive function which was associated with faster rates of decline with age in women compared to men (Levine et al., 2021). Gurd et al. (2002) found that activity in the right superior parietal cortex was associated with switching on continuous-series verbal fluency tasks involving both semantic categories and overlearned sequences. Thus, age-related changes in the structure and function of parietal cortex, particularly in areas showing volume reduction in parallel with hormone changes at perimenopause (for review see, Rehbein et al., 2021), may have underpinned the association found in the current study between age, 3-series switch rate and cost. In contrast, the marginal trends in semantic verbal fluency observed in the current study's ANCOVA may be neurologically based in changes to the broader network of frontal, temporal and parietal cortical regions associated with category-based fluency in older adults (Vonk et al., 2019).

Along with demographic factors, the correlations and ANCOVAs revealed a degree of association between reproductive factors and word-finding abilities. An early age at menarche was associated with shorter naming latencies, and more reproductive years with more accurate naming abilities. It is reported that an early age at menarche is associated with early onset of ovulatory cycles (Vihko & Apter, 1984) and higher levels of estradiol in young adults in the follicular phase of the menstrual cycle (Apter et al., 1989; Bernstein, 2002) which could contribute to increased cumulative hormone exposure across the life-span. Greater reproductive years may expose a woman to high estrogen states for a longer duration which in turn would increase the cumulative hormone exposure. An association between longer reproductive periods across the life span and better verbal fluency (Ryan et al., 2009) is consistent with the current study's results, and with the hypothesis that estrogen may protect against decline in word-finding abilities in later life. However, it should be noted that the relationships between estrogen exposure and cognition observed in healthy women are specific to age and to cognitive domain. Moreover, these do not automatically extend to provide protective effects against dementia (Paganini-Hill et al., 2020; Ryan et al., 2009).

4.1. Strengths, limitations and future directions

The current study has a number of strengths. It provides a comprehensive picture of word-finding abilities in healthy midlife and late life women by examining their performance using multiple measures that are sensitive to age, hormonal fluctuations, and higher order cognitive functioning. Although the primary aim of the study was to examine the effects of age on word-finding abilities, it also considered the interactive roles of demographic and reproductive factors. In comparison to larger cohort-based investigations of menopause that focussed primarily on verbal memory and processing speed (e.g., Epperson et al., 2013; Greendale et al., 2010; Kilpi et al., 2020), the present study takes in an in-depth look specifically targeting word-finding ability in fluency and naming tasks. Thus, the current findings shed light on how immediate and remote life course factors impact specific subdomains of word-finding after menopause, and how these factors shape multiple dimensions of word-finding that involve lexical processing and spoken language. This in turn has the potential to underpin powerful hypotheses for future research in order to predict, protect and support women's word-finding at mid and later life.

Despite the strengths, there were some limitations. Participants were primarily recruited from universities and/or social groups in England and had high levels of formal education. This limits the generalisability of findings to other populations such as women with lower levels of education, different ethnic, cultural or linguistic backgrounds, and thus, can be explored in future research. Information regarding reproductive factors was collected retrospectively via interviews which might have been affected by reporting or recall bias. The current study was a small-scale cross-sectional study and therefore limits the types of conclusions that one can draw from the sample in comparison to larger scale cohort studies (Kilpi et al., 2020).

The results presented in this paper were derived mainly from the construction and implementation of five omnibus ANCOVAs, followed by a subset of post hoc partial correlations based on significant main or interaction effects. The omnibus tests were designed specifically to reduce the complexity of the models by selecting covariates from the ten background, demographic, cognitive and reproductive variables based on the evidence from correlation patterns in Tables 2, 3, and 4. In this context, findings presented in the results were not adjusted for multiple comparisons. When Bonferroni-type corrections are applied as adjustments for within-comparison type 1 error rates, the post hoc partial correlations do not survive correction; i.e., p-values $<$ .005, .003, and .01 would be needed, respectively, to retain significance of the partial correlations for letter fluency and years of education (uncorrected p-value = .008), for 3-series rate and age (uncorrected p-value = .005), and for naming accuracy and years of education (uncorrected p-value = .034). It should be noted that such corrections assume independent contrasts and may overestimate what is required for adjusting across correlated measures (Bender & Lange, 2001).

Despite its limitations, this study has adequate statistical power, yielded a pattern of results that withstood sensitivity analysis via retesting a subset of women, and importantly, adds exploratory value in an under investigated area of research. Moreover, a degree of protection against type 1 errors was provided by way of the statistical design and by avoiding multiplicity of contrasts through the post hoc testing of only ANCOVA effects that met the $p < .05$ criterion (Cohen et al., 2003). Covariance models were used to reduce the error variance for the repeated measures testing which is another strength of the approach. The statistically significant effects reported in the results were associated with partial eta squared values between 9 and 13 %, which may be considered to reflect medium effect sizes (Cohen, 1977). This interpretation is consistent with the magnitude of the bivariate correlations and partial correlations that underpinned the ANCOVA models and supported its significant results (Cohen, 1992); although there is some variation in scientific opinion relating to partial eta squared as an estimator of effect size (Richardson, 2011). Overall, the evidence from the current study provides support for novel hypotheses and thereby clearly sets the direction for future research. However, additional data collection and replication would be required to yield confirmatory findings, particularly in light of the subset of ANCOVA effects that were supported by marginal statistical trends.

In conclusion, the present study indicates that while age-based changes in word-finding abilities in healthy postmenopausal women are detectable, they are complex, and shaped by educational and reproductive factors. Findings highlight a cognitive system that changes with advancing age, with sensitivity in particular measures of performance, and in relation to events that women experience at various stages across the life span. This study adds to a growing body of evidence in support of the view that verbal abilities in women are organised and continually developing in relation to a constellation of factors associated with their early (e.g., education), reproductive (e.g., age at menarche), and later years (e.g., number of reproductive years). Aspects of this research that address neurocognitive plasticity and reserve in relation to verbal ability are of particular importance for retaining quality of life in the social-communicative domain.

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CRediT authorship contribution statement

Ramya Maitreyee: Conceptualisation, Methodology, Formal analysis, Investigation, Data curation, Writing - Original draft preparation. **Rosemary Varley:** Conceptualisation, Methodology, Writing – Review and Editing. **Patricia E. Cowell:** Conceptualisation, Methodology, Formal analysis, Writing - Original draft preparation, Supervision.

Declaration of competing interest

None.

Data availability

The authors do not have permission to share data.

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Appendix A

Appendix Table 5
Results of the ANCOVAs for the five dependent variables are displayed as a function of within-subject (internal-to-task repeated measures and their interactions with covariates) and between-subject effects (covariates) (N = 53, unless otherwise specified). Partial eta squared values provided by SPSS GLM were computed using the formula: SSeffect / (SSeffect + SSerror), where the SSerror terms are defined, respectively, for the Within-subjects effects and for the Between-subjects effects. Statistically significant effects ($p < .05$) are highlighted in bold type.

Factor	Task				
	Verbal Fluency	Continuous series Switch rate	Continuous series Switch cost	Naming accuracy[a]	Naming latency[a]
Within-subject effects					
Task	$F(1, 47) = 1.07, p = .305, \eta_p^2 = 0.02$	$F(1.71, 80.17) = 1.56, p = .218, \eta_p^2 = 0.03$	$F(1.47, 69.26) = 1.96, p = .160, \eta_p^2 = 0.04$	$F(1, 45) = 0.11, p = .744, \eta_p^2 = 0.00$	$F(1, 45) = 0.83, p = .368, \eta_p^2 = 0.02$
Task × Age	$F(1, 47) = 3.43, p = .070, \eta_p^2 = 0.07$	$\boldsymbol{F(1.71, 80.17) = 5.03, p = .012, \eta_p^2 = 0.10}$	$F(1.47, 69.26) = 2.99, p = .072, \eta_p^2 = 0.06$	$F(1, 45) = 0.44, p = .511, \eta_p^2 = 0.01$	$F(1, 45) = 2.54, p = .118, \eta_p^2 = 0.05$
Task × Education	$\boldsymbol{F(1, 47) = 6.72, p = .013, \eta_p^2 = 0.13}$	$F(1.71, 80.17) = 2.64, p = .086, \eta_p^2 = 0.05$	$F(1.47, 69.26) = 0.96, p = .363, \eta_p^2 = 0.02$	$F(1, 45) = 0.56, p = .457, \eta_p^2 = 0.01$	$F(1, 45) = 0.18, p = .673, \eta_p^2 = 0.00$
Task × Vocabulary	$F(1, 47) = 1.54, p = .220, \eta_p^2 = 0.03$	$F(1.71, 80.17) = 0.65, p = .500, \eta_p^2 = 0.01$	$F(1.47, 69.26) = 0.29, p = .683, \eta_p^2 = 0.01$	$F(1, 45) = 0.01, p = .908, \eta_p^2 = 0.00$	$F(1, 45) = 0.36, p = .549, \eta_p^2 = 0.01$
Task × Age at menarche	$F(1, 47) = 2.09, p = .155, \eta_p^2 = 0.04$	$F(1.71, 80.17) = 0.13, p = .843\ \eta_p^2 = 0.00$	$F(1.47, 69.26) = 0.34, p = .648, \eta_p^2 = 0.01$	$F(1, 45) = 0.83, p = .367, \eta_p^2 = 0.02$	$F(1, 45) = 2.77, p = .103, \eta_p^2 = 0.06$
Task × Number of reproductive years	$F(1, 47) = 0.43, p = .517, \eta_p^2 = 0.009$	$F(1.71, 80.17) = 0.12, p = .853, \eta_p^2 = 0.00$	$F(1.47, 69.26) = 0.13, p = .812, \eta_p^2 = 0.00$	$F(1, 45) = 0.02, p = .904, \eta_p^2 = 0.00$	$F(1, 45) = 2.10, p = .155, \eta_p^2 = 0.04$
Between-subject effects (covariates)					
Age	$F(1, 47) = 0.05, p = .830, \eta_p^2 = 0.00$	$F(1, 47) = 1.65, p = .206, \eta_p^2 = 0.03$	$F(1, 47) = 0.36, p = .551, \eta_p^2 = 0.01$	$F(1, 45) = 0.86, p = .360, \eta_p^2 = 0.02$	$F(1, 45) = 1.90, p = .175, \eta_p^2 = 0.04$
Education	$F(1, 47) = 3.46, p = .069, \eta_p^2 = 0.07$	$F(1, 47) = 0.29, p = .592, \eta_p^2 = 0.01$	$F(1, 47) = 0.01, p = .941, \eta_p^2 = 0.00$	$\boldsymbol{F(1, 45) = 4.31, p = .044, \eta_p^2 = 0.09}$	$F(1, 45) = 0.56, p = .458, \eta_p^2 = 0.01$
Vocabulary	$\boldsymbol{F(1, 47) = 4.87, p = .032, \eta_p^2 = 0.09}$	$F(1, 47) = 2.99, p = .091, \eta_p^2 = 0.06$	$F(1, 47) = 0.03, p = .854, \eta_p^2 = 0.00$	$F(1, 45) = 1.97, p = .167, \eta_p^2 = 0.04$	$F(1, 45) = 0.57, p = .453, \eta_p^2 = 0.01$
Age at menarche	$F(1, 47) = 0.23, p = .633, \eta_p^2 = 0.01$	$F(1, 47) = 1.02, p = .317, \eta_p^2 = 0.02$	$F(1, 47) = 0.63, p = .433, \eta_p^2 = 0.01$	$F(1, 45) = 0.49, p = .489, \eta_p^2 = 0.01$	$F(1, 45) = 3.82, p = .057, \eta_p^2 = 0.08$
Number of reproductive years	$F(1, 47) = 0.65, p = .423, \eta_p^2 = 0.01$	$F(1, 47) = 0.01, p = .905, \eta_p^2 = 0.00$	$F(1, 47) = 0.80, p = .375, \eta_p^2 = 0.02$	$F(1, 45) = 3.15, p = .083, \eta_p^2 = 0.07$	$F(1, 45) = 0.05, p = .829, \eta_p^2 = 0.00$

[a] Due to technical reasons, data were missing from two participants for the auditory naming task and therefore, $n = 51$.

Appendix Table 6
Sensitivity comparison of ANCOVA results between the complete study sample (N = 53) and the subsample of women who reported never using HRT ($n = 45$). Findings that were not significant in the complete sample, but that yielded a significant effect in the subsample are designated in bold. Due to technical reasons, data were missing from two participants for the auditory naming task and therefore, [a]$n = 51$ for the complete sample and [b]$n = 44$ for the subsample.

ANCOVA model task	Statistical effect (in order of presentation in the results)	Complete study sample (N = 53 unless specified for missing values)	Subsample who never used HRT ($n = 45$ unless specified for missing values)
Semantic and letter verbal fluency	Task × Education	$F(1, 47) = 6.72, p = .013.$	$F(1, 39) = 3.90, p = .055.$
	Vocabulary	$F(1, 47) = 4.87, p = .032$	$F(1, 39) = 5.32, p = .027$
	Education	$F(1, 47) = 3.46, p = .069$	$F(1, 39) = 3.39, p = .073$
	Task × Age	$F(1, 47) = 3.43, p = .070$	$F(1, 39) = 2.33, p = .135$
C-series with 2-, 3-, 4-series switch rate	Switch Rate series × Age	$F(1.71, 80.17) = 5.03, p = .012$	$F(2, 78) = 6.16\ p = .003$
	Switch Rate series × Education	$F(1.71, 80.17) = 2.64, p = .086$	$F(2, 78) = 2.38, p = .099$
	WASI-vocab	$F(1, 47) = 2.99, p = .091$	$F(1, 39) = 5.27\ p = .027$
C-series with 2-, 3-, 4-series switch cost	Switch Cost series × Age	$F(1.47, 69.26) = 2.99, p = .072$	$F(1.46, 56.78) = 2.98, p = .074$
Picture and auditory naming accuracy ($n = 51$)[a] ($n = 44$)[b]	Education	[a]$F(1, 45) = 4.31, p = .044$	[b]$F(1, 38) = 4.73, p = .036$
	Reproductive years	[a]$F(1, 45) = 3.15, p = .083$	[b]$F(1, 38) = 5.80, p = .021$
	WASI-vocab	**[a]$\boldsymbol{F(1, 45) = 1.97, p = .167}$**	**[b]$\boldsymbol{F(1, 38) = 4.51, p = .040}$**
Picture and auditory naming latency ($n = 51$)[a] ($n = 44$)[b]	Age at menarche	[a]$F(1, 45) = 3.82, p = .057$	[b]$F(1, 38) = 5.44, p = .025$
	Task × Age	**[a]$\boldsymbol{F(1, 45) = 2.54, p = .118}$**	**[b]$\boldsymbol{F(1, 38) = 4.36, p = .044}$**

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