The Open Psychology Journal
DOI: 10.2174/0118743501354793241220043615, 2025, 18, e18743501354793

ISSN: 1874-3501
1

RESEARCH ARTICLE

OPEN ACCESS

Effects of Normal Cognitive Aging on Spoken Word Frequency: Older Adults Exhibit Higher Function Word Frequency and Lower Content Word Frequency than Young Adults

Erin Burke[1,*], Karlee Patrick[1], Phillip Hamrick[1] and John Gunstad[1]

[1]Department of Psychological Sciences, Kent State University, Kent, OH, USA

Abstract:

Background: Recent work indicates that word frequency (WF), broadly defined as an estimate of how often a given word is produced during spontaneous speech, has been shown to be a sensitive marker for conditions like mild cognitive impairment (MCI) and Alzheimer's disease (AD). WF has been linked to cognitive declines observed in these groups. However, it is largely unknown how WF for distinct word classes change as part of normative cognitive aging, and to what extent factors like education and life experience may protect against age-related cognitive decline.

Objective: The current study examined WF and its association with cognitive test performance in older and younger adults. Higher WF values indicate the use of more common, higher frequently used words that are more readily retrieved from the lexicon, whereas lower WF values indicate the use of less common, lower frequency words.

Methods: Expository speech transcripts of 70 older and 130 younger adults were analyzed. Subject-level WF indices were computed for all words (AWs), content words (CWs) and function words (FWs). Between-group differences in WF and neuropsychological test performance were examined using independent samples t-tests and associations between WF and cognitive performance were evaluated with Pearson correlations. Follow-up analyses clarified the possible contribution of education.

Results: Higher average AW and CW frequency was observed in younger adults and higher AW frequency was associated with poorer performance on a test of mental reasoning (Cognitive Estimation Test). Though small, differences between age groups remained significant after accounting for education levels.

Conclusion: The current results show generally preserved WF in older adults and suggest that healthy cognitive aging and formal education do not drive the age-related changes in WF found in other studies. If replicated, such findings suggest that a shift from lower to higher frequency words in the spontaneous speech of older adults may be a marker of early neuropathological changes rather than normative cognitive aging and that the specific pattern may be influenced by sociocultural factors like language exposure and life experience. Future studies examining changes in lexical retrieval with advancing age will help clarify the impact of normative cognitive aging on WF indices and the extent to which analysis of spontaneous speech may help with early detection for conditions like MCI and AD.

Keywords: Cognitive aging, Speech, Language, Word frequency, Alzheimer's disease, Mild cognitive impairment.

*Address correspondence to this author at the Department of Psychological Sciences, 600 Hilltop Drive, Kent Hall, Kent State University, Kent, OH 44240, USA; Tel: 330-672-2589; Fax: 330-672-3786; E-mail: eburke14@kent.edu

Cite as: Burke E, Patrick K, Hamrick P, Gunstad J. Effects of Normal Cognitive Aging on Spoken Word Frequency: Older Adults Exhibit Higher Function Word Frequency and Lower Content Word Frequency than Young Adults. Open Psychol J, 2025; 18: e18743501354793. http://dx.doi.org/10.2174/0118743501354793241220043615

Received: September 01, 2024
Revised: November 26, 2024
Accepted: November 27, 2024
Published: January 10, 2025

1. INTRODUCTION

1.1. Cognitive Changes in Healthy Aging

The aging process is associated with normative brain alterations and well-characterized patterns of cognitive change [1-4], which include declines in fluid intelligence [5]. Specifically, cognitive aging in the absence of neurodegenerative conditions (such as Alzheimer's disease or vascular dementia) is most typically associated with diminished fluid abilities such as executive functioning, episodic memory, and processing speed [6-8], and preservation of crystallized aspects of cognition in the context of aging [2, 5, 9-11]. These crystalized abilities include vocabulary knowledge, mathematical abilities, knowledge of general information, or ability to carry out specific skills, all of which reflect applied knowledge acquired over a lifetime. In many cases, the preservation of crystallized aspects of cognitive function may help to compensate for declines in fluid abilities [12, 13]. For example, having greater domain-specific knowledge can assist in the successful completion of day-to-day activities that would otherwise require problem solving or new processing [14]. In effect, although age-related patterns suggest older adults may process information more slowly, performance for many activities may remain intact through use of strategies learned from experience and practice [15].

1.2. Spontaneous Speech across Healthy Aging

Though these patterns of normative cognitive aging are well-documented [16, 17], much less is known about how they influence changes in spontaneous speech, the unscripted, unrehearsed, spoken utterances that are naturally-occurring during verbal communication [18]. Older adults (OAs) exhibit word-finding difficulty (*i.e.*, less effective lexical retrieval) and dysfluencies related to declines in executive function and processing speed [19-22] in spoken discourse, which can lead to reliance on compensatory communicative strategies (*e.g.*, circumlocutions) [23]. Such changes are reflected in spontaneous speech that is characterized by an increased number of pauses and repetitions (*i.e.*, slower speech rate), production of fewer words overall, difficulty staying on topic, and even impoverished speech [2, 24-27]. However, in contrast to these declines, OAs also simultaneously exhibit preserved vocabulary [28-30], use of syntax [31], and lexical-semantic knowledge [32-34]. This selective preservation of speech function has been attributed to compensatory processes, as a combination of educational attainment, language-related experiences, and learned strategies over time [5, 35, 36] buffer the impact of cognitive decline, suggesting that crystalized abilities may compensate for reduced fluid abilities and obscure early signs of MCI or dementia [37].

1.3. Exploring Lexical-semantic Aspects of Spontaneous Speech: Word Frequency

Recent work has shown that lexical-semantic aspects of spontaneous speech can be quantified using automated detection tools to identify conditions like mild cognitive impairment (MCI) [38-42] and Alzheimer's disease (AD) [43]. An especially important feature of such speech is word frequency (WF): the degree to which individuals use common, high-frequency words rather than less-common, lower frequency words [25, 44-47]. Referred to as the "Word Frequency Effect," higher frequency words are generally easier to recognize, access, retrieve, and process than lower frequency words [44, 48-50]. WF is often used as an index in word recognition, naming, and lexical decision paradigms [46, 51-54], reflecting factors such as an individuals' vocabulary size, language exposure, and mental lexicon [44]. However, these WF metrics are often dated [55] and have rarely been used to investigate speech changes associated with healthy cognitive aging at the word class level. This warrants further exploration of the intersectionality between lexical retrieval and cognitive functioning in aging samples across WF indices derived from regularly updated word corpora such as the Corpus of Contemporary American English (COCA).

Initial studies suggest that WF may be sensitive to age-related cognitive changes [56, 57]. However, the known declines in fluid cognitive abilities and relative stability of crystalized cognitive abilities would predict different trajectories for WF. On one hand, WF relies on crystalized aspects of language (*e.g.*, vocabulary, general knowledge), which grows in early life and becomes relatively stable in later adulthood [30, 44, 58] suggesting that WF would remain stable. Consistent with this possibility, initial studies show that OAs use lower frequency words (*i.e.*, less common, more specific words) in speech compared to younger adults, perhaps due to the accumulation of knowledge over a lifetime [32, 59-61]. In contrast, other studies show OAs may be more likely to use higher frequency words that would require less cognitive burden [56, 57, 62] associated with declines in fluid cognitive abilities like executive function. These findings raise the question whether WF would decline, remain stable, or even improve in the context of normal cognitive aging. Clarifying WF patterns among different word classes may further address this question regarding the impact of fluid and crystallized abilities.

1.4. Specific Word Classes

Although WF appears to be a promising speech feature that may be sensitive to cognitive changes, not all words have the same kinds of WF characteristics. While words may vary in their estimated WF, certain kinds of words are consistently high in frequency. For example, function words (FWs), also known as "closed class" words as there are only so many to choose from, vary in their frequency, but are generally very high frequency. On the other hand, content words (CWs), also known as "open class" words as new learning and exposure grows the lexicon, vary in their frequency, too, but much more widely, with some being very high frequency and others being exceptionally rare. In addition to determining the effect of healthy aging on WF generally, research is also needed to better understand potential changes in specific word subcategories related to normative cognitive aging [63].

FWs serve grammatical and structural purposes, such as linking sentences together (*e.g.*, prepositions, articles, conjunctions, pronouns, auxiliary verbs), and are not based in conceptual semantic representations [64-66]. FWs are more automatically accessed and typically maintained across the course of aging [67], perhaps because they are overlearned and do not require extensive searching within the semantic network. In fact, OAs may rely more heavily on FWs to maintain fluency in conversation and compensate for difficulties retrieving semantically dense CWs, which could lead to the expression of less specific ideas or a shift in topic focus [65]. CWs carry specific information and semantic meaning (*e.g.*, nouns, verbs, adjectives, adverbs) and tap into vocabulary complexity [64]. Past work has shown that OAs may use fewer content words than YAs, which could be partly attributable to cognitive changes that lead to difficulties with processing speed, memory, or lexical retrieval (*i.e.*, naming) from the semantic network [21].

Disruption in speech-related function manifests differently in function *vs*. content words [68, 69], which may partly reflect their differential distribution patterns throughout the brain as alluded to in early work [66, 70]. For instance, FW use is relatively preserved early in MCI and AD, perhaps owing to its greater localization [66, 71]. In contrast, average CW frequency is distinguishable between healthy controls and persons with MCI and AD [72]. This is consistent with semantically-richer words being broadly distributed in brain areas including temporal regions disrupted early in the course of AD [73, 74]. This notion may also help to explain the differences in FW and CW frequency observed across neurological conditions with differential impact on subcortical *vs*. cortical structures (*e.g.*, AD *vs*. Parkinson's disease) [75-77].

Despite its scientific and applied value, no study to date has examined the possible differential effects of normative cognitive aging on FW and CW in spontaneous speech. Such findings have the potential to provide new insight into the neurocognitive processes that mediate word choice during spontaneous speech and the extent to which changes in FW or CW frequency reflect normal *vs*. pathological cognitive aging.

1.5. Present Study

This study has two primary goals: 1) assess group differences between healthy younger adults (YAs) and older adults (OAs) on variables of spoken WF and 2) examine the extent to which spoken WF is associated with cognitive test performance. Based on established models that delineate more language experiences gathered over the lifespan refine the language system and mental lexicon [78, 79], it was hypothesized that OAs would produce words that are on average lower frequency (*i.e.*, less common) compared to YAs. Given mixed findings in existing work regarding differential properties between FWs and CWs [66, 68, 80], we expected differences to emerge as a function of these WF values within age groups. If confirmed, these findings would suggest that differences in WF between healthy older and younger adults reflect changes in retrieval processes during spontaneous speech due to normative cognitive aging and any significant associations with cognitive test performance would identify possible mechanisms for these changes.

2. METHODS

2.1. Participants

A total of 202 YAs (aged 18-23) and 116 community-dwelling OAs (aged 55-88) completed a remotely-administered cognitive test battery as part of a larger project. To be eligible, individuals had to meet the following criteria: age within specified ranges (YAs 18-25, OAs ≥ 55), be able to speak/read English, and have sufficient internet access to complete testing. Exclusion criteria included the self-reported presence of diagnosed memory disorder, stroke, or traumatic brain injury, current or past diagnosis of a severe psychiatric condition (*e.g.*, schizophrenia, bipolar disorder), or reported gender as “other” to permit group comparisons and standardized score calculation as part of the larger project. To promote generalizability, individuals were not excluded on the basis of self-reported elevations in anxiety or depression scores, as there is no strong evidence from previous work that these conditions impact lexical processes and their prevalence is high in otherwise healthy samples [81, 82].

Potential participants for the current study were further excluded if the audio of spoken responses was undetectable due to poor video quality or insufficient data was collected due to experimenter error (*e.g.*, the standardized administration protocol was not followed properly). Consistent with conventions in neuropsychological research, participants were also excluded if they exhibited questionable effort or engagement during testing, as this would lead to cognitive test scores not reflecting their true abilities. Poor cognitive effort was operationalized as falling below threshold on the Reliable Digit Span index (*i.e.*, ≤7, calculated by summing the longest raw string forwards and backwards of which both trials were correct) [83, 84]. Exclusion due to technical issues, experimental error, and poor effort (total excluded: n=72 YAs; n=46 OAs) produced a final sample of 130 YAs (aged 18-22) and 70 OAs (aged 55-88) to be examined in primary analyses (N=200). Notably, excluded participants did not differ (all $p > .05$) from those retained in demographic variables (*i.e.*, age, education, sex, race, ethnicity), suggesting these activities did not introduce selection bias.

2.2. Measures

2.2.1. Demographic and Medical Characteristics

Participants self-reported demographic and medical information, including age, race, ethnicity, gender, education and current and past medical history.

2.3. Assessment of Speech

2.3.1. Expository Speech Task

As part of a remotely administered test battery, participants were asked to respond to an expository speech prompt. Specifically, participants were asked to identify the four most important people in their life and were then prompted by the examiner to discuss the second person listed for at least two minutes. Participants were asked to consider the following questions prior to their response*: “What is [important person] like as a person? Why is he/she important to you? What about them impresses you? How has he/she influenced who you are as a person? And, if you could change one thing about yourself to be more like [important person], what would it be?”* Only initial responses were analyzed for the current study to promote standardization (*i.e.*, utterances following examiner prompting were not included).

2.3.2. Calculating Speech Indices

Recorded speech samples were manually transcribed by trained research staff. Initial transcriptions were reviewed by an additional research assistant, and these were compared and checked for accuracy a third time by the first author. Consensus for each transcription was achieved. Only task-relevant speech was transcribed to reduce potential noise in WF values introduced by speech that does not address the prompt. For example, fillers such as “uh,” “umm,” or “you know,” (transcribed as “filler”), speech unrelated to the prompt (*e.g.*, “that would be it I guess…,”), and meta-conversations (*e.g.*, “like I told you before…,” or “you’re going to make me cry…”) were not transcribed. Omission of “filler” instances from transcription appears justified and allows for the refining of WF value accuracy, as filler words do not significantly contribute to the overall lexical interpretation of transcripts, are not associated with WF [45, 85], and are excluded from transcript calculations in past studies of spontaneous speech in neurological samples [86, 87].

WF indices for AWs (all words), CWs (content words), and FWs (function words) were extracted from the COCA spoken corpus [88]. A WF value was computed for each participant as the mean WF computed across all task-relevant words that the participant produced. The COCA spoken corpus (*i.e.*, a word database created from a collection of texts of unscripted conversation from radio programs and television shows) was selected as it is dynamic (*i.e.*, last updated in March 2020) and the current study utilizes transcripts from spontaneous speech samples, whereas other COCA sub-corpora utilize text from academic journals, magazines, or newspapers. Consistent with past work, log-transformed WF values were used in the current study to reduce the undue influence of high-frequency words on the distribution [89-92].

2.4. Neuropsychological Test Battery

A brief neuropsychological test battery was administered remotely through Microsoft Teams teleconferencing to assess cognitive function using commonly administered measures known to be valid through this modality. Raw, uncorrected test scores were used for the current analyses to facilitate comparison across age groups. These were gathered from the following measures within the following cognitive domains: a) Oral Trail Making Test A (OTMTA [93]) and Digit Span Forward (DSF [94]) (attention); b) Oral Trail Making Test B (OTMTB [93]), Cognitive Estimation Test (CET [95]), Digit Span Backward (DSB [94]), and Digit Span Sequencing (DSS [94]) (executive function); c) Craft Story-21 (CS-21 immediate and delayed verbatim recall [96] (episodic memory) and d) Animal/Vegetable and CFL Letter Fluency [7, 97] (language). MCI status was defined as having two test performances $\geq$1 SD below the mean within a single cognitive domain in accordance with past work [98].

2.5. Procedure

YAs self-selected to participate *via* an online research platform as part of their educational experience and OAs were recruited through a combination of an existing repository of persons who indicated interest in research participation, as well as new sign-ups following a talk given to a local senior living community. After providing consent, participants completed a recorded 60-minute videoconference session on Microsoft Teams consisting of neuropsychological testing, questionnaires, and speech tasks. Recordings of the speech tasks were extracted and reviewed for transcription and analysis. Participants were compensated for their time upon completion of study activities. YAs were provided academic research credits and OAs were compensated with a $25 gift card. All procedures were approved by the Kent State University Institutional Review Board (IRB#: 20-300).

2.6. Analytic Strategy

All analyses were performed in SPSS version 29.0.1.0 (171) and R version 2023.03.0 (Build 386). T tests compared YAs and OAs on WF indices and raw cognitive test performance to identify between-group differences. Pearson correlations determined whether WF indices were negatively associated with raw cognitive test performance among the whole sample and within each group. To mitigate risk of Type I error, p values were corrected for multiple comparisons using the widely used Benjamini-Hochberg method [99, 100]. This method was chosen as it is empirically validated, relatively conservative, and ideal for exploratory analyses with small associations [101], but still reduces risk of Type II error compared to some other corrections for multiple comparisons. For instance, Benjamini-Hochberg methods are often preferred and preserve more statistical power than other options such as Bonferroni methods [102]. Also, Benjamini-Hochberg methods are commonly used in past work examining lexical indices such as WF [42]. Regression analyses explored whether raw cognitive test scores predicted WF. Finally, a post-hoc ANCOVA was conducted to determine whether between-group differences remained significant after controlling for education.

3. RESULTS

3.1. Preliminary Analyses

Raw neuropsychological test scores were normally distributed with the exception of OTMTB (which was positively skewed and had skewness and kurtosis values greater than 2 and 7, respectively). However, this pattern is consistent with the distributions found in a normative dataset for this task and thus was not transformed [103]. Log transformed WF indices were normally distributed for CW, but not AW and FW. To avoid further modification of the already log-transformed COCA spoken WF indices, these were not transformed. This non-normal distribution is to be expected considering the higher frequency of both common words and FWs in spoken language and was considered during the interpretation of study findings.

3.2. Primary Analyses

3.2.1. Group Characteristics

On average, the YA group was less educated, t(84.36) = 9.17, $p < .001$, more racially diverse, $X2$ (1) = 17.478, $p < .001$, and performed worse on measures of executive function (CET: t(198) = -6.2, $p < .001$; DSB: t(198) = 2.82, $p = .005$), episodic memory (CS-21, immediate recall: t(198) = 2.36, $p = .019$) and language (vegetable fluency: t(116.36) = 7.69, $p < .001$; CFL letter fluency: t(198) = 5.48, $p < .001$) than OAs (Table **1**).

3.2.2. Group WF

YA exhibited higher average WF values than OAs for AWs, t(104.67) = -4.23, $p < .001$, $d = .67$, and CWs, t(116.41) = -5.23, $p < .001$, $d = .77$, whereas OAs had higher average FW frequency, t(198) = 2.22, $p = .028$, $d = .34$. Group-level variances were unequal regarding AWs and CWs (as indicated by Levene's test $p < .05$), though this did not impact overall interpretation (Table **1**).

3.2.3. WF Associations with Raw Cognitive Test Performance

AW frequency showed a significant correlation with raw performance on a test of executive function (CET, r = .20, $p = .004$). Because lower CET scores represent better cognitive performance, this correlation represents a negative relationship, whereby poorer CET performance was associated with higher WF (Table **2**). This effect size was small.

Regarding group level associations, YA AW frequency was significantly associated with performance on a test of attention (Digit Span Forward; $r = -.18$, $p = 0.036$). OA AW frequency was also significantly associated with Digit Span Forward ($r = .26$, $p = 0.027$) as well as a test of episodic memory (Craft Story Immediate Recall; $r = .27$, $p = 0.027$). OA CW frequency was significantly associated with Craft Story Immediate Recall ($r = .27$, $p = 0.025$). There were no significant associations with FWs within either group.

Table 1. Characteristics of older and younger adults.

Characteristics	Older Adults (n=70)	Young Adults (n=130)	Test
Demographic			
Age (M +/ SD)	69.33 +/ 7.16	19.47 +/ 1.37	t(71.73) = 57.66, $p < .001$
Education (years) (M +/ SD)	15.97 +/ 2.55	13.03 +/ 1.15	t(84.36) = 9.17, $p < .001$
Sex (% male)	37.1% (26)	26.2% (34)	$X2$ (1) = 2.62, $p = .106$
Race (% nonwhite)	3% (2)	27% (35)	$X2$ (1) = 17.48, $p < .001$
Ethnicity (Hispanic/Latino)	1.4% (1)	2.3% (3)	$X2$ (1) = .179, $p = .672$
Word Frequency Indices (M +/ SD)			
All Words*	2.88 +/ 0.28	3.04 +/ 0.19	t(104.67) = 4.23, $p < .001$
Content Words*	2.21 +/ 0.3	2.42 +/ 0.24	t(116.41) = 5.23, $p < .001$
Function Words*	3.88 +/ 0.12	3.79 +/ 0.35	t(198) = 2.22, $p = .028$
Cognitive Performance (M +/ SD)			
Executive Function			
Oral Trails B	30.93 +/ 34.16	40.74 +/ 33.87	t(198) = 1.95, $p = .053$
Cognitive Estimation Test*	4.03 +/ 1.98	6.14 +/ 2.45	t(198) = 6.20, $p < .001$
Digit Span Backward*	9.4 +/ 2.08	8.58 +/ 1.88	t(198) = 2.82, $p = .005$
Digit Span Sequencing	9.11 +/ 1.76	9.08 +/ 2.33	t(198) = 0.09, $p = .926$
Attention			
Oral Trails A	8.64 +/ 2.59	9.06 +/ 2.5	t(198) = 1.12, $p = .266$
Digit Span Forward	10.63 +/ 1.94	10.05 +/ 1.89	t(198) = 2.03, $p = .044$
Episodic Memory			
Craft Story 21 Immediate*	21.21 +/ 5.36	19.13 +/ 6.25	t(198) = 2.36, $p = .019$
Craft Story 21 Delay	17.77 +/ 5.32	17.11 +/ 5.95	t(198) = 0.78, $p = .436$
Language			
Animal Fluency	23.07 +/ 5.02	22.83 +/ 4.91	t(198) = 0.33, $p = .743$
Vegetable Fluency*	15.41 +/ 4.35	10.79 +/ 3.44	t(116.36) = 7.69, $p < .001$
CFL Letter Fluency*	45.13 +/ 10.67	37.08 +/ 9.48	t(198) = 5.48, $p < .001$

Note: *=significance remains after controlling for multiple comparisons using the BenjaminiHochberg method.

3.2.4. Predictors of WF

Multiple regression analyses were used to predict WF averages using raw scores from cognitive testing.

3.2.4.1. AW Frequency

For AW frequency, raw cognitive test scores were a significant predictor and accounted for 12% of the variability, $F(11, 188) = 2.23$, $p = .014$, $R^2 = 0.116$. Specifically, CET (β = 0.20. $p = .006$) and Vegetable fluency (β = -0.16, $p = .047$) emerged as significant predictors of AW, with DSS trending toward significance (β = 0.15, $p = .051$). All effect sizes were small (Table **3**).

3.2.4.2. CW Frequency

For CW frequency, raw cognitive test scores were a significant predictor and accounted for 10% of the variability, $F(11, 188) = 1.981$, $p = .032$, $R^2 = 0.104$. Vegetable fluency was the only significant predictor (β = -0.20, $p = .015$), with DSS (β = 0.15, $p = .051$) and CET (β = 0.14, $p = .056$) trending toward significance. All effect sizes were small (Table **4**).

3.2.4.3. FW Frequency

Raw cognitive performance did not predict FW frequency, and only accounted for 3% of the variability, $F(11, 188) = .514$, $p = .893$, $R^2 = 0.029$).

3.3. Post-hoc Analyses

3.3.1. Examining the Potential Impact of Education on Between Group Differences

Pearson correlations showed that years of education significantly correlated with all WF variables (AWs: $r = -.193$, $p = .006$; CWs: $r = -.210$, $p = .003$; FWs: $r = .161$, $p = .023$). Using ANCOVA controlling for education, the main effects showing differences between age groups (*i.e.*, YAs *vs*. OAs) remained significant for the following

Table 2. Pearson correlations between word frequency and cognitive performance (N=200).

			Word Frequency			
	All Words		Content Words		Function Words	
Cognitive Performance	*r*	*p*	*r*	*p*	*r*	*p*
Oral Trails B	0.07	.322	0.07	.324	-0.03	.651
Cognitive Estimation Test	0.20	.004*	0.16	.026	-0.05	.499
Digit Span Backward	-0.09	.232	-0.06	.433	0.00	.965
Digit Span Sequencing	0.10	.143	0.11	.124	-0.01	.913
Oral Trails A	0.10	.147	0.09	.195	-0.03	.651
Digit Span Forward	-0.03	.658	-0.04	.533	-0.05	.485
Craft Story 21 Imm.	0.07	.346	0.06	.412	-0.04	.605
Craft Story 21 Delay	0.02	.777	0.01	.920	0.02	.765
Animal Fluency	0.02	.804	0.04	.558	-0.08	.241
Vegetable Fluency	-0.15	.033	-0.17	.014	0.01	.918
CFL Letter Fluency	-0.03	.685	-0.06	.429	0.01	.905

Note: *=significance remains after controlling for multiple comparisons using the Benjamini-Hochberg method.

Table 3. Regression analysis summary for cognitive measures predicting all word frequency (N=200).

Predictors	R^2	R^2 Change	Sig. F Change	B	SE	β	*p*	95% CI
Cognitive Variables	0.116	0.116	0.014					
(Constant)				2.665	0.172		<.001	2.326 to 3.005
Oral Trails B				0.000	0.001	0.042	.560	-0.001 to 0.001
Cognitive Estimation Test				0.019	0.007	0.203	.006	0.006 to 0.033
Digit Span Backward				-0.015	0.010	-0.127	.117	-0.035 to 0.004
Digit Span Sequencing				0.017	0.009	0.152	.051	0.000 to 0.034
Oral Trails A				0.011	0.007	0.111	.134	-0.003 to 0.024
Digit Span Forward				0.001	0.010	0.008	.921	-0.019 to 0.021
Craft Story 21 Imm.				0.008	0.005	0.193	.158	-0.003 to 0.018
Craft Story 21 Delay				-0.006	0.006	-0.141	.288	-0.017 to 0.005
Animal Fluency				0.003	0.004	0.065	.405	-0.004 to 0.011
Vegetable Fluency				-0.009	0.004	-0.163	.047	-0.018 to 0.000
CFL Letter Fluency				0.002	0.002	0.077	.376	-0.002 to 0.006

Table 4. Regression analysis summary for cognitive measures predicting content word frequency (N=200).

Predictors	R^2	R^2 Change	Sig. F Change	B	SE	β	*p*	95% CI
Cognitive Variables	0.104	0.104	0.032					
(Constant)				2.074	0.201	-	<.001	1.677 to 2.470
Oral Trails B				0.000	0.001	0.040	.579	-0.001 to 0.001
Cognitive Estimation Test				0.016	0.008	0.140	.056	0.000 to 0.032
Digit Span Backward				-0.011	0.011	-0.075	.356	-0.033 to 0.012
Digit Span Sequencing				0.020	0.010	0.154	.051	0.000 to 0.040
Oral Trails A				0.009	0.008	0.078	.299	-0.008 to 0.025
Digit Span Forward				-0.004	0.012	-0.030	.715	-0.028 to 0.019
Craft Story 21 Imm.				0.010	0.006	0.215	.117	-0.003 to 0.022
Craft Story 21 Delay				-0.009	0.006	-0.176	.187	-0.021 to 0.004
Animal Fluency				0.006	0.004	0.115	.148	-0.002 to 0.015
Vegetable Fluency				-0.013	0.005	-0.201	.015	-0.023 to -0.002
CFL Letter Fluency				0.000	0.002	0.019	.829	-0.004 to 0.005

Table 5. Post-hoc ANCOVA exploring the impact of education on between group differences (N=200).

Covariate = Education on OA *vs* YA	Edu *F*	Edu *p*	*SS*	*df*	*MS*	*F*	*p value*
All Words (AWs)	0.011	0.917	0.734	1	0.734	13.991	< .001
Content Words (CWs)	0.159	0.690	1.446	1	1.446	21.352	<.001
Function Words (FWs)	1.363	0.244	0.086	1	0.086	1.017	0.315
Oral Trails B	4.838	0.029	30.438	1	30.438	0.027	0.870
Cognitive Estimation Test	0.064	0.8	115.782	1	115.782	21.866	<.001
Digit Span Backward	0.344	0.558	12.850	1	12.850	3.371	0.068
Digit Span Sequencing	0.221	0.639	0.619	1	0.619	0.134	0.715
Oral Trails A	1.797	0.182	18.597	1	18.597	2.923	0.089
Digit Span Forward	0.323	0.570	5.530	1	5.530	1.509	0.221
Craft Story 21 Imm.	1.652	0.200	38.680	1	38.680	1.094	0.297
Craft Story 21 Delay	4.477	0.036	16.054	1	16.054	0.496	0.482
Animal Fluency	0.255	0.614	8.005	1	8.005	0.326	0.569
Vegetable Fluency	0.264	0.608	654.418	1	654.418	45.610	<.001
CFL Letter Fluency	0.011	0.916	1854.571	1	1854.571	18.787	<.001

Note: Edu *F*= *F* statistic for education effects alone, Edu *p*= *p* value for education effects alone; Group effects: *SS*= sum of squares, *df*= degrees of freedom, *MS*= mean square, *F*= *F* statistic, *p value*= significance level.

variables: AWs, $F(1,197) = 13.99$, $p < .001$, $\eta^2 = .07$; CWs, $F(1,197) = 21.35$, $p < .001$, $\eta^2 = .10$; CET, $F(1,197) = 21.87$, $p < .001$, $\eta^2 = .10$; Vegetable Fluency, $F(1,197) = 45.61$, $p < .001$, $\eta^2 = .19$; and CFL Fluency, $F(1,197) = 18.79$, $p < .001$, $\eta^2 = .09$. Regarding FWs, the main effect for age group was no longer significant after controlling for education, $F(1,197) = 1.02$, $p = .315$, $\eta^2 = .01$ (Table 5).

4. DISCUSSION

4.1. Summary of Study Findings

The current study examined indices of spoken WF and neuropsychological test performance in a sample of healthy younger and older adults. Analyses revealed higher AW and CW frequencies in young adults compared to older adults and these indices were associated with poorer performance on a test of executive function. Follow-up analyses revealed education did not account for all of these findings.

4.2. Differences in WF between YAs and OAs

Based on past work, it was hypothesized that healthy OAs would produce speech containing words that are less common and thus on average lower frequency than YAs [59-61] given the known protective effects of greater life experience, education, and exposure to words that maintain vocabulary, expand the mental lexicon with generally lower frequency words, and underlie WF [30, 104, 105]. This hypothesis was partially supported. Finding higher average WF for AWs and CWs in YAs is consistent with these hypotheses and previous WF research [32], suggesting that lifelong learning and verbal experiences may play a key role in sustaining the mental lexicon and shaping uncommon lexical-semantic decisions in speech.

However, OAs exhibited higher average FW frequency than YAs and the exact explanation for this inconsistent pattern across WF indices is unclear. One possibility is that the higher average FW frequency in OAs is due to increased reliance on more accessible, non-content words due to other speech difficulties that can arise with age (*e.g.*, staying on topic, maintaining the flow of speech) [106]. This pattern could reflect the utilization of FWs as a compensatory mechanism when more specific content words are sought but not easily accessible or retrievable (*e.g.*, FWs function as the “cement” that link CWs together [65]). However, OAs in the current sample used lower frequency CWs and performed better on most neuropsychological tests of language functioning compared to YAs (*i.e.*, vegetable fluency, CFL), arguing against the need for frequent compensatory strategy use. An alternative explanation is that FWs leverage different neural processes than the more semantically-dense CWs. Broadly, FWs appear to be more left-hemisphere lateralized within the language network, whereas CW representations are bilaterally distributed across the neocortex [66], suggesting separability in the lexicon and differential lexical-semantic processing for words not rooted in semantic meaning. Indeed, processing conceptual-semantic information associated with CWs may actually involve the medial temporal lobe structures [107], which are also impacted in OAs. As there are relatively few “closed class” FWs to choose from, it is also possible that higher FW frequency in OAs reflects more developed and efficient grammatical processing abilities [108]. This limited set of higher frequency words may be more readily accessible in OAs with more language exposure, the utilization of these words becoming more efficient in spontaneous speech with aging [79]. This, coupled with their lower CW frequency, suggests OAs likely have richer linguistic systems in which they are more grammatically complete and know rarer words. Further, it is thought that OAs rely more heavily on automatic bottom-up processes during lexical access [109], which could explain why FW frequency is higher if they are often processed more readily than CWs [67]. Future studies are needed to clarify these and other possible explanations for the pattern of age effects found across WF indices.

4.3. Association between Word Frequency and the Cognitive Estimation Test

It was hypothesized that WF would be associated with cognitive performance as language production (*e.g.*, word choice) requires the coordination of multiple cognitive abilities, including executive function and various memory processes [52, 56, 110]. We expected a differential pattern between specific word classes to emerge across age groups based on their distinctions observed in past work [66, 68, 79, 80].

Correlation analyses showed that poorer performance on a measure of reasoning and mental estimation (*i.e.*, CET) was associated with higher average WF (AWs). Regression analyses also showed that CET was the strongest predictor of AW frequency and trended toward significance for CWs, consistent with the notion that the correlation with CWs disappeared after correcting for multiple comparisons. Finding a significant association between CET and WF – but not other measures of executive function – is somewhat unexpected. Past work suggests that CET may not exclusively measure executive functioning, but instead tap into multiple domains of cognition, including crystallized abilities closely tied to life experience [111, 112]. Recent cognitive aging research suggests cumulative experiences develop one’s knowledge structure [13, 113], so it is possible that less life experience may limit knowledge representations (contributing to worse CET performance) and restrict access to less common words in the YA group. No other neuropsychological task in the current study requires engagement with knowledge of this nature, which may explain why this association was not found in any other measure. However, the effects were small, suggesting that external factors (*e.g.*, life experience) may drive this observed relationship with WF [114], rather than the specific mechanisms engaged during the CET. As such, future work must continue to account for individual differences across participants.

Other measures of executive function in the current study included commonly used instruments of working memory (DSB, DSS) and set-shifting (OTMTB) and these abilities have been associated with WF in past work [52]. Given these tasks recruit similar neuroanatomical regions and cognitive processes as the CET, it is unclear why performance on these measures were not also associated with WF. Past work shows that executive functions are highly related with many aspects of the language system that underlie WF [115], so our results may reflect a muddying of these processes. Further, our results may not detect the neural compensation that can allow for the maintenance of overall levels of cognitive function in OAs [116], or their association with lexical retrieval abilities. Future studies are needed to clarify these findings, as well as the better performance on the CET in OAs compared to YAs (which is counter to typical patterns of declining executive function with advancing age) [5, 117] that may relate to increased life experience.

4.4. Association between Word Frequency and Cognitive Performance within Age Groups

Findings for the association between WF and cognitive test performance within age groups were generally consistent with past work [16]. Within younger and older adult groups, higher AW frequency was significantly associated with better performance on a measure of attention (*i.e.*, Digit Span Forward), aligning with the importance of attention systems in word retrieval [118]. In OAs, better performance on a measure of immediate episodic memory was also correlated with higher AW and CW frequency. It is possible that, similar to higher frequency words being more accessible, repeating a story that was just heard also taps into mechanisms involved in retrieving information from readily available storage [52]. Again, these effects were not large (potentially reflecting that WF is mediated by multiple cognitive abilities and no specific cognitive ability drives WF [115]) and will need to be explored in future work among specific age brackets.

4.5. Lack of Association between WF and Performance on Other Cognitive Tests

The lack of association between FWs and performance on any cognitive test across the full sample and within groups could reflect several possibilities. Some past work shows that FWs are minimally related to test performance as their use engages fewer cognitive resources [65, 69]. For instance, if the semantic representations of CWs cannot be accessed efficiently during speech, FWs may instead be sought as a compensatory mechanism because they are much more readily available and do not require additional cognitive resources associated with lexical search and retrieval (*i.e.*, FWs are likely overlearned and more automatically processed) [65, 67, 116]. This automaticity of FW generation may explain why minimal correlations with other cognitive tests arose. However, as OAs still had better verbal fluency and lower AW and CW frequency than YAs, it is also possible that our findings may be a result of the range of FWs, perhaps driven by their inherently higher frequency, structural/grammatical role, and independence from vocabulary complexity, semantic meaning, experience, and language exposure [64, 104].

It is also possible that small effect sizes and the general lack of association between cognitive tests and WF indices in the current study reflect the notion that WF is the result of multiple, complex, and overlapping processes [119] and influenced by factors such as education and life experience [78]. Similarly, methodological choices such as the personally relevant nature of the expository speech task, the neuropsychological measures used (*e.g.*, remotely administered), and characteristics of the sample (*e.g.*, minimal diversity, highly educated) could also have influenced the findings of the current study. Depending on the type or difficulty level of a speech task, different underlying cognitive abilities may be recruited and elicit various qualities of speech [120, 121]. For example, the speech prompt used in the current study (*i.e.*, asking participants to describe an important person in their lives) may not have been sufficiently cognitively demanding to match the level of cognitive effort needed for performance on neuropsychological testing, thus reducing their observed correlations. It is also unclear to what extent remote administration of the speech task and cognitive measures may have had an impact on responses and performance compared to in-person administration, though existing evidence shows that teleneuropsychology is comparable to face-to-face administration [122].

4.6. The Role of Education

Findings from the current study also suggest that factors other than the cognitive abilities measured on testing are important contributors to WF and may influence word choice. It is largely accepted that older age and greater educational attainment are related to vocabulary size and lexical retrieval processes [104, 123-125]. Past work shows that individuals with less education take longer to make lexical decisions involving lower frequency words [126]. However, analyses from the current study revealed that between group differences in WF indices for AWs and CWs remained after controlling for education levels. This raises the possibility that lifestyle activities (*e.g.*, reading for leisure, completing crossword puzzles, watching documentaries, socializing with other individuals) contribute to the maintenance of spoken language abilities with advancing age, which is consistent with past work showing increased engagement with cognitively stimulating activities is associated with better memory and verbal fluency performance [127]. Replication of these findings in other samples is needed.

4.7. General Discussion

Taken in combination, the current findings provide important new insight that informs work in this area. Overall, better cognitive test performance was associated with lower average AW frequency, consistent with the idea that the more precise utilization of lower frequency words is a marker of better cognitive function, language abilities, and/or greater knowledge which may promote access to those less common words [79, 128]. However, other findings are more difficult to interpret. For example, finding that OAs generated lower frequency AWs and CWs while also performing better on cognitive tests of episodic memory and attention than YAs is consistent with the known contribution of these mental abilities to WF [118, 129], but runs counter to the age-related cognitive decline typically seen in these cognitive abilities [4, 117]. The exact reason for this discrepancy is unclear, but may reflect the bolstering of the semantic network as a result of lifelong learning in OAs [78]. Also new to this literature, the pattern of results for FWs often diverged from that of CWs and AWs, supporting the possibility that production of different types of words may be mediated by different neural substrates and separable in the lexicon. The automaticity of FW generation may explain why minimal correlations with other cognitive tests arose. As effect sizes in the current study are small, additional work exploring differential properties between function and content WF in cognitive aging is warranted. Finally, results suggest that advancing age does not independently limit WF in the absence of pathological cognitive decline, highlighting the role of crystalized cognitive abilities that underlie WF during speech and the possible protective effect of life experience on language function.

When interpreting these results, it is crucial to note contextual factors can also influence the type and quality of spontaneous speech produced. For example, speech samples can be obtained from interviews or conversations (open or semi-structured), as well as traditional tests of verbal fluency, picture description and expository speech tasks [130-132], which may elicit varying WF values. Further, qualities and/or characteristics of speech may present differently in timed *vs*. flexible tasks; timed tasks (*e.g.*, verbal fluency) rely more heavily on fluid processes (*e.g.*, executive functions), whereas more flexible tasks (*e.g.*, a semi-structured interview) may allow more opportunity to engage with compensatory strategies (*e.g.*, word substitutions, increased pauses) to help navigate the fluid difficulties that arise in older age [133]. Picture description tasks that prompt individuals to talk about the elements of or events depicted in a drawing (*e.g.*, Cookie Theft [134]) have often been used to assess lexical-semantic aspects of spoken language (*e.g.*, word choice, word finding difficulties, empty speech, or repetitions) in healthy YAs and OAs [25, 135], as well as compare the syntactic speech characteristics (*e.g.*, number of clauses, incomplete sentences) of OAs with and without neurodegenerative pathology [130]. However, speech obtained from picture description tasks may produce less cognitive demand than other tasks (because the picture stimulus is ever-present) and inherently limit the variety of lexical choices in a response compared to other verbal tasks that are more open-ended and un-aided by a stimulus. Responding to open-ended questions or creating narratives in conversation may be more ecologically valid [136], as it better represents natural spontaneous speech without the aid of a visual stimulus. Overall, the association between WF and cognitive processes may be influenced by the nature of the speech elicitation task used to generate the speech sample and this important variable should be more fully investigated in future work.

5. LIMITATIONS

Several methodological limitations of the current study deserve brief mention. First, it is important to note that the current sample is comprised of generally healthy individuals of higher socioeconomic status (SES) and educational background and may not fully represent or generalize to the general population. Also, the wide age range of the OA group may increase heterogeneity and could have contributed to the small effects observed; future studies with larger samples should research within specific, narrower age brackets to highlight any subtle nuances. Larger and more diverse samples with formal neuropsychological evaluation and review of medical records (rather than self-report) are needed to promote sample characterization and generalization. This includes individuals from other SES brackets, races, and cultures, but also those with affective (*e.g.*, anxiety, depression), neurodegenerative (*e.g.*, MCI, AD) disorders, and/or medical comorbidities that could accelerate neurocognitive decline in aging (*e.g.*, cardiovascular disease and/or type 2 diabetes). More work using a variety of statistical methods is needed to determine how other potential covariates, such as overall health or other lifestyle factors, play a role in the current findings. It is possible that the current study may have been underpowered as effect sizes across results were small and selection bias due to participant exclusion within the study could also have played a role (despite lack of group differences between those excluded *vs*. retained). Replication is needed.

Future work should also explore spoken WF indices through a variety of speech prompts to capture lexical-semantic differences that may arise across tasks. Additionally, comparing WF to other linguistic variables (*e.g.*, semantic distinctiveness [89, 91, 137]), as well as affective processes and level of engagement (*e.g.*, validity measures), will help contextualize lexical-semantic aspects of spontaneous speech across the lifespan. For example, less engagement with speech tasks may result in less rich speech content. Similarly, the corpus chosen for analyses is an important consideration, as cohort effects may have influenced results; future work should expand upon this work to determine which corpora are most appropriate for specific participant groups. These factors may have contributed to the small effect sizes observed in the current study, however, smaller effect sizes are common in studies that utilize corpus methodologies [138]. Future work should also investigate a broader collection of neuropsychological tests that may help explain lexical selection, such as measures that capture inhibition (*e.g.*, Stroop Color Word Test) and reflect key age-related changes, such as processing speed (*e.g.*, Continuous Performance Test). Neuroimaging may also enhance understanding of neural recruitment across WF indices, particularly the distinction between FWs and CWs [139].

CONCLUSION

The current study examined WF and cognitive test performance in healthy younger and older adults. Broadly, WF differences emerged between OAs and YAs, with distinctions observed between FWs and CWs. Minimal associations with specific cognitive abilities highlight an important role for age and life experiences on lexical access. Lexical-semantic variables such as WF should continue to be investigated in future studies with larger, more diverse samples to better understand the possible impact of normative cognitive changes on linguistic abilities throughout the life course.

AUTHORS' CONTRIBUTION

K.P. and E.B.: Data collection; E.B. and J.G.: Draft manuscript; P.H. and E.B: Conceptualization. All authors reviewed the results and approved the final version of the manuscript.

LIST OF ABBREVIATIONS

YAs	=	Younger adults
COCA	=	Corpus of Contemporary American English
OAs	=	Older adults
AWs	=	All words
CWs	=	Content words
FWs	=	Function words
MCI	=	Mild cognitive impairment
WF	=	Word frequency
AD	=	Alzheimer's disease

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

All study procedures were approved by the Kent State University Institutional Review Board (IRB#: 20-300, "Memory Testing Through Videoconferencing"), USA. Data collection was performed in accordance with the relevant guidelines and regulations.

HUMAN AND ANIMAL RIGHTS

All human research procedures followed were in accordance with the ethical standards of the committee responsible for human experimentation (institutional and national), and with the Helsinki Declaration of 1975, as revised in 2013.

CONSENT FOR PUBLICATION

Informed consent was obtained from all participants.

AVAILABILITY OF DATA AND MATERIALS

The data and supportive information is available within the article.

FUNDING

This project was funded in part by NIH grant R01AG065432.

CONFLICT OF INTEREST

The authors declare no conflict of interest, financial or otherwise.

ACKNOWLEDGEMENTS

Declared none.

REFERENCES

[1] Kirova AM, Bays RB, Lagalwar S. Working memory and executive function decline across normal aging, mild cognitive impairment, and Alzheimer's disease. BioMed Res Int 2015; 2015: 1-9. http://dx.doi.org/10.1155/2015/748212 PMID: 26550575

[2] Murman D. The impact of age on cognition. Semin Hear 2015; 36(3): 111-21. http://dx.doi.org/10.1055/s-0035-1555115 PMID: 27516712

[3] Newman LM, Trivedi MA, Bendlin BB, Ries ML, Johnson SC. The relationship between gray matter morphometry and neuropsychological performance in a large sample of cognitively healthy adults. Brain Imaging Behav 2007; 1(1-2): 3-10. http://dx.doi.org/10.1007/s11682-007-9000-5 PMID: 18836573

[4] Blinkouskaya Y, Caçoilo A, Gollamudi T, Jalalian S, Weickenmeier J. Brain aging mechanisms with mechanical manifestations. Mech Ageing Dev 2021; 200: 111575. http://dx.doi.org/10.1016/j.mad.2021.111575 PMID: 34600936

[5] Harada CN, Natelson Love MC, Triebel KL. Normal cognitive aging. Clin Geriatr Med 2013; 29(4): 737-52. http://dx.doi.org/10.1016/j.cger.2013.07.002 PMID: 24094294

[6] Antonenko D, Flöel A. Healthy aging by staying selectively connected: A mini-review. Gerontology 2014; 60(1): 3-9. http://dx.doi.org/10.1159/000354376 PMID: 24080587

[7] Lezak MD, Howieson DB, Bigler ED, Tranel D. Neuropsychological Assessment. Oxford University Press 2012.

[8] Zelinski EM, Dalton SE, Hindin S. Cognitive Changes in Healthy Older Adults. J Am Soc Aging 2011; 35(2): 13-20.

[9] Shafto MA, Henson RN, Matthews FE, *et al.* Cognitive diversity in a healthy aging cohort: Cross-domain cognition in the cam-can project. J Aging Health 2020; 32(9): 1029-41. http://dx.doi.org/10.1177/0898264319878095 PMID: 31592706

[10] Schaie KW. The impact of longitudinal studies on understanding development from young adulthood to old age. Int J Behav Dev 2000; 24(3): 257-66. http://dx.doi.org/10.1080/01650250050118231

[11] Oschwald J, Guye S, Liem F, *et al.* Brain structure and cognitive ability in healthy aging: A review on longitudinal correlated change. Rev Neurosci 2019; 31(1): 1-57. http://dx.doi.org/10.1515/revneuro-2018-0096 PMID: 31194693

[12] Pichora-Fuller K M. Use of supportive context by younger and older adult listeners: Balancing bottom-up and top-down information processing. Int J Audiol 2008; 47(sup2): S72-82. http://dx.doi.org/10.1080/14992020802307404

[13] Savarimuthu A, Ponniah RJ. Cognition and cognitive reserve. Integr Psychol Behav Sci 2024; 58(2): 483-501. http://dx.doi.org/10.1007/s12124-024-09821-3 PMID: 38279076

[14] Li Y, Gao J, Enkavi AZ, Zaval L, Weber EU, Johnson EJ. Sound credit scores and financial decisions despite cognitive aging. Proc Natl Acad Sci USA 2015; 112(1): 65-9. http://dx.doi.org/10.1073/pnas.1413570112 PMID: 25535381

[15] Glisky E L. Changes in cognitive function in human aging. Brain Aging: Models, Methods, and Mechanisms . Boca Raton (FL):: CRC Press/Taylor & Francis 2007.

[16] Stolwyk R, Bannirchelvam B, Kraan C, Simpson K. The cognitive abilities associated with verbal fluency task performance differ across fluency variants and age groups in healthy young and old adults. J Clin Exp Neuropsychol 2015; 37(1): 70-83. http://dx.doi.org/10.1080/13803395.2014.988125 PMID: 25658578

[17] Kirk A. Cognition in normal aging – A brief review. Can J Neurol Sci 2024; 51(2): 157-60. http://dx.doi.org/10.1017/cjn.2023.259 PMID: 37539707

[18] Dufour R, Estève Y, Deléglise P. Characterizing and detecting spontaneous speech: Application to speaker role recognition. Speech Commun 2014; 56: 1-18. http://dx.doi.org/10.1016/j.specom.2013.07.007

[19] Bortfeld H, Leon SD, Bloom JE, Schober MF, Brennan SE. Disfluency rates in conversation: Effects of age, relationship, topic, role, and gender. Lang Speech 2001; 44(2): 123-47. http://dx.doi.org/10.1177/00238309010440020101 PMID: 11575901

[20] Burke DM, Shafto MA. Aging and language production. Curr Dir Psychol Sci 2004; 13(1): 21-4. http://dx.doi.org/10.1111/j.0963-7214.2004.01301006.x PMID: 18414600

[21] Mortensen L, Meyer AS, Humphreys GW. Age-related effects on speech production: A review. Lang Cogn Process 2006; 21(1-3): 238-90. http://dx.doi.org/10.1080/01690960444000278

[22] Wright HH, Capilouto GJ, Srinivasan C, Fergadiotis G. Story processing ability in cognitively healthy younger and older adults. J Speech Lang Hear Res 2011; 54(3): 900-17. http://dx.doi.org/10.1044/1092-4388(2010/09-0253) PMID: 21106701

[23] Nicholas M, Obler L, Albert M, Goodglass H. Lexical retrieval in healthy aging. Cortex 1985; 21(4): 595-606. http://dx.doi.org/10.1016/S0010-9452(58)80007-6 PMID: 4092486

[24] Bilodeau-Mercure M, Tremblay P. Age differences in sequential speech production: Articulatory and physiological factors. J Am Geriatr Soc 2016; 64(11): e177-82. http://dx.doi.org/10.1111/jgs.14491 PMID: 27783395

[25] Cho S, Nevler N, Shellikeri S, *et al*. Lexical and acoustic characteristics of young and older healthy adults. J Speech Lang Hear Res 2021; 64(2): 302-14. http://dx.doi.org/10.1044/2020_JSLHR-19-00384 PMID: 33439761

[26] Hoffman P, Loginova E, Russell A. Poor coherence in older people's speech is explained by impaired semantic and executive processes. eLife 2018; 7: e38907. http://dx.doi.org/10.7554/eLife.38907 PMID: 30179156

[27] Juncos-Rabadán O, Pereiro AX, Rodríguez MS. Narrative speech in aging: Quantity, information content, and cohesion. Brain Lang 2005; 95(3): 423-34. http://dx.doi.org/10.1016/j.bandl.2005.04.001 PMID: 15913755

[28] Ben-David BM, Erel H, Goy H, Schneider BA. "Older is always better": Age-related differences in vocabulary scores across 16 years. Psychol Aging 2015; 30(4): 856-62. http://dx.doi.org/10.1037/pag0000051 PMID: 26652725

[29] Kavé G, Halamish V. Doubly blessed: Older adults know more vocabulary and know better what they know. Psychol Aging 2015; 30(1): 68-73. http://dx.doi.org/10.1037/a0038669 PMID: 25602490

[30] Abrams L, White K. Healthy aging and communication: The complexities of, um, fluent speech production. The Routledge International Handbook of Psycholinguistic and Cognitive Processes. New York: Routledge 2023; pp. 49-60. http://dx.doi.org/10.4324/9781003204213-5

[31] Nippold MA, Cramond PM, Hayward-Mayhew C. Spoken language production in adults: Examining age-related differences in

syntactic complexity. Clin Linguist Phon 2014; 28(3): 195-207. http://dx.doi.org/10.3109/02699206.2013.841292 PMID: 24093162
[32] Burke DM, Shafto MA. Language and Aging. Psychology Press 2008; pp. 373-443.
[33] Lacombe J, Jolicoeur P, Grimault S, Pineault J, Joubert S. Neural changes associated with semantic processing in healthy aging despite intact behavioral performance. Brain Lang 2015; 149: 118-27. http://dx.doi.org/10.1016/j.bandl.2015.07.003 PMID: 26282079
[34] Wlotko EW, Lee CL, Federmeier KD. Language of the aging brain: Event-related potential studies of comprehension in older adults. Lang Linguist Compass 2010; 4(8): 623-38. http://dx.doi.org/10.1111/j.1749-818X.2010.00224.x PMID: 20823949
[35] Shafto MA, Tyler LK. Language in the aging brain: The network dynamics of cognitive decline and preservation. Science 2014; 346(6209): 583-7. http://dx.doi.org/10.1126/science.1254404 PMID: 25359966
[36] Folia V, Liampas I, Ntanasi E, *et al.* Longitudinal trajectories and normative language standards in older adults with normal cognitive status. Neuropsychology 2022; 36(7): 626-39. http://dx.doi.org/10.1037/neu0000843 PMID: 35797176
[37] Thorvaldsson V, MacDonald SWS, Fratiglioni L, *et al.* Onset and rate of cognitive change before dementia diagnosis: Findings from two Swedish population-based longitudinal studies. J Int Neuropsychol Soc 2011; 17(1): 154-62. http://dx.doi.org/10.1017/S1355617710001372 PMID: 21083966
[38] Beltrami D, Gagliardi G, Rossini Favretti R, Ghidoni E, Tamburini F, Calzà L. Speech analysis by natural language processing techniques: A possible tool for very early detection of cognitive decline? Front Aging Neurosci 2018; 10: 369. http://dx.doi.org/10.3389/fnagi.2018.00369 PMID: 30483116
[39] Burke E, Gunstad J, Hamrick P. Comparing global and local semantic coherence of spontaneous speech in persons with Alzheimer's disease and healthy controls. Applied Corpus Linguistics 2023; 3(3): 100064. http://dx.doi.org/10.1016/j.acorp.2023.100064 PMID: 37476646
[40] Burke E, Gunstad J, Pavlenko O, Hamrick P. Distinguishable features of spontaneous speech in Alzheimer's clinical syndrome and healthy controls. Neuropsychol Dev Cogn B Aging Neuropsychol Cogn 2023; 1-12. PMID: 37272884
[41] Roark B, Mitchell M, Hosom JP, Hollingshead K, Kaye J. Spoken language derived measures for detecting mild cognitive impairment. IEEE Trans Audio Speech Lang Process 2011; 19(7): 2081-90. http://dx.doi.org/10.1109/TASL.2011.2112351 PMID: 22199464
[42] Sanborn V, Ostrand R, Ciesla J, Gunstad J. Automated assessment of speech production and prediction of MCI in older adults. Appl Neuropsychol Adult 2022; 29(5): 1250-7. http://dx.doi.org/10.1080/23279095.2020.1864733 PMID: 33377800
[43] Szatloczki G, Hoffmann I, Vincze V, Kalman J, Pakaski M. Speaking in alzheimer's disease, is that an early sign? Importance of changes in language abilities in alzheimer's disease. Front Aging Neurosci 2015; 7: 195. http://dx.doi.org/10.3389/fnagi.2015.00195 PMID: 26539107
[44] Brysbaert M, Mandera P, Keuleers E. The word frequency effect in word processing: An updated review. Curr Dir Psychol Sci 2018; 27(1): 45-50. http://dx.doi.org/10.1177/0963721417727521
[45] Horton WS, Spieler DH, Shriberg E. A corpus analysis of patterns of age-related change in conversational speech. Psychol Aging 2010; 25(3): 708-13. http://dx.doi.org/10.1037/a0019424 PMID: 20677883
[46] Newman RS, German DJ. Life span effects of lexical factors on oral naming. Lang Speech 2005; 48(2): 123-56. http://dx.doi.org/10.1177/00238309050480020101 PMID: 16411502
[47] Revill KP, Spieler DH. The effect of lexical frequency on spoken word recognition in young and older listeners. Psychol Aging 2012; 27(1): 80-7. http://dx.doi.org/10.1037/a0024113 PMID: 21707175
[48] Brysbaert M, Buchmeier M, Conrad M, Jacobs AM, Bölte J, Böhl A. The word frequency effect: A review of recent developments and implications for the choice of frequency estimates in German. Exp Psychol 2011; 58(5): 412-24. http://dx.doi.org/10.1027/1618-3169/a000123 PMID: 21768069
[49] Navarrete E, Basagni B, Alario FX, Costa A. Does word frequency affect lexical selection in speech production? Q J Exp Psychol 2006; 59(10): 1681-90. http://dx.doi.org/10.1080/17470210600750558 PMID: 16945853
[50] Nozari N, Kittredge AK, Dell GS, Schwartz MF. Naming and repetition in aphasia: Steps, routes, and frequency effects. J Mem Lang 2010; 63(4): 541-59. http://dx.doi.org/10.1016/j.jml.2010.08.001 PMID: 21076661
[51] Allen PA, Bucur B, Grabbe J, Work T, Madden DJ. Influence of encoding difficulty, word frequency, and phonological regularity on age differences in word naming. Exp Aging Res 2011; 37(3): 261-92. http://dx.doi.org/10.1080/0361073X.2011.568805 PMID: 21534029
[52] Berglund-Barraza A, Tian F, Basak C, Evans JL. Word frequency is associated with cognitive effort during verbal working memory: A functional near infrared spectroscopy (fNIRS) study. Front Hum Neurosci 2019; 13: 433. http://dx.doi.org/10.3389/fnhum.2019.00433 PMID: 31920592
[53] Spieler DH, Balota DA. Factors influencing word naming in younger and older adults. Psychol Aging 2000; 15(2): 225-31. http://dx.doi.org/10.1037/0882-7974.15.2.225 PMID: 10879577
[54] Tainturier MJ, Tremblay M, Lecours A. Aging and the word frequency effect: A lexical decision investigation. Neuropsychologia 1989; 27(9): 1197-202. http://dx.doi.org/10.1016/0028-3932(89)90103-6 PMID: 2812303
[55] Kuiera H, Francis W. Computational analysis of present-day American English. Providence, RI: Brown University Press 1967.
[56] Ostrand R, Gunstad J. Using automatic assessment of speech production to predict current and future cognitive function in older adults. J Geriatr Psychiatry Neurol 2021; 34(5): 357-69. http://dx.doi.org/10.1177/0891988720933358 PMID: 32723128
[57] Vonk JMJ, Geerlings MI, Avila-Rieger JF, *et al.* Semantic item-level metrics relate to future memory decline beyond existing cognitive tests in older adults without dementia. Psychol Aging 2023; 38(5): 443-54. http://dx.doi.org/10.1037/pag0000747 PMID: 37199965
[58] Kuperman V, Van Dyke JA. Reassessing word frequency as a determinant of word recognition for skilled and unskilled readers. J Exp Psychol Hum Percept Perform 2013; 39(3): 802-23. http://dx.doi.org/10.1037/a0030859 PMID: 23339352
[59] Dennis PA, Hess TM. Aging-related gains and losses associated with word production in connected speech. Neuropsychol Dev Cogn B Aging Neuropsychol Cogn 2016; 23(6): 638-50. http://dx.doi.org/10.1080/13825585.2016.1158233 PMID: 26963869
[60] Gomez R. Word frequency effects in priming performance in young and older adults. J Gerontol B Psychol Sci Soc Sci 2002; 57(3): P233-40. http://dx.doi.org/10.1093/geronb/57.3.P233 PMID: 11983734
[61] Kavé G, Samuel-Enoch K, Adiv S. The association between age and the frequency of nouns selected for production. Psychol Aging 2009; 24(1): 17-27. http://dx.doi.org/10.1037/a0014579 PMID: 19290734
[62] Mutter SA, Hashtroudi S. Cognitive effort and the word frequency effect in recognition and lexical decision. Am J Psychol 1987; 100(1): 93-116. http://dx.doi.org/10.2307/1422644 PMID: 3592027
[63] Chapman RM. Function and content words evoke different brain potentials. Behav Brain Sci 1999; 22(2): 282-4. http://dx.doi.org/10.1017/S0140525X99231822

[64] Clarke N, Foltz P, Garrard P. How to do things with (thousands of) words: Computational approaches to discourse analysis in Alzheimer's disease. Cortex 2020; 129: 446-63. http://dx.doi.org/10.1016/j.cortex.2020.05.001 PMID: 32622173

[65] Chung C, Pennebaker J. The psychological functions of function words. In: Fiedler K, Ed. Social communication. Psychology Press 2007; pp. 343-59.

[66] Pulvermüller F. Words in the brain's language. Behav Brain Sci 1999; 22(2): 253-79. http://dx.doi.org/10.1017/S0140525X9900182X PMID: 11301524

[67] Gollan TH, Goldrick M. Aging deficits in naturalistic speech production and monitoring revealed through reading aloud. Psychol Aging 2019; 34(1): 25-42. http://dx.doi.org/10.1037/pag0000296 PMID: 30265018

[68] Gollan TH, Smirnov DS, Salmon DP, Galasko D. Failure to stop autocorrect errors in reading aloud increases in aging especially with a positive biomarker for Alzheimer's disease. Psychol Aging 2020; 35(7): 1016-25. http://dx.doi.org/10.1037/pag0000550 PMID: 32584071

[69] Schotter ER, Li C, Gollan TH. What reading aloud reveals about speaking: Regressive saccades implicate a failure to monitor, not inattention, in the prevalence of intrusion errors on function words. Q J Exp Psychol (Hove) 2019; 72(8): 2032-45. http://dx.doi.org/10.1177/1747021818819480 PMID: 30509156

[70] Diaz MT, McCarthy G. A comparison of brain activity evoked by single content and function words: An fMRI investigation of implicit word processing. Brain Res 2009; 1282: 38-49. http://dx.doi.org/10.1016/j.brainres.2009.05.043 PMID: 19465009

[71] Gollan TH, Stasenko A, Li C, Smirnov DS, Galasko D, Salmon DP. Autocorrection if→of function words in reading aloud: A novel marker of Alzheimer's risk. Neuropsychology 2023; 37(7): 813-26. http://dx.doi.org/10.1037/neu0000829 PMID: 35925735

[72] Clarke N, Barrick TR, Garrard P. A comparison of connected speech tasks for detecting early Alzheimer's disease and mild cognitive impairment using natural language processing and machine learning. Front Comput Sci 2021; 3: 634360. http://dx.doi.org/10.3389/fcomp.2021.634360

[73] Vonk JMJ, Bouteloup V, Mangin JF, *et al.* Semantic loss marks early Alzheimer's disease-related neurodegeneration in older adults without dementia. Alzheimers Dement 2020; 12(1): e12066. http://dx.doi.org/10.1002/dad2.12066 PMID: 32775598

[74] Taler V, Monetta L, Sheppard C, Ohman A. Semantic function in mild cognitive impairment. Front Psychol 2020; 10: 3041. http://dx.doi.org/10.3389/fpsyg.2019.03041 PMID: 32038404

[75] Krajcovicova L, Klobusiakova P, Rektorova I. Gray matter changes in Parkinson's and Alzheimer's disease and relation to cognition. Curr Neurol Neurosci Rep 2019; 19(11): 85. http://dx.doi.org/10.1007/s11910-019-1006-z PMID: 31720859

[76] Altmann LJP, Troche MS. High-level language production in Parkinson's disease: A review. Parkinsons Dis 2011; 2011(1): 1-12. http://dx.doi.org/10.4061/2011/238956 PMID: 21860777

[77] Yokoi K, Iribe Y, Kitaoka N, *et al.* Analysis of spontaneous speech in Parkinson's disease by natural language processing. Parkinsonism Relat Disord 2023; 113: 105411. http://dx.doi.org/10.1016/j.parkreldis.2023.105411 PMID: 37179151

[78] Wulff DU, De Deyne S, Jones MN, Mata R. New perspectives on the aging lexicon. Trends Cogn Sci 2019; 23(8): 686-98. http://dx.doi.org/10.1016/j.tics.2019.05.003 PMID: 31288976

[79] Ramscar M, Hendrix P, Love B, Baayen RH. Learning is not decline. Ment Lex 2013; 8(3): 450-81. http://dx.doi.org/10.1075/ml.8.3.08ram

[80] Abrusán M, Asher N, Van de Cruys T. Content *vs*. function words: The view from distributional semantics. Proc Sinn und Bedeutung 2018; 22(1): 1-21.

[81] Salari N, Hosseinian-Far A, Jalali R, *et al.* Prevalence of stress, anxiety, depression among the general population during the COVID-19 pandemic: A systematic review and meta-analysis. Global Health 2020; 16(1): 57. http://dx.doi.org/10.1186/s12992-020-00589-w PMID: 32631403

[82] Shafto MA, James LE, Abrams L, Can C. Age-related changes in word retrieval vary by self-reported anxiety but not depression symptoms. Neuropsychol Dev Cogn B Aging Neuropsychol Cogn 2019; 26(5): 767-80. http://dx.doi.org/10.1080/13825585.2018.1527284 PMID: 30282517

[83] Greiffenstein MF. Validation of malingered amnesia measures with a large clinical sample. Psychol Assess 1994; 6(3): 218-24.

[84] Schroeder RW, Twumasi-Ankrah P, Baade LE, Marshall PS. Reliable digit span: A systematic review and cross-validation study. Assessment 2012; 19(1): 21-30. http://dx.doi.org/10.1177/1073191111428764 PMID: 22156721

[85] Dinkar T, Clavel C, Vasilescu I. Fillers in spoken language understanding: Computational and psycholinguistic perspectives. arXiv 2023; 2301.10761.

[86] Chen L, Dodge HH, Asgari M. Topic-based measures of conversation for detecting mild cognitive impairment. Proceedings of the conference. 2020: 63.

[87] Doyle PJ, Goda AJ, Spencer KA. The communicative informativeness and efficiency of connected discourse by adults with aphasia under structured and conversational sampling conditions. Am J Speech Lang Pathol 1995; 4(4): 130-4. http://dx.doi.org/10.1044/1058-0360.0404.130

[88] Davies M. The corpus of contemporary american english as the first reliable monitor corpus of English. Lit Linguist Comput 2010; 25(4): 447-64. http://dx.doi.org/10.1093/llc/fqq018

[89] Adelman JS, Brown GDA, Quesada JF. Contextual diversity, not word frequency, determines word-naming and lexical decision times. Psychol Sci 2006; 17(9): 814-23. http://dx.doi.org/10.1111/j.1467-9280.2006.01787.x PMID: 16984300

[90] Bell A, Brenier JM, Gregory M, Girand C, Jurafsky D. Predictability effects on durations of content and function words in conversational English. J Mem Lang 2009; 60(1): 92-111. http://dx.doi.org/10.1016/j.jml.2008.06.003

[91] Johns BT, Gruenenfelder TM, Pisoni DB, Jones MN. Effects of word frequency, contextual diversity, and semantic distinctiveness on spoken word recognition. J Acoust Soc Am 2012; 132(2): EL74-80. http://dx.doi.org/10.1121/1.4731641 PMID: 22894319

[92] Jones MN, Johns BT, Recchia G. The role of semantic diversity in lexical organization. Can J Exp Psychol 2012; 66(2): 115-24. http://dx.doi.org/10.1037/a0026727 PMID: 22686160

[93] Ricker JH, Axelrod BN. Analysis of an oral paradigm for the trail making test. Assessment 1994; 1(1): 47-51. http://dx.doi.org/10.1177/1073191194001001007 PMID: 9463499

[94] Wechsler D. Wechsler Adult Intelligence Scale. APA PsycTests. 2008. http://dx.doi.org/10.1037/t15169-000

[95] Axelrod BN, Millis SR. Preliminary standardization of the cognitive estimation test. Assessment 1994; 1(3): 269-74. http://dx.doi.org/10.1177/107319119400100307

[96] Craft S, Newcomer J, Kanne S, *et al.* Memory improvement following induced hyperinsulinemia in alzheimer's disease. Neurobiol Aging 1996; 17(1): 123-30. http://dx.doi.org/10.1016/0197-4580(95)02002-0 PMID: 8786794

[97] Boucher C, May N, Shahein A, Roth RM, Erdodi LA. Examining the effect of repeat administration, alternate versions, and performance validity on letter fluency tests in a mixed clinical sample. Psychol Neurosci 2023; 16(2): 105-24. http://dx.doi.org/10.1037/pne0000299

[98] Bondi MW, Edmonds EC, Jak AJ, *et al.* Neuropsychological criteria for mild cognitive impairment improves diagnostic precision, biomarker associations, and progression rates. J Alzheimers Dis 2014; 42(1): 275-89. http://dx.doi.org/10.3233/JAD-140276 PMID: 24844687

[99] Benjamini Y, Hochberg Y. Controlling the false discovery rate: A practical and powerful approach to multiple testing. J R Stat Soc

Series B Stat Methodol 1995; 57(1): 289-300.
http://dx.doi.org/10.1111/j.2517-6161.1995.tb02031.x
[100] Palejev D, Savov M. Estimating the statistical power of the Benjamini-Hochberg procedure. Advances in High Performance Computing. Borovets, Bulgaria, 08 August 2020, pp. 298-308. http://dx.doi.org/10.1007/978-3-030-55347-0_26
[101] Menyhart O, Weltz B, Győrffy B. MultipleTesting.com: A tool for life science researchers for multiple hypothesis testing correction. PLoS One 2021; 16(6): e0245824. http://dx.doi.org/10.1371/journal.pone.0245824 PMID: 34106935
[102] Williams VSL, Jones LV, Tukey JW. Controlling error in multiple comparisons, with examples from state-to-state differences in educational achievement. J Educ Behav Stat 1999; 24(1): 42-69. http://dx.doi.org/10.3102/10769986024001042
[103] Mrazik M, Millis S, Drane DL. The oral trail making test: Effects of age and concurrent validity. Arch Clin Neuropsychol 2010; 25(3): 236-43. http://dx.doi.org/10.1093/arclin/acq006 PMID: 20197294
[104] Verhaeghen P. Aging and vocabulary score: A meta-analysis. Psychol Aging 2003; 18(2): 332-9. http://dx.doi.org/10.1037/0882-7974.18.2.332 PMID: 12825780
[105] Wulff DU, Hills TT, Lachman ME, Mata R. The aging lexicon: Differences in the semantic networks of younger and older adults. CogSci 2016; 907-12.
[106] Higby E, Cahana-Amitay D, Vogel-Eyny A, Spiro A III, Albert ML, Obler LK. The role of executive functions in object- and action-naming among older adults. Exp Aging Res 2019; 45(4): 306-30. http://dx.doi.org/10.1080/0361073X.2019.1627492 PMID: 31216948
[107] Hamrick P, Lum JAG, Ullman MT. Child first language and adult second language are both tied to general-purpose learning systems. Proc Natl Acad Sci USA 2018; 115(7): 1487-92. http://dx.doi.org/10.1073/pnas.1713975115 PMID: 29378936
[108] Weber-Fox C, Neville HJ. Sensitive periods differentiate processing of open- and closed-class words: An ERP study of bilinguals. J Speech Lang Hear Res 2001; 44(6): 1338-53. http://dx.doi.org/10.1044/1092-4388(2001/104) PMID: 11776369
[109] Payne BR, Federmeier KD. Contextual constraints on lexico-semantic processing in aging: Evidence from single-word event-related brain potentials. Brain Res 2018; 1687: 117-28. http://dx.doi.org/10.1016/j.brainres.2018.02.021 PMID: 29462609
[110] Rosselli M, Ardila A, Matute E, Vélez-Uribe I. Language development across the life span: A neuropsychological/neuroimaging perspective. Neurosci J 2014; 2014: 1-21. http://dx.doi.org/10.1155/2014/585237 PMID: 26317109
[111] D'Aniello GE, Castelnuovo G, Scarpina F. Could cognitive estimation ability be a measure of cognitive reserve? Front Psychol 2015; 6: 608. http://dx.doi.org/10.3389/fpsyg.2015.00608 PMID: 25999909
[112] Spencer RJ, Johnson-Greene D. The cognitive estimation test (CET): Psychometric limitations in neurorehabilitation populations. J Clin Exp Neuropsychol 2009; 31(3): 373-7. http://dx.doi.org/10.1080/13803390802206398 PMID: 18649163
[113] Wulff DU, De Deyne S, Aeschbach S, Mata R. Using network science to understand the aging lexicon: Linking individuals' experience, semantic networks, and cognitive performance. Top Cogn Sci 2022; 14(1): 93-110. http://dx.doi.org/10.1111/tops.12586 PMID: 35040557
[114] Beaman KV, Buchstaller I. Language Variation and Language Change Across the Lifespan. Routledge 2021; p. xxvi-286. http://dx.doi.org/10.4324/9780429030314
[115] Desai RH, Choi W, Henderson JM. Word frequency effects in naturalistic reading. Lang Cogn Neurosci 2020; 35(5): 583-94. http://dx.doi.org/10.1080/23273798.2018.1527376 PMID: 33015218
[116] Baciu M, Roger E. Finding the words: How does the aging brain process language? A focused review of brain connectivity and compensatory pathways. Top Cogn Sci 2024; tops.12736. http://dx.doi.org/10.1111/tops.12736 PMID: 38734967
[117] Baghel MS, Singh P, Srivas S, Thakur MK. Cognitive changes with aging. Proc Natl Acad Sci India Sect B Biol Sci 2019; 89: 765-73. http://dx.doi.org/10.3389/fnagi.2020.607449
[118] Balota DA, Burgess GC, Cortese MJ, Adams DR. The word-frequency mirror effect in young, old, and early-stage Alzheimer's disease: Evidence for two processes in episodic recognition performance. J Mem Lang 2002; 46(1): 199-226. http://dx.doi.org/10.1006/jmla.2001.2803
[119] Hertrich I, Dietrich S, Ackermann H. The margins of the language network in the brain. Front Commun 2020; 5: 519955. http://dx.doi.org/10.3389/fcomm.2020.519955
[120] Filiou RP, Bier N, Slegers A, Houzé B, Belchior P, Brambati SM. Connected speech assessment in the early detection of Alzheimer's disease and mild cognitive impairment: A scoping review. Aphasiology 2020; 34(6): 723-55. http://dx.doi.org/10.1080/02687038.2019.1608502
[121] Slegers A, Filiou RP, Montembeault M, Brambati SM. Connected speech features from picture description in Alzheimer's disease: A systematic review. J Alzheimers Dis 2018; 65(2): 519-42. http://dx.doi.org/10.3233/JAD-170881 PMID: 30103314
[122] Alegret M, Espinosa A, Ortega G, *et al.* From face-to-face to home-to-home: Validity of a teleneuropsychological battery. J Alzheimers Dis 2021; 81(4): 1541-53. http://dx.doi.org/10.3233/JAD-201389 PMID: 33935075
[123] Aguasvivas J, Carreiras M, Brysbaert M, Mandera P, Keuleers E, Duñabeitia JA. How do Spanish speakers read words? Insights from a crowdsourced lexical decision megastudy. Behav Res Methods 2020; 52(5): 1867-82. http://dx.doi.org/10.3758/s13428-020-01357-9 PMID: 32072567
[124] Kosmidis MH, Tsapkini K, Folia V. Lexical processing in illiteracy: Effect of literacy or education? Cortex 2006; 42(7): 1021-7. http://dx.doi.org/10.1016/S0010-9452(08)70208-9 PMID: 17172182
[125] Simos PG, Kasselimis D, Mouzaki A. Age, gender, and education effects on vocabulary measures in Greek. Aphasiology 2011; 25(4): 475-91. http://dx.doi.org/10.1080/02687038.2010.512118
[126] Tainturier M, Tremblay M, Lecours AR. Educational level and the word frequency effect: A lexical decision investigation*1. Brain Lang 1992; 43(3): 460-74. http://dx.doi.org/10.1016/0093-934X(92)90112-R PMID: 1446213
[127] Cegolon A, Jenkins A. Older adults, cognitively stimulating activities and change in cognitive function. Int J Lifelong Educ 2022; 41(4-5): 405-19. http://dx.doi.org/10.1080/02601370.2022.2082574
[128] Jefferies E, Thompson H, Cornelissen P, Smallwood J. The neurocognitive basis of knowledge about object identity and events: Dissociations reflect opposing effects of semantic coherence and control. Philos Trans R Soc Lond B Biol Sci 2020; 375(1791): 20190300. http://dx.doi.org/10.1098/rstb.2019.0300 PMID: 31840592
[129] Almond NM, Morrison CM, Moulin CJA. Episodic intertrial learning of younger and older adults: Effects of word frequency. Neuropsychol Dev Cogn B Aging Neuropsychol Cogn 2013; 20(2): 174-94. http://dx.doi.org/10.1080/13825585.2012.679914 PMID: 22574638
[130] Cummings L. Describing the Cookie Theft picture: Sources of breakdown in Alzheimer's dementia. Pragmatics and Society 2019; 10(2): 153-76. http://dx.doi.org/10.1075/ps.17011.cum
[131] Dijkstra K, Bourgeois M, Petrie G, Burgio L, Allen-Burge R. My recaller is on vacation: Discourse analysis of nursing-home residents with dementia. Discourse Process 2002; 33(1): 53-76. http://dx.doi.org/10.1207/S15326950DP3301_03
[132] Dijkstra K, Bourgeois MS, Allen RS, Burgio LD. Conversational coherence: Discourse analysis of older adults with and without dementia. J Neurolinguist 2004; 17(4): 263-83. http://dx.doi.org/10.1016/S0911-6044(03)00048-4
[133] Kavé G, Goral M. Do age-related word retrieval difficulties appear

(or disappear) in connected speech? Neuropsychol Dev Cogn B Aging Neuropsychol Cogn 2017; 24(5): 508-27. http://dx.doi.org/10.1080/13825585.2016.1226249 PMID: 27583986

[134] Goodglass H, Kaplan E. Boston diagnostic aphasia examination booklet. PA: Lea & Febiger Philadelphia 1983.

[135] Kavé G, Nussbaum S. Characteristics of noun retrieval in picture descriptions across the adult lifespan. Aphasiology 2012; 26(10): 1238-49. http://dx.doi.org/10.1080/02687038.2012.681767

[136] Prins R, Bastiaanse R. Analysing the spontaneous speech of aphasic speakers. Aphasiology 2004; 18(12): 1075-91. http://dx.doi.org/10.1080/02687030444000534

[137] Hamrick P, Pandža NB. Contributions of semantic and contextual diversity to the word frequency effect in L2 lexical access. Can J Exp Psychol 2020; 74(1): 25-34. http://dx.doi.org/10.1037/cep0000189 PMID: 31580087

[138] Boulton A, Cobb T. Corpus use in language learning: A meta-analysis. Lang Learn 2017; 67(2): 348-93. http://dx.doi.org/10.1111/lang.12224

[139] Kauf C, Tuckute G, Levy R, Andreas J, Fedorenko E. Lexical-semantic content, not syntactic structure, is the main contributor to ANN-brain similarity of fMRI responses in the language network. Neurobiol Lang 2024; 5(1): 7-42. http://dx.doi.org/10.1162/nol_a_00116