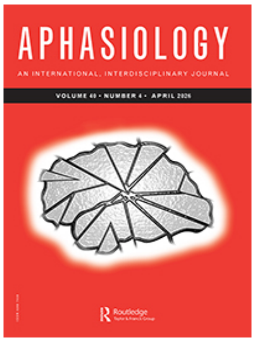

Aphasiology

ISSN: 0268-7038 (Print) 1464-5041 (Online) Journal homepage: www.tandfonline.com/journals/paph20

Cross-linguistic differences in the semantic networks for animal fluency between English and Korean speakers with and without aphasia

Junyoung Shin, Michael Scimeca, Ran Li, Swathi Kiran & Jee Eun Sung

APHASIOLOGY
https://doi.org/10.1080/02687038.2026.2648119

Routledge
Taylor & Francis Group

Cross-linguistic differences in the semantic networks for animal fluency between English and Korean speakers with and without aphasia

Junyoung Shin[a], Michael Scimeca[b], Ran Li[c], Swathi Kiran[b] and Jee Eun Sung[a]

[a]Department of Communication Disorders, Ewha Womans University, Seoul, Korea; [b]Department of Speech, Language & Hearing Sciences, Center for Brain Recovery, Boston University, Boston, MA, USA; [c]Department of English Language and Literature, Hong Kong Baptist University, Hong Kong

ABSTRACT

Background: Semantic fluency tasks are widely used to assess lexical – semantic retrieval in healthy aging and aphasia; however, growing evidence indicates that semantic organization is influenced by culturally grounded lexical experience. Prior cross-linguistic work suggests that Korean speakers rely on culture-specific semantic schemas – such as zodiac animals – during animal fluency, yet it remains unclear how such differences manifest in retrieval strategies or semantic network structure in aging and aphasia.
Aims: The current study investigated cross-linguistic differences in clustering, switching, and semantic network structure during animal fluency in English- and Korean-speaking older adults (OA) and persons with aphasia (PWA).
Methods & Procedures: Participants included English- and Korean-speaking OA ($n = 30$) and PWA ($n = 67$). All participants completed a one-minute animal fluency task. Clustering and switching were computed using SNAFU, and group-level semantic networks were constructed using co-occurrence – based Semantic Network Analysis. Global graph metrics – average shortest path length (ASPL), clustering coefficient (CC), and modularity (Q) – were compared across language groups.
Outcomes & Results: Behaviorally, English- and Korean-OA produced comparable total number of correct responses; however, English-OA generated significantly larger cluster sizes than Korean-OA. In PWA, English speakers produced significantly more correct items and significantly more switches than Korean speakers. Semantic network analyses revealed that Korean-OA networks demonstrated significantly longer ASPL, significantly lower CC, and significantly higher Q relative to English-OA. In PWA, Korean speakers also exhibited significantly longer ASPL than English speakers, indicating reduced global connectivity. Together, these results demonstrate that significant cross-linguistic differences in semantic network structure are evident in healthy aging and remain observable in aphasia.

ARTICLE HISTORY
Received 15 December 2025
Accepted 8 March 2026

KEYWORDS
Cross-linguistic; semantic network; aphasia; animal fluency

CONTACT Jee Eun Sung jeesung@ewha.ac.kr Department of Communication Disorders, Ewha Womans University, 52 Ewhayeodae-gil, Seodaemun-gu, Seoul 03760, Korea

Introduction

Aphasia is a spectrum of acquired language disorders that disrupt language production and comprehension following damage to language-related regions of the left hemisphere (McNeil & Pratt, 2001). Among its defining symptoms, word retrieval impairment, or anomia, remains the most persistent and universally observed deficit across aphasia presentations (Laine & Martin, 2023). People with aphasia (PWA) experience pronounced word-finding difficulties, including prolonged pauses, semantic substitutions, circumlocutions, and other retrieval-related disruptions (Goodglass & Wingfield, 1997). The severity and expression of anomia vary widely depending on lesion location, extent of neural damage, and demographic factors such as age that substantially influence lexical access (Laine & Martin, 2023).

To assess word retrieval deficits in aphasia, verbal fluency tasks serve as sensitive measures of lexical – semantic retrieval and strategic search processes. In these tasks, participants are asked to generate as many items as possible within a fixed time window (typically 30–60 s) according to a category-based rule. Semantic fluency tasks – typically involving categories such as animals, vegetables, or clothing – are widely included in aphasia assessments such as the Boston Diagnostic Aphasia Examination (Goodglass et al., 2001) and the Western Aphasia Battery (Kertesz, 2006). Generating exemplars under time pressure requires efficient activation and navigation of one's semantic network, the ability to cluster semantically related items, and the flexibility to shift between subcategories. These performance features not only index the efficiency of lexical access but also reveal how one retrieved item leads to the next, providing a window into the temporal dynamics and relational structure of semantic search.

Although semantic fluency tasks are often treated as accessing universal semantic networks, growing evidence shows that the organization of semantic knowledge – and thus the structure of fluency performance – is shaped not only by cognitive mechanisms but also by culturally mediated lexical experience (Acevedo et al., 2000; Kempler et al., 1998, Kiran & Thomson, 2003; Sung et al., 2024, 2025). For example, while Sung and Kim (2011) reported that Korean speakers tended to generate scallion as a prototypical exemplar of the vegetable category, Kiran and Thompson (2003) found that English speakers more frequently produced celery as a typical item. As discussed by Sung et al. (2024), such differences are likely shaped by culturally grounded lexical experience; in Korean contexts, items such as scallion and garlic are regarded as highly typical because they are central ingredients in kimchi, a staple dish served at nearly every meal. Such findings suggest that even within seemingly universal semantic categories, the accessibility and salience of exemplars reflect culturally shaped conceptual schemas.

Sung et al. (2025) examined a culturally specific semantic subcategory within the animal fluency task, focusing on the influence of the East Asian zodiac system. Their analysis showed that speakers from cultures familiar with the zodiac tradition produced disproportionately more zodiac-related animals than non-zodiac animals, suggesting that culturally salient semantic groupings can meaningfully shape lexical retrieval patterns. Building on this culturally driven clustering effect, Sung et al. (2025) further applied LASSO regression to identify which specific animal items best distinguished Korean- and English-speaking adults with and without aphasia. Strikingly, all predictors that characterized Korean speakers – regardless of aphasia status – were exclusively drawn from the twelve zodiac animals ("Rat", "Ox", "Tiger", "Rabbit", "Dragon", "Snake", "Horse", "Sheep", "Monkey", "Rooster", "Dog", "Pig"). Together, these results indicate that zodiac animals function as a culturally embedded semantic subfamily within the broader animal category, strongly constraining how Korean speakers navigate semantic space. Accordingly, semantic fluency performance should be interpreted not as culturally neutral but as reflecting culturally structured semantic systems that guide retrieval pathways.

Although the total number of correct responses is the most commonly analyzed metric in clinical interpretations of semantic fluency, this metric only captures overall productivity and provides little insight into how retrieval unfolds over time. To examine the underlying structure of retrieval more comprehensively, semantic grouping patterns are often analyzed using two behavioral measures – clustering and switching – that index the local and global organization of semantic search (Troyer, 2000; Troyer et al., 1997). Clustering refers to the production of successive words drawn from the same semantic subcategory, whereas switching reflects transitions between different subcategories. Troyer et al. (1997) widely used taxonomy delineates 22 animal subcategories based on habitat and ecological classification (e.g., African mammals, birds, reptiles, amphibians), providing a structured framework for characterizing these retrieval dynamics. More recently, the Semantic Network and Fluency Utility (SNAFU; Zemla et al., 2020) has enabled automated computation of clustering and switching metrics, offering greater reliability and efficiency than traditional hand-scoring procedures (Zemla & Austerweil, 2018a, 2019).

Beyond traditional behavioral indices, recent advances in network science offer a complementary framework for characterizing retrieval dynamics during verbal fluency tasks (Kenett et al., 2013; Lebkuecher et al., 2024; Zemla, 2022). In this approach, fluency responses are represented as semantic networks, in which produced words serve as nodes and associative relations – typically inferred from temporal adjacency or co-occurrence – form the edges linking them (Cosgrove et al., 2021; Goñi et al., 2013; Kenett et al., 2013; Zemla & Austerweil, 2018b). This graph-based representation allows investigators to quantify both local and global properties of semantic structure, thereby revealing how concepts are stored, interconnected, and accessed within the semantic system (Christensen & Kenett, 2023). Accordingly, the sequential patterns characteristic of fluency production reflect latent organization in the lexico-semantic space: highly related words tend to cluster together due to strong associative links and shared semantic features (Troyer et al., 1997).

Semantic network analysis computes graph-theoretic measures that serve as direct indices of semantic system integrity (Christensen & Kenett, 2023). Here, each generated word serves as a node in the network, and edges are constructed based on semantic relatedness, estimated from how words co-occur or appear in sequence during the task. Three core metrics are commonly examined (see Siew et al., 2019): The Average Shortest Path Length (ASPL) indexes global organization by estimating the average number of steps required to connect any two nodes; higher ASPL reflects a more diffuse and sparsely linked network, whereas lower ASPL indicates a more integrated semantic space that supports efficient associative transitions. The Clustering Coefficient (CC) captures local interconnectedness by measuring how often a node's neighbors are also connected to one another, with higher values reflecting dense and cohesive semantic neighborhoods. The Modularity Coefficient (Q) quantifies how well the network separates into distinct subcommunities – for example, groups of animals sharing habitats or taxonomic features. Lower Q values indicate that these subcommunities are less sharply separated, reflecting a more integrated and coherent semantic structure. These indices extend beyond traditional clustering and switching measures by providing a global, system-level characterization of semantic architecture for verbal fluency.

Applying semantic network analysis to clinical populations has yielded compelling evidence of how semantic structure changes with cognitive or neurological impairment. Studies of Alzheimer's disease, for example, have shown that patients generate fewer nodes and exhibit more densely constrained networks than healthy controls (Arias-Trejo et al., 2021; Lerner et al., 2009; Zemla et al., 2019). Research on semantic network structure in aphasia remains limited, but the only large-scale investigation to date—Pham et al. (2025)—reported systematic disruptions in the lexical – semantic networks of individuals with post-stroke aphasia. Relative to healthy controls, PWA networks showed longer ASPL, lower CC, and higher Q, with nonfluent PWA displaying the most pronounced disruptions. Importantly, this study highlighted that lexical representations themselves are not missing in aphasia – because the same word pool was used across groups – but that the interconnections among those words differ markedly across clinical profiles. Thus, semantic network analysis reveals qualitative patterns of semantic disruption in aphasia – such as reduced integration or increased fragmentation – that are not apparent from traditional fluency measures alone.

Building on the cross-linguistic work by Sung et al. (2025), which compared English and Korean speakers primarily in terms of overall fluency output, the present study extends this line of inquiry by examining both retrieval strategies and semantic network structure in animal fluency among neurologically healthy older adults (OA) and PWA. In addition to analyzing strategic behaviors – clustering and switching – we further investigated the semantic structure by applying network analysis to animal fluency responses. We constructed group-level semantic networks for each language group and compared global network metrics (ASPL, CC, and Q) as indices of integration, local cohesion, and community structure. Our network construction approach captures group-level co-occurrence structure: two words contribute equally to an edge regardless of whether they were produced consecutively or several positions apart (Christensen & Kenett, 2023; Pham et al., 2025). By integrating behavioral indices with graph-theoretic measures, this study provides, to our knowledge, the first cross-linguistic comparison of semantic network organization in both aging and aphasia.

Methods

Participants

All data analyzed in the present study were drawn from Sung et al. (2025). A total of 97 individuals participated, including 67 monolingual PWA and 30 neurologically healthy monolingual OA. The PWA group comprised 30 native American English speakers and 37 native Korean speakers. Aphasia diagnoses were confirmed using standardized assessments: the Western Aphasia Battery – Revised (WAB-R; Kertesz, 2006) for English speakers and its Korean adaptation (PK-WAB-R; Kim & Na, 2012) for Korean speakers. Although the English- and Korean-speaking PWA groups differed significantly in age ($p = .016$) and

Table 1. Demographic information for each language group.

	PWA group		OA group	
Variables	English ($n = 30$)	Korean ($n = 37$)	English ($n = 15$)	Korean ($n = 15$)
Age (years)	63 (11)	55 (13)	67 (9)	67 (11)
	$F_{(1,65)} = 6.121$ $p = .016$*		$F_{(1,28)} = .004$ $p = .953$	
Education (years)	15.5 (2.9)	13.4 (2.8)	20.3 (4.1)	18.6 (2.4)
	$F_{(1,65)} = 6.121$ $p = .016$*		$F_{(1,28)} = .004$ $p = .953$	
MMSE (total = 30)	N/A	N/A	28.27 (1.1)	27.87 (1.5)
	N/A		$F_{(1,28)} = .072$ $p = .403$	
WAB AQ (total = 100)	70.56 (19.21)	68.43 (15.59)	N/A	N/A
	$F_{(1,65)} = .249$ $p = .619$		N/A	

Note. Values represent mean (standard deviation). PWA = persons with aphasia. OA = older adults. M(SD) = means (standard deviation); MMSE = Mini-Mental State Examination; WAB = western aphasia battery; AQ = aphasia quotient; N/A = not applicable; *F* and p values from one way analysis of variance (ANOVA); *$p < .05$.

years of education ($p = .016$), they did not differ in overall aphasia severity as indexed by the Aphasia Quotient (AQ) ($p = .619$). Table 1 summarizes the demographic and clinical characteristics; additional individual-level clinical profiles can be found in Sung et al. (2025).

The neurologically healthy OA group included 30 OA —15 American English speakers and 15 Korean speakers – who were matched across languages based on age ($p = .953$), years of education ($p = .183$), and Mini-Mental State Examination (MMSE; Folstein et al., 1975 for the English version; Kang, 2006 for the Korean version) scores ($p = .403$, see Table 1). This study was approved by the Human Research Ethics Committee at Ewha Womans University (Protocol 2022–0140) and the Institutional Review Board of Boston University's Charles River Campus (IRB #3309E). All participants provided written informed consent prior to participation.

Semantic fluency task

Participants completed an animal fluency task in which they were asked to generate as many words as possible from the category "animals" within a 60-second period (Troyer et al., 1997).

Data analysis

All statistical analyses were performed in R Studio (Version 4.2.3) for the PWA and the OA group analyzed separately. Only correct animal responses were included for analysis; intrusions, repetitions, and non-animal items were excluded prior to scoring.

Behavioral indices

Behavioral measures characterizing the strategy of verbal fluency performance were extracted using the Semantic Network and Fluency Utility (SNAFU; Zemla et al., 2020), which provides automated, reliability-enhanced scoring relative to traditional hand coding

(Zemla & Austerweil, 2018b, 2019). For each participant, three indices were derived: 1) the total number of correct responses, 2) the mean cluster size, and 3) the number of switches. Group differences between English- and Korean-speaking participants were examined separately within each diagnostic group (PWA; OA) using independent-samples t-tests.

Network metrics

Semantic network analyses followed the SemNA framework (Christensen & Kenett, 2023). Fluency responses were first preprocessed using SemNetDictionaries (v0.2.0) and SemNetCleaner (v1.3.4), which involved removing repetitions and non-category items, correcting misspellings, and consolidating morphological variants to their root forms (e.g., dogs → dog).

As part of the standard SemNA pipeline for cross-group comparisons, two built-in constraints were applied during network construction to ensure that differences reflected semantic structure rather than lexical inventory. Specifically, SemNA 1) retains only items produced by at least two participants within each group, and 2) constructs equated networks, such that only animals produced by all groups serve as nodes in the final graphs. These steps ensure that cross-linguistic differences arise from connectivity patterns among shared lexical items rather than differences in item availability.

A binary response matrix was then constructed with participants as rows and unique animal exemplars as columns, coded as 1 if the item was produced and 0 otherwise. Networks were estimated as undirected and unweighted graphs in which nodes represented animal exemplars and edges reflected co-occurrence across participants; although association strengths were initially cosine-weighted, all network metrics were computed on binarized adjacency matrices in accordance with standard SemNA procedures.

From the resulting semantic networks, three global graph-theoretic indices were extracted: 1) ASPL, indexing global semantic organization; 2) CC, indexing local semantic cohesion; and 3) Q, indexing the degree to which the network separates into distinct subcommunities.

To evaluate the robustness of between-group differences in global network metrics, we conducted a bootstrap-based partial network analysis using the bootSemNeT function. Bootstrapping was performed at the node level (type = "node"), whereby 50% of nodes were randomly retained in each resampled network (prop = 0.50). For each bootstrap iteration, networks were re-estimated using cosine similarity and the TMFG filtering method, and global metrics (ASPL, CC, Q) were recomputed. This procedure was repeated for 1000 iterations (iter = 1000) with parallel processing (cores = 4), yielding empirical distributions of each network metric for both groups. Group differences were assessed based on the bootstrap distributions using test.bootSemNeT. In addition, we conducted tests against matched random networks using randnet.test with 1000 iterations to determine whether each observed network structure significantly deviated from random topology.

Results

Table 2 summarizes the means, standard deviations, and descriptive statistics for the behavioral indices derived from SNAFU and the semantic network metrics obtained through SemNA for both the OA and PWA groups.

Table 2. Descriptive statistics from the SNAFU and SemNA analysis.

Analysis	Variables	OA group			PWA group		
		English	Korean	Statistics	English	Korean	Statistics
SNAFU	Total Number of Correct Responses	20.73 (4.04)	17.80 (5.89)	$t = 1.589$ $p = .123$	10.40 (5.75)	6.08 (2.72)	$t = 3.398$ $p = .001$*
	Average Cluster Size	2.37 (0.32)	1.70 (0.62)	$t = 3.719$ $p < .001$*	1.74 (1.60)	1.59 (1.33)	$t = 0.762$ $p = .450$
	Number of Switches	14.40 (5.08)	12.40 (3.01)	$t = 1.310$ $p = .201$	5.24 (5.00)	3.36 (3.00)	$t = 2.290$ $p = .026$*
SemNA	ASPL	1.62 (0.05)	1.73 (0.11)	$t = -29.958$ $p < .001$*	1.46 (0.06)	1.48 (0.09)	$t = -6.093$ $p < .001$*
	CC	0.75 (0.01)	0.72 (0.05)	$t = 23.771$ $p < .001$*	0.76 (0.05)	0.76 (0.04)	$t = -1.632$ $p = .103$
	Q	0.22 (0.04)	0.25 (0.04)	$t = -16.608$ $p < .001$*	0.14 (0.04)	0.14 (0.05)	$t = -1.782$ $p = .075$

Note. Values represent mean (standard deviation). OA=; PWA=; SNAFU = Semantic Network and Fluency Utility; SemNA = Semantic Network Analysis; ASPL = Average Shortest Path Length; CC = Clustering Coefficient; Q = maximum modularity coefficient; * indicates statistical significance at p < 0.001.

Behavioral indices

OA groups

No significant group differences were observed in the total number of correct responses or number of switches (both $p > .05$). However, English-OA demonstrated significantly larger mean cluster sizes compared with Korean-OA ($p = .045$).

PWA groups

English-PWA produced significantly more correct responses ($p = .001$) and a greater number of switches ($p = .026$) than Korean-PWA, whereas the groups did not differ in mean cluster size ($p = .450$).

Network metrics

Figure 1 presents the results of the bootstrap comparisons for the three semantic network metrics – ASPL, CC, and Q – derived from the SemNA analyses for both the OA and PWA groups.

OA groups

English-OA demonstrated significantly shorter ASPL ($p < .001$) and significantly higher CC ($p < .001$) compared with Korean-OA. However, Korean-OA showed significantly higher modularity (Q) than English-OA, see Figure 2.

PWA groups

English-PWA exhibited significantly shorter ASPL relative to Korean-PWA ($p < .001$), whereas group differences were not significant for CC ($p = .103$) or Q ($p = .075$). See Figure 3.

Discussion

The present study examined cross-linguistic differences in animal fluency performance between English- and Korean-speaking OA and PWA by comparing their retrieval

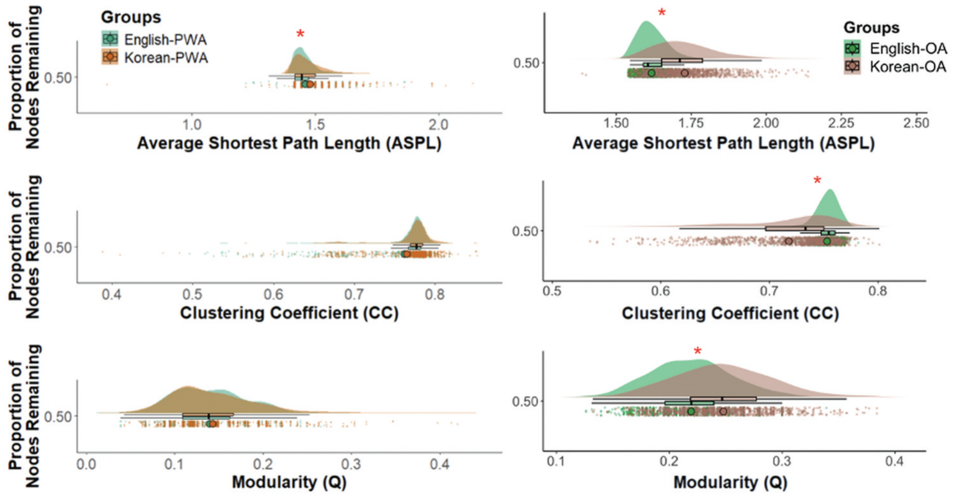

Figure 1. Bootstrap comparison results for semantic network metrics in the people with aphasia (PWA) and neurologically healthy older adults (OA) groups.

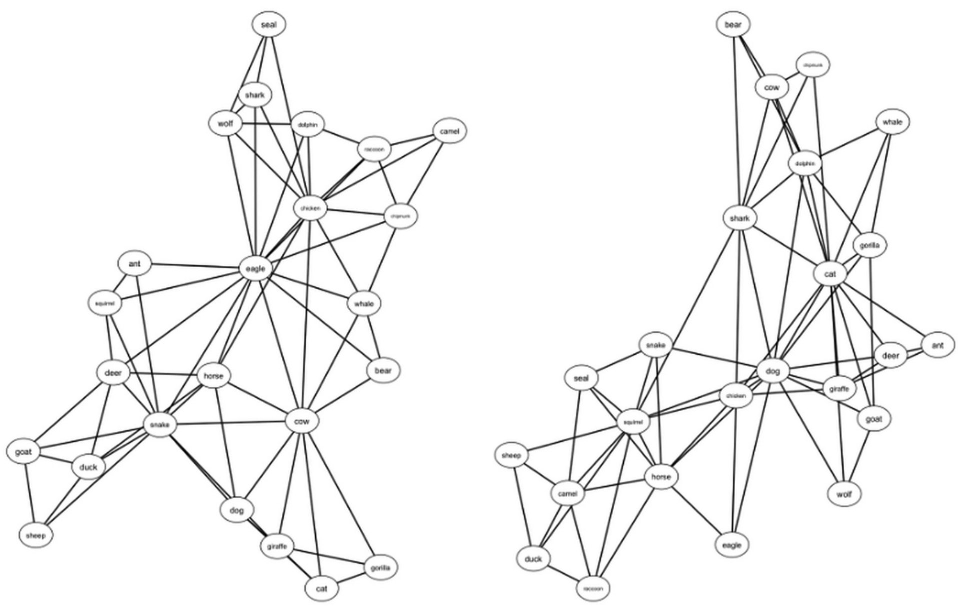

Figure 2. Graphical representation of the semantic network comparisons between English-speaking (left) and Korean-speaking older adults (right). Nodes (circles) represent each lexical item from the "animal" category, and edges (lines) indicate the similarity or co-occurrence of the items.

strategies and the structure of their semantic networks. Building on the cross-linguitic findings of Sung et al. (2025), we analyzed clustering and switching behaviors to characterize how speakers organize and navigate semantic space during lexical retrieval. Beyond behavioral performance, we constructed group-level semantic networks using SemNA and quantified global graph properties (ASPL, CC, Q) to examine structural

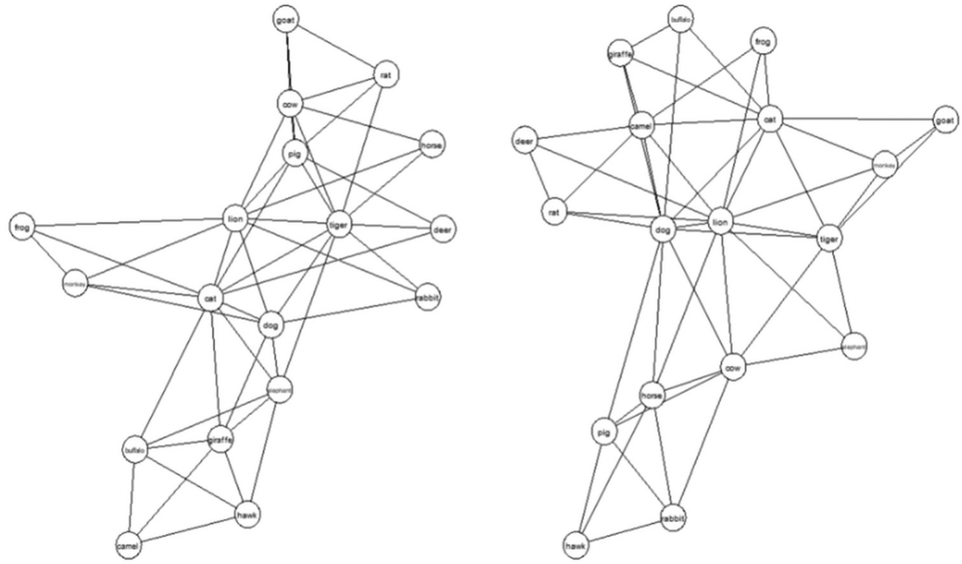

Figure 3. Graphical representation of the semantic network comparisons between English-speaking (left) and Korean-speaking people with aphasia (right). Nodes (circles) represent each lexical item from the "animal" category, and edges (lines) indicate the similarity or co-occurrence of the items.

differences in the efficiency and cohesion of semantic representations across English and Korean, restricting networks to the animal items produced by all groups.

In the behavioral analyses, although English- and Korean-speaking OA did not differ in their total number of correct responses, English-OA produced significantly larger average cluster sizes than their Korean-speaking counterparts. Average cluster size was computed using SNAFU, which applies Troyer et al. (1997) rule-based criteria for defining taxonomic and ecological clusters (e.g., mammals, birds). Because SNAFU defines clusters according to these predetermined categorical boundaries, the larger clusters produced by English-OA suggest that their retrieval sequences align closely with these taxonomic and ecological structures. In contrast, the smaller clusters in Korean-OA indicate that their retrieval patterns mapped less directly onto these English-centric predefined criteria.

These results are likely to be accounted for by previous findings suggesting that semantic network structure may be shaped by culturally grounded lexical experience. In particular, Sung et al. (2025) showed that Korean speakers – both OA and PWA – retrieve a disproportionately large number of zodiac animals during the animal fluency task. Notably, this pattern emerged even though Korean-PWA produced fewer total correct responses overall, underscoring that zodiac animals function as an exceptionally accessible semantic schema rather than as a by-product of higher output. Because the zodiac set forms a dominant and tightly bounded subcategory within the Korean animal domain, retrieval may become concentrated within this single subgroup rather than distributed across multiple taxonomic or ecological categories. Under SNAFU's fixed clustering criteria, which do not incorporate culture-specific schema such as zodiac categories, such concentrated retrieval strategy is likely to elicit smaller cluster sizes for Korean-OA.

Notably, English-PWA produced a significantly greater total number of correct responses and more switches than Korean-PWA. According to Troyer et al'.s (1997) framework, which first formalized the computation of clustering and switching in verbal fluency, switching is the primary driver of total output because each switch enables movement out of exhausted clusters into new semantic regions. This pattern has been consistently supported in subsequent research: reduced switching is closely tied to reduced output in MCI and Alzheimer's disease (Cintoli et al., 2024; Ramanan et al., 2015), and in aphasia, where fewer switches are associated with increased between-cluster pause durations and lower overall productivity (Bose et al., 2017, 2022; Carpenter et al., 2021). Thus, the present findings – greater switching accompanied by greater total output in English-PWA – are consistent with prior observations showing that switching frequency is positively associated with overall verbal fluency performance and may contribute to eliciting a larger number of responses.

To further examine how semantic network structure is differentially organized between languages, we constructed group-level networks using co-occurrence – based semantic network analysis (Christensen & Kenett, 2023). SemNA imposes two constraints that make cross-group comparisons directly interpretable: (1) only animals produced by at least two participants within each group are retained; and (2) networks are "equated" so that only items produced by all groups serve as nodes. These constraints ensure that any observed differences reflect how semantic relations among shared items are structured, rather than differences in lexical inventory. By constructing all networks from this shared and frequency-filtered node set, our comparisons isolate variation in the organization of semantic relations across languages, rather than differences in which animal concepts are represented.

Under these comparable network constructions – ensuring that both language groups were evaluated on an identical set of shared animal items – all three global metrics showed significant cross-linguistic group differences among OA: the Korean-OA network exhibited significantly longer ASPL, lower CC, and higher Q than the English-OA network. Interpreted concretely, longer ASPL indicates that moving from one animal concept to another requires traversing more intermediate nodes – for instance, reaching penguin from lion may involve several intervening animals rather than a direct connection – signaling a less efficiently organized semantic structure. Lower CC further reflects reduced local cohesion, such that animals belonging to the same subcategory (e.g., lion – tiger – leopard) are not as tightly interlinked. Higher Q suggests that the broader lexical – semantic space is more strongly partitioned into distinct subcommunities (e.g., farm animals, sea animals, insects) with fewer connecting pathways between them. Taken together, this constellation of longer ASPL, lower CC, and higher Q characterizes networks in which it is harder to move both within and across clusters, ultimately constraining efficient retrieval during the animal fluency task.

Importantly, these network-level differences emerged despite the absence of group differences in total correct responses, indicating that semantic network analysis captures cross-linguistic variation that is not detectable through traditional behavioral measures alone. Recall that ASPL indexes the average number of steps required to link any two nodes in the network; lower values reflect more direct associative pathways and a semantic space that can be navigated with greater efficiency. The longer ASPL observed in Korean-OA therefore suggests that semantic activation must travel through a greater number of intermediate nodes to reach related concepts – even when the total number of retrieved items is comparable. This elongated path structure makes it more difficult to transition across semantic subcategories, because switching relies on rapid movement along the shortest available associative routes (Kenett et al., 2014, 2017). In contrast, the shorter ASPL in English-OA reflects a more integrated and efficiently connected network that affords more direct pathways between concepts, thereby supporting smoother and more flexible semantic navigation during the fluency task. Taken together, even though English- and Korean-OA did not differ in total correct responses, the network analyses revealed significant cross-linguistic differences in semantic organization that cannot be detected through accuracy-based measures alone.

It is important to note that the two OA groups were carefully matched on age, years of education, and MMSE performance, and that they demonstrated comparable overall fluency output. Therefore, the cross-linguistic differences observed at the network level – constructed from an identical set of shared items – are unlikely to reflect disparities in general cognitive functioning. Instead, these findings suggest that semantic categories such as "animals" may not be organized identically across English and Korean. Even when overall productivity is equivalent, the internal structure of semantic space – including patterns of connectivity, clustering, and modular segmentation – may be influenced by linguistic context. Such variation reflects differences in semantic organization rather than differences in cognitive integrity.

With the observation of lower clustering (CC) and higher modularity (Q) in Korean-OA, these patterns indicate that the semantic neighborhoods in their networks were less locally cohesive and that the lexical – semantic space was more strongly partitioned into distinct subcommunities (Kenett et al., 2014; Pham et al., 2025; Siew et al., 2019). This structural profile aligns closely with the behavioral finding that Korean-OA produced smaller mean cluster sizes than English-OA. Smaller clusters typically emerge when semantic neighborhoods offer fewer locally interconnected pathways, providing limited support for continued retrieval within a given subcategory (Kenett et al., 2017; Zemla & Austerweil, 2018a). In such networks, once a speaker enters a semantic neighborhood, weaker local connectivity restricts the ability to remain within that cluster before a switch is required. Further, the more segmented structure observed in Korean-OA – indexed by higher modularity – suggests that the semantic space is divided into more sharply separated subcommunities with fewer linking pathways between them (Goñi et al., 2013; Siew et al., 2019). Therefore, even when total correct responses are comparable, a network organized into more isolated modules offers fewer locally accessible associative routes and may contribute to eliciting in smaller semantic clusters.

In the PWA group's network analysis, only ASPL showed a significant cross-linguistic difference, with Korean-PWA exhibiting longer ASPL than English-PWA. This pattern parallels network differences already present among older adults – such as the longer ASPL observed in Korean-OA – even though these structural differences did not translate into behavioral disparities in the OA group. Unlike the OA group, in which total correct responses did not differ across languages, Korean-PWA produced fewer items and switched less frequently than English-PWA. One possibility is that cross-linguistic differences in network organization – indexed specifically by the longer ASPL in the Korean groups, reflecting less efficient global connectivity – may become more behaviorally consequential when lexical – semantic processing is challenged in the context of aphasia.

Taken together, these patterns raise the possibility that pre-existing cross-linguistic differences in semantic organization may interact with aphasia-related degradation, contributing to the retrieval difficulties observed in Korean-PWA when lexical – semantic processing is compromised.

As a follow-up to prior cross-linguistic findings (Sung et al., 2024, 2025), the present study demonstrates that both behavioral retrieval strategies and semantic network structure converge to reveal systematic cross-linguistic differences in semantic organization between English- and Korean-speaking OA and PWA. The results illustrate how language and cultural background affect retrieval processes – affecting clustering, switching, and the coherence of emerging semantic networks – in both neurologically healthy adults and individuals with aphasia. Importantly, this work extends cross-linguistic semantic network analysis to aphasia for the first time, offering potential evidence that culturally dominant subcategories – such as zodiac animals in Korean – may interact with semantic control processes and thereby contribute to less efficient network integration. Accordingly, traditional animal fluency tasks – often treated as culturally neutral – may yield qualitatively different patterns depending on a speaker's cultural background (Sung et al., 2024, 2025). Incorporating culturally salient subcategories, examining the diversity and distribution of retrieved items, and evaluating the organization of semantic transitions may therefore offer a more accurate and clinically informative characterization of lexical – semantic functioning than relying on total output alone.

In clinical settings where Korean – English bilinguals with aphasia are evaluated, the present findings warrant careful interpretation. In Korean animal networks characterized by greater modular segmentation, disruption may more readily limit transitions between semantic categories in that language. Such patterns should not be construed as reflecting greater severity per se, but rather as differences in the organization of semantic space across languages. Accordingly, treatment planning in bilingual individuals may benefit from consideration of language-specific semantic structure. When networks appear more segmented, interventions that strengthen connections across subcategories and promote broader semantic integration may be particularly relevant.

More broadly, these findings suggest that structural indices derived from verbal fluency – such as clustering and switching – should be interpreted in light of culturally grounded patterns of semantic organization. Recent work (e.g., Yoo et al., 2025) has also emphasized that clustering constructs may not operate identically across linguistic contexts. Rather than replacing established measures, their application and interpretation may need to be informed by language-specific semantic structure. These considerations do not imply inherent differences in impairment across languages; instead, they recognize that baseline semantic organization may shape patterns of breakdown and recovery. Incorporating information about language history and language-specific semantic structure may therefore support more context-sensitive and targeted rehabilitation strategies.

Several limitations should be noted. First, the present study examined only a single semantic category (animals), leaving open whether similar cross-linguistic patterns would emerge for categories that are less culturally influenced. Second, caution is warranted when interpreting the network findings for the PWA groups because the English-PWA and Korean-PWA participants differed significantly in years of education, and such demographic variability cannot be statistically controlled in group-level network analyses. Prior work shows that greater educational experience is associated with more efficiently organized and less modular semantic networks (Siew & Guru, 2023), and that older adults tend to exhibit longer ASPL and more rigid network structure than younger adults (e.g., Cosgrove et al., 2023). Given these findings, it is possible that some portion of the observed cross-linguistic differences may reflect demographic influences rather than language-specific properties alone. Finally, the present study did not consider potential neural differences between groups, which may also affect semantic network structure and retrieval dynamics. Cross-linguistic variation in cortical atrophy, lesion profiles, or functional connectivity could interact with language-specific semantic organization to influence fluency performance. Future work combining behavioral network measures with neuroimaging approaches will be helpful for determining the extent to which cross-linguistic variation reflects linguistic, demographic, or neurobiological factors.

Conclusion

The present study revealed that cross-linguistic differences in semantic fluency emerge at both the behavioral and network levels among English- and Korean-speaking OA and PWA. Among older adults, English speakers produced larger semantic clusters and demonstrated more cohesive and integrated semantic networks than Korean speakers – indexed by shorter ASPL, higher CC, and lower Q – even in the absence of group differences in total correct responses. For PWA, English speakers generated more switches and a greater number of correct items than Korean speakers, and the network analysis similarly showed shorter ASPL for English-PWA than for Korean-PWA, indicating more globally efficient semantic connectivity within a shared animal inventory. These findings underscore that network-based analyses provide information beyond what accuracy alone can capture, revealing structural differences in semantic organization that are shaped by language- and culture-specific experience. Accordingly, clinical interpretations should move beyond total output alone and incorporate culturally informed indicators – such as the diversity of retrieved subcategories and the connectivity of semantic networks – to more accurately evaluate semantic processing in both older adults and individuals with aphasia.

Acknowledgements

We express our gratitude to all individuals with and without aphasia who participated in this study.

Author contributions

Junyoung Shin: Conceptualization, Data analysis, Writing – original draft; **Michael Scimeca**: Writing – review & editing; **Ran Li**: Writing – review & editing; **Swathi Kiran**: Writing – review & editing; **Jee Eun Sung**: Conceptualization, Supervision, Writing – review & editing.

Disclosure statement

No potential conflict of interest was reported by the author(s).

ORCID

Junyoung Shin http://orcid.org/0000-0003-4198-6753
Michael Scimeca http://orcid.org/0000-0002-1683-7767
Ran Li http://orcid.org/0000-0002-5034-7294
Swathi Kiran http://orcid.org/0000-0003-1586-8913
Jee Eun Sung http://orcid.org/0000-0002-1734-0058

Funding

This work was supported by the National Research Foundation of Korea (NRF) grants funded by the Ministry of Science and ICT (MSIT) [RS-2022-NR070151], [RS-2024-00461617] awarded to Jee Eun Sung; NIH/NIDCD grant [1F31DC021628] awarded to Michael Scimeca; the Hong Kong Baptist University Start-up Grant [21.4131.165536] awarded to Ran Li; and NIH/NIDCD grants [1U01DC014922]and [R01DC020653]awarded to Swathi Kiran.

Data availability statement

The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request. The data are not publicly available due to privacy considerations.

References

Acevedo, A., Loewenstein, D. A., Barker, W. W., Harwood, D. G., Luis, C., Bravo, M., Aguero, H., Greenfield, L., Duara, R., & Duara, R. (2000). Category fluency test: Normative data for English- and Spanish-speaking elderly. *Journal of the International Neuropsychological Society*, *6*(7), 760–769. https://doi.org/10.1017/S1355617700677032

Arias-Trejo, N., Luna-Umanzor, D. I., Angulo-Chavira, A., Ríos-Ponce, A. E., González-González, M. M., Ramírez-Díaz, J. F., Arias-Carrión, O., Marín-García, G., & Arias-Carrión, O. (2021). Semantic verbal fluency: Network analysis in Alzheimer's and Parkinson's disease. *Journal of Cognitive Psychology*, *33*(5), 557–567. https://doi.org/10.1080/20445911.2021.1943414

Bose, A., Patra, A., Antoniou, G. E., Stickland, R. C., & Belke, E. (2022). Verbal fluency difficulties in aphasia: A combination of lexical and executive control deficits. *International Journal of Language & Communication Disorders*, *57*(3), 593–614. https://doi.org/10.1111/1460-6984.12710

Bose, A., Wood, R., & Kiran, S. (2017). Semantic fluency in aphasia: Clustering and switching in the course of 1 minute. *International Journal of Language & Communication Disorders*, *52*(3), 334–345. https://doi.org/10.1111/1460-6984.12276

Carpenter, E., Peñaloza, C., Rao, L., & Kiran, S. (2021). Clustering and switching in verbal fluency across varying degrees of cognitive control demands: Evidence from healthy bilinguals and bilingual patients with aphasia. *Neurobiology of Language*, *2*(4), 532–557. https://doi.org/10.1162/nol_a_00053

Christensen, A. P., & Kenett, Y. N. (2023). Semantic network analysis (SemNA): A tutorial on preprocessing, estimating, and analyzing semantic networks. *Psychological Methods*, *28*(4), 860–879. https://doi.org/10.1037/met0000463

Cintoli, S., Favilli, L., Morganti, R., Siciliano, G., Ceravolo, R., & Tognoni, G. (2024). Verbal fluency patterns associated with the amnestic conversion from mild cognitive impairment to dementia. *Scientific Reports*, *14*(1), 2029. https://doi.org/10.1038/s41598-024-52562-x

Cosgrove, A. L., Beaty, R. E., Diaz, M. T., & Kenett, Y. N. (2023). Age differences in semantic network structure: Acquiring knowledge shapes semantic memory. *Psychology and Aging*, *38*(2), 87–102. https://doi.org/10.1037/pag0000721

Cosgrove, A. L., Kenett, Y. N., Beaty, R. E., & Diaz, M. T. (2021). Quantifying flexibility in thought: The resiliency of semantic networks differs across the lifespan. *Cognition*, *211*, 104631. https://doi.org/10.1016/j.cognition.2021.104631

Folstein, M. F., Folstein, S. E., & McHugh, P. R. (1975). “Mini-mental state.” a practical method for grading the cognitive state of patients for the clinician. *Journal of Psychiatric Research*, *12*(3), 189–198. https://doi.org/10.1016/0022-3956(75)90026-6

Goñi, J., Avena-Koenigsberger, A., Velez de Mendizabal, N., van den Heuvel, M. P., Betzel, R. F., & Sporns, O. (2013). Exploring the morphospace of communication efficiency in complex networks. *PLOS ONE*, *8*(3), e58070. https://doi.org/10.1371/journal.pone.0058070

Goodglass, H., Kaplan, E., & Barresi, B. (2001). *The Boston diagnostic aphasia examination* (3rd ed.). Lippincott Williams & Wilkins.

Goodglass, H., & Wingfield, A. (Eds.). (1997). *Anomia: Neuroanatomical and cognitive correlates*. Academic Press.

Kang, Y. (2006). A normative study of the korean-mini mental state examination (K-MMSE) in the elderly. *The Korean Journal of Psychology: General*, *25*(2), 1–12. https://doi.org/10.15842/kjcp.2006.25.2.001

Kempler, D., Teng, E. L., Dick, M., Taussig, I. M., & Davis, D. S. (1998). The effects of age, education, and ethnicity on verbal fluency. *Journal of the International Neuropsychological Society*, *4*(6), 531–538. https://doi.org/10.1017/S1355617798466013

Kenett, Y. N., Anaki, D., & Faust, M. (2014). Investigating the structure of semantic networks in low and high creative persons. *Frontiers in human neuroscience*, *8*, 407.

Kenett, Y. N., Levi, E., Anaki, D., & Faust, M. (2017). The semantic distance task: Quantifying semantic distance with semantic network path length. *Journal of Experimental Psychology: Learning, Memory & Cognition*, *43*(9), 1470.

Kenett, Y. N., Wechsler-Kashi, D., Kenett, D. Y., Schwartz, R. G., Ben-Jacob, E., & Faust, M. (2013). Semantic organization in children with cochlear implants: Computational analysis of verbal fluency. *Frontiers in Psychology*, *4*, 543.

Kertesz, A. (2006). *Western aphasia battery-revised (WAB-R)*. Pearson. https://doi.org/10.1037/t15168-000

Kim, H., & Na, D. L. (2012). *Paradise-Korean version of the Western Aphasia Battery-Revised (PK-WAB-R)*. Paradise Welfare Foundation.

Kiran, S., & Thompson, C. K. (2003). The role of semantic complexity in treatment of naming deficits. *Journal of Speech, Language, & Hearing Research*, *46*(4), 773–787.

Laine, M., & Martin, N. (2023). *Anomia: Theoretical and clinical aspects*. Routledge.

Lebkuecher, A. L., Cosgrove, A. L., Strober, L. B., Chiaravalloti, N. D., & Diaz, M. T. (2024). Multiple sclerosis is associated with differences in semantic memory structure. *Neuropsychology*, *38*(1), 42. https://doi.org/10.1037/neu0000924

Lerner, A. J., Ogrocki, P. K., & Thomas, P. J. (2009). Network graph analysis of category fluency testing. *Cognitive and Behavioral Neurology*, *22*(1), 45. https://doi.org/10.1097/WNN.0b013e318192ccaf

McNeil, M. R., & Pratt, S. R. (2001). Defining aphasia: Some theoretical and clinical implications of operating from a formal definition. *Aphasiology*, *15*(10–11), 901–911. https://doi.org/10.1080/02687040143000276

Pham, C., Castro, N., & Lee, J. (2025). Lexical retrieval in fluent and nonfluent aphasia: A network analysis of verbal fluency data. *Frontiers in Human Neuroscience*, *19*, 1710907. https://doi.org/10.3389/fnhum.2025.1710907

Ramanan, S., Narayanan, J., D’Souza, T. P., Malik, K. S., & Ratnavalli, E. (2015). Total output and switching in category fluency successfully discriminates Alzheimer’s disease from mild cognitive impairment, but not from frontotemporal dementia. *Dementia and Neuropsychologia*, *9*(3), 251–257. https://doi.org/10.1590/1980-57642015dn93000007

Siew, C. S. Q., & Guru, A. (2023). Investigating the network structure of domain-specific knowledge using the semantic fluency task. *Memory & Cognition*, *51*(3), 623–646. https://doi.org/10.3758/s13421-022-01314-1

Siew, C. S. Q., Wulff, D. U., Beckage, N. M., & Kenett, Y. N. (2019). Cognitive network science: A review of research on cognition through the lens of network representations, processes, and dynamics. *Complexity*, *2019*(1), 2108423. https://doi.org/10.1155/2019/2108423

Sung, J. E., & Kim, J. K. (2011). Differential performance on generative naming and typicality rating between young and older adults. *The Journal of Speech and Hearing Disorders*, *20*(1), 31–49.

Sung, J. E., Scimeca, M., Li, R., & Kiran, S. (2024). Cross-linguistic and multicultural considerations in evaluating bilingual adults with aphasia. *American Journal of Speech-Language Pathology*, *33*(6), 2716–2731. https://doi.org/10.1044/2024_AJSLP-23-00496

Sung, J. E., Shin, J., Scimeca, M., Li, R., & Kiran, S. (2025). Cross-linguistic and multicultural effects on animal fluency performance in persons with aphasia. *American Journal of Speech-Language Pathology*, *34*(6S), 1–11. https://doi.org/10.1044/2025_AJSLP-24-00398

Troyer, A. K. (2000). Normative data for clustering and switching on verbal fluency tasks. *Journal of Clinical and Experimental Neuropsychology*, *22*(3), 370–378. https://doi.org/10.1076/1380-3395(200006)22:3;1-V;FT370

Troyer, A. K., Moscovitch, M., & Winocur, G. (1997). Clustering and switching as two components of verbal fluency: Evidence from younger and older healthy adults. *Neuropsychology*, *11*(1), 138–146. https://doi.org/10.1037/0894-4105.11.1.138

Yoo, Y. R., Park, J., Lim, Y., & Sung, J. E. (2025). Establishing automated analysis systems in the animal fluency task reflecting Korean-specific clustering criteria. *Communication Sciences and Disorders*, *30*(2), 395–411. https://doi.org/10.12963/csd.250095

Zemla, J. C. (2022). Knowledge representations derived from semantic fluency data. *Frontiers in Psychology*, *13*. https://doi.org/10.3389/fpsyg.2022.815860

Zemla, J. C., & Austerweil, J. L. (2018a). Estimating semantic networks of groups and individuals from fluency data. *Computational Brain & Behavior*, *1*(1), 36–58. https://doi.org/10.1007/s42113-018-0003-7

Zemla, J. C., & Austerweil, J. L. (2018b). Analyzing semantic fluency data using a graph-based approach. *Behavior Research Methods*, *50*(2), 603–627.

Zemla, J. C., Austerweil, J. L., Mueller, K. D., & Austerweil, J. L. (2019). SNAFU: The semantic network and fluency utility. *Psychological Methods*, *24*(4), 590–610. https://doi.org/10.3758/s13428-019-01343-w

Zemla, J. C., Cao, A., Mueller, M. L., & Austerweil, J. L. (2020). Snafu: A computational approach to assessing semantic organization from fluency data. *Behavior Research Methods*, *52*(4), 2434–2449. https://doi.org/10.3758//s13428-019-01343-w