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A Systematic Investigation into the Generation of Words Using Semantic Priming Experiments

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Abstract

Semantic priming facilitates word generation by improving the ability to produce semantically related words. However, age-related neurobiological changes may diminish this capacity. This study investigates the effect of aging on word generation across different semantic categories in 150 healthy individuals, aged 31 to 80, divided into five age groups. Participants were tasked with generating words in the categories of synonym, antonym, abstract, and concrete, using the DMDX software. The number of words generated and the accuracy of responses were recorded. The findings revealed statistically significant differences ($p < 0.05$) in the number of words generated across most age groups, with the exception of adjacent age groups (31–40 vs. 41–50, 41–50 vs. 51–60, and 61–70 vs. 71–80), where no significant differences were observed. These results suggest that neurobiological changes between adjacent age groups are subtle. The reduced performance observed in older adults may be attributed to a diminished ability to strategically access and retrieve lexical forms from semantic memory. However, semantic priming appears to mitigate these age-related declines, preventing significant differences between adjacent age groups.

Keywords: priming, aging, word generation, semantics

1. Introduction

Priming is a phenomenon in which the identification of a word is facilitated by prior exposure to a related word, often occurring without conscious awareness. This demonstrates how past experiences influence perception, memory, and behavior. Schacter (2019) defines priming as the process by which recent experiences increase the accessibility of a schema, trait, or concept, making it more likely to be employed in subsequent cognitive tasks. Priming plays a crucial role in word recognition, as it involves the presentation of material that must be reacted to before the word is spoken. When a sound is uncertain, our brains use contextual cues to fill in the gaps and determine what those sounds represent.

Priming exercises can be utilized to elicit linguistic representations, operating at two different levels in language: a surface syntactic form devoid of lexical material and independent of meaning, and a semantic form that contains details about thematic roles, quantifier scope, and information structure. Priming aids in the storage and retrieval of language representations as needed.

A significant concept in priming is semantic priming, which has robust findings in cognitive linguistics and has been reported across a variety of tasks, including lexical decision-making. Semantic priming facilitates a reaction when a semantically associated word is presented, making it easier to generate a related word. Consequently, semantic priming enhances an individual's ability to produce related words. However, this ability inevitably declines alongside various mental and physical capacities, with numerous reports documenting cognitive decline in older adults (Bishop, 2016; Salthouse, 2019). Numerous studies have established the role of semantic priming in word recognition tasks, where presenting a semantically related word leads to faster and more accurate word retrieval (Collins & Loftus, 1975; McNamara, 2005).

Age-related changes in cognitive function, particularly in semantic memory, have been extensively studied. Semantic memory, which involves the storage and retrieval of general knowledge and concepts, remains relatively stable throughout much of adulthood. However, research indicates that it is susceptible to decline in older adults (Rönnlund, Nyberg, Bäckman, & Nilsson, 2005). Aging affects word retrieval, as older adults often experience increased difficulty accessing appropriate lexical forms (Burke & Shafto, 2004). This decline is often linked to atrophy in brain structures critical to memory, such as the hippocampus and prefrontal cortex (Raz et al., 2005). Research by Taylor and Burke (2002) suggests that older adults may rely more on contextual cues, such as those provided by semantic priming, to support word retrieval.

The impact of semantic priming on older adults has produced mixed results. Some studies indicate that priming effects are preserved in aging, particularly in tasks involving implicit memory, which tends to remain relatively intact as people age (Howard, 2004). Additionally, research has demonstrated that older adults can benefit from priming in lexical tasks, suggesting that their semantic networks remain functional even as other cognitive abilities decline (Laver & Burke, 1993). Neuroimaging studies further support this finding, showing that semantic priming activates overlapping brain areas in both younger and older adults, although the degree of activation may differ (Madden et al., 2009). Moreover, Fernandino and Conant (2024) found that semantic priming is primarily driven by experiential similarity between the prime and target. Ouyang and Zhang (2020) also support this notion, demonstrating bidirectional connections between semantic and phonological nodes in speech production. Their study on the effects of semantic and phonological priming on the tip-of-the-tongue phenomenon highlights how these connections can help establish a steady relationship between the prime and target, thereby mitigating the effects of aging.

In contrast, other research points to a diminished priming effect in older adults, particularly in tasks requiring fine semantic distinctions or involving explicit memory retrieval. Although older adults may struggle with tasks demanding nuanced semantic distinctions, their ability to use broader semantic categories generally remains intact. The cognitive decline associated with aging leads to several challenges, including deterioration in semantic memory (Ekem-Ferguson, 2023), reduced visual working memory (Tröndle & Langer, 2024; Kronovsek et al., 2021), decreased cognitive flexibility (Cleal et al., 2021), slower processing speed (Zhu et al., 2022; Rasooli, 2023), and impaired executive functions (Buckner, 2004; Arulsamy et al., 2019). These factors contribute to weakened semantic nodes, making semantic memory retrieval more challenging.

More recent studies have emphasized the role of cognitive control in semantic processing. Neuropsychological and neuroimaging research indicates that the prefrontal cortex and inferior temporal lobes, which are critical for word retrieval and selection, undergo structural and functional decline with age (Chao et al., 2005; Voss & Paller, 2008). These brain changes likely contribute to the diminished ability of older adults to strategically access and retrieve appropriate lexical forms. However, semantic priming, which relies on implicit memory processes, may help mitigate some of these effects by triggering existing connections between prime and target words (Finlay, Marmurek, & Morton, 2005; Ober, Shenaut, & Reed, 1995).

In our study, we aimed to analyze the effect of semantic priming in aging by comparing various semantic categories, such as synonyms and antonyms, using word generation tasks. Our primary objective is to examine the impact of aging on the effectiveness of semantic priming across different semantic categories. Specifically, we aim to investigate how aging affects an individual's ability to benefit from semantic priming in tasks involving synonyms, antonyms, abstract words, and concrete words. By comparing these categories, we seek to identify which aspects of word generation are most influenced by semantic priming and which remain relatively stable despite age-related cognitive decline.

2. Aim

To investigate the impact of aging on word generation tasks in different domains of semantic categories

3. Method

The study was conducted in two phases:

Phase 1 involved the development of a word list, programming of stimuli, and subject selection;

Phase 2 included administration, data analysis, and statistical analysis.

3.1.1. Phase 1

A list of words was developed across four semantic categories—concrete words, synonyms, antonyms, and abstract words—to assess the effect of semantic priming through a generation task. Synonyms and antonyms were chosen for their effectiveness in exploring the semantic system and tapping into implicit memory functions (Graf & Schacter, 1985; Schacter, 1983). Concrete and abstract words were selected for their ability to investigate the semantic system at a higher level, as well as for their strong imagery effects on semantic priming (Nittono et al., 2002; Paivio, 1991).

The words were sourced from the typical speaking vocabulary of adults. A pilot study was conducted to refine the word selection process. Initially, 20 words per category were selected and reviewed by four Malayalam teachers, who identified the 10 most appropriate words based on familiarity and frequency of usage. These selected words were then further evaluated by ten qualified Speech-Language Pathologists to ensure their appropriateness and suitability.

3.1.2. Phase 2

After finalizing the word list, a pilot study was conducted to determine the optimal stimulus presentation duration. This duration was tested using DMDX software at intervals of 5, 10, 15, and 20 seconds with ten adults from each age group. The results indicated that 20,000 milliseconds were the optimal duration for obtaining appropriate responses across all age groups. Consequently, the stimulus presentation duration was set at 20,000 milliseconds for all experiments.

A similar pilot study was conducted to establish the response time limit for the generation tasks. The response duration was also tested at intervals of 5, 10, 15, and 20 seconds with ten adults from each age group. The optimal response time limit was determined to be 20,000 milliseconds. If participants failed to respond within this time frame, the maximum duration of 20,000 milliseconds was recorded as their reaction time.

3.2. Programming of stimulus

The appropriately formulated words were presented using DMDX software in Auto mode (Forster & Forster, 2003) on an HP Pavilion X360 convertible with a display resolution of 1920 x 1080. Additionally, Time DX and Check Vocal software were installed to record reaction times and vocal responses.

3.3. Participant selection

A total of 150 right-handed, healthy aging adults aged 30 to 80 years were selected and grouped into five age brackets: 31-40, 41-50, 51-60, 61-70, and 71-80, with each group consisting of 30 participants. All participants had no history of neurological, speech-language, or psychological issues. Malayalam was their mother tongue, and they had attained an education level of at least the 10th standard. Additionally, participants were proficient in speaking, reading, and writing in Malayalam. It was essential that they were physically fit to participate in the tests and had normal or corrected vision and hearing.

3.4. Administration

Test administration began by obtaining consent from both participants and caregivers, followed by establishing rapport and explaining the purpose and nature of the evaluation. Participants underwent informal screening for hearing loss, and demographic data were collected. The testing environment was kept quiet and minimally distracting, with the laptop screen adjusted to align with each participant's line of vision. Stimuli were presented using DMDX software in Auto mode.

Participants received a set of 10 words for each experiment and were instructed to generate as many related words as possible for each category within the prescribed time limit. Reaction times, task completion times, and responses were recorded, with a 10-second interval between the presentation of each word. Instructions varied according to the semantic category being tested.

3.5. Data Analysis

Data were collected from 150 participants through a structured manner. No data transformations or pre-processing steps were applied to the data prior to analysis.

3.6. Statistical analysis

Statistical analyses were performed using SPSS version 26.0. Descriptive statistics were used to summarize the demographic characteristics, and inferential analyses were conducted to examine group differences. Descriptive statistics including mean, standard deviation, and frequency distribution were calculated for word generation across different age groups.

A Kruskal-Wallis Test was performed to assess whether there were statistically significant differences in the number of words generated across different age groups. This non-parametric test was selected because it does not assume normal distribution and is suitable for comparing more than two independent groups. A significance level of $\mathbf{p < 0.001}$ was adopted for this analysis, indicating that any observed differences would be considered statistically significant at the 0.1% level.

When the Kruskal-Wallis Test indicated a significant difference among the age groups, Dunn's pairwise comparison was used as a post-hoc analysis to identify specific group differences. The Bonferroni correction was applied to adjust for multiple comparisons and control the family-wise error rate. Results are presented with test statistics and adjusted p-values to highlight the specific age groups where differences were observed

4. Result

Figure 1 presents the mean and standard deviation for each age group. Tables 1 and 2 display the results of the Kruskal-Wallis Test and Dunn's pairwise comparison regarding the number of words generated across the age groups, respectively.

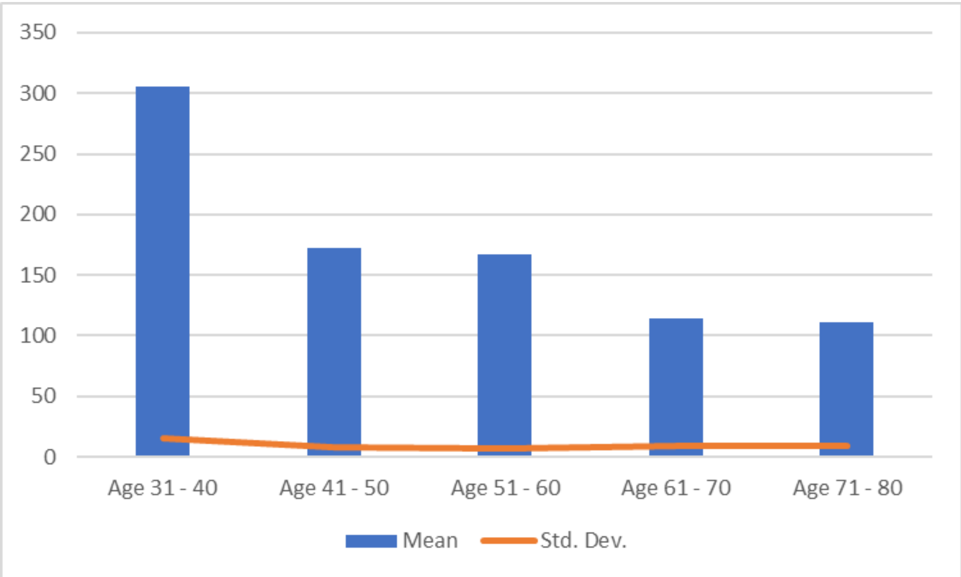

Figure 1

Mean and standard deviation of word generation across different age groups. The data indicates how aging impacts word generation tasks within various semantic categories.

Table 1

Kruskal-Wallis Test Table of Statistics Showing Significant Difference in the Distribution of Number of Words Generated

Total N	150
Test Statistic	129.677
Degree Of Freedom	4
Asymptotic Sig.(2-sided test)	<0.001

Level of significance = 0.05.

The H-value of 129.677 indicates a notable difference in the ranks of word generation across the five age groups, with 4 degrees of freedom. The p-value of < 0.001 signifies that these differences are statistically significant, meaning the distribution of word generation is significantly different among the age groups. Furthermore, a large effect of age on word generation was observed, signifying a substantial impact of age on word generation.

Table 2

Dunn's pairwise comparison on number of words generated across age groups

Sample 1-Sample 2	Test Statistic	Sig.	Adj. Sig.[a] (P)
Age 71-80-Age 61-70	4.167	0.710	1.000
Age 71-80-Age 51-60	57.283	<0.001	<0.001
Age 71-80-Age 41-50	66.883	<0.001	<0.001
Age 71-80-Age 31-40	107.083	<0.001	<0.001
Age 61-70-Age 51-60	53.117	<0.001	<0.001
Age 61-70-Age 41-50	62.717	<0.001	<0.001
Age 61-70-Age 31-40	102.917	<0.001	<0.001
Age 51-60-Age 41-50	9.600	0.392	1.000
Age 51-60-Age 31-40	49.800	<0.001	<0.001
Age 41-50-Age 31-40	40.200	<0.001	0.003

In Figure 1, it is evident that the mean word generation decreases steadily with age, while the standard deviation remains relatively constant, except for the 31–40-year age group, where it exhibits a slight increase. This observation is further supported by the values in Table 1, which demonstrate a significant difference (sig < 0.001) in word generation as age advances.

Table 2 reveals a significant difference ($p < 0.05$) in the distributions of the number of words generated across most age groups, except for the comparisons between the 71-80 and 61-70 age groups, as well as between the 51-60 and 41-50 age groups. Additionally, it was observed that the 31-40 age group generated the highest number of words.

5. Discussion

The findings of this study have significant implications for understanding the relationship between aging and semantic memory processing. As demonstrated, the substantial impact of aging on word retrieval likely arises from the diminished ability of older adults to access and retrieve appropriate lexical and semantic representations. This observation aligns with previous research indicating that the cognitive processes involved in word retrieval—such as searching semantic stores, evaluating potential word choices, and exerting cognitive control—become less efficient with age due to the decline of frontally mediated brain structures, including the parietal and inferior temporal lobes (Alexander et al., 1997; Carter et al., 2000; Chao et al., 2005; Ishai et al., 2000).

Despite the expected cognitive decline, our results reveal no significant differences in performance between immediate age groups, which can be attributed to the mitigating effects of semantic priming. The ability of priming to facilitate word retrieval suggests that older adults can still utilize their crystallized memory—long-term stored knowledge and experience—more effectively than fluid memory, which typically declines with age. This supports the theory that implicit memory, a cognitive function that remains relatively intact with age, plays a critical role in maintaining performance in word retrieval tasks through semantic priming (Finlay, Marmurek, & Morton, 2005; Stevens, Wig, & Schacter, 2008; Ward, Berry, & Shanks, 2013).

Our findings resonate with prior studies, such as those by Lezama, Gómez-Ariza, and Bajo (2023), which demonstrated the beneficial role of semantic priming in cognitive tasks, including creative thinking and lexical decision-making. The experiential similarity between prime and target words, as suggested by Fernandino and Conant (2024), further reinforces this connection and emphasizes the importance of semantic networks in preserving cognitive function. Additionally, the relative stability of implicit memory across aging (Ward et al., 2020) provides a crucial mechanism by which older adults can compensate for age-related declines in fluid memory and executive function.

Implications of this study suggest that interventions focusing on priming and enhancing implicit memory could be promising strategies for mitigating age-related declines in semantic processing. By strengthening the connections between prime and target representations, older adults may experience improved word retrieval and cognitive performance in everyday tasks. Furthermore, the findings highlight the potential for tailored cognitive training programs to leverage semantic priming as a tool for maintaining language processing and semantic memory in older populations.

6. Conclusion

In conclusion, our study provides compelling evidence that aging significantly impacts semantic memory and word retrieval, primarily due to structural and functional changes in frontally mediated regions and other critical areas of the brain. Specifically, we found that older adults exhibit a marked decline in their ability to retrieve words, which can be attributed to their diminished capacity to access lexical forms and semantic representations effectively.

However, our findings also reveal that semantic priming serves as an effective intervention to mitigate these age-related declines. By leveraging crystallized memory, which tends to remain intact with age, priming enhances the retrieval process, allowing older adults to access words more readily despite the deterioration of cognitive reserves and fluid memory typically associated with aging.

These results align with existing literature highlighting the protective effects of semantic priming on cognitive functioning in older adults. Notably, the ability to use priming to bolster word retrieval underscores the potential for targeted interventions to support language processing in aging populations. This study not only reinforces the understanding of how aging affects semantic processing but also emphasizes the importance of exploring strategies like priming that can enhance cognitive performance, ultimately contributing to better communication outcomes for older adults.

7. Limitations of study

- Sample Size: While the study included 150 participants, a larger sample size could improve the statistical power and generalizability of the findings. Smaller samples may not fully capture the diversity within the population.
- Demographic Representation: The sample may not be representative of the broader population, particularly concerning age, gender, socio-economic status, or cultural background. This limitation may affect the applicability of the results to different demographic groups.
- Lack of Data Transformations: While no data transformations or pre-processing steps were applied, this could lead to issues if the data contained outliers or non-normal distributions that might have benefited from such transformations to meet the assumptions of the statistical tests.
- Causality vs. Correlation: The study design is correlational, and while significant differences were found among age groups, causal inferences cannot be made. Future research should consider longitudinal designs to establish causality.
- External Validity: The findings may be limited to the specific context or setting of the study, which could restrict their generalizability to other environments or populations.

8. Future Directions

- Longitudinal Studies: Future research could employ longitudinal designs to examine changes in word generation abilities over time across different age groups. This approach would allow for a better understanding of developmental trends and the potential causal relationships between age and cognitive performance.
- Intervention Studies: Future research could explore the effectiveness of specific interventions or training programs designed to enhance word generation skills, particularly in

older adults. Such studies could evaluate the impact of these interventions on cognitive functioning and language performance.

- Exploration of Underlying Mechanisms: Investigating the underlying cognitive and linguistic mechanisms that contribute to age-related differences in word generation could provide valuable insights. Future research might explore factors such as vocabulary size, processing speed, or working memory capacity.

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