Research Article

Effect of Ageing on Semantic and Phonetic Information Processing

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Short running title: Effect of Ageing on Semantic and Phonetic…

Highlights:
- Aging affects both phonetic and semantic information processing
- Phonetic information processing shows earlier aging effects
- The developed test can be used as an natural test of speech comprehension

ABSTRACT
Background and Aim: To understand the difficulties of elderly in natural listening situations, the present study assessed the ability of participants to extract phonetic information and semantic information in noise. The main objective was to evaluate the relationship between age and performance in Semantic Information Processing (SIP) and Phonetic Information Processing (PIP) tasks.
Methods: Fifty-three normal hearing participants aged 40 to 65 years were categorized into five age groups. Participants underwent information processing assessments using standardized semantic and phonetic questions from Kannada stories under Signal-to-Noise Ratios (SNR) i.e., quiet, 0 dB SNR, and –4 dB SNR conditions.
Results: Younger participants outperformed older participants in both SIP and PIP tasks. Performance was optimal in quiet conditions, followed by 0 dB and –4 dB SNR. Except at –4 dB, PIP scores exceeded SIP scores. A significant differences was observed between the groups 1–4 and group 5 at 0 dB SNR in PIP condition only. A moderate negative correlations indicated that performance in both SIP and PIP declined with age, with linear regression revealing reductions of 0.216 and 0.210 each year in SIP and PIP respectively.
Conclusion: Age-related declines in PIP were noted at one SNR, while SIP remained stable, aligning with the Transmission Deficit Hypothesis (TDH). Nonetheless, regression analyses indicated a general decline in both SIP and PIP with age, supporting the Inhibitory Deficit Hypothesis (IDH).
Keywords: Semantic information processing; phonetic information processing; test of speech comprehension; transmission deficit hypothesis; inhibitory deficit hypothesis

Introduction

Speech recognition in noise tasks involves mere repetition of different types of sentences, which can be low-predictive nonsense sentences or meaningful, simple sentences presented in competing background stimuli [1, 2]. Jerger et al. [3] suggested that speech discrimination, reception, detection, and word recognition scores do not genuinely reflect speech understanding. Stanley [4] stated that repetition tasks intentionally limit the utility of higher-order linguistic and cognitive skills essential for speech understanding. Hence, speech perception tasks aimed at recognizing and repeating the stimuli are not representative of problems faced by elderly hearing-impaired individuals in real-life communication. Instead, the task should be able to extract meaning from speech. Behavioural methods use the presentation of part of a passage or story, followed by a set of questions to assess the understanding of the content [5, 6]. However, this task placed higher demands on the person's cognitive resources. To overcome this, decision-based semantic judgement tasks have been developed [7, 8]. Xia et al. [7] assessed the amplification benefit by presenting a story. Their participants were instructed to respond to either phonetic (keywords heard) or semantic (meaning of the heard segment) questions related to the heard story. A question was visually presented in random order, where a participant was instructed to select the appropriate option under each question. A significant amplification benefit was observed only in phonetic conditions, with limited or no benefit in semantic conditions.

Effects of ageing on Semantic Information Peocessing (SIP) and Phonetic Information Processing (PIP) are explained by the Inhibitory Deficit Hypothesis (IDH) and the Transmission Deficit Hypothesis (TDH). The IDH [9] suggests that as individuals age, their ability to filter out irrelevant information deteriorates, resulting in excessive activation of both semantic and phonological systems. This inability to inhibit unnecessary distractions contributes to declines in cognitive functions, including language processing, and affects semantic and phonological processes equally [10]. Several studies support the IDH, demonstrating that older adults have difficulty suppressing irrelevant information during language tasks [11, 12], with inhibitory control playing a crucial role in age-related differences in semantic fluency [12]. The IDH provides additional insights into age-related difficulties, such as increased sensitivity to distractions and difficulty inhibiting competing lexical items [13, 14]. The reduced ability to suppress activated semantic neighbours, combined with age-related declines in inhibitory control, is associated with poorer phoneme perception in sentences, particularly for older adults with hearing loss [15]. These findings suggest that, although inhibitory deficits play a role in speech perception decline, the extent of this impact varies, and the relationship between ageing, inhibition, and language processing remains complex and multifaceted. However, other studies present mixed results, indicating that semantic and phonological processing may not decline symmetrically with age [16].

On the other hand, the TDH [17] attributes ageing-related language difficulties to weakened connections between semantic and phonological nodes. A decline in transmission efficiency as a function of age primarily affects lexical retrieval, leading to more frequent tip-of-the-tongue states and difficulty retrieving phonologically similar words [18, 19]. While semantic processing is somewhat preserved due to redundancy in the system, phonological processing is more susceptible to age-related decline [19].

The purpose of this study was to investigate how ageing affects SIP and PIP across different Signal-to-Noise Ratios (SNRs). By examining the relative decline of these processes in older adults, the study aims to clarify the distinct mechanisms underlying these changes, specifically whether they align more closely with the IDH or the TDH. Understanding the interaction between age, noise conditions, and the processing of semantic and phonetic information will provide critical insights into the communication challenges faced by older adults such as difficulty in perceiving speech in everyday noisy environments. Perspectively, the findings may contribute to improved interventions or strategies for mitigating these age-related declines in real-life communication settings. Thus, the present study aimed to investigate the age-related changes in SIP and PIP tasks by comparing their performance among participants across five age groups (40–65 years) at varying SNRs. The objectives of the study were 1) to compare recognition scores at different SNRs between a) groups in each task and b) SIP and PIP in each group and 2) to explore the relationship between age and recognition scores on each task.

Methods

Participants

The test population comprised 53 native Kannada-speaking normal-hearing participants aged 40–65 years (mean age: 54.89 years). They were divided into groups 1 to 5 based on their age. In group 1, the age range was 40 to

45 years (n=9, mean age=44 years). The age range of group 2, group 3, group 4 and group 5 were 46 to 50 years (n=9, mean age=48.56 years), 51 to 55 years (n=13, mean age=53.15 years), 56 to 60 years (n=13, mean age=58.61 years), 61 to 65 years (n=9, mean age=63.22 years), respectively. Despite being divided into five groups, the participants were only divided into two groups based on inferential statistics. The effective sample size was determined by considering the η^2 (0.13) value obtained from an earlier study [7]. The determined sample size was 24 participants with a required significance level at 0.05, yielding an actual power of 0.83.
All the participants had normal peripheral hearing in both ears, as indicated by pure tone thresholds of 15 dB HL or less between the octave frequencies of 250 to 2000 Hz and less than 25 dB HL at 4000 and 8000 Hz; normal middle ear functioning suggested by type A tympanogram with reflexes present; and Transient Evoked Otoacoustic Emissions (TEOAE) present indicative of normal outer hair cell functioning. Through a structured interview, it was ascertained that none of the individuals had any history of exposure to noise or music for a long duration or was under prolonged medication for associated problems. Further, none of the participants scored less than 25 on the mini-mental state examination and did not report a current or previous history of otological or neurological problems.

Semantic and phonetic information processing

Semantic processing involves understanding word meanings and context, while phonetic processing focuses on sound structures [20]. In the present study 'on-the-go' structure [21] was used to assess both SIP and PIP. During SIP assessment questions participants had to understand the speech segment and answer them as there were no repeated key words, where as in PIP assessment the words presented in the speech segment were repeated in the questions.

Stimuli

A standardized story in Kannada comprised of semantic and phonetic-related questions developed by Ajith and Hemanth [22] was used. Phonetic questions were prepared using the keywords heard from the story segment to evaluate the PIP. Semantic questions were framed to deduce meaning from the heard story segment to test SIP. Out of five standardized stories, only three stories and their corresponding semantic and phonetic questions were used for the testing. Each story was segmented into 30, and each segment was comprised of both semantic and phonetic questions. The number of questions delivered depends on the stop criteria, where a specified number of each of the phonetic and semantic questions from the story were delivered randomly, and then testing was stopped. Suppose 15 is selected as the stop criteria, and then 15 questions, each phonetic and semantic, were randomly selected and displayed with two options for the corresponding 30 segments of the story. Each segment in the story is comprised of 8–12 words recorded in the range of 3.5 to 4.5 seconds to have a normal rate of 2 words per second [23]. The question corresponding to each story segment comprised of 4–5 words. Two options were provided with 2–3 words for each question. The questions and the two options are visually displayed on the monitor. The test used an 'on-the-go' structure [10]; that is, a segment of the story was played, and then either a phonetic or semantic question was displayed, and after the response (selecting an option from binary choice), the next segment of the story start automatically. This process continues till the stoppage criteria are reached. This way of presenting the segmented story followed by displaying its corresponding question either in semantics or in phonetics and eventually seeking the response reduces the influence of episodic memory, which is contrary to the previously developed tests to assess comprehension [6, 24].

Noise

The noise used was speech-shaped. The sentences of each story were concatenated, and its Long-Term Average Speech Spectrum (LTASS) was derived by spectral analysis. The Infinite Impulse Response (IIR) filter was designed in MATLAB 2015a (Mathworks Inc, Natick, MA) using the LTASS. White noise was subjected to the designed IIR filter to obtain speech-shaped noise with similar spectral characteristics of recorded stories. The speech-shaped noise level was varied in reference to speech level to obtain the desired 0 dB SNR and –4 dB SNR.

Procedure

A Dell Inspiron 15 (Dell Inc. United States), having Intel Core i5 processor loaded with listening effort presentation software [22] delivered a story through a sound card with an audio-router to the designated loudspeakers. Three loudspeakers were used for the presentation of the stories and noise. They were placed at –

45°, 0° and +45° at a distance of 1 m from the participant. The sentences were presented in the loudspeaker numbered 2 (at 0°), and noise through the loudspeakers labelled 1 and 3 (at –45°and +45°). The following parameter was set in the Semantic Information Processing (SIP) presentation software. The stop criterion was set to 15. The interval between the end of the story segment and the beginning of the displayed question was considered to be the intra stimulus duration, set at 1.5 seconds. The response window for the participant to answer the question was set to 10 seconds. The inter-stimulus duration of 2 seconds was set between the end of the response window (option selected by the participant) and the following next presentation of a segment of the story. The software settings window is shown in Figure 1.
The Kannada story segments were presented sequentially through SIP presentation software routed through a sound card with audio router to the designated loudspeaker at the participant's comfortable level. Following the presentation of each segment, the questions corresponding to either phonetic or semantic with binary options were visually displayed on a monitor placed in front of the participants (Figure 2). Each participant was instructed to listen to the segments of the story carefully and select the appropriate option for the displayed question. They were encouraged to guess if they did not know the correct answers. A similar procedure was carried out in three conditions, 0 dB SNR and 4 dB SNR, and in quiet using three different stories. SIP testing across conditions was counterbalanced among participants in each group.

Scoring

A score of 1 and 0 was awarded for correct and incorrect/no response, respectively. The scoring was the same for both semantic and phonetic questions. The maximum score that could be obtained for each question category was 15. The raw score was converted into a percentage. The percentage score was then converted into a Rationalized Arcsine Unit (RAU) transformation [25]. The scores were converted into RAU to stabilize the error variance. The RAU scores were used for statistical analysis. The formulae for conversion of percentile scores into arcsine and rationalized arcsine units are given below.

$$AU = ASIN\left[SQRT\left(\frac{S}{N+1}\right)\right] + ASIN\left[SQRT\left(\frac{S+1}{N+1}\right)\right] \text{ ----------------------------- } (1)$$

AU: the score is transformed to arcsine units.
S: score: the cell in the Excel sheet containing your number of correct responses.
N: number: the cell in the Excel sheet containing the number of trials that were performed.

$$RAU = (46{,}47324337 \times AU) - 23 \text{ -- }(2)$$

AU: the cell in the Excel sheet containing scores is transformed into arcsine units using equation (1).
The scoring was performed separately for each question category (semantic and phonetic).

Statistical analysis

Group differences for the perception of semantic and phonetic information were analyzed separately using repeated measures ANOVA, followed by independent samples' t-test. Further, paired samples t-test were administered to compare the semantic and phonetic scores at different SNRs. Pearson's correlation coefficient was used to find the relationship between SIP scores and age at different SNRs. A linear regression model was developed to predict PIP and SIP from age.

Results

As expected, the mean RAU scores were higher for the younger group than the older adult group for both PIP and SIP. In addition, a higher score was observed in quiet, followed by 0 dB SNR and –4 dB SNR in both SIP and PIP conditions. Except at –4 dB SNR, the PIP score was higher than the SIP score in each group at different SNRs (Table 1).

Comparison between groups in semantic information processing and phonetic information processing

A repeated measures ANOVA with a between-subject factor as groups on the SIP revealed a significant main effect of SNR ($F_{(1,48)}$=32.802, p=0.001) and group ($F_{(1,48)}$=3.873, p=0.009) but no significant interaction effect of group*SNR ($F_{(8,96)}$=1.873, p=0.133). Further, an independent samples t-test with corrected means (significance value of 0.005) was performed between groups at each SNR. A significant difference was revealed only between groups 1 and 5 at 0 dB SNR (t=4.662, p=0.001) on SIP. Furthermore, a significant main effect of SNR ($F_{(1,48)}$=57.622, p<0.001), group ($F_{(1,48)}$=3.766, p=0.010) and a significant interaction effect of group*SNR

($F_{(8,96)}$=3.972, p=0.008) were found in PIP. An independent sample test revealed a significant difference only between groups 1 and 5 at 0 dB SNR (t=6.513, p<0.001) in PIP.

Comparison of semantic information processing and phonetic information processing scores at different signal-to-noise ratios

Since there was no difference between groups 1 to 4, the data were grouped, and a paired sample t-test was administered to compare participants' performance on SIP and PIP at different SNRs. Results revealed a significantly higher score in PIP than SIP only at 0 dB SNR in the 1–4 combined group (t=–5,686, p<0.001). At 4 dB SNR (t=–1.77, p=0.08) and quiet (t=–1.17, p=0.24), differences were not significant. Group 5 showed no significant differences at all the signal conditions, even though the PIP scores was higher than the SIP.

Relationship between semantic information processing and phonetic information processing scores with age

Results of correlation showed a significant moderate negative correlation between age and SIP scores (r=–0.520, p<0.001, n=48) at 0 dB SNR (Figure 3), mild but a significant negative correlation (r=–0.353, p=0.014, n=48) at –4 dB SNR (Figure 4) such that SIP score reduces with advance in age. However, no significant correlation was observed between age and SIP in quiet condition.

Similarly, a significant moderate negative correlation between age and PIP scores (r=–0.537, p<0.001, n=48) at 0 dBSNR (Figure 5), weak but significant negative correlation (r=–0.294, p=0.043, n=48) at –4 dB SNR (Figure 6) and mild negative correlation (r=–0.313, p=0.030, n=48) at quiet (Figure 7) were found such that PIP score reduces with advance in age.

Predicting semantic information processing and phonetic information processing from age

Further, the linear regression model was developed to predict PIP and SIP from age. Equation y=a(x)+b (r^2=0.289; a=–0.210; b=68.526; x=age) was used to predict PIP from age and for predicting SIP yielded the following values (r^2=0.271; a=–0.216; b=67.552; x=age) at 0 dB SNR. Using the equation, we can predict SIP and PIP scores based on age, i.e., with a year increase in age, PIP reduces by 0.210 and SIS by 0.216 when tested at 0 dB SNR. These results indicate a decline in PIP and SIP with advancing age.

Discussion

Effect of age in semantic information processing and phonetic information processing

A significant effect was observed on SIP due to both the SNR and group. It suggests that both noise level and age significantly influence semantic processing abilities. However, the lack of a significant interaction effect between the group and SNR indicates that the decline in semantic processing with age is relatively consistent across different noise levels rather than being exacerbated at higher noise levels. Similar to the results of semantic processing, the study found a significant main effect of SNR and group on PIP. Notably, a significant interaction effect between the group and SNR was also observed, indicating that age-related decline in phonetic processing is more pronounced only at 0 dB SNR. Significant differences were probably not observed at –4 dB SNR and quiet due to ceiling and floor effects. The results indicate an age-related decline in PIP at least at 0 dB SNR, whereas no such decline was present in SIP. These findings suggest that advancing age causes more transmission deficits in top-down pathways required for the retrieval of phonetic cues. This finding is in accordance with the popular findings of the differential decline of semantic and phonologic processing. At the same time, semantic abilities remain relatively stable throughout the lifespan, and phonological processing declines with age [26]. Older adults typically perform worse than younger adults on phonological tasks, exhibiting slower reaction times and lower accuracy [27]. Taylor and Burke [16], reported age-related declines in word production and spelling, whereas no performance decrements in online perception and comprehension. They also hypothesized that production tasks rely on top-down priming to retrieve phonology or orthography, whereas comprehension tasks depend on bottom-up processing to access semantic information. The age-related behavioural asymmetry highlights that the phonological system's top-down priming is more susceptible to transmission deficits than the bottom-up priming in the semantic system [28].

The results with reference to the different SNRs were also interesting. Higher noise (distractor) effects were expected for both SIP and PIP measures in the older group as compared to the younger groups. Older adults are less able to inhibit irrelevant information and process it further for word retrieval and meaning [11, 29]. However, except at 0 dB SNR for PIP, none of the SNRs failed to elicit age-related decline due to general cognitive slowing. It could be due to the older adults' ability to inhibit irrelevant information when salient cues were accessible [29], as speech-shaped noise may have caused only energetic masking, not informational masking. Hence, there is a need to use perceptually similar distractors, such as speech babble, which may readily demonstrate an age-related decline in SIP and PIP.

Comparison between phonetic and semantic information processing scores

The mean rationalized arcsine scores were higher for the phonetic task than the semantic task in all the age groups and at all the SNRs. One of the reasons for this could be the difference in task difficulty. Since no inference needs to be drawn in the phonetic task, the participant found it easier than the semantic task, where an individual has to remember the passage and answer by understanding the meaning of words in the passage and the question. Similar findings were reported by Stanley et al. [8], who compared younger and older adults' performance on semantic word recognition tasks in noise and found reduced semantic task scores at lower SNR, with older adults obtaining significantly lower scores.

Relation between age and each processing score and predicting the processing score from age

There was a negative correlation between PIP and SIP scores and the age of the participants, suggesting that ageing reduces the ability to process phonetic and semantic information. In the PIP task, the correlation with ageing was significant at all the SNRs, whereas in SIP, there was a correlation only in the noise conditions but not in quiet conditions. As an individual's performance is solely based on the audibility of speech information in phonetic tasks, the scores were less influenced by noise as long as they were sufficiently audible. Additionally, scores were significantly lower in the presence of noise than quiet in the semantic task. That being said, phonetic tasks could be performed even at lower SNRs than semantic tasks.

A regression model was established to predict the semantic and phonetic scores using age. Equation y=ax+b was utilized to predict SIP and PIP with age as the base factor. The linear regression models provided prediction of PIP and SIP from age at 0 dB SNR. Negative slopes obtained in both PIP (a=–0.210) and SIP (a=–0.216) suggests that the performance of these measure decreases with increase in age. The results indicate a mild decline in both PIP and SIP as people age between 40 to 65-years. For each one-year increase in age, PIP and SIP decreases by 0.210 and 0.216 units respectively. For instance, if the PIP and SIP scores of a 48-year-old individual are 64.243 and 65.971, respectively, the score at 53 years would be 63.193 and 54.891. The slopes and intercepts (b=67.552 for SIP; b=68.526 for PIP) are quite similar for SIP and PIP suggesting that the rate of decline with age is nearly the same for both processes, thus supporting inhibition deficit hypothesis.

The model also indicate that age explains a significant but limited portion of the variability in these measures. Age as a sole predictor variable considered in the present study, is able to explain variability of only 28.9% for PIP (r^2=0.289) and 27.1% for SIP (r^2=0.271). The remaining variability might be due to factors not accounted in the present study including cognitive, linguistic and/or auditory processing abilities.

Additionally, since the study was conducted on a small sample of individuals with normal hearing, it is important to investigate a larger population, particularly those with hearing loss. The study's participants were native Kannada speakers with normal hearing, aged 40 to 65 yearss. This specific demographic might limit the generalisability of the findings to other populations with different linguistic backgrounds, hearing abilities, or age ranges

Conclusion

The results of the present study highlight the difference in performance on speech perception tasks involving speech reception (phonetic) versus meaning-based assessment (semantic). Unlike the widely used sentence repetition tasks, the study uses a realistic task to assess speech understanding. While results demonstrated age-related changes for Phonetic Information Processing (PIP) at one of the Signal-to-Noise Ratios (SNRs), no such difference was noted for Semantic Information Processing (SIP), thus supporting the transmission deficit hypothesis. However, linear regression prediction of SIP and PIP scores based on age at 0 dB SNR supports the inhibition deficit hypothesis. For further understanding, it would be helpful to investigate other variables or interactions, as a significant percentage of the variance is still unaccounted for.

Ethical Considerations

Compliance with ethical guidelines

According to the 1964 Helsinki declaration, the research complies with ethical standards. The research was approved by JSS Institutional Ethics Committee (JSSMC/IEC/110612/18NCT/2022-23). Informed consent was obtained prior to the evaluation after a briefing about the study was given to all the participants.

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Authors' contributions

VK: Study design, interpretation of results, statistical analysis and drafting the manuscript; HNS: Acquisition of data, interpretation of the results, supervison, statistical analysis and critical revision of the manuscript.

Conflict of interest

There is no conflict of interest to disclose

Declaration: Not applicable

Declaration of Generative AI and AI assisted technologies in the writing process

We have not used AI in the manuscript preparation process.

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References

1. Polišenská K, Chiat S, Comer A, McKenzie K. Semantic effects in sentence recall: the contribution of immediate vs delayed recall in language assessment. J Commun Disord. 2014;52:65-77. [DOI:10.1016/j.jcomdis.2014.08.002]
2. Hagerman B. Sentences for testing speech intelligibility in noise. Scand Audiol. 1982;11(2):79-87. [DOI:10.3109/01050398209076203]
3. Jerger J, Wilson R, Margolis R. Suggestion for terminological reform in speech audiometry. J Am Acad Audiol. 2014;25(2):229-30. [DOI:10.3766/jaaa.25.2.11]
4. Stanley NS. The Effects of Linguistic and Non-linguistic Masking on Auditory Event-Related Potentials Related to Semantic Processing: An Aging Study. [Doctoral Dissertation]. Gulf Shores: University of South Alabama; 2019.
5. Murphy DR, Daneman M, Schneider BA. Why do older adults have difficulty following conversations? Psychol Aging. 2006;21(1):49-61. [DOI:10.1037/0882-7974.21.1.49]
6. Tye-Murray N, Sommers M, Spehar B, Myerson J, Hale S, Rose NS. Auditory-visual discourse comprehension by older and young adults in favorable and unfavorable conditions. Int J Audiol. 2008;47 Suppl 2(Suppl 2):S31-7. [DOI:10.1080/14992020802301662]
7. Xia J, Kalluri S, Micheyl C, Hafter E. Continued search for better prediction of aided speech understanding in multi-talker environments. J Acoust Soc Am. 2017;142(4):2386.
8. Stanley N, Davis T, Estis J. The Effect of Signal-to-Noise Ratio on Linguistic Processing in a Semantic Judgment Task: An Aging Study. J Am Acad Audiol. 2017;28(3):209-21. [DOI:10.3766/jaaa.16025]
9. Hasher L, Zacks RT. Working Memory, Comprehension, and Aging: A Review and a New View. Psychol Learn Motiv. 1988;22:193-225. [DOI:10.1016/S0079-7421(08)60041-9]
10. Hasher L. Inhibitory deficit hypothesis. In: Whitbourne SK, editor. The Encyclopedia of Adulthood and Aging. 1st ed. Chichester: John Wiley & Sons Inc; 2015. p. 1-5.
11. Cameli L, Phillips NA. Age-related differences in semantic priming: evidence from event-related brain potentials. Brain Cogn. 2000;43(1-3):69-73.
12. Fong MC, Law TS, Ma MK, Hui NY, Wang WS. Can inhibition deficit hypothesis account for age-related differences in semantic fluency? Converging evidence from Stroop color and word test and an ERP flanker task. Brain Lang. 2021;218:104952. [DOI:10.1016/j.bandl.2021.104952]
13. Nozari N. The dual origin of semantic errors in access deficit: activation vs. inhibition deficit. Cogn Neuropsychol. 2019;36(1-2):31-53. [DOI:10.1080/02643294.2019.1587397]
14. Stothart G, Kazanina N. Auditory perception in the aging brain: the role of inhibition and facilitation in early processing. Neurobiol Aging. 2016;47:23-34. [DOI:10.1016/j.neurobiolaging.2016.06.022]
15. van Knijff EC, Coene M, Govaerts PJ. Speech understanding in noise in elderly adults: the effect of inhibitory control and syntactic complexity. Int J Lang Commun Disord. 2018;53(3):628-42. [DOI:10.1111/1460-6984.12376]
16. Taylor JK, Burke DM. Asymmetric aging effects on semantic and phonological processes: naming in the picture-word interference task. Psychol Aging. 2002;17(4):662-76. [DOI:10.1037//0882-7974.17.4.662]

17. MacKay DG, Burke DM. Cognition and aging: A theory of new learning and the use of old connections. In: Hess TM, editor. Aging and Cognition: Knowledge Organization and Utilization. North-Holland: Elsevier Science Publishers; 1990. p. 213-64.
18. O'Hanlon L, Kemper S, Wilcox KA. Aging, encoding, and word retrieval: distinguishing phonological and memory processes. Exp Aging Res. 2005;31(2):149-71. [DOI:10.1080/03610730590915001]
19. Ouyang M, Cai X, Zhang Q. Aging Effects on Phonological and Semantic Priming in the Tip-of-the-Tongue: Evidence From a Two-Step Approach. Front Psychol. 2020;11:338. [DOI:10.3389/fpsyg.2020.00338]
20. Shaywitz BA, Pugh KR, Constable RT, Shaywitz SE, Bronen RA, Fulbright RK, et al. Localization of semantic processing using functional magnetic resonance imaging. Hum Brain Mapp. 1994;2(3):149-58. [DOI:10.1002/hbm.460020304]
21. Best V, Keidser G, Buchholz JM, Freeston K. Development and preliminary evaluation of a new test of ongoing speech comprehension. Int J Audiol. 2016;55(1):45-52. [DOI:10.3109/14992027.2015.1055835]
22. Ajith KU, Hemanth N. Development of some auditory related cognitive tests: Assessment of cognitive reserve in individuals with older adults. Mysore: ARF Funded project submitted to All India Institute of Speech and Hearing, Mysuru; 2017. http://203.129.241.86:8080/xmlui/handle/123456789/4031
23. Levelt WJ. Timing in speech production with special reference to word form encoding. Ann N Y Acad Sci. 1993;682:283-95. [DOI:10.1111/j.1749-6632.1993.tb22976.x]
24. Sommers MS, Hale S, Myerson J, Rose N, Tye-Murray N, Spehar B. Listening comprehension across the adult lifespan. Ear Hear. 2011;32(6):775-81. [DOI:10.1097/AUD.0b013e3182234cf6]
25. Hoen M. Using the rationalized arcsine unit transform with excel. Technical Report, February, 2015;1–3.
26. Kavé G, Knafo-Noam A. Lifespan development of phonemic and semantic fluency: Universal increase, differential decrease. J Clin Exp Neuropsychol. 2015;37(7):751-63. [DOI:10.1080/13803395.2015.1065958]
27. Diaz MT, Johnson MA, Burke DM, Madden DJ. Age-related differences in the neural bases of phonological and semantic processes. J Cogn Neurosci. 2014;26(12):2798-811. [DOI:10.1162/jocn_a_00665]
28. MacKay DG, Abrams L, Pedroza MJ. Aging on the input versus output side: theoretical implications of age-linked asymmetries between detecting versus retrieving orthographic information. Psychol Aging. 1999;14(1):3-17. [DOI:10.1037//0882-7974.14.1.3]
29. Hasher L, Zacks RT, May CP. Inhibitory Control, Circadian Arousal, and Age. In: Gopher D, Koriat A, editors. Attention and Performance. Cambridge, MA: MIT Press; p. 653-75.

Table 1. Mean and standard deviation for phonetic information processing and semantic information processing scores of all the groups at different signal conditions

	Mean and standard deviation of rationalized arcsine scores for phonetic information processing			Mean and standard deviation of rationalized arcsine scores for semantic information processing		
	0 dB SNR	**–4 dB SNR**	**Quiet**	**0 dB SNR**	**–4 dB SNR**	**Quiet**
Group 1	80.31(7.31)	65.93(5.00)	89.07(7.60)	71.35(9.12)	67.88(2.19)	76.45(8.00)
Group 2	74.26(14.19)	63.48(6.61)	76.48(7.18)	68.67(17.89)	64.96(17.89)	75.93(10.25)
Group 3	65.69(15.60)	66.00(11.35)	71.81(4.55)	59.41(13.81)	59.06(5.21)	71.44(8.06)
Group 4	62.72(16.05)	62.44(10.25)	74.08(6.22)	54.11(12.57)	59.51(6.96)	71.08(9.47)
Group 5	51.05(7.53)	55.84(7.83)	70.83(7.89)	47.87(8.08)	59.84(2.49)	69.88(11.40)

SNR; signal-to-noise ratio

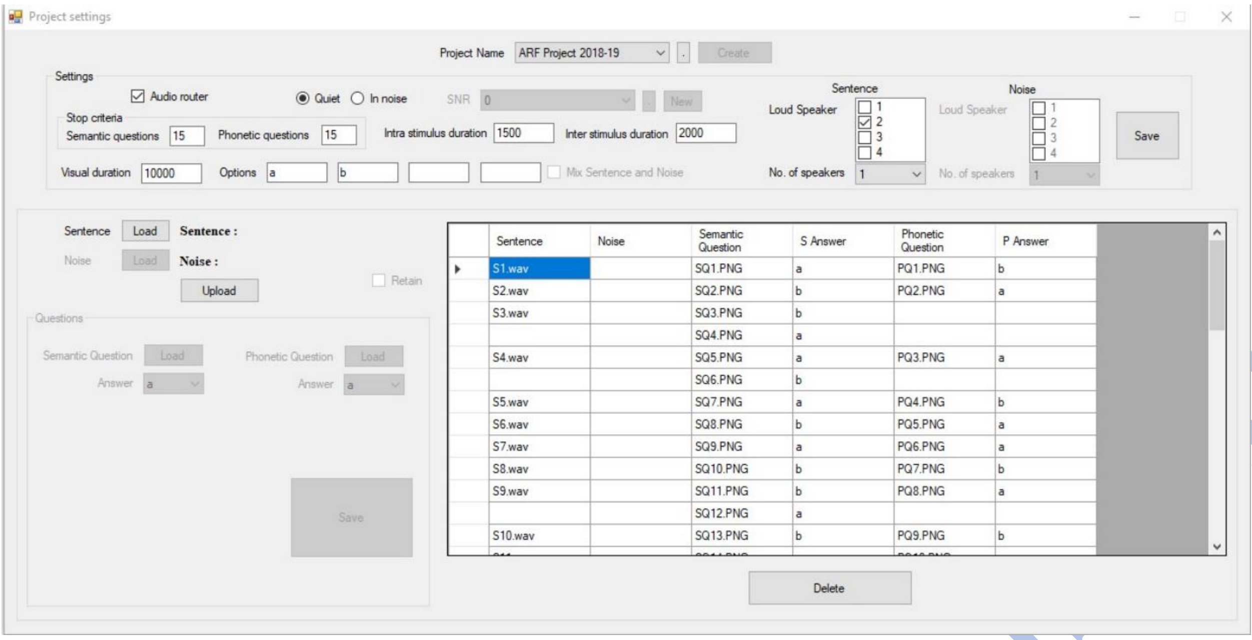

Figure 1. Screenshot of stimulus preparation for semantic information processing

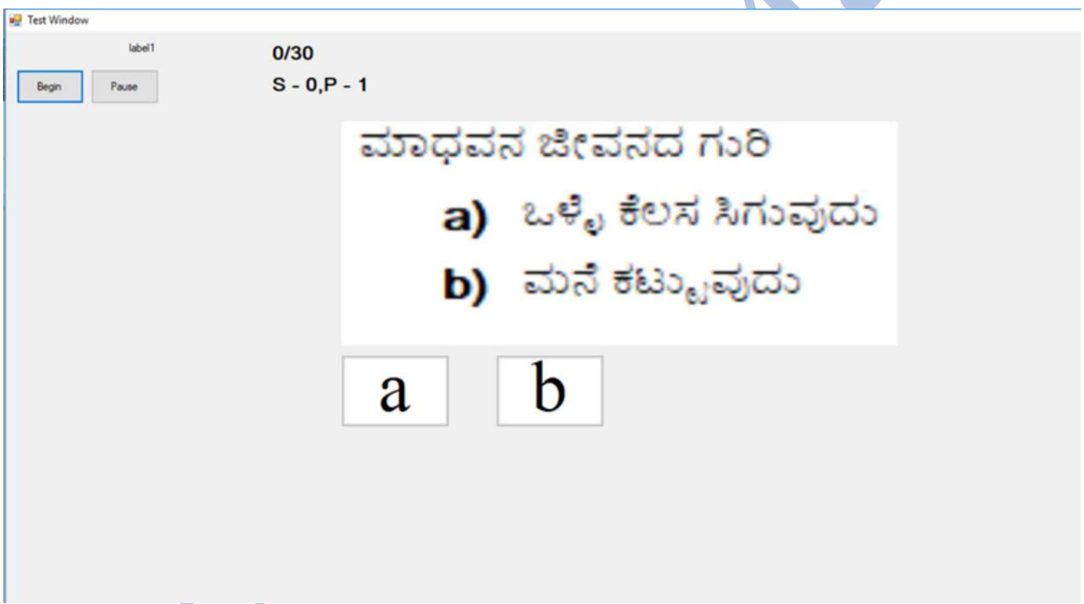

Figure 2. Screenshot of a question in semantic information processing

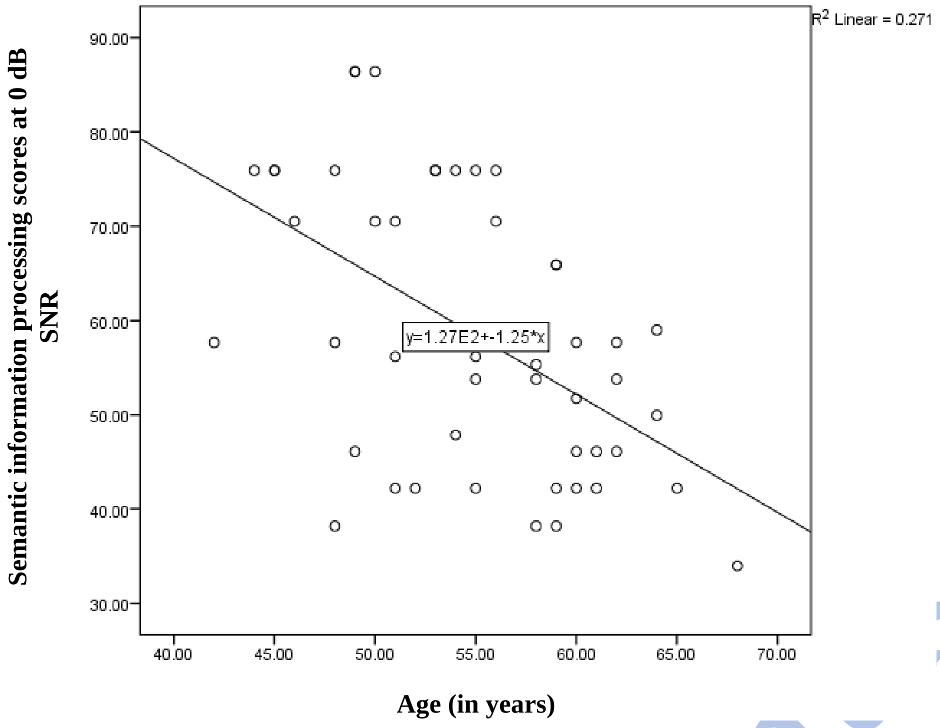

Figure 3. Scatter plot showing the relationship between semantic information processing scores and age at 0 dB signal-to-noise ratios. SNR; signal-to-noise ratios

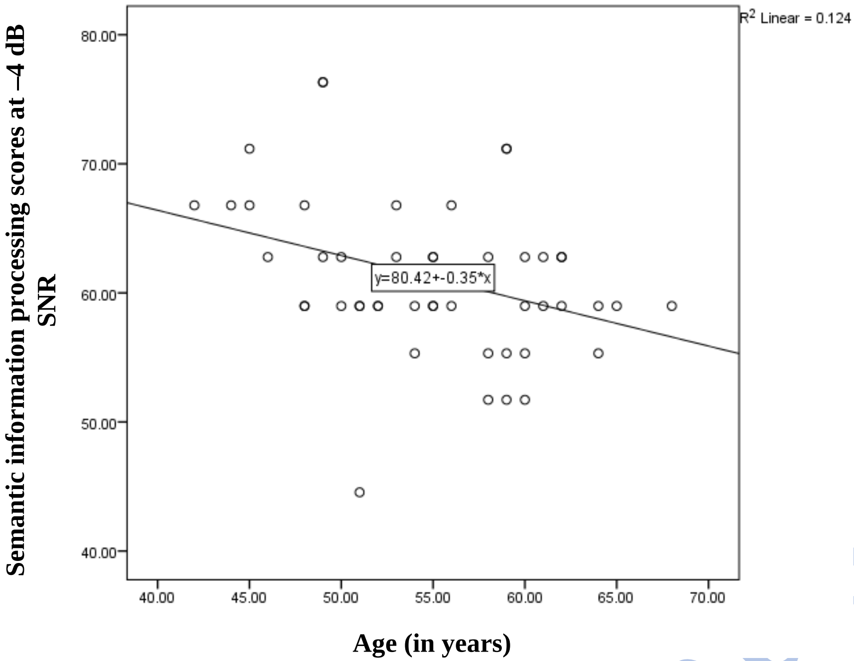

Figure 4. Scatter plot showing the relationship between semantic information processing scores and age at –4 dB signal-to-noise ratios. SNR; signal-to-noise ratios

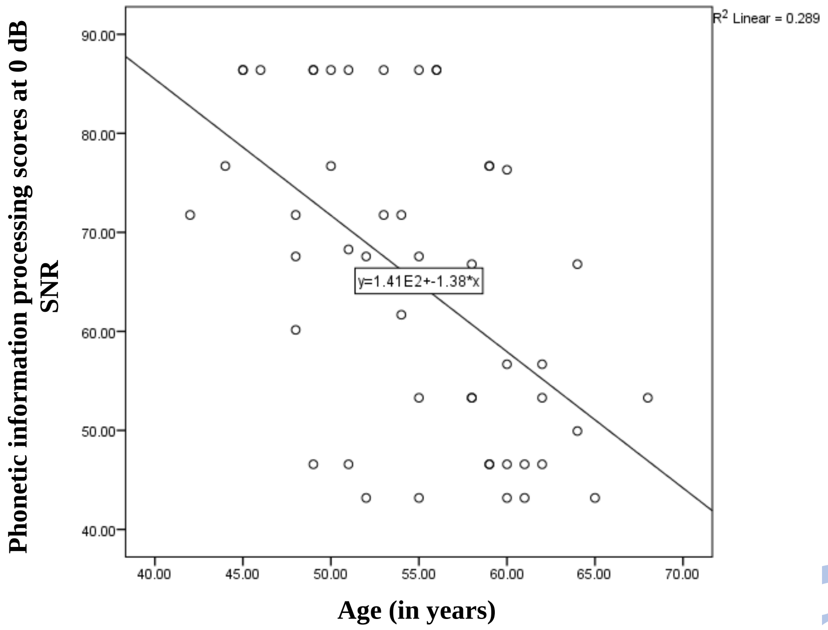

Figure 5. Scatter plot showing the relationship between phonetic information processing scores and age at 0 dB signal-to-noise ratios. SNR; signal-to-noise ratios

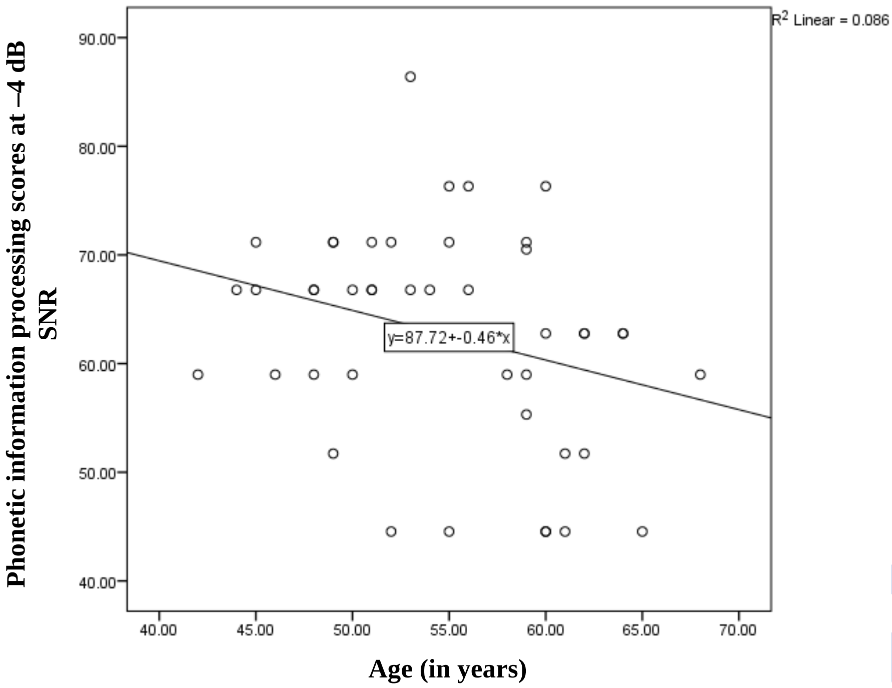

Figure 6. Scatter plot showing the relationship between phonetic information processing scores and age at –4 dB signal-to-noise ratios. SNR; signal-to-noise ratios

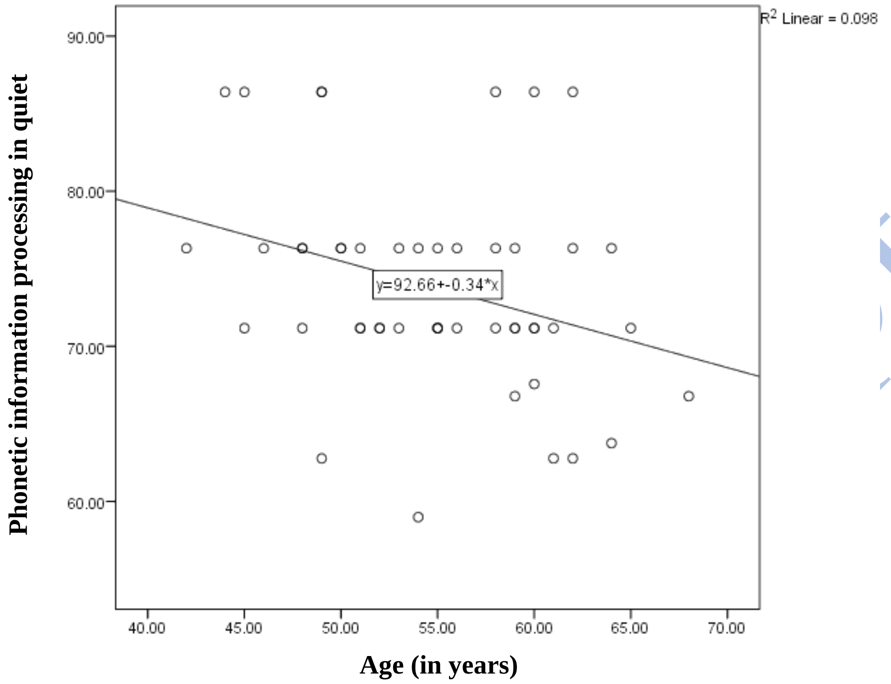

Figure 7. Scatter plot showing the relationship between phonetic information processing scores and age at quiet