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RESEARCH ARTICLE

Spatial and semantic interference on an auditory Stroop test: comparison of young and older adults

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Abstract

Background and Aim: Age related changes in cognitive functioning have been shown to vary depending on the task used. Thus, the study aimed to compare the responses of young and older adults to an auditory Stroop test that assessed spatial (responses to location of the stimuli) and semantic (responses to meaning of the stimuli) localization.

Methods: The "Auditory spatial and semantic localization Stroop test", developed as a part of the study was administered on 30 young adults aged 18 to 30 years and 30 older adults aged 58 to 70 years having normal hearing. The response accuracy and reaction time of the participants were determined for the words "right", "left", "front", and "back."

Results: The older adults had significantly poorer response accuracy and reaction time than the young adults for both spatial and semantic localization tasks. Within each participant group, semantic localization had better response accuracy than spatial localization, while such differences in reaction time were found only in the older adults. In both groups, a congruency effect was seen for spatial but not for semantic localization when response accuracy was calculated, whereas it was observed only for semantic and not for spatial localization when reaction time was measured.

Conclusion: The auditory Stroop test, which measures stimulus interference and cognitive skills, could be used as a simple tool to assess the same for stimuli presented through the auditory modality. This would be especially helpful in older adults who may demonstrate cognitive decline with ageing to auditory stimuli.

Keywords: Spatial localization; semantic localization; auditory Stroop test; age related changes

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Introduction

The use of conflicting stimuli to study the interference in perception of stimuli has been used to measure cognitive processes such as inhibitory control mechanism. The Stroop test [1] is one such test that uses the ability of an individual to selectively attend to specific stimuli, inhibiting the presence of conflicting stimuli. The Stroop effect was initially demonstrated by Stroop [1], wherein the participants were required to name the colour of a printed word, when the word spelt the name of a different colour.

The Stroop effect has been studied extensively using visual stimuli where the interaction between perceptual factors and semantic influences were examined using printed congruent and incongruent names of colours. These studies have reported better responses to congruent stimuli than incongruent stimuli [2-5]. Similar results were reported in studies using auditory stimuli. They also evaluated the effect of congruency and found that the participants had better responses with lesser reaction time for congruent stimuli compared to incongruent stimuli. These results were reported in studies evaluating Stroop effect using acoustical stimuli that varied in terms of the gender of the speaker [6,7], duration [8], and frequency of the stimuli [9,10]. The effect of congruency was attributed to the congruent stimuli having physical attributes that were consistent with the semantic content unlike the incongruent stimuli. The increase in reaction time for incongruent stimuli was ascribed to automatic processing of the conflicting dimension of the stimuli, in preference to the target dimension required to be identified by the subject [11]. Further, Klein [12] noted that more meaningful conflicting stimuli resulted in greater Stroop interference.

The conflicting stimuli used in a Stroop effect have been shown to measure inhibitory processes and also other cognitive functions such as selective attention, automaticity, task-switching, processing speed, and executive control [3,4,13,14]. Studies have reported of age-related decline in an inhibitory control mechanism due to decreased ability to supress irrelevant information during conflicting stimuli conditions [15-20]. This inefficiency in inhibitory control mechanism has also been shown to have larger effects on other cognitive processes such as attention, memory and language [16,21], affecting everyday activities in older individuals [17]. Such age related decline in cognitive processes has been studied primarily using visual Stroop test [3-5,14,22]. These studies reported an increase in Stroop interference in older adults who were found to have larger reaction time and poorer response accuracy compared to young adults. This was seen especially for incongruent stimuli. However, unlike the visual Stroop test, studies evaluating age related decline in the cognitive processes using an auditory Stroop test are sparse. The use of auditory and visual Stroop interference in predicting speech-in-noise perception in older adults has been recently studied [23]. Although the study did not measure age related decline, they observed that performance of the older adults varied across the two modalities employed. This notion of modality specificity in performance on Stroop tests have been noted in studies using electrophysiological and neuroimaging techniques, where different regions were found to be activated depending on the modality evaluated [24,25]. Thus, it is possible that the age-related changes seen in a visual Stroop task may not occur when using an auditory Stroop task. Hence, it needs to be established whether age-related changes in performance, using an auditory Stroop test, is similar to what was established using visual based Stroop tests.

It is reported in literature that any simple auditory localization task is influenced by inhibitory control mechanism [26,27] and attention [27-29]. Also, studies have shown the influence of semantic content of the stimuli on localization ability. The semantic content of stimuli was found to augment auditory spatial localization or degrade/delay localization of stimuli [30-33]. Further, it is speculated that auditory cognition is different from general cognition as studies have demonstrated that auditory memory, a component of auditory cognition, is different from general memory [34-36]. Also, memory has been shown to vary depending on the modality being assessed [34]. Hence, an auditory Stroop test that evaluates spatial and semantic localization would be useful in determining cognitive abilities specific to the auditory modality, which may be different from measures that utilize other stimuli modality.

In the literature, contradicting results have been reported in auditory-based Stroop studies that evaluated congruency effect and the interference of spatial and semantic information on auditory localization [30,31]. Palef and Nickerson [30], who compared the responses of young adults to congruent and incongruent stimuli, reported of a congruency effect for spatial localization but not for semantic localization. The participants were observed to have a faster reaction time for the semantic localization task compared to the spatial localization task. They evaluated spatial and semantic localization using four loud speakers located in the “right”, “left”, “front”, and “back” of the participants. Four words, “right”, “left”, “front”, and “back” were presented from any of the four loudspeakers, with the stimuli being congruent or incongruent. The interference of semantic information on spatial localization was assessed using a “location condition”, where the participants were instructed to identify the location of the stimuli source irrespective of the word meaning. Further, the interference of spatial information on the perception of semantic localization was assessed through a “word meaning condition”, where the participants had to respond to the meaning of the word irrespective of its location.

Unlike Palef and Nickerson [30], Yao [31] reported that the reaction time was faster for spatial localization than semantic localization. However, the responses to congruent stimuli were reported to be better compared to incongruent stimuli during semantic localization and not during spatial localization. Thus, there is no consensus regarding congruency effect between the two localization tasks and the interfering effect of spatial and semantic information on the task, despite both studies being done on young adults. In addition, there is a lack of studies regarding the effect of ageing on the congruency as well as the interfering effects of spatial and semantic information in an auditory Stroop test. Thus, it is hypothesised that an auditory Stroop test that evaluates spatial and semantic localization can be employed in evaluating age related changes that are specific to the auditory modality. Thus, the study aimed to compare spatial as well as semantic localization within and between young and older adults using an auditory-localization Stroop test. Further, the study also aimed to assess the effect of congruency by comparing the responses to congruent and incongruent stimuli for both the localization tasks within and between the participant groups.

Methods

The study was carried out using a standard-comparison design. The participants were selected using a purposive sampling technique.

Participants

The participants included 30 young adults aged 18 to 30 years (24.8 ± 3.73) and 30 older adults aged 58 to 70 years (62.63 ± 3.81). The presence of normal symmetrical hearing was confirmed in the participants as they had pure-tone air conduction and bone conduction thresholds ≤ 20 dB HL from 250 to 8000 Hz and 250 Hz to 4000 Hz, respectively. The young and older adult groups were matched in terms of their pure-tone average. Additionally, all the participants had normal middle-ear functioning, confirmed from their case history, visual inspection of the ear using an otoscope, and tympanometric evaluation. To confirm the presence of normal middle-ear function, the normative values given by Roup, Wiley [37] were used. The participants also had both ipsilateral and contralateral reflexes present. They were included only if they obtained speech identification scores of more than 80% in both ears using the test developed by Yathiraj and Vijayalakshmi [38]. None of the participants had any history of otological, neurological, or speech and language problems. Only those who had a score of ≥ 24 on the Mini-Mental State Examination test [39] indicating no general cognitive deficit were included in the study. This general cognitive test was selected as it was a relatively less influenced by literacy compared to other available measures and interpretation could be made based on different education levels. The test was also found to be useful on the Indian population [40,41]. Further, the participants had completed at least middle school, with English being taught as the primary language or as a second language. It was ensured that all the participants were highly familiar with the vocabulary of the tests used in the study. It was also ascertained that all the participants had normal vision using a Snellen chart [42]. The participants were

Table 1. Demographic details of the young and older adults group included in the study

Variables	Mean (SD)/#number of participants	
	Young adults	Older adults
Age	24.8 (3.73)	62.3 (3.81)
Pure tone average (right ear)	7.33 (2.36)	8.31 (2.18)
Pure tone average (left ear)	7.33 (2.06)	8.26 (1.81)
Speech identification scores (right ear %)	99.46 (1.38)	98.66 (2.84)
Speech identification scores (left ear %)	99.33 (1.84)	98.93 (2.33)
MMSE scores	27.96 (0.76)	27.56 (0.85)
Education level		
High school	#9	#11
Undergraduate	#12	#11
Postgraduate	#9	#8

MMSE; mini-mental state examination

asked to read the letters of the alphabet on the chart placed six meters in front of them. Those using corrective lenses were tested with them on. Only those individuals with 6/6 vision, indicating the presence of normal vision [43], were included in the study. These inclusion and exclusion criteria ensured that vocabulary, hearing, visual, and general cognitive impairment were not confounding variables influencing the results of the study. The demographic details for each participant group are given in Table 1.

Test environment

The recording of the stimuli for the study, administration of diagnostic audiological tests to select the participants, and the localization test were carried out in a sound-treated test-suite that met the specification of ANSI [44]. The test-room was well-illuminated, free from visual distractions, with four loudspeakers placed at 0º, 90º, 180º and 270º azimuth, one meter away from the head of the participant.

Material

A software-based test, Auditory spatial and semantic localization Stroop test was developed to present stimuli and obtain responses from the participants. The words "right", "left", "front", and "back", representing spatial locations, were audio recorded. The English words were used as they are commonly used by most individuals, irrespective of their native language, thus making the test available to evaluate a larger population. The words were spoken by a female having a neutral Indian-English accent using uniform vocal effort. The stimuli were recorded using Adobe Audition software, Version 3 (Adobe systems, United States) installed in a personal laptop with Intel Core i5 processor. A condenser microphone (B-2 PRO, Behringer, Germany), connected to the laptop via an audio interface (MOTU Micro book II, MOTU Inc., Cambridge, Massachusetts) was used for recording the stimuli. The condenser microphone was placed at a distance of 12 cm from the mouth of the speaker. The recording was done with a sampling frequency of 44100 Hz and 16-bit resolution. The words were scaled such that the average root mean square values of the four words varied only by 1 dB. The intelligibility of

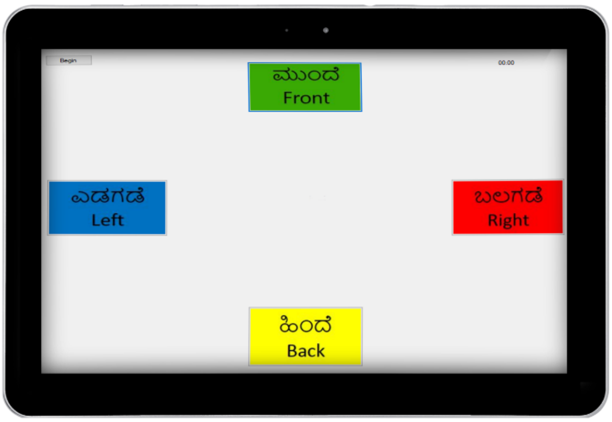

Fig. 1. Touchscreen displaying the response button

the words was checked on 10 young adults who reported that the recording was clear. Additionally, a 1 kHz warble-tone was generated and stored in order to evaluate responses to a neutral stimulus.

To obtain the responses from the participants, the software was designed to acquire information from a touch-screen tablet (Linx 8, Exertis (UK) Ltd) having a screen dimension of 21.5 x 12.5 cm. The software was programmed to constantly display the printed words “right”, “left”, “front”, and “back”, within “red”, “blue”, “green”, and “yellow” response buttons (5.8 × 3.1 cms), respectively. The printed words were provided in English and Kannada, in Times New Roman and Tunga font types respectively, having a size of 20. While the script was written in black, the background of the response buttons had the different colours (Fig. 1).

The software enabled automatically presenting the stimuli randomly through the four loudspeakers and recording the responses obtained from the participants. The software was designed to present 48 stimuli for the spatial and the same 48 stimuli for the semantic localization tasks with an inter-stimulus duration of 4 s, during which the participants responded. Each set of 48 stimuli had 12 that were congruent, where the stimulus meaning and location matched, and 36 that were incongruent, where the stimulus meaning and location did not match. A total of 12 stimuli were presented from each speaker randomly, with three being congruent and nine being incongruent. This ratio of congruent and incongruent stimuli was chosen in order to maintain equal representation of stimuli from each loudspeaker and also for better understanding of congruency effect with a minimum number of stimuli and time. The software automatically saved the response of the participants and calculated their reaction time for each stimulus.

Procedure

The participants were evaluated following the ethical guidelines of the institute, with clearance from the All India Institute of Speech and Hearing Ethics Committee for bio-behavioural research projects involving human subjects (Ref No.Ph.D./WF- 177/2018-19, dated 21.12.2020). A written informed consent was obtained from every participant before the commencement of the procedure. Initially, diagnostic audiological evaluation was carried out to ensure that the participants met the inclusion criteria. A calibrated diagnostic audiometer (Inventis Piano, Inventis Audiology Equipment, Italy) was used for pure-tone audiometry and speech audiometry. Air-conduction and bone conduction thresholds were estimated using TDH-39 headphones and Radio ear B-71 bone vibrator, respectively.

The auditory localization testing was carried out on participants who met the inclusion criteria. A personal laptop (Dell Inspiron 15, Dell Inc., India) loaded with the Auditory spatial and semantic localization Stroop test was used to present the stimuli. The stimuli were routed to an audio interface (U-PHORIA UM2, Behringer, Germany) and a control switch. The control switch had four channels, the outputs of which were relayed to one of the four loudspeakers that were connected to it (JBL Control One, Harman International Industries, Inc., United States). The control switch allowed a single input from the laptop to be relayed randomly to one of the four loudspeakers. The loudspeakers were automatically selected based on a software code written.

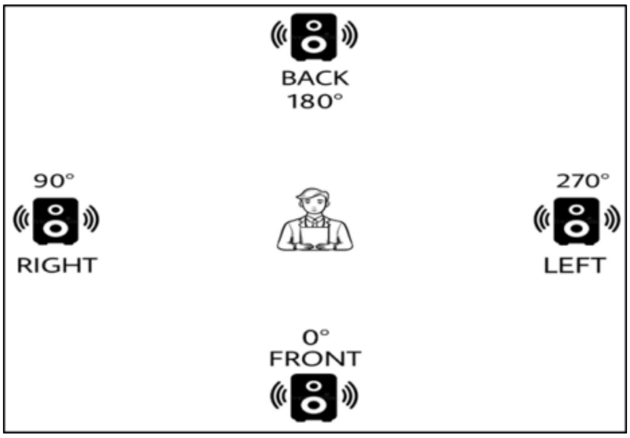

Fig. 2. Setup used to evaluate the participants.

The loudspeakers were placed at a radius of one meter from the head of the participant in the front (0º azimuth), right (90º azimuth), back (180º azimuth) and left (270º azimuth). Each loudspeaker was calibrated individually using a sound level meter (Larson and Davis 824 with 2540 free-field microphone) to provide an output of 65 dB SPL, which represents the average value of conversational speech in different listening conditions [45]. The desired intensity was obtained from the loudspeakers by adjusting the volume controls of the laptop and the audio interface. The participants were tested individually with them seated facing the loudspeaker located at the front (Fig. 2).

The participants were informed that they would hear the words "right", "left", "front", and "back", one at a time, from any of the four loudspeakers. The participants were evaluated only after confirming that they were highly familiar with the stimuli. This was done by asking them to demonstrate the meaning of the words and also noting their reaction time to carry out the action. The test was administered only on those who could point to the required direction immediately after the stimulus presentation. Half the participants were initially instructed that they had to respond to the location of the stimulus, irrespective of the meaning of the words (spatial localization), while the other half were initially informed to respond to the meaning of the words, irrespective of the location (semantic localization). All the participants were evaluated for spatial and semantic localization. They were also told that the stimulus location and meaning may match (congruent stimuli) or may not match (incongruent stimuli). They were also informed to respond as fast as possible after hearing each stimulus by pressing on the appropriate response-button labelled "right", "left", "front", and "back" on the touchscreen tablet provided to them (Fig. 1). To ensure that they understood the instructions, practice was provided prior to evaluating the spatial and semantic localization tasks. For each task, practice was provided for four congruent and four incongruent stimuli. If required, the instructions were repeated for a few older adults. The test stimuli were presented after completion of the practice session. Additionally, 20% (n = 6) of the participants from each group were tested using a 1 kHz warble-tone that served as a neutral stimulus. This was done to check if there was any difference in the motor skills of the two groups. The participants were instructed to respond by pressing the button labelled "front" on the tab when they heard the neutral stimulus. Each participant was tested thrice with the neutral stimulus to check for variability in their responses. The entire testing procedure per participant took approximately 15 minutes.

The response accuracy and the reaction time were scored separately for each stimulus for both spatial and semantic localization. These were calculated from the downloadable output from the software for each participant. For response accuracy a score of one was given for every correct response and zero for every incorrect response, with the maximum possible score being 48 for each of the tasks. The average reaction time was computed for each task. The response accuracy and average reaction time were computed separately for the congruent and incongruent stimuli for both spatial as well as semantic localization.

Test-retest reliability was conducted on 10% of the participants, with equal representation from both groups. The participants were retested by the same experimenter within a span of three weeks.

Analyses

Descriptive and inferential statistics were carried out using SPSS software (version 21). A Shapiro Wilks test of normality indicated that the data were not normally distributed. However, both parametric and non-parametric equivalent statistics were done to check if identical results were obtained as the mean and median values were similar. As there were no differences between the results of the two forms of statistics, the results of the parametric statistics are reported as it is considered to be more robust and powerful [46,47]. Parametric statistics was preferred so that the interaction between the variables could be obtained [48]. A three-way mixed ANOVA was done separately for the response accuracy and the reaction time, with between-subject factor being age (young and older adults), and within-subject factors being tasks (spatial and semantic localization) as well as congruency conditions (congruent and incongruent).

Results

The results are provided regarding the comparison in pure-tone average thresholds and speech identification scores between the participant groups; the interaction of age groups, localization tasks and congruency; comparison of responses to spatial and semantic localization between the young and older adults as well as within each group; and the effect of congruency between as well as within the participant groups. These results are illustrated separately in terms of response accuracy and reaction time. The analyses for reaction time were done after calculating the average time taken for each localization task (semantic and spatial) and each congruency condition (congruent and incongruent) by each participant.

The mean and standard deviation of pure-tone average thresholds; speech identification scores for each ear along with other demographic details such as age, educational level for young and older adult groups are depicted in Table 1. It can be seen from the Table 1 that the pure-tone thresholds and speech identification scores are similar for the two groups.

An independent sample t-test confirmed that there was no significant difference between the groups in their right ear ($p = 0.099$) as well as left ear ($p = 0.068$). In addition, the speech identification scores were also not found to differ significantly between the two groups in their right ear ($p = 0.171$) and their left ear ($p = 0.464$). Further, symmetrical hearing was confirmed in the young adults ($p = 0.893$) as well as older adults ($p = 1.000$) using a paired sample t-test. No significant difference was also found in the reaction times of the two groups ($p = 0.155$) for the neutral stimuli evaluated in the present study.

The mean response accuracy and reaction time were found to be better in the young adults compared to the older adults for both spatial and semantic localization. In addition, the mean semantic localization scores were better than the spatial localization scores in both groups (Table 2). Further, the mean scores for the congruent stimuli were also better than the incongruent stimuli in terms of response accuracy and reaction time for both the tasks in the two groups (Table 3).

To confirm whether the difference in responses of the two groups was statistically significant, a three-way mixed ANOVA was done. While calculating localization response-accuracy for congruent and incongruent stimuli, the scores were converted to percentage, as the number of stimuli in the two-congruency conditions was unequal. This was done separately for response accuracy (2 localization tasks x 2 congruency conditions x 2 groups) and reaction time (2 localization tasks x 2 congruency conditions x 2 groups). For the response accuracy scores it was found that there existed a significant main effect of age [$F_{(1,58)} = 42.14$, $p < 0.001$, $\eta^2p = 0.42$], localization tasks [$F_{(1,58)} = 45.72$, $p < 0.001$, $\eta^2p = 0.44$], and congruency conditions [$F_{(1,58)} = 9.72$, $p < 0.001$, $\eta^2p = 0.14$]. In addition, there was a significant interaction between age and the localization tasks [$F_{(1,58)} = 38.14$, $p < 0.001$, $\eta^2p = 0.39$]. Post-hoc paired comparison revealed significantly higher response accuracy in the young adults compared to the older adults for both spatial ($p < 0.001$) and semantic

Table 2. Mean and standard deviation of the response accuracy and reaction time of young and older adults for spatial and semantic localization

	Mean# (SD)	
Response accuracy	**Spatial localization**	**Semantic localization**
Young adults	47.16 (1.28)	47.73 (0.52)
Older adults	36.26 (6.87)	42.76 (7.07)
Reaction time (ms)		
Young adults	742.17 (264.03)	700.31 (206.70)
Older adults	1185.43 (334.35)	943.08 (297.58)

#Maximum possible score = 48, ms; millisecond

localization ($p < 0.001$). Further, response accuracy for semantic localization was found to be significantly higher than spatial localization in the younger adults ($p = 0.027$) and the older adults ($p < 0.001$).
The results also indicated the presence of a significant interaction between age and the congruency conditions [$F_{(1,58)} = 41.75$, $p < 0.001$, $\eta^2p = 0.06$]. The post-hoc paired sample t-test showed significantly better response accuracy in the young adults than the older adults for congruent stimuli ($p < 0.001$) and incongruent stimuli ($p < 0.001$) during spatial localization. Similar results were obtained for congruent stimuli ($p < 0.001$) and incongruent stimuli ($p < 0.001$) for semantic localization. The paired sample t-test also indicated that significantly better responses were obtained for the congruent stimuli than the incongruent stimuli in the young adults ($p < 0.001$) as well as older adult ($p = 0.038$) for spatial localization. However, no such differences were obtained in both young adults ($p = 0.154$) and older adults ($p = 0.502$) for semantic localization. These findings between the congruent and incongruent stimuli, within each group, are depicted in Fig. 3. However, there was no significant interaction seen between the localization tasks and the congruency conditions [$F_{(1,58)} = 3.55$, $p = 0.065$, $\eta^2p = 0.05$].
In terms of reaction time, the results showed a significant main effect of age [$F_{(1,58)} = 29.59$, $p < 0.001$, $\eta^2p = 0.33$]. It also revealed a significant effect of localization task [$F_{(1,58)} = 18.94$, $p < 0.001$, $\eta^2p = 0.24$] and congruency conditions [$F_{(1,58)} = 24.17$, $p < 0.001$, $\eta^2p = 0.29$]. In addition, there was a significant interaction between age and the localization tasks [$F_{(1,58)} = 7.33$, $p < 0.001$, $\eta^2p = 0.11$]. A post-hoc analysis indicated significantly faster reaction times in the young adults compared to the older adults for spatial ($p < 0.001$) as well as semantic localization ($p < 0.001$). However, a paired sample t-test indicated a significantly faster reaction time for semantic localization than spatial localization only in the older adults ($p < 0.001$) and not in the young adults ($p = 0.259$).
In addition, a significant interaction was seen between age and the congruency conditions [$F_{(1,58)} = 4.05$, $p = 0.049$, $\eta^2p = 0.06$]. A post-hoc analysis comparing the two age groups revealed that for spatial localization the young adults had significantly faster reaction times compared to the older adults. This was observed for both congruent stimuli ($p < 0.001$) and incongruent stimuli ($p < 0.001$). Likewise, the reaction times for semantic localization was significantly faster in the younger group than the older group for congruent ($p < 0.001$) and incongruent stimuli ($p < 0.001$). However, for spatial localization no significant difference in

Table 3. Mean and standard deviation for response accuracy and reaction time of congruent and incongruent stimuli for spatial and semantic localization in both the groups

	Mean (SD)	
	Spatial localization	**Semantic localization**
Congruent		
Response Accuracy (%)		
Young adults	99.72 (1.52)	99.16 (2.54)
Older adults	80.55 (14.06)	92.22 (13.29)
Reaction Time (ms)		
Young adults	715.84 (264.06)	627.23 (199.34)
Older adults	1155.98 (410.04)	908.19 (296.12)
Incongruent		
Response Accuracy (%)		
Young adults	97.77 (3.29)	99.53 (1.28)
Older adults	75.27 (16.43)	90.18 (13.58)
Reaction Time (ms)		
Young adults	751.38 (269.64)	724.64 (211.34)
Older adults	1202.29 (330.83)	954.90 (301.68)

%; Percentage, ms; milliseconds

the reaction time to the congruent and incongruent stimuli was not found in the young adults ($p = 0.077$) as well as the older adults ($p = 0.263$). Unlike what was seen for spatial localization, there was a significantly faster reaction time for the congruent stimuli compared to the incongruent stimuli for semantic localization in both young ($p < 0.001$) and older adults ($p < 0.001$) as can be seen in Fig. 4. In contrast, there was no interaction found between the localization tasks and the congruency conditions [$F_{(1,58)} = 1.36$, $p = .247$, $\eta^2p = 0.02$].

Test-retest reliability

The test-retest reliability, administered on 10% of the participants from each age group, was measured using an intra-class correlation coefficients (two-way mixed-effects model, based on single-rater, and absolute agreement) given by Koo and Li [49]. The results revealed that there was excellent test-retest reliability for spatial localization (reaction time: $r = 0.92$; response accuracy: $r = 0.97$) as well as semantic localization (reaction time: $r = 0.94$; response accuracy: $r = 0.95$). Additionally, Cronbach's alpha coefficient was found to be greater than 0.95 for all parameters, indicating that the measures were reliable.

Discussion

The results of the present study showed that the older adults exhibited poorer response accuracy and larger reaction time compared to the young adults, indicating an age-related decline in underlying cognitive mechanism. Further, the response to semantic localization was found to

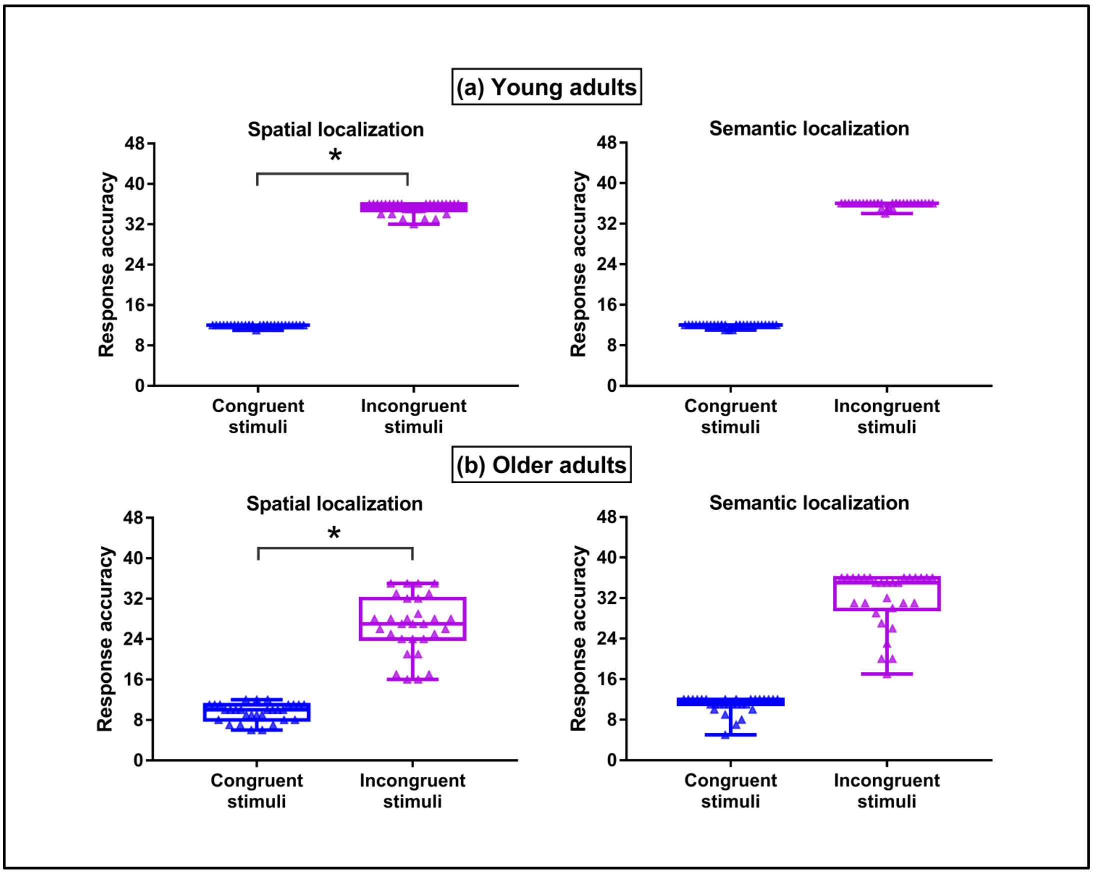

Fig. 3. Individual scores of response accuracy for congruent and incongruent stimuli for spatial and semantic localization as well as significance of difference in response accuracy in young adults (a) and older adults (b).
*** = p < 0.05; Maximum possible score for congruent stimuli = 12; Maximum possible score for incongruent stimuli = 36.**

be better than spatial localization for both younger and older participants in terms of response accuracy. However, in terms of reaction time, the faster reaction time for semantic than spatial localization was found only in older adults and not in young adults. These results revealed that the semantic information had a greater interfering effect on spatial localization than spatial information on semantic localization. In addition, the effect of congruency was seen for spatial localization but not semantic localization in terms of response accuracy in both the participant groups. However, in terms of reaction time, such congruency effects were observed only during semantic localization and not for spatial localization in both young as well as older adults.

Comparison of pure-tone thresholds and speech identification between the young and older adults indicated that there were no significant differences between the groups for both tests. This confirms that the differences observed between the young and older adults on the “Auditory spatial and semantic localization Stroop test” were not on account of their audiometric thresholds or their speech identification abilities. Thus, it can be inferred that the differences between the participant groups was a true reflection of their performance on the auditory Stroop test and not on account of confounding variables.

Comparison of responses to localization tasks and congruent and incongruent stimuli between

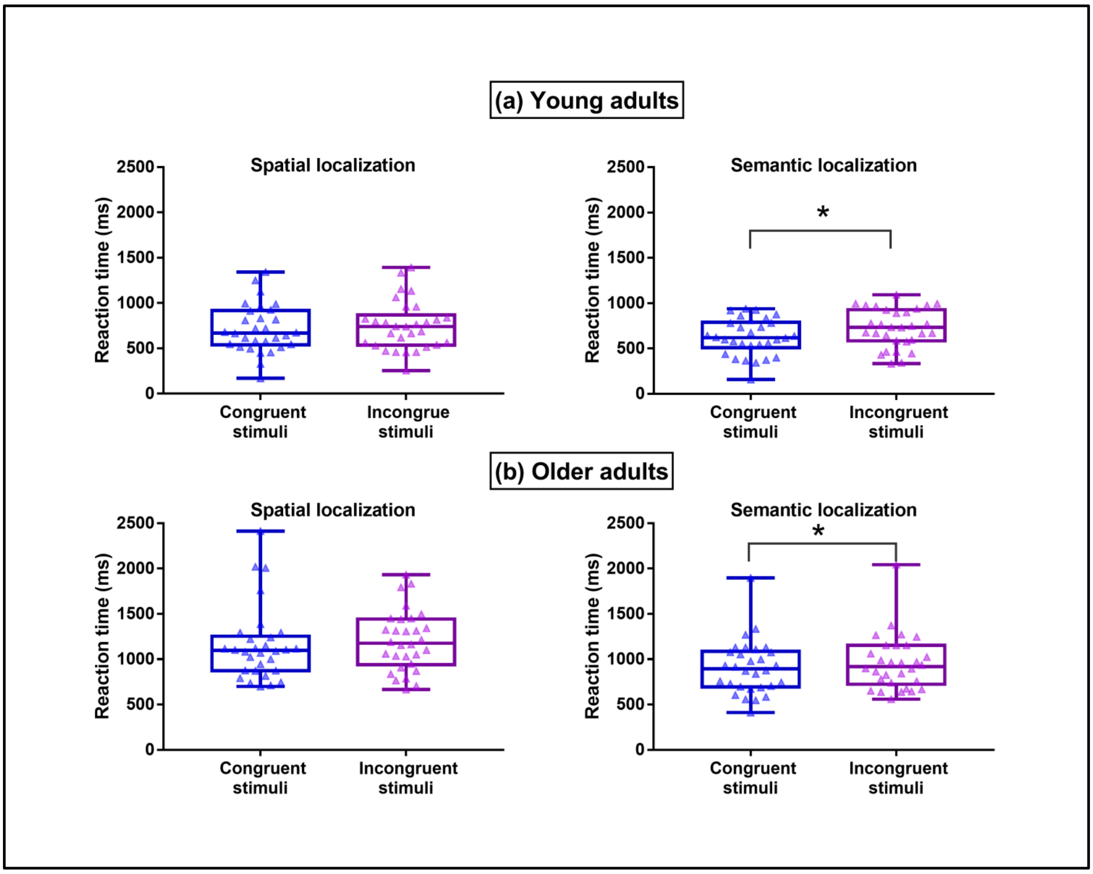

Fig. 4. Individual scores of reaction time for congruent and incongruent stimuli for spatial and semantic localization as well as significance of difference in reaction time in young adults (a) and older adults (b).
*** = p < 0.05; Maximum possible score for congruent stimuli = 12; Maximum possible score for incongruent stimuli = 36.**

the young and older adult groups indicated that the latter group performed significantly poorer compared to the former group. The older adults were found to have poorer response accuracy and larger reaction time compared to the young adults. This was seen for both spatial as well as semantic localization tasks. The involvement of dexterity influencing the results can be ruled out as no significant difference in reaction time was found between younger and older adults when tested with a neutral stimulus. This indicates that the longer reaction time seen in the older adults was not on account of their dexterity being poorer.

Also, when the effect of congruency was compared across the two groups, the older adults were found to have poorer response accuracy and longer reaction time compared to younger adults. This probably occurred due to the decline in cognitive abilities with ageing in the older adults resulting in generalized slowing and reduced processing speed. Such age-related decline has also been found in studies that have used visual Stroop tests. They observed that decline in cognitive abilities such as attention, processing speed, and inhibitory functioning led to larger Stroop interference in older adults compared to young adults [3,4,13,14,18-20]. Thus, from the age-related decline seen in the current study it can be inferred that the "Auditory spatial and semantic localization Stroop test" is sensitive to auditory based cognitive differences between young and older adults. However, a study involving analogous auditory and visual based Stroop task might provide better insight regarding the modality-specificity of the Stroop task rather than independent evaluation of auditory or visual modalities.

Comparison of spatial and semantic localization within each participant groups showed that the response accuracy was significantly better for the latter task compared to the former task in both groups. These findings indicate that the participants focused more to the meaning of the stimuli (semantic information) rather than the location (spatial information). Thus, it can be inferred that the influence of semantic information during spatial localization is greater than the influence caused by spatial information during semantic localization task.

Unlike what was observed for response accuracy, the reaction time for spatial and semantic localization was not significantly different in the young adults, suggesting that these tasks were equally easy for them. On the other hand, the older adults had significantly faster reaction time for the semantic localization task compared to the spatial localization task. This variation in reaction time in the older adults can be attributed to the automatic processing of semantic information leading to faster reaction time, but larger interference during spatial localization resulting in a slower reaction time. Older adults probably relied more on automatic processing than information that required greater cognitive processing.

The findings of the present study are in concurrence with that of Palef and Nickerson [30] who reported better responses to a word meaning condition than a location identification condition. This was also ascribed to automatic processing of the meaning of the stimuli than its location. However, unlike the findings of the current study and that of Palef and Nickerson [30] Yao [31] noted that individuals located the direction of the stimuli better and faster compared to the meaning. The faster reaction time to spatial localization was attributed by Yao [31] to the participants only requiring to identify the presence of the stimuli. However, they opined that semantic localization requiring the participants to process the presence of the stimuli as well as respond to its meaning, which would have resulted in the reaction time being longer for it compared to spatial localization. This probably occurred as their participants were required to give an orientation response towards the stimuli, which was automatic during spatial localization whereas it was not during semantic localization.

Unlike the response paradigm used by Yao [31] that involved an orientation response, the current study and the study by Palef and Nickerson [30] required the participants to respond by pressing appropriate response buttons representing the words in response keys placed in front of them. This form of response would have led the response to the meaning of the stimuli to be more automatic than the location of the stimuli, resulting in faster responses for semantic localization than spatial localization. The response to the meaning would have required only one stage of processing (pressing a response button representing the word), whereas spatial localization would have involved two stages of processing (spatially locating the stimulus and identifying the word on the tablet or response button).

Comparison of responses to congruent and incongruent stimuli within each participant groups revealed that the response accuracy for the former was better compared to the latter for spatial localization but no such difference was seen for semantic localization.

During spatial localization, the better responses for the congruent condition reflect the ease of the activity compared to the incongruent condition. During the congruent condition, the spatial and semantic information would have augmented each other, leading to better response accuracy. Whereas, in case of the incongruent condition, the mismatch created between the spatial and semantic information would have resulted in confusion, resulting in poorer accuracy. However, automatic processing of semantic information irrespective of whether the stimuli is congruent or incongruent would have resulted in lack of congruency effect during semantic localization. In terms of reaction time, slower responses were observed for incongruent semantic stimuli compared to the congruent semantic stimuli in the present study. This was observed in both young and older adults. The slower reaction time for incongruent stimuli might be due to the confusion when the meaning and location did not match in contrast to congruent stimuli where the meaning and location matched with each other. However, for the spatial localization task, in both participant groups, the participants required equally long duration to attend to signals for the congruent and incongruent stimuli, resulting in no significant difference in reaction time. This longer reaction time for the spatial localization task probably reflects the involvement of both brainstem and cortical areas unlike semantic localization where primarily only cortical areas probably participated. The coordination of both lower and higher auditory centers for spatial localization could have led to the reaction time for it being longer unlike the semantic localization that did not require such coordinated functioning.

The findings of the present study are supported by the results of Yao [31] who also reported that their participants had significantly shorter reaction time for the congruent than for the incongruent stimuli for a semantic localization task and not spatial localization task. Thus, the orientation response paradigm, which was justified by Yao to be the reason behind the lack of a congruency effect, is refuted as the current study did not employ such a response paradigm. This indicates that the effect of congruency is not determined by the response mode that is utilized. Rather, it is possible that the participants would have mainly utilized their brainstem for the spatial responses, and thus were not influenced by congruency. However, for the semantic localization they would have used more of their cortical function, where the influence of congruency would have been prominent, resulting in a congruency effect.

Unlike these findings, Palef and Nickerson [30] found that for a spatial localization task their participants had faster reaction time for the congruent stimuli compared to incongruent stimuli and not for semantic localization. The congruency effect, obtained only during spatial localization, was ascribed to the faster processing of irrelevant information (meaning) than the target (location). A possible reason for Palef and Nickerson getting results that differed from the congruency effect observed in the present study might be due to variation in the performance of their participants as each task was evaluated on different participant groups. However, in the present study comparisons were made on the same group of individuals who were evaluated on both the tasks and hence eliminating the variations in the abilities of the participants biasing the results.

Thus, the findings of the present study indicate that with ageing the performance of older adults on an auditory Stroop test deteriorates, highlighting the probability of a modality specific decline in cognitive functioning such as inhibitory control mechanism. This decline was more evident for spatial localization than semantic localization. In addition, the test has the advantage of not having to be adapted to different languages and can be done on those with relatively low literacy levels. This would be an advantage in countries where a large number of the older population has relatively low literacy levels. Further, the test makes use of vocabulary that is commonly used by native speakers of different languages, which makes it a simple tool. Hence, from the findings of the study it can be construed that the “Auditory spatial and semantic localization Stroop test” can serve as quick measure to measure age related cognitive abilities measured in an auditory Stroop test.

Conclusion

The outcome of the study confirms that the “Auditory spatial and semantic localization Stroop test” can be used to measure age related decline in interfering effects of spatial and semantic information during spatial and semantic localization tasks. The decline is seen for reaction time and response accuracy for semantic as well as spatial localization. Further, the effect of congruency was found to vary in terms of response accuracy and reaction time for the two localization tasks. As spatial localization was affected more than semantic localization, the former can probably be used more effectively for detection of an auditory based cognitive decline. Thus, the auditory Stroop test could be used as a simple, quick measure to detect age-related decline in cognitive abilities that may be specific to the auditory modality. It is recommended that those with poorer performance on the auditory Stroop test be referred for further detailed evaluation to confirm the presence of a cognitive decline.

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Conflict of interest

No conflicts of interest, financial or otherwise, are declared by the authors.

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