Asymmetric Dual-Task Interference of Auditory Message in Change Detection in Older Adults

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This study investigated the effect of aging on the dual task interference when an auditory task of answering to questions was combined with a visual search task. The study focused on the effect of unilateral auditory input, which is usually the case when we use cellular phone by applying it to one ear while driving. Participant’s task was to detect a probe from among distracters. In the dual task condition, participant detected the probe, while listening to a simple open-ended question. Both younger and older participants showed comparable dual task interference in detection RT. In the older participants, however, the auditory task interfered with the probe detection more when they heard the questions with their left ear than when they did so with their right ear, suggesting that the dual task cost was especially large when they answered to question heard from their left ear.

KEYWORDS: cellular phone, interference, dual task cost, senior drivers, conversation

1. Introduction

Aging affects various aspects of mental functions that are necessary for daily life, especially those that require voluntary control or executive attention, which is involved in doing things under increased task difficulty or in a dual-task situation.

Holding a conversation either with a co-passenger or through a cellular phone while driving is one instance of a dual task situation people experience every day (Strayer, Drews, & Johnston, 2003; Strayer & Johnston, 2001). Auditory messages may also come from an in-vehicle information system (IVIS) used for navigation assistance (Harms & Patten, 2003). Operation of a cellular phone while driving is prohibited in many countries, including Japan. However, using it with a headset that allows use of both hands for driving is not prohibited in Japan as well as in many other countries. Although many studies have focused on the use of cellular phones while driving, relatively little attention has been directed to the effect of the actual use of a cellular phone in that it is applied to one ear, being either right or left. Conversation through the cellular phone consumes a portion of attentional capacity. Therefore, the main task (i.e., driving) can use only the remaining amount of it, resulting in the impairment of performance. In this study, this reduction of performance is designated as dual task cost or interference. Although this study is not a direct investigation of the interfering effect of cellular phone use during driving, it is important to study the task interference in the dual task that shares some of the cognitive mechanisms with those involved in the cellular phone use during driving.

There are several explanations for the dual task cost (Pashler, 1998). One theory proposes that the dual task cost is incurred when competing tasks draws out attentional resources from its fixed amount of reservoir (Kahneman, 1973). In this theory, people possess a fixed amount of attentional resources that is allocated to each task according to its demand. The dual task cost arises because two tasks similarly requires more attentional resources. Although opinions differ as to whether there is only one common resource or multiple resources (Wickens, 1984) or processors (Allport, Antonis, & Reynolds, 1972), we assume that there is only one central capacity of limited resources that is consumed when voluntary attention or executive function is engaged for task control (Norman & Shallice, 1986).

Dual task interference or cost is a more serious problem for older people because aging reduces attentional resources (Craik & McDowd, 1987), and performing two simultaneously increases task difficulty, which taxes more on the reduced amount of attentional resources of older people. Task difficulty itself affects older people’s performance more than that of younger people (Salthouse, 1992). Dual task cost increases with age probably because voluntary or top-down control of attention required for dividing attentional resources between tasks depends on the prefrontal lobe, which is known to be one of the first brain regions that deteriorate with age (Raz, Gunning-Dixon, Head, Rodrigue, Williamson, & Acker, 2004).

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In this study, we explored the effect of aging on a visual search task, which is involved in many daily activities such as searching for a friend in a crowd or looking for a danger in driving, when it is combined with another task. Dual task was implemented by coupling visual search with auditory processing (answering questions), based on Recarte and Nunes (2003) finding that answering a question, not just listening to it, deteriorated visual search performance (detection and discrimination of probe stimuli while driving in a real traffic condition) even for younger people. We are particularly motivated by the recent popularization of cellular phone use while driving, which involves visual search as one cognitive component. There is a unique characteristic of cellular phone use that distinguishes it from other situations: the cellular phone is used on only one ear. Thus, input is lateralized to one ear, rather than bilateral as in usual conversation. To the best of our knowledge, the effect of lateralized input on a visual search task has not been studied (Caird, Willness, Steel, & Scialfa, 2008).

There are several possible mechanisms with which dual task interference occurs when visual search is combined with lateralized conversation. One possible mechanism is that it narrows the functional field of view (effective visual field area within which people can obtain information necessary for task completion), known as the useful field of view (UFOV). UFOV is modulated by increased load on vision. In older people UFOV may be affected by their deteriorated visual functioning in addition to increased load by visual cluttering (noise elements surrounding target locations).

Answering in conversations demands a certain amount of attentional resources, which can be voluntarily assigned to a task depending on its demand. Consequently people, especially older people whose frontal lobe is deteriorating, suffer from impairment of top-down control of attention. Therefore, they could pay less attention to other objects in their visual field, which may lead to slower responses to an event that requires appropriate responding. For example, failure to detect other road users sufficiently early has been pointed out to be a main source of error that leads to accidents (Rumar, 1990). A recent meta-analysis of the effects of cellular phone use on driving confirmed that conversation on cellular phones results in slower reaction time and that this is especially the case for older drivers (Caird, Willness, Steel, & Scialfa, 2008).

Another issue explored in this study is the possibility of asymmetric interference of direction of auditory input. Listening to lateralized messages, which seems to be a normal way of using a cellular phone even when used with a headset, may cause a lateral bias of attention. In this respect, there are two possible ways of lateral biasing of attention: one is that attention is biased to the right visual field due to left hemisphere activation by conversation, as suggested by Kinsbourne (1970, 1974). According to this hypothesis, the side of the ear from which messages are heard is inconsequential for the dual task interference effect: attention is lateralized to the right visual field because the processing of verbal stimuli depends on the left hemisphere in the vast majority of right-handers (Zatorre, Belin, & Penhune, 2002). Consequently, detection of events that occur in the left visual field may be impaired as compared to that of the right visual field. A second possibility is that as attention is directed to the ear from which messages are heard, attention may be biased toward the visual field ipsilateral to the side of the input ear. There is a crossmodal link of attention between sensory modalities (Driver & Spence, 1999). Gopher (1973) reported that selective monitoring of one ear in a dichotic listening task was accompanied by a consistent pattern of eye movements in the direction of the relevant ear. Given that eye movements are an overt manifestation of attentional orienting (Posner, 1980), this finding suggests that attention is biased to the side of the ear from which messages are heard. In a more ecologically valid condition using a driving simulator, Spence and Read (2003) found a frontal speech advantage effect that shadowing performance of messages heard from a speaker positioned in front of a driver was better than that of messages heard in a lateral speaker location condition in which gaze and listening were directed to different directions. This finding indicates that splitting attention to two directions is detrimental to shadowing performance.

The purpose of this study is to investigate the effects of responding to lateralized auditory input on a visual search task. Specifically, two issues were examined: The first one is whether the dual task cost is larger for older participants as compared to younger participants (aging effect on the dual task cost). It was expected that the dual task cost would be larger for older participants because their attentional resources are diminished relative to those of the younger participants (Craik & McDowd, 1987). This dual task cost would be reflected in longer detection latencies and more frequent detection failures for the older participants. In this study, we particularly focused on the exceptionally slower detection responses and detection failures when people were engaged in another task because these “misses” or delayed detection of dangers may be behind many accidents on the road.

Furthermore, the study examined whether lateralized auditory input caused any attentional bias in the target detection performance, and if any, how attention was biased by lateralized auditory input, either to the right visual field due to the left hemisphere activation caused by conversation irrespective of the input ear (Kinsbourne’s hemisphere activation hypothesis) or to the side of the ear from which auditory messages were heard (input side bias hypothesis).

In the present visual search task, participants were asked to detect a conspicuous change that occurred at one of the four pre-specified locations. Special care was taken to prevent probe onset from capturing attention. In the spatial attention literature, there is ample evidence indicating that attentional capture occurs when a sudden onset accompanies probe presentation or when it forms a singleton (a unique element among other uniform distracters; see Yantis, 1996). Attentional capture by probe onset was prevented by adopting the change blindness manipulation (Rensink, O’Regan, & Clark, 1997) and that of singleton by adding distracters identical to the probe around the possible probe locations.
2. Method

2.1 Participants

The participants were 22 older adults (11 men, 11 women) and 20 younger adults (9 men, 11 women). Two of the older participants were excluded from the data analysis because one could not answer a majority of the questions and the other did not follow the task instruction despite extensive practice. The mean age of the younger participants was 21.9 years (range: 18–23 years) and that of the older participants was 71.2 years (range: 66–75 years). All participants were right-handed and wore glasses when required. All gave written informed consent for participation. Older participants were recruited through a Silver Human Resources Center (SHRC), a non-profit organization that dispatches community-dwelling, older people for relatively light jobs. We asked SHRC to find those who were healthy and had no problems with daily conversation, having relatively good visual and hearing functions. Additionally, participants were individually tested before the start of the experiment to determine whether they could hear messages at the volume set individually for them and whether they could see the stimuli (stars and rings) presented on the display and detect the change from ring to star, which constituted the target event. Participants were compensated for their services.

2.2 Visual search task

The stimulus configuration is shown in Fig. 1. It consisted of an array of six rings and surrounding distracters (rings and stars). All stimuli were white against a black background. The top and bottom sides of the screen were painted gray to form a frame. Four of the six horizontal rings (both outermost and innermost pairs of rings) were used for target presentation. These four locations were designated as probe positions. The target event was a change from a ring to a star that occurred in one of six rings. The change was allowed to occur only in four positions (two positions for each visual field), excluding an intermediate ring flanked by the outermost and innermost rings of each field. The diameter of each ring was 1 cm (0.72 deg of visual angle), and there was an inter-ring distance of 9 cm (6.44 deg) between two adjacent rings. The four potential target rings were numbered from left (= 1) to right (= 4). The horizontal distance of the display (between the two outermost rings) was 31.4 deg.

The whole display flashed on and off at the frequency of 2 frames/sec. The on duration was 300 ms and the off duration was 200 ms. The intermittent manner of presentation was adopted to avoid the target’s onset capturing attention. This presentation method is borrowed from the change blindness study (Rensink et al., 1997), in which people found it very difficult to notice even a conspicuous change in a scene. In this procedure, global onset of the
scene is considered to be effective in masking the local change signal, thus preventing attention from being directed to the location of change, leading to prolonged observation time before detection of the change.

The target event was a replacement of one of the four rings by a star. It occurred randomly at the third to the seventh frame after the start of flashing, and the star, once presented, appeared repeatedly until response or until 4000 ms had elapsed, at which point the trial was terminated automatically.

To further suppress attentional capture, the rings were surrounded by other rings and stars. The stars were introduced as decoys to eliminate singleton, which was known to be another factor that captures attention (Yantis, 1996).

2.3 Apparatus

The stimuli were presented on a 26-inch LCD monitor (Sharp, IT-26M1), which was connected to an IBM-compatible computer. The computer controlled all the stimulus presentations and response collections. It also acted as a master computer to control a second slave computer (a Samsung laptop) for audio message presentation. The laptop stored questions used in the experiment as WAV files. The questions were replayed by trigger pulses generated by the master computer. The participants heard the messages through headphones (Audiotechnica, ATH-AD700) connected to the laptop. They faced the screen at a distance of 80 cm with their head rested on a chin rest.

2.4 Auditory task

For both younger and older participants, 288 simple questions of non-quiz type (e.g., “Please name a food that begins with [a particular letter]”) were used as an auditory task. Participants answered the questions by generating words appropriate for responses to the questions.

All the questions were read by one of the experimenters (MS) and recorded with an IC recorder (Olympus: DS-20), which recorded sound on IC memory as digital data. The recorded messages were then converted to WAV files and stored on a hard disk connected to the second computer that was used for message presentation.

2.5 Procedure

Participants were tested individually. They were instructed to detect a change in one of the six rings displayed on the screen. They were told that they should press the spacebar with their right hand when they noticed a change in one of the four rings (two outermost and two innermost ones). They were advised to scan the screen to detect the change as it was too difficult for them to do the task without eye movements. They were also told that the change was rather obvious—one of the six rings would be replaced by a star. They were warned that the change would occur in the two peripheral and two central locations only and that the two middle rings (one on each side of the display between peripheral and central rings in each visual field) were dummies that would never be replaced by the star, so that there was no need to check them.

Participants underwent two sessions of 20 practice trials each in the dual task condition. If they expressed concern about their understanding of the task requirements or any other points of the experiment, the practice session was repeated until they felt sure that they were familiar with the task.

Participants wore headphones for listening to the questions. The messages were played back to them through only one channel (either the left or right) of the headphones. The side of the message channel was fixed within a block. Therefore, the other side of the headphones set was completely silent during the whole block.

There were two listening conditions: single and dual task. In the single task condition, participants did not have to answer the questions they heard from the headphones. They were told to ignore them. In the dual task condition, they were told to pay equal attention to the two tasks (probe detection and listening to the questions) and to answer the questions. Participants answered by saying a word that they thought were appropriate as a response for each question. The answers were noted down by the experimenter (MS) as they were spoken and checked later for whether they were appropriate for the corresponding question.

Each trial started by presenting the stimulus display. Auditory message started 500 ms after the start of the flashing cycle. The target event (a ring changed to a star) occurred after three to seven flashing cycles (1500–3500 ms). Six seconds were allowed for participants to listen to a question and prepare its answer. There was about a four-second interval between the end of the message and the start of the next trial, during which participants were asked to answer the questions. After that, the next trial started automatically. The average reaction times (RTs) of the older participants for peripheral positions were about 1000 ms. As the auditory messages lasted nearly six seconds, they were still heard when participants made a detection response (total time required for the completion of visual search = 2000–4000 ms; 1500–3500 ms for the start of the target event + 1000 ms for the slowest average response latency minus 500 ms for the delay of the auditory message, so that the visual event ended before the termination of the auditory message, which lasted 6000 ms). Thus, manual detection response and verbal answer did not temporally overlap in the trial.

The order of conditions (i.e., the side of auditory messages and dual vs. single condition) was counterbalanced across participants. RTs of the trials in which participants did not respond to the questions were excluded from the analyses because it was thought possible that the participants had not listened with sufficient attention.

The overall experimental design consisted of two age groups and three within-subject factors (side of auditory messages, the task condition of either ignoring or answering to questions, and four probe positions). Participants...
underwent practice trials until they were confident that they understood the task before starting the experiment. A short rest was inserted between blocks. Participants filled out the questionnaires during a longer rest period inserted between the second and third blocks. The single versus dual task condition was separated between the first and second halves of the four blocks. Thus, if a participant underwent the single task condition for the first two blocks, then s/he was tested in the dual task condition in the last two blocks or vice versa. The side of the auditory message was switched twice, initially in the first half (between the first and second blocks) and again in the second half (between the third and fourth blocks) of the entire blocks. Each block consisted of 72 trials, with each of the four target locations repeated 18 times. There were 288 trials in all (72 trials by four blocks). It took about one and a half hours to complete the experiment, including rests and inventories.

3. Results

RTs less than 200 ms or longer than 2000 ms were excluded from analyses. Overall results were not affected when RTs longer than 2000 ms were included in the analyses (excluding those trials in which the participants failed to detect the probe, i.e., detection did not occur within the time limit of 4000 ms). These exclusion criteria were identical to those used by Harms and Patten (2003). The latter criterion (2000 ms) was adopted here because the response whose latency was longer than 2000 ms could be regarded as a “miss,” which might lead to potential accidents. RTs less than 200 ms were removed because they were judged to be premature responses. Another reason for this exclusion criterion was the pattern of RT distribution observed in our previous study with young participants (Sakurai & Iwasaki, 2008). In the study, RTs showed a bimodal distribution with a smaller second bump peaking at a point much longer than 2000 ms. Remaining valid RTs were averaged separately for each condition. The frequency of the “misses” was 5.27% for all trials of the older participants and 1.7% for the younger group. RTs less than 200 ms were negligible in number (average number of trials was 0.85 with a range of 0–6) for all trials for the younger participants and 1.15 (range: 0–5 trials) for the older ones.

All participants in the younger group showed satisfactory performance of the auditory task in the dual task condition. On average, they answered 93.8% (range: 86.8% to 100%) of the questions. Thus, no one was excluded from the statistical analysis of RT data due to low performance in the auditory task. In the older group, two participants (one male and one female) were excluded from the analysis; one was excluded because he could answer questions for less than 60% of the trials, and another because she could not understand the instructions. Among the remaining older participants, the overall response rate was relatively high (average score: 86.3%, range: 74% to 94%). The overall performance of the younger participants was better than that of the older participants, which was confirmed by a t-test ($t = 5.24, df = 38, p < 0.001$).

3.1 Reaction time

Median RTs were calculated after having excluded the trials in which RTs were shorter than 200 ms or longer than 2000 ms. In the dual task condition, RTs of those trials in which participants could not answer questions of the auditory task were also excluded.

A four-way ANOVA with Age Group as a between-subject factor and Input Channel (left or right ear), Task (dual or single), and Probe Position (four target positions: of six in the horizontal array of rings, two inner ones and two outer ones were replaced by the star; see Fig. 1) as within-subject factors was conducted on the median RTs. The ANOVA revealed significant main effects of Age Group ($F(3, 138) = 72.46, p < 0.001$), Task ($F(1, 38) = 28.05, p < 0.001$) and Probe Position ($F(3, 144) = 237.17, p < 0.05$). In the multiple comparison of Probe Position (Ryan, $\alpha = 0.05$), all the pairs (1-2 pair, 1-3 pair, 4-2 pair and 4-3 pair, $p < 0.001$) were significant except for the 1-4 pair ($F(1, 39) = 0.59, p = 0.44$) and the 2-3 pair ($F(1, 39) = 0.10, p = 0.74$). There were marginally significant three-way interaction between Age Group and Task and Probe Position ($F(3, 144) = 2.74, p < 0.10$). The interaction between Age Group and Probe Position was marginally significant ($F(3, 144) = 2.53, p < 0.10$). There was no effect of the Input Channel ($F(1, 38) = 1.14, p = 0.29$), nor it did not interact with Probe Position and Task ($F(3, 144) = 0.84, p = 0.47$).

To test the input side bias hypothesis (i.e., that attention was directed to the side of auditory input), a four-way ANOVA with Age Group × Task × Lateral Concordance (auditory and visual presentations were on the same vs. different sides) × Target Eccentricity (central vs. peripheral) was conducted, which revealed significant main effects of Age Group ($F(1, 38) = 72.46, p < 0.001$), Task ($F(1, 38) = 28.05, p < 0.001$) and Target Eccentricity ($F(1, 38) = 426.37, p < 0.001$). The interaction between Age Group and Target Eccentricity was also significant ($F(1, 38) = 4.56, p < 0.05$). However, there was no main effect of Lateral Concordance ($F(3, 114) = 0.74, p = 0.52$). Therefore, the input side bias hypothesis was not confirmed.

As seen in Fig. 2, the expected age effect was found: The older group was slower than the younger group. Probe Position also affected detection: Probe detection being slower when it was presented at the two peripheral locations relative to the two inner positions. The dual task interference was confirmed as expected in that the participants were slower to detect the probe when they had to answer the questions than when they could ignore them.
3.2 Missed detection

The older participants committed “misses” (i.e., detection RTs longer than 2000 ms, including trials with no response within 4000 ms) in 5.27% of the trials, whereas the younger participants in 1.7% of the trials. These frequency data were submitted to a four-way ANOVA with Group, Input Channel, Task, and Probe Position after being arcsine transformed, which revealed significant main effects of Age Group ($F(1, 38) = 25.82, p < 0.001$), Task ($F(1, 38) = 10.80, p < 0.01$), Probe Position ($F(3, 144) = 24.96, p < 0.001$) and an interaction including Group, Input Channel, and Task ($F(1, 38) = 6.45, p < 0.05$). In the multiple comparison of Probe Position (Ryan), all the pairs were significant ($p < 0.005$) except for the 2-3 pair ($p = 0.85$). Input Channel was marginally significant ($F(1, 38) = 3.24, p < 0.1$) with increased cost (i.e., difference in the number of misses between the single and dual task conditions) when the message was presented in the left ear.

To clarify the interaction, the data of the two age groups were analyzed separately. Data of the older participants were subjected to a three-way ANOVA with Input Channel, Task, and Probe Position as main factors after they were arcsine transformed. It revealed significant main effects of Input Channel ($F(1, 19) = 6.81, p < 0.05$), Task ($F(1, 19) = 9.75, p < 0.01$), and Probe Position ($F(3, 57) = 17.99, p < 0.001$). In the multiple comparison of Probe Position (Ryan), all the pairs ($p < 0.05$) were significant except for the 2-3 pair ($p = 0.60$). The main effect of Input Channel was due to the higher miss rate for the left ear. There were also significant interaction between Input Channel and Task ($F(1, 19) = 7.35, p < 0.05$) and between Task and Probe Position ($F(3, 57) = 3.78, p < 0.05$).

As there was a significant interaction between Input Channel and Task, dual task costs were calculated for each condition by subtracting miss rates of the single task from those of the dual task. A two-way ANOVA (with Input Channel and Probe Position as main factors) on the dual task costs revealed a significant main effect of Input Channel with higher miss rates when messages were presented through the left ear ($F(1, 19) = 6.17, p < 0.05$). Thus, older participants were especially susceptible to the dual task interference in terms of misses when they listened to questions.
with their left ears. The main effect of Probe Position was also significant ($F(3, 57) = 13.79, p < 0.01$), which was due to more misses for the probe presented at the peripheral positions relative to the central ones with little difference between the visual fields.

For the younger group, there were significant main effects of Probe Position ($F(3, 57) = 7.24, p < 0.05$) and interaction between Task and Probe Position ($F(3, 57) = 3.17, p < 0.05$). Input Channel had no effect on the misses ($F(1, 19) = 0.11, p = 0.74$).

### 3.3 The slowest quartile of RTs

It may be argued that the fixed criterion used to classify the RTs as “miss” (RT larger than 2000 ms) is arbitrary, which would automatically lead to more misses among the older participants due to their generally slower RTs. To remedy this problem, a dual task cost of the slow response was obtained for each data point. To obtain this score, first the 18 RTs of each participant for each cell formed by Probe Position, Input Channel, and Task (dual or single) were sorted separately, and the means of the slowest five RTs were calculated. For these calculations, RTs of the dual task condition in those trials in which participants could not answer the questions were excluded. RTs in those trials in which the participants failed to make responses were assigned a value of 4000 ms (the maximum time allowed for giving a response). Then, differences between means of the dual and single tasks of the respective data points were calculated. Only the data for the two end positions (the leftmost and the rightmost target locations) were subjected to the statistical analysis in order to assess a possible attentional bias caused by selectively attending to one input channel.

A three-way ANOVA with Age Group as a between-subject factor and Probe Position and Input Channel as within-subject factors applied to the dual task costs revealed significant main effects of the Probe Position ($F(1, 38) = 5.56, p < 0.05$) and Input Channel ($F(1, 38) = 5.89, p < 0.05$), marginally significant two-way interaction between the Age Group and the Input Channel ($F(1, 38) = 3.20, p = 0.082$). Age Group differences approached the conventional level of significance ($F(1, 38) = 3.42, p = 0.072$) with larger cost for the older group.

To clarify the marginally significant interaction between Age Group and Input Channel, the dual task costs of the two age groups were separately subjected to two-way ANOVAs with Probe Position and Input Channel as the within-subject factors. The analyses revealed a significant main effect of Input Channel for the older age group, indicating that the dual task cost was larger when the auditory messages were heard from the left ear (mean cost of 433.2 ms) than when it was heard from the right ear (140.8 ms). The Probe Position for the older group was not significant ($F(1, 19) = 1.54, p = 0.23$), nor was the interaction ($F(1, 19) = 0.18, p = 0.68$). In contrast to the older group, the only significant effect for the younger group was the Probe Position ($F(1, 19) = 6.08, p < 0.05$). The younger participants showed smaller cost of 43.5 ms when the probe appeared at the left position than when it appeared at the right position (mean cost of 192.7 ms). Neither the main effect of the Input Channel ($F(1, 19) = 0.24, p = 0.63, \text{ns.}$) nor the interaction between Input Channel and Probe Position was significant.
4. Discussion

In this study, the effect of aging on dual task cost was explored with a visual search task. In a previous study, Sakurai and Iwasaki (2008) showed that young participants were significantly slower to detect the probe when it was surrounded by decoys (distracters that were identical to the target), indicating that placing decoys around the probe locations succeeded in suppressing attentional capture by making the target to be non-singleton. A change blindness procedure may also be effective in suppressing the onset signal by the target. By thus minimizing attentional capture, it was expected that the observed dual task cost in terms of probe detection RT and “misses” would have reflected a limitation in attentional resources available to the executive attention.

A clear dual task cost was found in this study. Both younger and older age groups were slower in their probe detection RTs when they had to answer to the questions as compared with the condition in which they were allowed to ignore them. This finding is in line with the result of a study that explored the inference of conversation in a more realistic situation of cellular phone use (Strayer & Drews, 2004). It may be noted that dual task does not necessarily interfere with probe detection as was shown by Harms and Patten (2003). These researchers reported that the use of IVIS while driving impaired detection of probe light when messages were given by the modalities that involved vision, but not when auditory channel was the only IVIS information channel.

The finding that the older participants showed a larger dual task cost than the younger participants both in terms of misses and the averages of the slowest five detection RTs suggests that the dual task situation induced defective attentional deployment in the older participants. This suggests that older people are especially susceptible to the adverse effect of dividing attention between auditory and visual signals, perhaps due to diminished central attentional resources. The remaining question is why it was only when the message was heard from the left ear that the dual task cost was found.

In regard to the mechanism of the dual task cost found in this study, it may be suggested that answering questions caused shrinkage of UFOV. The significant interaction between Group and Probe Location as well as increased misses at the peripheral locations in the older participants is compatible with this possibility. Although the present experiment was not typical as a conventional UFOV study in that the participants were allowed to move their eyes freely, it may be
possible that the increased frequency of eye movements made by the older participants to compensate for the smaller UFOV led to the deterioration of detection performance.

As there was no right-side bias of attention as suggested by neither Kinsbourne’s hemisphere activation hypothesis nor detection RTs being biased toward the side of input channel (Driver & Spence, 1999), neither of the original hypotheses were supported. Unexpectedly, a larger dual task cost in terms of both the number of misses and the slowest RT quartile was found for the older participants when the messages were heard from the left ear than when they were heard from the right ear. Part of the reason why the larger left ear interference was obtained might be ascribed to the possibility that the messages heard from the left ear might have demanded larger portion of the attentional capacity due to the non-dominance of the right hemisphere for language processing (Zatorre, Belin, & Penhume, 2002).

Another possibility that there was some hearing impairment in the left ear of the older participants, which was suggested by small, marginally significant decrement of verbal response frequency in the left ear (85.0%) relative to the right ear (87.6%), seems unlikely because the older participants were recruited through SHRC on the condition that they had no hearing problems and they were asked about any hearing difficulty during practice sessions, to which they asserted that they had no problem in hearing the messages for either ear. Moreover, our previous study (Sakurai & Iwasaki, 2008) found that younger participants showed larger dual task cost when questions were heard from the left ear, suggesting that this lateral bias may not be a peculiarity of older participants. The finding that unlike our previous study (Sakurai & Iwasaki, 2008) no left-ear disadvantage was found for the young group of the present study may well have been due to the modification introduced in the auditory task in the present study. When the previous auditory task was tested with several older people it was found that they could not answer correctly many of the same questions used for the younger people, resulting in smaller number of usable detection RTs. So it was decided that the task was modified to be an open-ended type questions allowing answers being chosen freely. This modification, although making the task easier for the older people to perform, inadvertently introduced a change in the way they responded to the questions. That is, the participants had to choose their responses freely from multiple options, making their responses variable and more complicated as compared with the simple yes/no answers used in the previous study (Sakurai & Iwasaki, 2008). These differences in the auditory tasks make it difficult to compare the results of the younger participants of the two studies, with the previous group showing right-ear bias in attention (i.e., dual task cost was smaller when the message was heard from the right ear) and the present younger group showing left-side bias (i.e., dual task cost was smaller when the probe was presented at the left end position irrespective of the attended ear). Even the older group of this study tended to show non-significant left-side bias just like the younger group in addition to the significant right-ear bias. Therefore, the overall “misses” of the older participants were not discordant with the two types of the biases found in the younger participants across different auditory tasks of the two studies. It is not clear why the left-side bias was found when the task was a free choice of verbal responses. A speculation may be that choosing answers freely would have demanded higher left-hemisphere involvement in generating answers, which demanded to search memory for an answer. This memory search process might have induced attention being directed inwardly and interfered with directing it outwardly to the right side of the screen.

In summary, this study found that the task requiring the participants to answer questions, relative to just listening to it, required a larger amount of attentional resources, and the interference caused by this dual task was more conspicuous in older people due, perhaps to their reduced capacity of executive attention. An unexpected finding was the larger dual task cost for the older participants when the messages were heard from the left ear than when it was heard from the right ear.

These results have implications for real-life driving situations, suggesting that when older drivers engage in conversations on cellular phones while driving, they should avoid doing so with their cellular phones on their left ear to keep their attentional capacity as efficient as possible for detecting possible dangers on the road. If the right ear bias is a result of attentional shift toward the auditory source, then the present results may be a caveat for developers who design devices for assisting safe driving with auditory messages for user guidance. They should be careful of the location of the speaker, which should be placed on the right side of the driver rather than the left side to reduce interference with the driver’s efficient detection of potential dangers on the road.

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footnotes

1. Average response rates of the older participants were 87.5% (range: 73.6% to 97.2%) for the right ear and 85.1% (range: 73.6% to 94.4%) for the left ear. A t-test revealed that this difference was marginally significant ($t = 1.91, df = 19, p < 0.1$) with a higher response rate for the questions heard from the right ear.

2. Detection RTs including those longer than 2000 ms (but excluding no-response trials) were subjected to the three-way ANOVA (Age Group, Task, Probe Position) which revealed significant main effects of Age Group ($F(1, 38) = 59.49, p < 0.001$), Task ($F(1, 38) = 23.70, p < 0.001$), and Probe Position ($F(3, 144) = 142.16, p < 0.001$). None of the interaction were significant.