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Intentional switching in auditory selective attention: Exploring age-related effects in a spatial setup requiring speech perception☆

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ABSTRACT

Using a binaural-listening paradigm, age-related differences in the ability to intentionally switch auditory selective attention between two speakers, defined by their spatial location, were examined. Therefore 40 normal-hearing participants (20 young, Ø 24.8 years; 20 older Ø 67.8 years) were tested. The spatial reproduction of stimuli was provided by headphones using head-related-transfer-functions of an artificial head. Spoken number words of two speakers were presented simultaneously to participants from two out of eight locations on the horizontal plane. Guided by a visual cue indicating the spatial location of the target speaker, the participants were asked to categorize the target's number word into smaller vs. greater than five while ignoring the distractor's speech. Results showed significantly higher reaction times and error rates for older participants. The relative influence of the spatial switch of the target-speaker (switch or repetition of speaker's direction in space) was identical across age groups. Congruency effects (stimuli spoken by target and distractor may evoke the same answer or different answers) were increased for older participants and depend on the target's position. Results suggest that the ability to intentionally switch auditory attention to a new cued location was unimpaired whereas it was generally harder for older participants to suppress processing the distractor's speech.

PsycINFO classification

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1. Introduction

Communication in noisy situations is a great challenge for our auditory attention. Referred to as the “cocktail-party effect”, this has been in the focus of research since Cherry (1953) reported his first study where participants were asked to selectively listen to one ear while ignoring the speech from a distracting speaker in the other ear. Using dichotic-listening[1] paradigms, many different facets of auditory attention have been analyzed in the last decades (Broadbent, 1958; Bronkhorst, 2015; Hugdahl, 2011; Ihlefeld & Shinn-Cunningham, 2008; Pashler, 1999).

Recently, Koch, Lawo, Fels, and Vorländer (2011) employed dichotic listening to examine intentional attention switching using spoken number words as auditory stimuli. For that investigation, dichotic listening (Cherry, 1953) was combined with the methodology of task cueing (Meiran, 1996). This auditory task-switching paradigm differs from other studies on attention switches (Lachter, Forster, & Ruthruff, 2004; Rivenez, Guillaume, Bourgeon, & Darwin, 2008; Shinn-Cunningham, 2008), which reported about attention switches that were not instructed but occurred spontaneously and involuntary. In contrast, Koch et al. (2011) explicitly examined the endogenous, voluntary attention switches. Cued attention switches referred to the target's gender or the target's location (e.g. the target's location switched between trials; in the preceding trial the target was on the left side and in the following trial the target was on the right side). The main finding was that a cued switch of the relevant target resulted in a worse performance than in cued repetitions of the relevant target's speaker sex (Koch & Lawo, 2014; Koch et al., 2011; Lawo, Fels, Oberem, & Koch, 2014; Lawo & Koch, 2014). Furthermore, the role of attentional control in processing of task-irrelevant information in auditory attention switching has been explored. The participants' task was to always categorize the relevant number word presented by the target speaker as smaller than or greater than five and press the corresponding response button. The two presented stimuli of one trial could be congruent (both number words smaller than five or both

☆ Parts of this study were presented at the national conference: DAGA, Nürnberg, Germany, 2015 (Oberem, Wang, & Fels, 2017).

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[1] In the present investigation “dichotic” is referring to two different stimuli presented separately to the two ears.

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greater than five) and therefore call for the same response, or they could be incongruent (one digit was smaller and one was greater than five) and therefore call for different responses. The "congruency effect" (Kiesel et al., 2010), showing that participants respond faster in congruent trials than in incongruent trials, was confirmed (Koch et al., 2011), suggesting some processing of irrelevant information (i.e. of distractor's speech).

A fast and successful switch of attention between different target sources is very important in communicative everyday scenes. However, a dichotic presentation is a highly artificial situation compared to natural listening. That is why auditory selective attention has also been analyzed in spatial setups, for example in a setup with three loudspeakers positioned in front and to the sides of the participant (Best, Ozmeral, Kopčo, & Shinn-Cunningham, 2008; Helfer, Mason, & Marino, 2013; Singh, Pichora-Fuller, & Schneider, 2013). The dichotic-listening paradigm (Koch et al., 2011) to analyze intentional switching in auditory selective attention was extended to a binaural[2]-listening paradigm (Oberem, Lawo, Koch, & Fels, 2014; Oberem et al., 2017). For this purpose, a scene with more combinations of the speaker's locations than in the dichotic set-up was provided in an anechoic chamber with different binaural reproduction methods. Besides a set-up with real loudspeakers, head-related-transfer-functions were used to present binaural stimuli via headphones. Major advantage of a binaural synthesis via headphones is the independence from the room characteristics. For example, listening tests could be carried out in rooms with certain characteristics (e.g. reverberation time for a laboratory room might be 0.4 s) and the presented stimuli are placed in a drier room (i.e. anechoic chamber, no reverberation). In the investigation (Oberem et al., 2014) it was found that a required switch of the attention focus yielded longer reaction times and increased error rates than a repetition of the target's location, which were also dependent from the target's location itself.

All reported effects with the binaural-paradigm on intentional attention switching were found with young participants (18–35 years). As there is a trend towards an aging society, especially in western civilization, age-related effects have become of greater interest (McDowd & Shaw, 2000; Rogers, 2000). There were already several investigations on age-related effects in attention working with dichotic reproduction that reported increased performance costs in older people (Hirsch, Schwarzkopp, Declerck, Reese, & Koch, 2016; Kiesel et al., 2010; Kramer, Hahn, & Gopher, 1999; Kramer & Madden, 2008; Kray, Eber, & Karbach, 2008; Kray & Eppinger, 2006; Kray, Karbach, & Blaye, 2012; Kray & Lindenberger, 2000; Mayr, 2001; Meiran, Gotler, & Perlman, 2001; Salthouse, Fristoe, McGuthry, & Hambrick, 1998; Vandierendonck, Liefooghe, & Verbruggen, 2010). Age-related switch costs for guided attention switches were examined by Tun and Lachman (2008) and Lawo and Koch (2014). Tun and Lachman's results of larger switch costs for older participants were in contrast to these of the dichotic listening investigation by Lawo and Koch (2014) who used the described paradigm (Koch et al., 2011) examining the ability to prepare for an upcoming auditory attention switch. Lawo and Koch (2014) reported that older participants responded significantly slower than younger participants. However, the attention switch costs did not differ across age groups, confirming the idea of "general slowing," as confirmed in a meta-analysis by Wasylyshyn, Verhaeghen, and Sliwinski (2011), who did not find age-related differences in task switching using visual tasks.

There are several theories of cognitive aging assuming that the ability to inhibit irrelevant information declines with age (Braver & Barch, 2002; Hasher, Tonev, Lustig, & Zacks, 2001; Meiran et al., 2001); therefore it could be assumed that an increased congruency effect in older people was likely. However, Lawo and Koch's (2014) findings did not correspond to predictions from the inhibitory deficit theory, since they neither found an increased congruency effect nor increased switch costs for older participants.

Age-related effects have also been analyzed with binaural-listening-setups. The effect that younger participants outperform older participants was often observed in investigations that focused on tasks of perceiving competing speech (Duquesnoy, 1983; Helfer et al., 2013; Humes, Lee, & Coughlin, 2006; Li, Daneman, Qi, & Schneider, 2004; Marrone, Mason, & Kidd, 2008; Singh et al., 2013; Tun, O'Kane, & Wingfield, 2002; Tun & Wingfield, 1999).

Multiple source possibilities in a binaural-listening-setup build a more complex scene than a dichotic presentation of stimuli. To successfully focus on the stimulus of the target speaker in a binaural setup, the ability to localize different sound sources was necessary. The age-related effect in localization tasks was for example analyzed by Abel, Giguère, Consoli, and Papsin (2000). They focused on sound localization on the horizontal plane for participants aged between 10 and 81. Performance of older adults decreased, especially in front-back-confusions and on the right side of space. The deterioration of accuracy and precision by older individuals was also found by Dobreva, O'Neill, and Paige (2011).

Age-related effects in involuntary switches in binaural-listening-setups were examined by Singh et al. (2013). Using the Coordinate Response Measure Corpus (Bolia, Nelson, Ericson, & Simpson, 2000), participants were asked to repeat the color and number word preceded by a fixed callsign and consequently correct word-identification scores were measured. Participants were provided with advance information about the probability of the sentence being presented from one out of three possible frontal positions. No age-related differences in switching attention from one location to another were found. However, in a more complex task where the participant's attention was intentionally misdirected and the participant was therefore required to perform multiple switches of attention, age-related deficits were reported.

In the present investigation we combined the binaural reproduction of stimuli and the analysis of age-related effects in a task of instructed attention switches. Based on the findings of the previous binaural-listening experiment, two groups of different age were tested in the binaural-listening-setup. In general, we expected age-related effects in intentionally switching auditory selective attention comparable to these of the previous dichotic investigation (Lawo & Koch, 2014). Essential differences between this investigation and the investigation by Lawo and Koch (2014) were the reproduction method (dichotic vs. binaural) and the cue criterion (gender vs. location). Regarding the location of the target speaker we expected differences in reaction times and error rates. However, there were no firm expectations about the interaction of age group with attention switches and congruency.

To summarize, in this study we examined the ability of young and older adults to intentionally switch auditory attention in a spatial environment using a selective listening paradigm. Specifically, switch costs, congruency effects, and their interaction with the target's position in space were assessed to examine whether there were age-related performance effects in instructed switching of auditory selective attention.

2. Methods

2.1. Participants

20 young adults (age: 20–31 years; M = 25.1 years, SD = 3.3 years, 10 female, paid, non-experienced, students) and 20 older adults (age: 60–74 years; M = 67.8 years, SD = 3.4 years, 10 female, paid, non-experienced, academics) participated in the experiment. All listeners were screened by an ascending-pure-tone-audiometry procedure for frequencies between 125 Hz and 8 kHz. All younger participants had normal hearing (within 25 dBHL defined as no impairment by the WHO (1991), no greater between-ear-difference than 8 dB in all tested

[2] In the present investigation "binaural" does not only refer to the situation where sound reaches both ears, but it also includes spatial information.