BRIEF REPORT

Human Aging Compromises Attentional Control of Auditory Perception

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Older adults often experience hearing difficulties in multitalker situations. Attentional control of auditory perception is crucial in situations where a plethora of auditory inputs compete for further processing. We combined an intensity-modulated dichotic listening paradigm with attentional manipulations to study adult age differences in the interplay between perceptual saliency and attentional control of auditory processing. When confronted with two competing sources of verbal auditory input, older adults modulated their attention less flexibly and were more driven by perceptual saliency than younger adults. These findings suggest that aging severely impairs the attentional regulation of auditory perception.

Keywords: aging, auditory perception, attention, dichotic listening, hearing

In everyday life, we are often confronted with situations in which a plethora of auditory inputs competes for further processing. Such competitions can be biased by either properties of the sensory inputs (e.g., perceptual saliency) or cognitive mechanisms (e.g., attentional control). Attention and perception interact dynamically to facilitate auditory information processing. If the relevant information is perceptually salient, then attentional demand would be low; however, if the irrelevant information is more salient instead, then attentional demand would be high to suppress distractions (Desimone & Duncan, 1995; Kastner & Ungerleider, 2000).

Adult Age Differences in Perceptual and Attentional Processes

Normal aging impairs communications in multitalker situations, which likely reflects age-related declines in sensory and perceptual processes, as well as in more general changes in attentional mechanisms. Age-related hearing loss is one of the three most common chronic health conditions affecting adults aged 65 and older (for a review, see Gordon-Salant, Frisina, Popper, & Fay, 2010). Older adults' problems in speech understanding derive from several aspects of peripheral and central auditory processing (Committee on Hearing, Bioacoustics, and Biomechanics, 1988). First, hearing sensitivity declines progressively with increasing age (e.g., Cruickshanks et al., 1998). Second, deficits in central auditory temporal processing, relevant for phoneme and speech recognition in noisy environments, are consistently observed (see Gordon-Salant et al., 2010). Nevertheless, it has also been shown that older adults may compensate for some of these age-related decreases in audition by focusing attention on the relevant sound sources (Alain, McDonald, Ostroff, & Schneider, 2004). Put differently, age-related declines in peripheral and central auditory processing necessitate more attentional control during auditory processing (see Gordon-Salant et al., 2010). However, a prominent aspect of cognitive aging is attentional deficit and increased susceptibility to distractions across a broad range of visual tasks (e.g., Hommel, Li, & Li, 2004; Spieler, Balota, & Faust, 1996; Whiting, Madden, & Babcock, 2007) and auditory tasks (e.g., Helfer & Freyman, 2008; Sommers & Danielson, 1999).

Simple and forced-attention dichotic listening tasks have been used to study age effects on auditory attention (e.g., Drachman, Noffsinger, Sahakian, Kurdziel, & Fleming, 1980; Hugdahl,

Carlsson, & Eichele, 2001; Takio et al., 2009; Strouse, Wilson, & Brush, 2000). In dichotic listening, two different auditory stimuli are presented simultaneously to the right and left ear. Even with seemingly simple dichotic listening tasks that do not manipulate attentional focus, older adults recall less syllables correctly than younger adults when asked to report inputs from both ears. This finding has been interpreted as reflecting general age-related decreases in attention and memory (Drachman et al., 1980; Strouse et al., 2000).

Coupled with the use of elementary verbal materials, for example, consonant–vowel (CV) syllables, the dichotic listening tasks have also been applied to investigate the lateralization of speech processing. When asked to report the syllable heard most clearly, healthy right-handed participants usually report more syllables from the right than from the left ear (for a review, see Hugdahl, 2003; Jerger & Martin, 2004), reflecting the so-called right-ear advantage (REA). Traditionally, the REA is understood in a neuroanatomical model of verbal dichotic listening (Kimura, 1967). The model postulates that the REA arises from (a) the stronger contralateral (vs. ipsilateral) auditory projections and (b) the inhibition of the weaker ipsilateral pathways during dichotic listening. Given the left hemispheric dominance for speech processing, only the right-ear verbal auditory inputs are directly transferred to the relevant left hemisphere, whereas the left-ear inputs, initially conveyed to the right hemisphere, need to be transferred through the corpus callosum. Previous studies investigating whether the extent of REA changes with increasing age yielded rather inconsistent results, with some studies reporting an increased REA that was mainly driven by less report from the left ear (e.g., Gootjes, Van Strien, & Bouma, 2004; Jerger, Chmiel, Allen, & Wilson, 1994) or an invariant REA (e.g., Alden, Harrison, Snyder, & Everhart, 1997; Andersson, Reinvang, Wehling, Hugdahl, & Lundervold, 2008) in older compared with younger adults. These inconsistencies are due, in part, to differences in the stimulus materials (e.g., CV syllables, words, or sentences) and experimental procedures.

Attentional focus affects the REA in dichotic listening. Relative to the neutral-focus condition (i.e., attending to both ears), directing attention to the right ear usually further accentuates the REA, whereas directing attention to the left ear tends to "nullify" the ear advantage or even reverse it to a left-ear advantage (LEA; e.g., Bryden, Munhall, & Allard, 1983; Hugdahl & Andersson, 1986). In studies that investigated age differences in the effects of attentional control on the REA, older adults showed less increase in the REA when asked to attend to the right ear and a reduced ability to attend to the left ear when compared with younger adults (e.g., Hugdahl et al., 2001; Takio et al., 2009). However, thus far, no study has examined how the REA may be affected by age differences in the interaction between perceptual saliency and attentional control.

Recent research in younger adults showed that the intensity-modulated dichotic listening task combined with a manipulation of attentional focus is an ideal paradigm for investigating the interactive effects of attention and auditory perception in affecting the REA (Tallus, Hugdahl, Alho, Medvedev, & Hamalainen, 2007; Westerhausen et al., 2009). In this paradigm, the relative saliency of the auditory inputs from both ears is manipulated by gradually varying the intensity favoring either the right or left ear. Higher auditory input intensity from either the right or the left ear results in a stronger neural signal from the ear exposed to the louder stimulus (Boudreau & Tsuchitani, 1968). The greater the intensity difference between the ears, the greater the perceptual saliency of

the stimulus is from the stronger ear. In younger adults, interaural intensity differences interact with the REA: Decreasing left-ear input intensity while keeping the right-ear intensity constant results in enhanced REA, whereas reducing right-ear intensity while keeping the left-ear intensity constant reduces the REA and eventually results in a LEA (Hugdahl, Westerhausen, Alho, Medvedev, & Hämäläinen, 2008). Coupled with the manipulation of attentional focus, across all levels of interaural intensity differences, the REA in the neutral-focus condition was weaker than that in the focused-right condition and was stronger than that in the focused-left condition. Furthermore, the effect of attentional focus on the REA was smaller when perceptual saliency and attentional focus both favored the same ear than when perceptual saliency and attentional focus conflicted with each other in favoring opposing ears (e.g., Westerhausen et al., 2009).

Study Aims and Hypotheses

Our general aim was to investigate how aging may affect the interaction between perceptual saliency and attentional focus using a paradigm that manipulated both mechanisms (cf. Westerhausen et al., 2009). Given the REA of verbal auditory processing (for a review, see Hugdahl, 2003), we expected a REA in both younger and older adults. In line with previous studies of younger adults (Tallus et al., 2007; Westerhausen et al., 2009), we expected the effect of attentional focus on the REA to vary systematically with the degree of competition between perceptual saliency and attentional focus. However, given age-related declines in auditory attention (e.g., Helfer & Freyman, 2008; Sommers & Danielson, 1999), we hypothesized that older adults' performance would be less regulated by attention and, instead, would be more driven by perceptual saliency. This effect would be reflected in smaller deviations of the REA under focused attention relative to the neutral-focus conditions in older adults as compared with younger adults.

Method

Participants

Twenty-four right-handed younger and 40 right-handed older adults participated. Handedness was assessed with the Edinburgh Handedness Inventory (Oldfield, 1971). All participants were screened for hearing acuity and interaural threshold differences for the frequencies of 250, 500, 1000, 2000, and 3000 Hz with a pure-tone audiometer (MAICO Diagnostics MA 51, Berlin, Germany).[1] The common criterion of excluding participants with hearing thresholds ≥25 dB hearing level (HL) would have resulted

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[1] Mean pure-tone hearing thresholds (plus or minus one standard error of the mean [± 1*SE*]) across both ears and mean interaural threshold differences (± 1*SE*) for younger adults: For 250 Hz, 6.3 ± 0.8 and 2.9. ± 0.6, respectively; for 500 Hz, 5.7 ± 0.8 and 1.9 ± 0.5, respectively; for 1000 Hz, 3.9 ± 0.8 and 3.5 ± 0.6, respectively; for 2000 Hz, 5.7 ± 1.1 and 3.5 ± 0.7, respectively; for 3000 Hz, 4.1 ± 0.9 and 4.4 ± 0.5, respectively. The thresholds and threshold differences for older adults are as follows: For 250 Hz, 10.7 ± 1.3 and 3.0 ± 0.6, respectively; for 500 Hz, 9.8 ± 1.1 and 2.8 ± 0.7, respectively; for 1000 Hz, 12.7 ± 1.3 and 4.2 ± 0.9, respectively; for 2000 Hz, 20.3 ± 1.6 and 4.6 ± 0.9, respectively; for 3000 Hz, 22.2 ± 1.8 and 5.2 ± 0.9, respectively.

in a highly positively selected older adult sample (i.e., excluding 65% of the older adults). To reduce the selectivity of our sample, we relaxed the criterion to >35 dB HL for the five frequencies tested and adapted the stimulus intensity individually (more details are discussed later). Fifteen older adults (37.5% of our initial sample) had to be excluded because of either high hearing thresholds (>35 dB HL) or large interaural threshold differences (>10 dB) at any of the five frequencies tested. Thus, the effective sample consisted of 24 younger adults aged 23–35 years ($M = 25.96 \pm 2.7$ years; 12 women, 12 men) and 25 older adults aged 65–76 years ($M = 70.68 \pm 3.5$ years; 11 women, 14 men). Before the dichotic listening experiment, cognitive covariates including a marker of perceptual speed (digit symbol substitution test; Wechsler, 1981) and a marker of verbal knowledge (Spot-A-Word; Lehrl, 1977) were assessed. In line with two-component theories of life span intelligence (Baltes, 1987; Cattell, 1971; Horn, 1968) and empirical evidence (Li et al., 2004; Schaie, Maitland, Willis, & Intrieri, 1998) contrasting the fluid mechanics and crystallized pragmatics of cognition, our results showed a significant age-related decline in perceptual speed (for younger adults, 69.5 ± 13.4; for older adults, 46.4 ± 10.1; $t[47] = 6.82$, $p < .001$, $d = 1.94$) and significant higher scores in verbal knowledge for older adults (for younger adults, 18.0 ± 5.9; for older adults, 22.1 ± 4.8; $t[47] = -2.68$, $p < .01$, $d = 0.76$) confirming the age typicality of our samples. Mean educational levels were 13.38 ± 2.41 years for younger adults and 12.56 ± 4.35 years for older adults. All participants were native speakers of German, gave informed consent, and were paid for participation. The Ethics Committee of the Max Planck Institute for Human Development approved the study.

Stimuli and Procedure

The stimuli were paired presentations of six stop consonants, /b/, /d/, /g/, /p/, /t/, and /k/, together with the vowel /a/ to form three voiced (/ba/, /da/, /ga/) and three unvoiced (/pa/, /ta/, /ka/) CV syllable pairs. Given previous results showing an effect of voicing on the REA (Rimol, Eichele, & Hugdahl, 2007), only the syllable combinations with the same voicing were used; thus, there were 12 dichotic syllable pairs. All syllables were spoken by a young adult male speaker with constant intonation and intensity and with a mean duration of 400 ms. Each CV pair was edited for onset synchronization with a standard editing software (Cool Edit, now Adobe Audition 3.0, Adobe Systems Incorporated). Most of the spectral energy of these CV syllables is within a frequency range of 250 Hz to 5000 Hz (Hugdahl, 2003), with the highest amplitude in all of the six CV syllables being present in the frequency range below 1000 Hz. Thus, pure-tone thresholds at 500 Hz (the mean of the range from 0 Hz to 1000 Hz) were taken for individual adjustments of input intensity. This was done by adding a constant of 65 dB to each participant's personal hearing threshold (maximum threshold, 15 dB HL in younger adults and 20 dB HL in older adults). Because we included older adults with mild hearing loss (≤35 dB HL), we also checked for the differentiability of the syllables by conducting a syllable discrimination task before the experiment. The six syllables were presented diotically, and the participants had to choose one of six corresponding buttons. The chance level of this task was 16.7% (one of six possible choices), and

all participants performed well above chance at an accuracy level of 75% or better.

We manipulated perceptual saliency by decreasing the intensity of either the right- or the left-ear input in 5-dB steps until a maximum difference of 20 dB between ears was reached. This resulted in nine conditions with four favoring the left ear ([−20], [−15], [−10], and [−5]), four favoring the right ear ([20], [15], [10], and [5]), and one being neutral ([0]). The neutral condition served as baseline intensity and was adapted to each participant's individual hearing threshold at 500 Hz (as discussed earlier). Each of the 12 dichotic syllable pairs was presented twice for each of the nine interaural intensity conditions, resulting in a total of 216 intensity–stimulus pairs for each attentional condition, which were then split into four testing blocks of 54 trials each.

We manipulated attentional focus by instructing the participants to focus on the right ear, on the left ear, or on both ears (neutral-focus). In the neutral-focus condition, participants were asked to report the syllables they heard most clearly, whereas in the focused-right or the focused-left condition, the participants were asked to report only syllables presented to the attended ear. The neutral-focus condition was always tested first to avoid carryover effects from the focused conditions. Focused-right and focused-left blocks were counterbalanced in two presentation orders (i.e., ABBABAAB or BAABABBA). All testing was performed in a sound-attenuated booth. Presentation of the stimuli and response collection were controlled by means of the E-Prime 1.1 software run on a PC. All stimuli were presented through insert earphones (ER 3A, Etymotic Research, Inc., Elk Grove Village, IL).

Statistical Analysis

We conducted three sets of analyses to examine age differences in (a) the REA in conditions where both ears shared the same input intensity; (b) interactive effects of perceptual saliency and attentional focus in affecting the REA; and (c) how correct report of syllables from the attended ear differ between situations in which the conflict between attentional focus and perceptual saliency is either absent or present, resulting in low versus high attentional demands, respectively. Low attentional demand conditions were defined as conditions in which perceptual saliency and attentional focus favored the same ear. Conversely, in high attentional demand conditions, perceptual saliency favored the unattended ear.

The percentage of reported right-ear and left-ear syllables in the condition where both ears shared a same input intensity were analyzed in a repeated-measures analysis of variance (ANOVA) with attentional focus (neutral, right, and left) and ear (right and left) as within-subject factors and age group and gender as between-subject factors. We analyzed age differences in the Perception × Attention interaction with respect to a summary measure of ear advantage; that is, the laterality index, which expresses the amount of right-ear reports in relation to left-ear reports: $(RE - LE)/(RE + LE) \times 100$. The index ranges from −100% to 100%, with positive values indicating a REA and negative values indicating a LEA (Marshall, Caplan, & Holmes, 1975). The laterality indices for younger adults and older adults were analyzed in a repeated-measures ANOVA with attentional focus (neutral, right, and left) and perceptual saliency (nine conditions) as within-subject factors and age group and gender as between-subject factors. Age differences in performance under high versus low

attentional demands were analyzed on the basis of correct reports. Performance under high attentional demand was defined by the number of correctly reported syllables presented to the attended ear across all conditions of perceptual saliency that favored the unattended ear, whereas performance under low attentional demand was defined by correct reports across all conditions of perceptual saliency that also favored the attended ear. We performed a repeated-measures ANOVA with attentional demand (high, low) and attended ear (right, left) as within-subject factors and age group and gender as between-subject factors. Furthermore, conflict costs were calculated as ratio scores between correct reports in high and low attentional demand conditions separately for focused-right and focused-left conditions: (correct report low − correct report high)/(correct report high + correct report low) ×100. Including gender as a between-subject factor in the repeated-measures ANOVAs did not reveal any significant main or interaction effects (all ps > .05). Therefore, all subsequent analyses were performed by collapsing across men and women. When the sphericity assumption was violated ($p < .05$), the Greenhouse–Geisser correction was applied. Adjusted degrees of freedom and p values of the analyses are reported. Effect sizes of main or interaction effects are given as η^2, representing the proportion of variance of the dependent factor explained by the independent variable. Effect sizes of follow-up t tests were given as Cohen's d and d_z.

Results

Age Differences in the REA of Processing Verbal Material

The three-way repeated-measures ANOVA showed a significant Attentional Focus × Ear × Age Group interaction, $F(1.56, 73.1) = 7.63$, $p < .01$, $\eta^2 = 0.11$; reflecting age differences in

attentional regulation of the REA (see second analyses for further details). Given that the REA is commonly investigated without any perceptual and attentional manipulation, follow-up paired-sample t tests in the neutral-focus condition and no interaural intensity difference confirmed more reports from the right than from the left ear in younger adults (right ear report, 59.9 ± 11.2; left ear report, 39.1 ± 10.8), $t(23) = 4.67$, $p < .001$, $d_z = 1.34$. In contrast, no reliable differences between ears were observed in older adults (right ear report, 50.5 ± 17.8; left ear report, 43.7 ± 17.6), $p > .05$.

Age Differences in the Interaction Between Perceptual Saliency and Attentional Focus

A three-way repeated-measures ANOVA analyzing the laterality index revealed a significant three-way interaction, Attentional Focus × Perceptual Saliency × Age Group, $F(6.42, 301.63) = 8.67$, $p < .001$, $\eta^2 = 0.01$; indicating age differences in the interaction between perceptual saliency and attentional focus (see Figure 1). Although the post hoc ANOVAs separately for younger and older adults indicated significant interactions between attentional focus and perceptual saliency in younger adults, $F(4.92, 113.20) = 5.79$, $p < .001$, $\eta^2 = 0.02$; and in older adults, $F(7.15, 171.58) = 4.72$, $p < .001$, $\eta^2 = 0.01$; the effect sizes of the two factors differ considerably between the two age groups. The effect size of attentional focus was considerably larger in younger adults, $F(1.11, 25.42) = 19.22$, $p < .001$, $\eta^2 = 0.20$; than in older adults, $F(1.43, 34.38) = 6.80$, $p < .01$, $\eta^2 = 0.01$; whereas the effect size of perceptual saliency was larger in older adults, $F(2.31, 55.37) = 181.47$, $p < .001$, $\eta^2 = 0.85$; compared with younger adults, $F(1.80, 41.35) = 123.08$, $p < .001$, $\eta^2 = 0.68$. These results indicate that older adults were not as flexible in regulating their attentional focus as younger adults and that their performance was mainly driven by perceptual saliency.
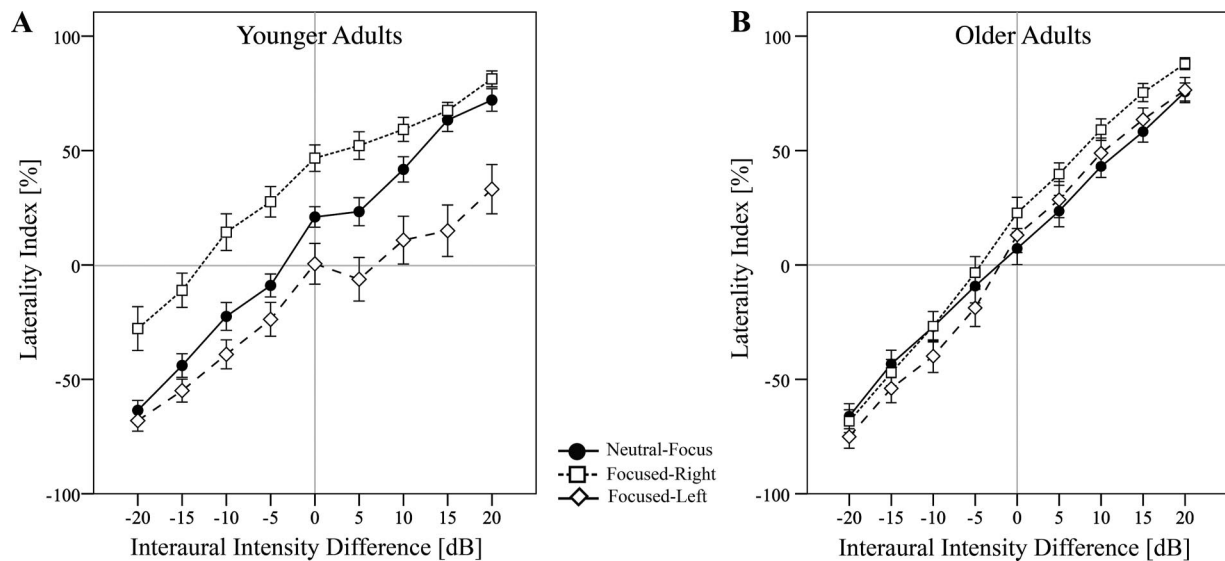

Figure 1. Mean laterality index for younger adults (Panel A) and older adults (Panel B) across all interaural intensity difference conditions and for each attentional condition. Error bars indicate 1 standard error of the mean.

Follow-up paired-sample *t* tests revealed that, in younger adults, the laterality index in the focused-right condition was significantly larger than that in the neutral-focus condition in the range from 20 dB in favor of the left ear to 10 dB in favor of the right ear. In older adults, this was only present in the range from 5 dB to 20 dB in favor of the right ear (i.e., in conditions where perceptual saliency also favored the attended ear). Younger adults showed a significantly higher laterality index in the neutral-focus condition than in the focused-left condition in the range from15 dB to 20 dB in favor of the right ear, whereas older adults showed this difference again only in conditions when perceptual saliency also favored the attended ear (i.e., 10 dB to 20 dB in favor of the left ear).

Age Differences in the Effects of Attentional Demands

Regarding age effects on performances in the high versus low attentional demand conditions, the repeated-measures ANOVA revealed main effects of age group, $F(1, 47) = 10.02$, $p < .01$, $\eta^2 = .03$; attentional demand, $F(1, 47) = 427.06$, $p < .001$, $\eta^2 = .75$; and attended ear, $F(1, 47) = 12.58$, $p < .01$, $\eta^2 = .03$. Of specific interest, the Attentional Demand $\times$ Age Group interaction was also significant, $F(1, 47) = 18.70$, $p < .001$, $\eta^2 = .03$. Follow-up *t* tests indicated significantly higher correct reports in younger adults, compared with older adults, in high attentional demand conditions: For the focused-right condition, $t(47) = -3.90$, $p < .001$, $d = 1.11$; for the focused-left condition, $t(47) = -3.32$, $p < .01$, $d = .94$ (see Figure 2, Panel A). In low attentional demand conditions, both age groups performed equally well (all ps > .05). Furthermore, we computed a ratio score of conflict costs (for the mathematical definition, see the Statistical Analysis section), which reflects reduction in performance due to the conflict between perceptual saliency and attentional focus. Conflict costs were significantly higher in older compared with younger adults in both the focused-right condition, $t(47) = 4.18$, $p < .001$, $d = 1.20$;

and the focused-left condition, $t(47) = 3.77$, $p < .001$, $d = 1.08$ (see Figure 2, Panel B).

Discussion

Combining the intensity-modulated dichotic listening paradigm with the manipulation of attentional focus, this study revealed three key findings: First, the typical REA in verbal auditory processing was weaker, if not entirely absent, in older adults. Second, the patterns of interaction between perceptual saliency and attentional focus and how these affect the REA differed drastically between younger and older adults. Third, older adults' performance accuracy in reporting syllables from the attended ear were particularly impaired, relative to younger adults, when conflicts between attention and perception were present; that is, when attentional demands were high.

To the best of our knowledge, our result is the first report of an absent REA in older adults under dichotic listening situations. Previous studies have investigated age differences in the extent of the REA but reported inconsistent results showing either an increased (e.g., Gootjes et al., 2004; Jerger et al., 1994) or an invariant REA (e.g., Alden et al., 1997; Andersson et al., 2008) in older adults compared with younger adults. The absence of an REA in older adults may be in line with the results from a recent fMRI study that showed a bilateralized functional language network in older adults (Tyler et al., 2010). At a more general level, this effect may also reflect age-related differences in the distinctiveness of brain activations (Li & Sikström, 2002), be it across hemispheres (Cabeza et al., 2004; Reuter-Lorenz, 2002) or within one hemisphere independent of hemispheric lateralization (Park et al., 2004). It should be noted, however, that the absence of a significant REA in older adults may also reflect low statistical power. Future studies including more participants should validate whether the REA is reduced or absent in older adults and identify
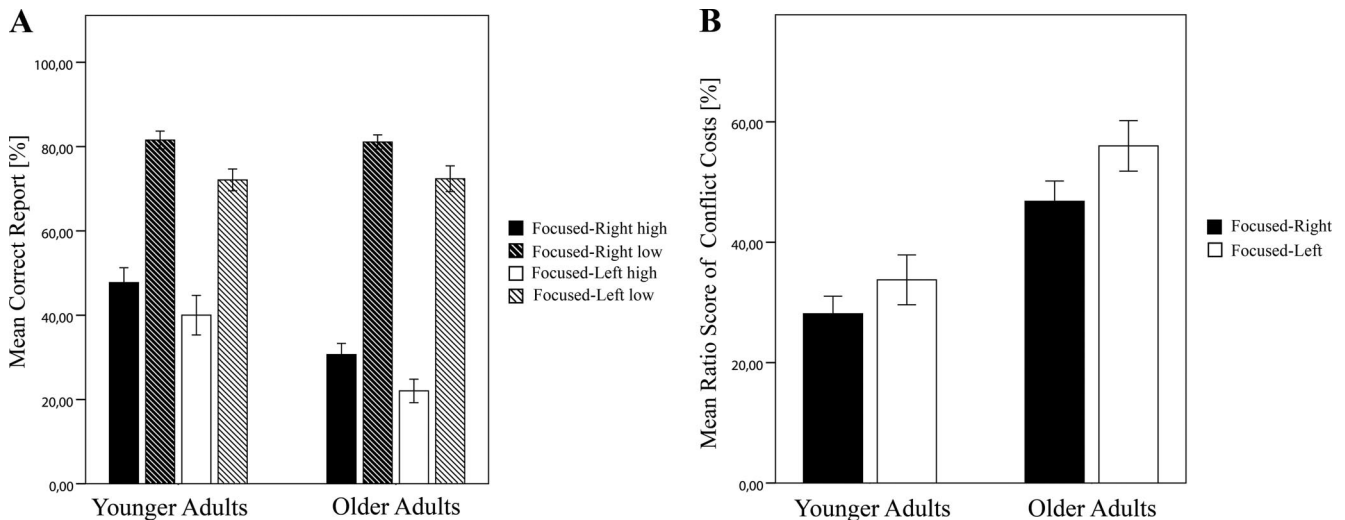

Figure 2. (A) Mean correct reports (reports of the syllable presented to the instructed ear) for younger adults and older adults in focused-right high, focused-right low, focused-left high, and focused-left low attentional demand conditions. (B) Mean ratio scores of conflict costs [(correct report low − correct report high)/(correct report high + correct report low) × 100] for younger adults and older adults in focused-right and focused-left conditions. Error bars indicate 1 standard error of the mean.

the mechanisms that contribute to individual differences in the age-related attenuation of the REA.

Extending earlier findings in younger adults (Tallus et al., 2007; Westerhausen et al., 2009), we found clear age differences in the interaction between attentional focus and perceptual saliency. In younger adults, the laterality indices for focused-attention conditions (focused-right and focused-left) and the laterality indices for neutral-focus conditions were quite distinct, and the differences between them were adaptively modulated by the extent of attentional demand (see Figure 1, Panel A). These findings indicate that younger adults were capable of flexibly focusing their attention on auditory inputs from either the right or left ear, even in conditions when the inputs from the attended ear were perceptually less salient (cf. Tallus et al., 2007; Westerhausen et al., 2009). In contrast, in older adults, the laterality indices were practically indistinguishable across the different conditions of attentional focus (cf. Hugdahl et al., 2001; Takio et al., 2009); instead, older adults' performance was mainly driven by perceptual saliency, particularly in conditions when attentional focus and perceptual saliency favored opposing ears (see Figure 1, Panel B).

A recent fMRI study of younger adults identified two distinct brain networks, a frontoparietal and a medial–lateral frontal control network, that are involved in solving conflicts between perceptual saliency and attentional control processes (Westerhausen et al., 2010). Juxtaposing this result with another recent finding showing age-related changes in task-dependent recruitment of the frontoparietal attentional control network during a visual conflict monitoring task (Prakash, Erickson, Colcombe, Kim, Voss, & Kramer, 2009), one may expect that a similar deficit in recruiting this circuitry according to attentional demands underlies the age differences reported here. Future studies need to investigate functional brain correlates of older adults' less flexible attentional allocation in intensity-modulated dichotic listening.

Furthermore, conflicts between attention and perception had a greater effect in older adults than in younger adults (Figure 2), indicating that older adults are less able to suppress perceptually more salient input from the unattended ear. This result is in accordance with the inhibitory deficit hypothesis, according to which age-related declines across a number of cognitive domains result from an inability to inhibit the influence of task-irrelevant information (Gazzaley et al., 2008; Hasher & Zacks, 1988). More generally, the finding of a more perceptually driven behavior and less efficient attentional control in older adults supports the observation that aging individuals are confronted with a quandary in the sense that attentional control is needed more often but increasingly less able to counteract the wide-ranging adverse consequences of sensory, perceptual, and motor deficits (Lindenberger, Marsiske, & Baltes, 2000, p. 434). Future studies in speech perception should explore whether training programs, focusing on the improvement of auditory attentional control, can enable older adults to reduce their perceptual dependencies and whether those trainings have transfer effects on more realistic listening situations, such as efficient communication in multitalker situations.

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