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Research Report

Interaural intensity difference and ear advantage in listening to dichotic consonant–vowel syllable pairs

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ABSTRACT

The right-ear advantage (REA) is typically observed in verbal dichotic listening, indicating a left hemisphere superiority for speech processing. The REA could be thought of as a bottom–up, stimulus-driven laterality effect, caused by the preponderance of the contralateral neural fibers from the right ear to the auditory/speech processing areas in the left temporal lobe. The REA can, however, be modified by explicitly requiring the listeners to focus their attention alternatively on the left or right-ear stimuli, thus either countering or enhancing the bottom–up processes through top–down attentional control. In the present study, we manipulated the strength of the bottom–up REA by inducing an intensity difference between the right-ear and left-ear speech inputs in order to make the REA either weaker (left-ear input>right-ear input) or stronger (left-ear input<right-ear input) and also examined how this manipulation affected the top–down attention modulation effects. Twenty healthy participants listened to dichotic presentations of consonant–vowel syllable pairs with different attention instructions. The results showed that the interaural intensity difference significantly affected the ear advantage in the predicted way. It also interacted with the top–down control effects, attentional control having a stronger effect when attending to the ear that had a weaker sound intensity, as compared to when the intensities were equal.

1. Introduction

Dichotic listening is a commonly used vehicle for exploring hemispheric asymmetry in auditory perception (Kimura, 1961; Bryden, 1988; Hugdahl, 1995). The participant is presented simultaneously with two different stimuli, one to the right ear and the other to the left ear. With speech stimuli, a right-ear advantage (REA) is typically observed (Hugdahl and Anderson, 1984; Bryden, 1988). The REA means that more correct reports are made of stimuli presented to the right ear than of stimuli presented to the left ear, and this is not accounted for by hearing disturbances. REA has commonly been explained as being due to the structural organization of the auditory system. In particular, it has been suggested that the right ear has stronger and more preponderant neural connections to the auditory processing areas in the temporal lobe of the left

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hemisphere than the left ear and that the left hemisphere is dominant for language and speech processing in most individuals (Kimura, 1967). An additional or alternative view of the REA was put forward by Kinsbourne (1970). According to this view, called the attentional hypothesis, increased activation of either hemisphere serves to project attention to the contralateral side of the body and space. In a verbal dichotic listening task, the left hemisphere would be more strongly pre-activated because of the language-processing demands of the task. As a result, attention would be biased towards the right auditory hemispace in verbal tasks, resulting in the REA (cf. also Hiscock and Kinsbourne, 1980; Wood et al., 2000).

A variant of the dichotic listening paradigm is the so-called "forced-attention paradigm" (Bryden et al., 1983; Hugdahl and Anderson, 1986) in which the participant is instructed to listen only to the stimulus presented to the left ear (a forced-left condition) or to that delivered to the right ear (a forced-right condition). A typical finding in this paradigm is an increase of the REA in the forced-right condition and a decrease of the REA, or sometimes a shift to a LEA (left-ear advantage) in the forced-left condition (Hugdahl and Anderson, 1986; Asbjørnsen and Hugdahl, 1995). Asbjørnsen and Hugdahl (1995) suggested that attention modulates the ear advantage in dichotic listening primarily by suppressing, or inhibiting, the perceptual input from the non-attended ear. They further suggested that the attentional suppression may act through callosal and subcortical pathways. In line with this, the corpus callosum cross-sectional area and microstructure have been found to reflect the magnitude of REA observed when no special attention instruction is given (a non-forced condition), as well as the attentional modulation occurring in the forced-left condition (Westerhausen et al., 2006; see also Hugdahl, 2003a). The proportion of correct left-ear and right-ear reports in the attentional conditions would thus result from interacting top–down and bottom–up processes (Hugdahl, 2003b). Top–down attention control could be regarded as an example of what Engle (2002) called executive attention, which refers to the ability to process and maintain relevant information in spite of stimulus interference. The right-ear stimulus in the forced-left condition could be thought of as an interfering stimulus which would have to be overcome by some executive control function.

Both the bottom–up REA and the top–down attention modulation have been validated through functional neuroimaging studies showing that the dichotic listening paradigm applying consonant–vowel syllables engages wide brain networks, including the middle and inferior frontal gyri, temporal lobes, cingulate cortex, and parietal cortex (Hugdahl et al., 1999, 2000; Jäncke and Shah, 2002; Lipschutz et al., 2002; Thomsen et al., 2004). In the present dichotic listening study, the question we asked was whether making the bottom–up REA stronger or weaker would interfere with top–down attention modulation. Therefore, we aimed at varying the strength of the REA by manipulating the intensity difference between the right-ear and left-ear inputs and then examined how this affected the top–down attention modulation effects. It was hypothesized that a stronger input to the right ear than to the left ear would result in an increased bottom–up REA in the non-forced condition and that the opposite manipulation would decrease the REA. It was further hypothesized that making the bottom–up REA stronger or weaker would interact with the attention modulation effect in forced-right and forced-left conditions. The strength of REA was experimentally manipulated by systematically varying the interaural intensity difference, with 1/3 of the trials having equal right-ear and left-ear intensities (L=R), 1/3 of the trials with left-ear intensity>right-ear intensity (L>R), and 1/3 of the trials with left-ear intensity<right-ear intensity (L<R).

2. Results

The mean response accuracy (calculated from percentages of responses corresponding to input from either ear) varied between 85.5 and 90.7%, with no significant differences (one-way ANOVA) across the experimental conditions. A

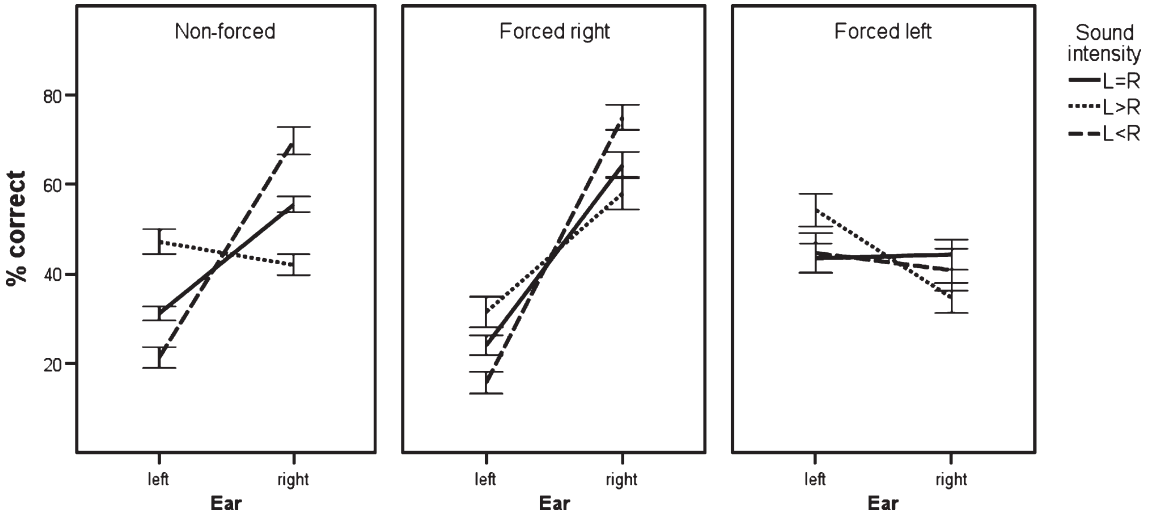

Fig. 1 – Left- and right-ear stimulus reports in different test conditions. Results from different attention conditions are plotted separately, interaural intensity difference conditions are shown with separate lines: 100% correct from either ear would mean that the participant has only reported syllables presented to that ear.