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Research report

Role of the right inferior parietal cortex in auditory selective attention: An rTMS study

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ABSTRACT

Selective attention is the process of directing limited capacity resources to behaviourally relevant stimuli while ignoring competing stimuli that are currently irrelevant. Studies in healthy human participants and in individuals with focal brain lesions have suggested that the right parietal cortex is crucial for resolving competition for attention. Following right-hemisphere damage, for example, patients may have difficulty reporting a brief, left-sided stimulus if it occurs with a competitor on the right, even though the same left stimulus is reported normally when it occurs alone. Such "extinction" of contralesional stimuli has been documented for all the major sense modalities, but it remains unclear whether its occurrence reflects involvement of one or more specific subregions of the temporo-parietal cortex. Here we employed repetitive transcranial magnetic stimulation (rTMS) over the right hemisphere to examine the effect of disruption of two candidate regions – the supramarginal gyrus (SMG) and the superior temporal gyrus (STG) – on auditory selective attention. Eighteen neurologically normal, right-handed participants performed an auditory task, in which they had to detect target digits presented within simultaneous dichotic streams of spoken distractor letters in the left and right channels, both before and after 20 min of 1 Hz rTMS over the SMG, STG or a somatosensory control site (S1). Across blocks, participants were asked to report on auditory streams in the left, right, or both channels, which yielded focused and divided attention conditions. Performance was unchanged for the two focused attention conditions, regardless of stimulation site, but was selectively impaired for contralateral left-sided targets in the divided attention condition following stimulation of the right SMG, but not the STG or S1. Our findings suggest a causal role for the right inferior parietal cortex in auditory selective attention.

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1. Introduction

In a noisy and dynamic auditory environment, we must selectively attend to the most relevant signal amongst several competing stimuli. Because conscious perception is capacity limited, we cannot attend to all signals concurrently. Instead, we must shift our attention from moment-to-moment, location-to-location or even from ear-to-ear. For example, we may need to pick out of several ongoing conversations the one most relevant to us, or shift attention from a speaker on the left to another on the right or from a conversation in the left ear to another on the phone in our right ear. Investigations of the mechanisms underlying how the brain resolves this ongoing competition have focused primarily on vision, with little research on the auditory system. Here, we aimed to determine the causal role of two cortical regions, the supramarginal gyrus (SMG) and the superior temporal gyrus (STG), in the voluntary control of auditory attention.

The brain's ability to resolve competition between auditory signals has been formally described in behavioural studies. For example, Duncan, Martens, and Ward (1997) presented neurologically normal participants with strings of spoken syllables to each ear simultaneously, with target words embedded within the strings. Participants were asked to attend to just one ear (focused attention) or both ears (divided attention) and report the target words. Performance was high in the focused attention (one ear) condition, indicating successful suppression of the information in the unattended ear. Performance was poorer in the divided attention condition, however, suggesting that dividing attention renders listeners more susceptible to interference from competing auditory inputs.

These limits on attentional capacity have also been demonstrated in clinical populations. Of note is the clinical condition of spatial neglect following unilateral (usually right) hemisphere damage. Neglect patients often miss sensory events arising from the contralesional side of space due to a strong attentional bias to the ipsilesional side and a deficit in shifting attention to the contralesional side when required to do so. Many such patients also demonstrate a difficulty with stimuli on the left (following right hemisphere damage) when competing stimuli occur simultaneously on the right – an effect called *spatial extinction* (De Renzi, Gentilini, & Pattacini, 1984; De Renzi, Gentilini, & Barbieri, 1989; Pavani, Ladavas, & Driver, 2003). In the laboratory, the phenomenon of extinction has been shown for auditory stimuli using dichotic listening tasks. Patients have greater difficulty reporting events presented to the left ear when instructed to divide their attention and report on two different auditory streams in each ear simultaneously (Bellmann, Meuli, & Clarke, 2001; Carlyon et al., 2001), or show spatial extinction for brief, concurrent auditory events (De Renzi et al., 1984, 1989; Pavani et al., 2003).

Neuroimaging studies have implicated the right parietal lobule (Wu et al., 2007), in particular the SMG [BA 40; (Bushara et al., 1999)] in auditory spatial orienting and control. A study by Pugh et al. (1996) investigated differences in fMRI activation between binaural and dichotic listening conditions. In the binaural condition, participants received one stream of information to both ears, whereas in the dichotic condition they received two different streams-one to each ear-simultaneously. Participants were instructed to attend to one ear or the other. Under dichotic listening conditions, in which attentional demands were greater, there was an increase in activation in the inferior parietal lobe (IPL) and superior temporal gyri (with stronger effects in the right parietal cortex) relative to the binaural condition. Similarly, Westerhausen et al. (2010) presented a group of healthy participants with a dichotic listening task that varied the relative salience of stimuli in the left or right ears. Participants were instructed to attend to either the louder or the softer stream, and thus had to hold their attention to stimuli in one ear or the other. Neural activation reflected an interaction between the salience of the stimuli and top-down attentional instructions, and included the right IPL and SMG in particular. Specifically, increases in activity within the SMG depended on the extent to which stimulus salience had to be compensated for by top-down attentional control (Westerhausen et al., 2010).

Evidence from neuropsychological studies have shed further light on the neural substrates of auditory selective attention. As mentioned above, neglect patients typically have lesions centered around the right IPL and temporoparietal junction (Karnath & Rorden, 2012; Mort et al., 2003; Verdon et al., 2010). In terms of spatial extinction, a recent meta-analysis has implicated the right angular gyrus (AG) and temporoparietal junction as critical lesion sites (Molenberghs, Sale, & Mattingley, 2012). However, lesion sites may vary widely between patients and are often large, spreading across multiple neighbouring regions. Moreover, as stroke is more common in older individuals, patients often have peripheral sensory loss that can contribute to any attentional deficit (Suetterlin & Sayer, 2013).

Brain stimulation techniques such as repetitive transcranial magnetic stimulation (rTMS) can be used to produce temporary and reversible disruption of focal regions of the cortex (Chambers & Mattingley, 2005; Rushworth & Taylor, 2006). This allows testing of multiple sites within healthy individuals to determine regions of cortex that are causally involved in a specific perceptual, cognitive or motor task. Previous TMS studies have implicated the IPL as important for auditory processing and attention (Bolognini et al., 2009; Karhson, Mock, & Golob, 2015), and TMS studies in vision and touch have identified critical brain regions for selective attention. For example, rTMS of the right parietal region has been shown to impair detection of contralateral visual stimuli when an ipsilateral stimulus is also presented – producing an extinction-like effect in normal participants (Chambers et al., 2006; Hilgetag, Theoret, & Pascual-Leone, 2001; Pascual-Leone et al., 1994). In particular, regions in the right ventral attention network, such as the right SMG and STG, have been implicated in visual and tactile attention (Chambers et al., 2006, 2007; Schenkluhn et al., 2008) and in attentional deployment during visual search (Ellison et al., 2004).

Here we utilised low frequency rTMS to assess the causal roles of two key regions within the right hemisphere in auditory selective attention. Our choice of right hemisphere sites was informed by relevant neuroimaging and neuropsychological data reviewed above. Both the SMG and STG have been implicated in auditory spatial attention (Bushara et al., 1999) and in the voluntary allocation of auditory attention