Please cite this article in press as: Li J et al. Schizophrenia affects speech-induced functional connectivity of the superior temporal gyrus under cocktail-party listening conditions. Neuroscience (2017), http://dx.doi.org/10.1016/j.neuroscience.2017.06.043

Neuroscience xxx (2017) xxx–xxx

SCHIZOPHRENIA AFFECTS SPEECH-INDUCED FUNCTIONAL CONNECTIVITY OF THE SUPERIOR TEMPORAL GYRUS UNDER COCKTAIL-PARTY LISTENING CONDITIONS

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Abstract—The superior temporal gyrus (STG) is involved in speech recognition against informational masking under cocktail-party-listening conditions. Compared to healthy listeners, people with schizophrenia perform worse in speech recognition under informational speech-on-speech masking conditions. It is not clear whether the schizophrenia-related vulnerability to informational masking is associated with certain changes in FC of the STG with some critical brain regions. Using sparse-sampling fMRI design, this study investigated the differences between people with schizophrenia and healthy controls in FC of the STG for target-speech listening against informational speech-on-speech masking, when a listening condition with either perceived spatial separation (PSS, with a spatial release of informational masking) or perceived spatial co-location (PSC, without the spatial release) between target speech and masking speech was introduced. The results showed that in healthy participants, but not participants with schizophrenia, the contrast of either the PSS or PSC condition against the masker-only condition induced an enhancement of FC of the STG with the left superior parietal lobule and the right precuneus. Compared to healthy participants, participants with schizophrenia showed declined FC of the STG with the bilateral precuneus, right SPL, and right supplementary motor area. Thus, FC of the STG with the parietal areas is normally involved in speech listening against informational masking under either the PSS or PSC conditions, and declined FC of the STG in people with schizophrenia with the parietal areas may be associated with the increased vulnerability to informational masking.

Key words: schizophrenia, speech perception, precedence effect, functional connectivity, masking, superior temporal gyrus.

INTRODUCTION

Successful speech recognition under speech-on-speech masking (cocktail-party) conditions involves multiple perceptual/cognitive processes, including target detection, selective attention, sensory/working memory, and speech production. Thus, speech recognition against informational speech masking are based on activation of different brain regions with various perceptual/cognitive functions (e.g., Hill and Miller, 2010; Nakai et al., 2005; Scott and McGettigan, 2013; Scott et al., 2004; Wu et al., 2017a,b; Zheng et al., 2016). Among the brain regions that are related to speech recognition against informational masking, the superior temporal gyrus (STG) has been the most studied cortical structure, because speech-evoked activation of the STG can be enhanced by introducing a masking voice, suggesting that the STG is involved in overcoming informational-masking-induced difficulties in speech listening (e.g., Dole et al., 2014; Evans et al., 2016; Nakai et al., 2005; Scott et al., 2004, 2009). More specifically, the dorsolateral superior temporal lobes are consistently activated in speech perception within an informational masking context (speech-in-speech listening conditions compared to either rest or speech-in-noise listening conditions, for a review see Scott and McGettigan, 2013) and some MEG/EEG studies have demonstrated the critical role of the lateral STG in the selective representation of target speech in the presence of competing speech (Bidelman and Dexter, 2015; Ding and Simon, 2012, 2013). Particularly, the lateral STG is more activated by the introduction of informational masking conditions (speech-in-speech) than that of energetic masking conditions (speech-in-noise) (Scott et al., 2004; Scott and McGettigan, 2013). Thus, it is reasonable to hypothesize that the involvement of the STG in speech listening against informational masking may be largely dependent on functional connectivity (FC) of the STG with other brain regions that are critical to speech recognition against informational speech masking. For other brain regions,

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http://dx.doi.org/10.1016/j.neuroscience.2017.06.043
0306-4522/

such as the rostral and dorsal prefrontal cortices and the posterior parietal cortex whose activation is also vulnerable to masking sounds, greater activation occurs under energetic masking conditions (speech-in-noise) relative to informational masking conditions (speech-in-speech) (Scott et al., 2004; Scott and McGettigan, 2013), suggesting that these cortical regions may not be specific for overcoming informational masking.

People with schizophrenia experience more difficulties in filtering distracting signals to prevent information overflow that causes numerous cognitive dysfunctions (Gottesman and Gould, 2003; Braff and Light, 2005). Particularly, speech recognition in people with schizophrenia is markedly vulnerable to masking, especially informational masking (Lee et al., 2004; Ross et al., 2007; Wu et al., 2012, 2013, 2017a,b; Zheng et al., 2016). For example, both first-episode patients and chronic patients with schizophrenia perform worse than their matched healthy controls in recognizing target speech when a masker, particularly a two-talker-speech masker is presented (Wu et al., 2012, 2013, 2017a,b; Zheng et al., 2016). Up to date, the brain substrates underlying the schizophrenia-related augmentation of the vulnerability of speech recognition to informational speech masking largely remain unknown. Thus, it is important to investigate whether the schizophrenia-related vulnerability to informational masking is related to alterations in speech-listening-induced FC of the STG under speech-on-speech masking.

To improve speech recognition under cocktail-party listening condition with multiple talkers, listeners can use various perceptual/cognitive cues available to facilitate perceptual segregation between speech sources and enhance selective attention to the target speech. One of the cues is the precedence effect-induced perceived spatial separation (PSS) between target speech and masking speech (Freyman et al., 1999; Li et al., 2004; Wu et al., 2005; Rakerd et al., 2006; Huang et al., 2008; Zheng et al., 2016). Zheng et al. (2016) have recently reported that compared to the perceived spatial co-location (PSC) listening condition (where target speech and masking speech are perceived from same location on the basis of the auditory precedence effect), introducing the listening condition with perceived spatial separation (between target speech and masking speech), which releases target speech from informational speech masking, induces enhanced activation in the superior parietal lobule (SPL), precuneus, anterior cingulate cortex, lateral middle frontal gyrus, and triangular inferior frontal gyrus. It is not clear whether FC of the STG with these cortical regions is involved in speech listening against informational masking.

This study aimed to explore differences in speech-listening-induced FC of the STG under informational speech masking conditions between healthy listeners and listeners with schizophrenia. More specifically, general psychophysiological interaction (gPPI) analyses (McLaren et al., 2012) were used to identify FC of the STG associated with target-speech listening against speech masking in healthy listeners and listeners with schizophrenia, when the listening condition with either PSS or PSC between the target speech and masking speech was introduced (Zheng et al., 2016).

EXPERIMENTAL PROCEDURES

Participants

Participants with schizophrenia (whose first language was Mandarin Chinese), diagnosed with the Structured Clinical Interview for DSM-IV (SCID-DSM-IV, First et al., 1997), were recruited in the Affiliated Brain Hospital of Guangzhou Medical University (Guangzhou Huiai Hospital). Some patient participants were excluded from this study if they had comorbid diagnoses, substance dependence, and/or other conditions that affected experimental tests (e.g., hearing loss, a treatment of the electroconvulsive therapy (ECT) within the past three months, a treatment of trihexyphenidyl hydrochloride with a dose of more than 6 mg/day, and/or an age younger than 18 or older than 59) (Zheng et al., 2016).

Demographically matched healthy participants (i.e., healthy controls) were recruited from the communities around the hospital with the recruiting criteria used previously (Wu et al., 2012, 2013, 2017a,b; Zheng et al., 2016). They were telephone interviewed first and then those who passed the telephone interview were screened with the SCID-DSM-IV as used for patient participants. None of the selected healthy controls had either a history of Axis I psychiatric disorder as defined by the DSM-IV.

Twenty-four patients and 18 healthy controls participated in the study. Two patient participants and 1 healthy-control participant were excluded from data analyses due to their excessive head movements (more than 3 mm in translation and/or 3° in rotation). Two healthy participants and 4 patient participants were excluded due to failure in following the instructions to button-press. The remaining 20 patients (9 females and 11 males, aged 32 ± 9.8 years) and 16 controls (8 females and 8 males, aged 30.3 ± 9.1 years) were included in fMRI data analyses (Table 1). All participants were right-handed with normal pure-tone hearing thresholds at each ear (< 30 dB Hearing Level) at frequencies between 125 and 8000 Hz. All the participants had Mandarin Chinese as their first language. All the patient participants were clinically stable during their participation, and received antipsychotic medications during this study with the average chlorpromazine equivalent of 605 mg/day based on the conversion factors described by Woods (2003). Some of the patient participants received benzodiazepines based on doctors' advice for the purpose of improving sleeping.

The locally validated version of the Positive and Negative Syndrome Scale (PANSS) tests (Si et al., 2004) was conducted on the day of fMRI scanning for all participants. All participants and patients' guarantees gave their written informed consent for participation in this study. The procedures of this study were approved by the Independent Ethics Committee (IEC) of the Guangzhou Huiai Hospital.

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