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SCHIZOTYPAL PERSONALITY TRAITS: AUDITORY HALLUCINATION-LIKE EXPERIENCES AND ATYPICAL HEMISPHERIC LATERALIZATION

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ABSTRACT

Individual differences in schizotypal personality traits (schizotypy), which might be the predisposition to schizophrenia, have commonly been explored as a means of examining the nature and structure of schizophrenia symptoms. Research on schizotypal personality in the general population may provide a particular opportunity to study the biological and cognitive markers of vulnerability to schizophrenia without the confounding effects of long-term hospitalization, medication, and severe psychotic symptoms (Raine and Lencz, 1995).

A systematic review of general-population surveys indicated that the experiences associated with schizophrenia and related categories, such as paranoid delusional thinking and auditory hallucinations, are observed in an attenuated form in 5–8% of healthy people (Os et al., 2009). These attenuated expressions could be regarded as the behavioral marker of an underlying risk for schizophrenia and related disorders, just as high blood pressure indicates high susceptibility for cardiovascular disease in a dose–response fashion (Os and Kapur, 2009).

Auditory hallucination (AH) refers to the perception that one’s own inner speech originates outside the self. Patients with AH make external misattributions of the source of perceived speech. Recent studies have suggested that auditory hallucinations in patients with schizophrenia might occur in the right hemisphere, where they might produce irregular and unpredicted inner speech, which their auditory and sensory feedback processing system does not attribute to themselves.

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In the present study, general participants judged self–other attribution in speech subjectively in response to on-line auditory feedback presented through their right, left, and both ears. People with high auditory-hallucination-like experiences made external misattributions more frequently under the right- and left-ear only conditions compared with the both-ears condition. We interpreted this result as suggesting that people with a high degree of proneness to AH might have disorders in both the right and left hemispheric language-related areas: speech perception deficit in the left hemisphere and prediction violation in speech processing in the right hemisphere.

A perspective that situates schizophrenia on a continuum with general personality variations implies that this disorder constitutes a potential risk for everyone and, thus, helps to promote understanding and correct misunderstandings that contribute to prejudice.

**INTRODUCTION**

Many people with schizophrenia describe a sense of passivity to their experiences, in that their actions, thoughts, or emotions are experienced as created for them by some external agent rather than by their own will. These positive symptoms of schizophrenia are included among Schneider’s first-rank symptoms for the diagnosis of schizophrenia (Mellors, 1970; Schneider, 1959). In most cases, the actions carried out when people feel that they are being controlled by alien forces are not discrepant with their intentions (Frith, Blakemore and Wolpert, 2000a, 2000b). In other words, people with schizophrenia have an abnormal sense of agency, that is, of the feeling of causing our own actions (Gallagher, 2000). Phenomena such as delusions of control, auditory hallucinations, and thought insertion may all be caused by an abnormal sense of agency (Frith et al., 2000a; Gallagher, 2004; Lindner, Their, Kircher, Haarmeier and Leube, 2005). For example, one’s own speech could seem to be auditory hallucinations (McGuigan, 1966). The activation of Broca’s area, which can produce but cannot listen to speech, has been associated with auditory hallucinations (McGuire, Shah and Murray, 1993). Therefore, these people might produce speech but not think that they actually spoke. As a result, they may hear their own voices as the voices of others.

The abnormal sense of agency in schizophrenia has been shown empirically. Some studies reported that when required to make judgments about the origin of hand actions or movements based upon biased feedback (self-action recognition task), people with schizophrenia were more likely than normal controls to misattribute their own actions (Daprati et al., 1997; Franck et al., 2001), which might be interpreted as delusions of control. As well, schizophrenic patients with auditory hallucinations tend to misattribute their own speech (self-speech recognition task: e.g., Johns et al., 1999; 2001). It was recently suggested that psychopathological models of schizophrenia that include the sense of agency may also apply to schizotypal personality traits (schizotypy). Cyhlarova and Claridge (2005) indicated that schizotypal people, identified by questionnaires or semi-structured interviews, might have a predisposition to schizophrenia. Although schizotypal people can have schizophrenic-like experiences, many can live normal lives. The traits of schizophrenia are generally considered to span a continuum. By applying the paradigms of the previous studies (Johns et al., 1999; 2001; Franck et al., 2001; Sato and Yasuda, 2005), Asai and Tanno (2007, 2008) found that people high in schizotypy also tend to have an abnormal sense of agency in their actions including speech both on the explicit and implicit measures (Asai et al., submitted).
Individual differences in schizotypal personality have commonly been explored as a means of examining the nature and structure of schizophrenia symptoms. Research on schizotypal personality in the general population may provide a particular opportunity to study the biological and cognitive markers of vulnerability to schizophrenia without the confounding effects of long-term hospitalization, medication, and severe psychotic symptoms (Raine and Lencz, 1995). Relatives of schizophrenia patients score significantly higher on measures of schizotypal personality, which suggests that within the spectrum of schizophrenia disorders there is a range in which schizotypal traits may be expressed, and that this range is at least partly genetic (Kremen, Faraone, Toomey, Seidman and Tsuang, 1998; Lenzenweger, 2006; Plated and Gallup, 2002).

Recent studies have suggested that in schizophrenia, an abnormal sense of agency might be caused by an abnormal action prediction system in the sense of the agency model (e.g., Frith et al., 2000a; 2000b; Blakemore et al., 2002; Seal, Alemam, and McGuire, 2004; Jones and Fernyhough, 2007. In this model, two information processing pathways are implicated (the action-predictive and the executive pathways), and the discrepancy between the predicted and actual sensations causes the misplaced sense of agency (the sense that “I am the one who generates the action.”). With auditory hallucinations and self–other attributions in speech, patients with schizophrenia experiencing auditory hallucinations and those in the general population with high auditory-hallucination proneness do not attribute their own speech to themselves (e.g., Johns et al., 2001; Asai et al., submitted), and furthermore, they do not show sensory cancellation of self-produced speech, indicating that their implicit external misattribution occurs on a neural level (Ford and Mathalon, 2004, 2005; Ford et al., 2001). How does abnormal prediction lead to the external misattribution in speech? One possibility is that abnormal hemispheric lateralization occurs in patients with schizophrenia.

Atypical cerebral lateralization may represent a risk factor for developing schizophrenia (Crow, 2004). Patients with schizophrenia have shown differences in lateralization as measured by handedness (Reilly et al., 2001), and schizotypal personality scores are increased among mixed-handed general participants (Annett and Moran, 2006; Somers, Sommer, Boks, and Kahn, 2008) even in non-Western cultures (Asai and Tanno, 2009). These results might implicate a relationship between schizophrenia or schizotypal personality and non-lateralized cerebral functioning, at least with regard to motor ability. Furthermore, in schizophrenia, non-lateralization has been empirically suggested not only in motor skills, but also in language functions (e.g., Asai et al., 2009; Blyler, Maher, Manschreck, and Fenton, 1997; Hugdahl et al., 2008; Lenzenweger and Maher, 2002; Lohr and Caligiuri, 1997; Ngan et al., 2003; Tabarés-Seisdedos et al., 2003). Moreover, it has been suggested that the essential disconnection between the two hemispheres might equalize the two hemispheres, at least in relation to some motor and language functions (Asai et al., 2009). Patients with schizophrenia might have second language areas in the right hemisphere (e.g., “bicameral mind;” for a review, see Cavanna et al., 2007; Sher, 2000; Olin, 1999). Many studies have shown that the right homologues of the language-related areas are activated during auditory verbal hallucination (e.g., Sommer et al., 2007).

In line with this discussion, in considering the relationship between abnormal hemispheric laterality in schizophrenia and external misattribution in speech, Sommer et al. (2003) suggested a challenging but important hypothesis that connected the major theories explaining schizophrenia. As mentioned above, the decreased cerebral asymmetry found in schizophrenia has been replicated using several techniques. In addition, functional
imaging studies have reported decreased lateralization of language-related activation in patients with schizophrenia compared with healthy controls (Sommer et al., 2001). It could be hypothesized that inner speech, originating from right cerebral homologues of the language areas, is perceived as an auditory hallucination. In the right hemisphere, “prediction violation” might occur. Self-produced language activity normally leads to inhibition of the language perception areas (McGuire et al., 1996) because self-produced sensation can be predicted accurately and filtered (e.g., Blackmore et al., 1998). When this inhibitory mechanism fails, verbal thoughts may not be recognized as originating from the self and may be attributed erroneously to an external source. Indeed, inhibition of language perception might be more prone to failure when language activity is derived from an unusual site (i.e., from contralateral homologue areas in the right hemisphere). These serial hypotheses are summarized in Figure 1. Patients with auditory hallucinations might have a second language area in the right hemisphere, but this irregular language processing may not be predicted, and feedback sensations may not be filtered or attenuated. As a result of this prediction violation, individuals would perceive self-produced (inner) voices as originating externally. To examine this hypothesis, we administered a simple experiment assessing self–other speech attribution for each ear (hemisphere) in relation to auditory-hallucination proneness in the general population, as with our previous studies (Asai et al., submitted; 2008).

Methods

Participants

Fifty-one university students (aged 18–22 years, mean = 19.6; 30 men, 21 women) participated in the experiment and completed the questionnaire. Participants were recruited from a pool of students in an introductory psychology class. We sent an e-mail describing the experiment and the questionnaire, to which interested participants responded voluntarily. None had a history of mental disease or hearing difficulties, and none reported any hearing
problems at the time of the experiments. We obtained written informed consent from all participants before conducting the experiment.

**Apparatus**

The experiment was conducted in a soundproof room. The visual stimuli were created and the experiments conducted using MATLAB (MathWorks, Natick, MA, USA) and Psychophysics Toolbox (Brainard, 1997; Pelli, 1997). Participants spoke into a microphone attached to headphones (SENNHEISER HMD280PRO), and the auditory input was amplified (BEHRINGER MIC200). Auditory input below 1 kHz was filtered at +3 dB, and auditory input above 1 kHz was filtered at -3 dB using an equalizer (BEHRINGER FBQ800) in order to obtain a subjective approximation of each participant’s own voice (Shuster and Durrant, 2003). Then, the pitch was either unchanged (no distortion) or raised by 1 (moderate) or 4 (severe) semi-tones using an effecter (ZOOM RFX-2200) and fed back to the subjects through headphones (SENNHEISER HMD280PRO). These parameters were decided in accordance with our previous study (Asai et al., submitted). We predicted that participants would attribute the fed-back voice to themselves about 50% of the time under the moderate-distortion condition but 0% of the time under the severe condition.

To reduce any effects of bone conduction and to prevent participants from hearing their own voices directly, pink noise at 70 dB SPL was generated and mixed into the fed-back voice using a sound mixer (YAMAHA MW10C) (Toyomura et al., 2007). Their fed-back voice was presented to the right, the left, or both ears through headphones using the mixer (pan-pot function) so that the total signal levels were equal under each ear condition. Pink noise was also presented through the bone-conduction headphone (Golden Dance co., Ltd. MGD-701BK) to suppress the bone conduction sound of their speech. For example, under the right-ear condition, while pink noise was presented to both ears through the headphones, participants first read aloud the presented word and then listened as their voice was presented to the right ear only through the headphones. During this time, only pink noise was presented to the left ear. A few signals were sent from the right ear to the right auditory cortex (ipsilateral) through the preponderance of the contralateral auditory pathways (Rosenzweig, 1951). The noise from the contralateral ear was supposed to reduce this ipsilateral pathway relatively (Asai et al., 2009). Participants were briefly trained to speak aloud at approximately 65–70 dB, as if murmuring. Under these conditions, each participant was able to clearly recognize their voice over the noise through the headphones.

**Materials**

We used 50 four-mora (the prosodic unit in Japanese) words as visual stimuli, selected from an established list of words for speech (Amano et al., 2009). This list was controlled for familiarity and phonological balance. We chose 50 of the most familiar words for the present experiment (five for the practice trials and 45 for the test trials).
Procedure

Participants read the presented words aloud into the microphone. They were required to finish reading within approximately 400 ms after the words were presented following a countdown from three to one, during which time they could prepare for speech while viewing the presented words.

After they heard the feedback voice, participants were required to judge intuitively whether the voice they heard was their own, regardless of the feeling of distortion. That is, they could answer, “This is my own voice,” even when they could detect distortion, and vice versa (self-other attribution task).

Nine conditions were used (three distortion conditions × three ear conditions), and participants completed 45 trials (five repetitions for each of the nine conditions). The orders of the 45 words and the three conditions were double randomized.

Questionnaire

After the participants finished the experiment, they completed a battery of questionnaires. We assigned a random number to each participant, and data from the questionnaires were crosschecked with experimental data using this randomly assigned number. The battery included the following questionnaires, all of which, except for the AHES-17 and SOAS, have been translated into Japanese and demonstrate good reliability and validity.

1. Auditory hallucination proneness: the Auditory Hallucination Experience Scale 17 (AHES-17, Asai et al., 2009) is a brief version of the Auditory Hallucination Experience Scale (AHES, Sugimori, Asai, and Tanno, 2009), which has been developed in Japan because a scale for directly measuring auditory hallucination-like experiences was needed. The Launay–Slade Hallucination Scale (LSHS; Launay and Slade, 1981) and its revised version (LSHS-R; Waters, Badcock, and Matbery, 2003) measure hallucination-like experiences, including auditory hallucinations, but do not focus on auditory hallucinations separately. The AHES-17 is a self-report 17-item questionnaire with responses based on a 5-point Likert scale (1–5) measuring the frequency of auditory hallucination-like experiences (e.g., “I heard someone’s voice, but nobody was actually around.”). The scores for this scale range from 17 to 85. Test–retest reliability ($r = 0.78$, $p < .0001$) and internal reliability ($\alpha = 0.84$) were adequate, and the investigation of criterion-related validity showed that the AHES-17 was highly correlated with scales measuring positive schizotypy, including auditory hallucination proneness (Asai et al., 2009).

2. Positive schizotypal personality: the Oxford Schizotypal Personality Scale (STA; Claridge and Broks, 1984; Cyhlarova and Claridge, 2005; Gregory, Claridge, Clark, and Taylor, 2003) is a 37-item true–false self-report questionnaire based on the DSM-III diagnostic criteria for schizotypal personality disorder. It measures schizotypal traits, especially perceptual aberrations that are analogous to positive symptoms, such as auditory hallucinations, thought insertions, and delusions of control.
3. Schizotypal personality traits: the Schizotypal Personality Questionnaire Brief (SPQB: Raine and Benishay, 1995) is a shortened version of the Schizotypal Personality Questionnaire (SPQ: Raine, 1991). SPQB is a 22-item true–false self-report questionnaire measuring schizotypal personality traits. Though it consists of three subscales: Cognitive–Perceptual (Cog: positive schizotypy), Interpersonal (Int: negative schizotypy), and Disorganization (Dis: disorganized schizotypy), resent studies have suggested that this three factor structures in SPQ(B) might be open to question (e.g., Compton et al., 2009; Fonseca-Pedrero et al., 2009). Furthermore, each subscale score ranges, for example, from 0 to 6 (Dis). So we didn’t use these subscale scores and adopted total SPQB score as whole schizotypal personality.

4. Sense of agency: the Sense of Agency Scale (SOAS; Asai et al., 2009) is a newly developed prototype measure for assessing the sense of agency. It includes 22 items that are related to an abnormal sense of agency in the general population according to previous experimental studies. The scale consists of three subscales: misattribution of the agent (Mental Self: e.g., “I sometimes turn around feeling as if someone called my name in a crowd.”), uncontrollability of one’s own body (Physical Self: e.g., “I sometimes feel I cannot move my body as I want.”), and self-assertiveness in social situations (Social Self: e.g., “I sometimes feel my behavior has some effect on society.”). Responses are based on a 4-point Likert scale. Test–retest reliability (r = 0.73, p < .0001) and internal reliability (α = 0.77) were adequate.

5. Depression: the Self-rating Depression Scale (SDS; Zung, 1965) is a well-known self-report questionnaire comprised of 20 items; responses are based on a 4-point Likert scale measuring depressive tendencies.

6. Anxiety: the Trait Anxiety Inventory (STAI-T; Spielberger, Gorsuch, and Lushene, 1970) is a well-known self-report questionnaire consisting of 20 items; responses are based on a 4-point Likert scale measuring anxiety traits.

7. Handedness: the H.N. Handedness Scale (HNHS; Hatta and Kawakami, 1995; Hatta and Nakatsuka, 1975) is a revised version of the Edinburgh Inventory (Oldfield, 1971) for use with Japanese participants. Revisions were necessary because cultural differences render the original Edinburgh Inventory inappropriate for Japanese participants. The scale is often used in Japan to measure or control for handedness (e.g., Ogawa, Inui, and Sugio, 2006). Participants respond to this scale by indicating whether they use their right, left, or either hand for 10 common actions: handling an eraser; striking a match; thumb tacking; hammering; brushing their teeth; throwing; and using a pair of scissors, a knife, a screwdriver, and a shaver or lipstick. This scale ranges from -10 to +10; a “right” response is scored as +1, a “left” response is scored as -1 and a response of “either” is scored as zero.

Higher scores for all questionnaires indicate a stronger tendency on the relevant dimension. SDS and STAI were used as control measures; that is, we predicted that these scales would not be related to the present study although they might be related to schizotypal personality traits, especially to auditory hallucination proneness or abnormal experiences relating to the sense of agency (that is, “Mental Self”).
RESULTS

At least two methods are available to examine the relationship between questionnaire scores and experimental performances: linear relationships between scores and performance (e.g., Asai et al., 2008) and comparisons between groups according to questionnaire scores (e.g., Asai and Tanno, 2007). Multiple rather than single measures are most reliable (e.g., Asai et al., 2009). To examine the relationship between auditory-hallucination proneness and self-attribution, first we selected the participants scoring highest (top third; 17 participants) and lowest (bottom third; 17 participants) on the AHES (see Table 1 for demographic data), in accordance with previous studies. Later, we examined the relationships of our data to other questionnaires and other methods (e.g., linear relationships) to examine the individual differences.

Figures 2 and 3 show the relationship between self-attribution in speech and ear condition in each group, as in Asai and Tanno’s (2008) study. Repeated-measures analysis of variance (ANOVA) with pitch distortion and the ear condition as the within-subject variables showed that only the main effect of pitch distortion was statistically significant (F(2, 32) = 39.6, p < .001) in the low-AHES group (Figure 2). In contrast, in the high AHES group, the main effects of pitch distortion (F(2, 32) = 152.5, p < .001) and of ear condition (F(2, 32) = 4.01, p < .05) were significant (Figure 3). Regarding the main effects of ear condition, multiple comparisons using Ryan’s method (i.e., R-E-G-W’s F test) for post-hoc analysis revealed that scores under the both-ears condition were significantly higher than under either one-ear condition (right or left) (p < .05). These results suggest a relationship between the AHES, self-attribution in speech, and ear (hemisphere) conditions. In the low AHES group, there was no difference between the ear conditions. In contrast, in the high AHES group, less feedback was attributed to participants’ own voice under the one-ear conditions (right or left) than under the both-ears condition, regardless of the pitch distortion. To confirm these results, we then examined the linear relationship among these variables.

Table 1. The demographical data (Mean and Standard Deviation) between the low and the AHES groups

<table>
<thead>
<tr>
<th></th>
<th>N (M/F)</th>
<th>Age</th>
<th>HNHS</th>
<th>AHES</th>
<th>STA</th>
<th>SPQB</th>
<th>SOAS</th>
<th>STAI</th>
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<tr>
<td>Low AHES</td>
<td>17 (11/6)</td>
<td>19.6</td>
<td>8.3 (1.7)</td>
<td>42.4</td>
<td>6.9</td>
<td>5.9</td>
<td>39.5</td>
<td>10.4</td>
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<tr>
<td>High AHES</td>
<td>17 (8/9)</td>
<td>20.0</td>
<td>7.3 (4.5)</td>
<td>63.3</td>
<td>15.0</td>
<td>11.1</td>
<td>46.8</td>
<td>18.2</td>
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Note: The significances were revealed by χ² tests for sex ratio and the number of left-handers (HNHS scores <-4), and MANOVA for Age-STAI. HNHS=Hatta and Nakatsuka Handedness Scale, AHES=Auditory Hallucination Experience Scale, STA=Schizotypal personality scale, SPQB=Schizotypal Personality Questionnaire Brief, SOAS=Sense of Agency Scale, SDS=Selfrating Depression Scale, STAI=Trait anxiety inventory.
Figure 2. Self-attribution ratio and ear condition in low AHES group.

Figure 3. Self-attribution ratio and ear condition in high AHES group.
Table 2. Inter-correlations between the experimental laterality indexes and questionnaire scores

<table>
<thead>
<tr>
<th></th>
<th>AHES</th>
<th>STA</th>
<th>SPQB</th>
<th>SOAS</th>
<th>Mental</th>
<th>Physical</th>
<th>Social</th>
<th>SDS</th>
<th>STAI</th>
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<tbody>
<tr>
<td>LIR</td>
<td>-.29*</td>
<td>-.04</td>
<td>-.11</td>
<td>-.03</td>
<td>-.21</td>
<td>.01</td>
<td>.20</td>
<td>-.01</td>
<td>.03</td>
</tr>
<tr>
<td>LIL</td>
<td>-.25*</td>
<td>-.15</td>
<td>-.23</td>
<td>-.14</td>
<td>-.31</td>
<td>.01</td>
<td>.08</td>
<td>-.08</td>
<td>.04</td>
</tr>
</tbody>
</table>

Note: N = 51. Values are Pearson’s correlation coefficients. Correlations were tested for statistical significance using a one-tailed procedure based on a directional a priori hypothesis. LIR= (right ear)-(both ears), LIL=(left ear)-(both ears).

We calculated the two laterality indices under the both-ears conditions as baseline scores in accordance with the results of the group comparisons. The laterality index for the right ear (LIR) was calculated as follows: (self-attribution rate under the right-ear condition) — (self-attribution rate under the both-ears condition). Finally, these values were averaged across pitch distortion conditions. The laterality index for the left ear (LIL) was calculated in the same way. Negative LIR and LIL values meant that the participant attributed the feed-back voice to him or herself less under the one-ear condition (right or left) than under the both-ears condition. Table 2 shows the Pearson’s correlation matrix for these laterality indexes and questionnaire scores. Not surprisingly, AHES and LIR or LIL showed a significant negative correlation, confirming the results of the group comparison analysis. Furthermore, this correlation matrix revealed that other schizotypal traits, including positive or whole schizotypy, and other mental traits, including anxiety and depression, might not related to the lateralized self-attribution pattern. Auditory-hallucination proneness might be specific to this phenomenon. On the sense of agency scale, the “Mental Self (misattribution of the agent)” subscale was significantly correlated with LIL. Although the self–other attribution task is supposed to relate to this factor, unlike AHES, “Mental Self” was only correlated with LIL. We had hypothesized that people with high AHES would attribute the feed-back voice to themselves less under the left-ear (right hemisphere) condition than under either the both-ears or the right-ear condition. The results, however, suggest that under the right-ear condition, they also attributed the speech to themselves less. Yet, according to the results of SOAS, external misattribution of the agent should be related to the left ear (right hemisphere) condition only, as we hypothesized above. These findings are discussed below.

**DISCUSSION**

The objective in the present study was to examine self–other speech attribution in the right hemisphere in people with high proneness to auditory hallucination. First, in people with low AH, laterality of self–other speech attribution was not confirmed. They attributed the feedback voice to themselves with equal frequency regardless of ear condition. Fu et al. (2006) showed the relationship between bilateral temporal lobes and on-line self–other speech
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attribution: the speech information is sent to left language areas first and might then be returned to the bilateral temporal lobes. No effect of ear condition might indicate smooth transmission of these signals through the corpus callosum. In general, a laterality effect of ear condition in the general population would be observed only under specific experimental conditions, namely classic dichotic listening, in which participants hear a different auditory stimulus in each ear (e.g., Hugdahl et al., 2007) or a reaction time paradigm (e.g., Asai et al., 2009), because of the connection between the two hemispheres through the corpus callosum. Considering that the present study presented one speech stimulus and required participants to answer at their own pace, the absence of laterality effect in people with low AH was unsurprising.

On the other hand, the effect of ear condition appears in people with high AH. Because previous studies have suggested that external misattribution in speech (i.e., auditory hallucination) might occur in the right hemisphere (e.g., Sommer et al., 2007), we had hypothesized that, if an inter-hemispherical disconnection exists (e.g., Lohr et al., 2006)), under the left-ear condition, people with high AH would be more likely to attribute the feedback voice to an external source (i.e., to feel it is “the other’s voice”) than under the right-ear or both-ears conditions. Compared with the both-ears condition, under the left-ear condition, participants with high AH did misattribute the feedback voice to an external source, as expected. According to the hypothesis of Sommer et al. (2003), speech processing may occur in the right hemisphere (cerebral homologues of the language areas) in subjects with AH. This irregular language processing, however, cannot be predicted, and the feedback sensation cannot be filtered or attenuated (e.g., Ford et al., 2004). As a result of this prediction violation, subjects would hear the self-produced (inner) voices as the voices of others. The present study supports this view, providing the first data from a behavioral experiment in line with this challenging hypothesis, but from the viewpoint of the difference between the both-ears and left-ear conditions.

However, contrary to our expectation, the right-ear condition showed results similar to those for the left-ear condition. People with high AH made an equally high number of external misattributions under the right-ear condition compared with the both-ears condition. The “Mental Self” subscale in SOAS refers to the tendency for misattribution of the agent, including auditory hallucination. Participants with high Mental Self scores may also externally misattribute information reaching the right hemisphere. Given that AHES was highly correlated with Mental Self ($r = .53, p < .001$), this result seems inevitable. Under the right-ear condition, however, Mental Self was not correlated with LIR, indicating that the difference between the right-ear and both-ears condition may not have been the result of misattribution of the agent, but may have occurred for some other reason. Indeed, many studies have suggested that the language-related areas in the left hemisphere of patients with AH might be disordered.

Patients with AH might have a deficit in speech perception related to the left temporal lobe, regardless of whether the speech originates with the self or another (e.g., Hugdahl et al., 2007). In addition, Mechelli et al. (2007) suggested that when patients with AH appraised their own speech after the fact, they show impaired functional integration between the left superior temporal and anterior cingulate cortex. In a postmortem study, Allen et al. (2007) also showed that the misidentification of self-generated speech in patients with AH was associated with functional abnormalities in the anterior cingulate and left temporal cortex. These results suggested that patients with AH might have an abnormality in the left temporal
cortex that leaves them deficient in a self-voice representation. This creates a disorder in speech perception when they identify theirs retrospectively rather than on line. Therefore, it could be that not the on-line “prediction violation” but other reasons, perhaps including disorders of speech perception, explain the difference between the right-ear and both-ears condition. Further research should examine this possibility using brain-imaging techniques.

When taken together, our findings indicate that people with AH might have disorders in both the right and left language-related areas: speech perception deficit in the left hemisphere and prediction violation in speech processing in the right hemisphere. Indeed, Woodruff et al. (1997) have suggested that AH is associated with a reduced left and increased right temporal cortical response to auditory perception of speech. Patients with AH process speech stimuli less well in the left hemisphere but better in the right hemisphere. However, if speech stimuli are produced by the patients themselves, the speech being processed in the right hemisphere might be perceived as another’s voice. Further research should focus on both right and left hemisphere language processing and self-other attribution in speech. Although the present study showed the effect of laterality on self–other speech attribution for the first time by behavioral experiment, some unavoidable limitations should be noted. Because we discussed brain abnormalities from behavioral data alone, speculative interpretations were inevitable. Although the dichotic listening paradigm (e.g., Hugdahl et al., 2008), which we applied in the present study, has been developed to provide non-invasive brain measurements, particularly regarding neural pathways, a follow-up brain imaging study should provide further insight on this topic. We could present a basic experimental methodology for further research.

REFERENCES


