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Auditory verbal hallucinations in schizophrenia as aberrant lateralized speech perception: Evidence from dichotic listening

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ABSTRACT

We report evidence that auditory verbal hallucinations (AVH) in schizophrenia patients are perceptual distortions lateralized to the left hemisphere. We used a dichotic listening task with repeated presentations of consonant–vowel syllables, a different syllable in the right and left ear. This task produces more correct reports for the right ear syllable in healthy individuals, indicative of left hemisphere speech processing focus. If AVHs are lateralized to the left hemisphere language receptive areas, then this should interfere with correct right ear reports in the dichotic task, which would result in significant negative correlations with severity of AVHs. We correlated the right and left ear correct reports with the PANSS hallucination symptom, and a randomly selected negative symptom, in addition to the sum total of the positive and negative symptoms, in 160 patients with schizophrenia. The results confirmed the predictions with significant negative correlations for the right ear scores with the PANSS hallucination item, and for the sum total of positive symptoms, while all other correlations were close to zero. The results are unambiguous evidence for AVHs as aberrant speech perceptions originating in the left hemisphere.

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1. Introduction

Auditory verbal hallucinations (AVHs) are a key symptom in schizophrenia (Wing et al., 1974; David, 1999) which directs attention inwards towards the "voice", with consequences for social interaction and reality orientation. It is estimated that about 70% of diagnosed patients experience auditory hallucinations (Wing et al., 1974; Shergill et al., 1998). Auditory verbal hallucinations are the subjective experience and conviction of someone speaking to the patient despite the absence of an acoustic signal (Hugdahl et al., 2009). The "voices" are commonly characterized as having an out-of-head origin, often having a negative and commanding emotional valence, and not possible to cognitively control and to avoid for the patient. Patients also often struggle with complying with the demands and requirements imposed by the "voices" (cf. Daalman et al., 2011). There is an ongoing discussion in the literature regarding the underlying mechanisms for AVH, and whether these can best be described as inner speech (e.g. Blakemore et al., 1998; Allen et al., 2007), traumatic memory (e.g. Badcock et al., 2005; Waters et al., 2006), or as aberrant speech perceptions (e.g. Fiszdon et al., 2005; Spencer et al., 2009, see also Jones, 2010 for a thorough review and discussion of existing theoretical models for AVH). What is lacking, however, are hypothesis-driven empirical tests of the different models. In this study we aimed at an empirical test of a speech perception model, with the hypothesis that if AVHs are aberrant speech perceptions, then they should implicate the left hemisphere receptive language areas (Binder et al., 1996; van den Noort et al., 2008), and interfere with the processing of an external speech sound, that is processed in the same brain areas. Such a hypothesis is derived from previous functional neuroimaging studies showing that the language regions in the brain are in a hyper-excited state during AVHs (Spencer et al., 2009), and that neuronal activation in the left speech perception area is correlated negatively with frequency and severity of AVHs (Plaze et al., 2006). Such a prediction would also follow from the findings by Woodruff et al. (1997) that patients with severe hallucinations showed reduced left temporal cortex response sensitivity to external speech sounds. Adding to this, Aleman and Vercammen (2012) concluded after a review of the existing activation literature that "if auditory hallucinations share a processing system with auditory sense perception, one would not expect an increase in activity upon external auditory stimulation in the auditory areas of patients actively experiencing AVH" (p. 272). A disadvantage with imaging data is however that it is not clear whether an implicated brain region is necessary and sufficient for

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the function in question, this would require experimental behavioral data. A behavioral task that is a valid indicator of lateralization of speech perception, and has been shown to unequivocally probe left hemisphere function is the consonant–vowel (CV) syllables dichotic listening (DL) task (Studdert-Kennedy and Shankweiler, 1970; Hugdahl and Andersson, 1984; Bryden, 1988; van den Noort et al., 2008). The CV-syllables DL task produces a very robust right-ear advantage (REA) in the general population, with about 85–90% reliability (Hugdahl and Hammar, 1997), meaning that subjects correctly report the right ear syllable of the dichotic pair more frequently than the left ear syllable. Since the right ear report is a measure of lateralization of speech perception to the left hemisphere, a negative correlation with severity of AVHs, and a non-significant correlation for the left ear stimulus, will be direct evidence in support of a speech perceptual model. The reasoning is that the more frequent and severe AVHs are, the more should such experiences interfere with perception of an external speech sound, revealed as significant negative correlations between AVH scores and DL scores for the right, but not the left, ear stimulus. To test a perceptual hypothesis with a dichotic listening experimental paradigm, we examined a large sample of patients with schizophrenia diagnosis, and calculated the correlation between the patients' hallucination score on the Positive and Negative Symptom Scale (PANSS) (Kay et al., 1987), and correct reports for the right and left ear stimulus in the DL task, respectively. To examine whether the relationship between DL performance and PANSS score is specific for hallucinations, we also correlated the right and left ear DL correct reports with a negative symptom, randomly chosen among the PANSS negative symptoms. The hypothesis was that a negative symptom should not correlate with DL reports, neither right nor left ear reports, since they should be unrelated to any perceptual disturbances. We have previously reported on the overall structure of relationships between DL performance and the full range of symptom scores in a non-hypothesis driven approach (Hugdahl et al., 2008), we therefore now chose to focus on key symptoms where we would have a priori directed hypotheses.

2. Experimental/materials and methods

2.1. Subjects

The subjects were 160 patients with a DSM-IV or ICD-10 diagnosis of schizophrenia. The data were collected from different sub-samples, from three different countries, Norway (n = 120), USA (n = 28) and Turkey (n = 12), which differ in their culture and social norms. This was done in order to avoid any idiosyncrasies in diagnostic procedures and principles in different samples, countries and cultures, which would limit the generalizability of our findings. The differences in sample size precluded however any meaningful statistical comparison between the sub-samples, the trend of the findings was however similar at all the sites. Patients were interviewed for symptoms using the PANSS scale. The subjects in the USA sample underwent the Brief Psychiatric Rating Scale (BPRS) interview (Ventura et al., 1993), in which case the scores were correspondingly converted to PANSS scores, since these scales are highly positively correlated (Nicholson et al., 1995). All patients were on medication, with either typical or atypical antipsychotic medication. The patients' age was between 18 and 72 years, and with 116 males and 44 females in the sample (a separate analysis on the 44 females showed that the direction and magnitude of the correlations were similar as for the entire sample and for the males). There were 16 left-handers in the sample, who were included since data from our laboratory on a large database sample of 1782 healthy subjects have shown that handedness per se is not a modulatory factor in DL (see also Hugdahl, 2003). The distribution of the 160 patients across the range of PANSS scores for the P3 and N2 symptoms is seen in Table 1.

Table 1
Distribution of subjects across the PANSS positive and negative symptom scores.

PANSS score→ PANSS symptom↓	1	2	3	4	5	6	7
P3 hallucinations	52	9	19	27	32	10	11
N2 emotional withdrawal	42	25	33	37	18	5	0

2.2. The dichotic listening task

The DL task consisted of the presentation of CV-syllables via headphones to the patients. The stimuli were paired presentations of the six stop-consonants /b,d,g,p,t,k/ together with the vowel /a/ to form dichotic CV-syllable pairs of the type /ba–ga/, /ta–ka/ etc. The syllables were paired with each other for all possible combinations, thus yielding 36 dichotic pairs, including the homonymic pairs. The DL task, thus, consists of presenting two different CV-syllables, e.g. /ba/ and /ga/, at the same time but in different ears, such that one syllable is presented to the right and the other simultaneously to the left ear. To avoid confounding the eligibility of the CV-syllables for the different samples, all syllables were spoken in the respective languages, Norwegian, English and Turkish, but with the similar procedure being followed at all three sites. The homonymic pairs were not included in the statistical analysis. The maximum number of correct reports was thus 30 for each ear. The REA is caused by the crossing of the auditory pathways across the brain midline, the contralateral pathways being more preponderant than the ipsilateral pathways (Kimura, 1967; Pollmann et al., 2002). The right ear signal will thus have direct access to the speech processing centres in the speech dominant left hemisphere, which as a consequence will result in more correct reports for the right ear stimulus (see Hugdahl et al., 2009 for further details). The syllables were read by a male voice with constant intonation and intensity. Mean duration was 350–400 ms and the inter-trial interval was 4 s. The syllables were read through a microphone and digitized for later computer editing on a standard PC using state-of-the-art audio editing software (SWELL, Goldwave, CoolEdit). The syllables were recorded with a sampling rate of 44,000 Hz and an amplitude resolution of 16 bit. After digitization, each CV-pair was displayed on the PC screen and synchronized for simultaneous onset at the first identifiable energy release in the consonant segment between the right and left channels. The stimuli were played to the subject using a digital play-back equipment, connected to high-performance headphones, with an intensity between 70 and 75 dB. The subject was told that he/she would hear repeated presentations of the six CV-syllables (ba, da, ga, pa, ta, ka), and that he/she should report which one he/she heard from the six possible syllables after each trial. The subjects were furthermore told that "on some occasions there seems to be two sounds coming simultaneously". They should ignore this and just report the syllable they heard first, or best. They were shown a cardboard sheet with all six syllables written before the experiment started (because of slight differences in the procedure between labs, the cardboard was not always shown). The subject was explicitly instructed to orally report *one* item on each trial irrespective of whether he/she perceived one or both items. This procedure was originally introduced by Bryden (1988) in order to reduce working memory loading as when the subject has to provide two responses, or as in the original Kimura (1961) studies when the subject had to withhold his/her response until four stimulus pairs had been presented, and then perform a recognition procedure. The subjects were tested with either a PC or a cassette player version of the DL test, using the same CV-syllables stimulus set-up and instructions.

2.3. Statistical analysis

Percentage correct reports, separate for the right and left ears, were correlated with PANSS scores for the P3 and N2 items, as well

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