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SHORT REPORT

Stimulus-dependent effects on right ear advantage in schizophrenia

Jason Smucny[1,3]
Korey Wylie[3]
Jason Tregellas[1-3]

[1]Neuroscience Program, University of Colorado Anschutz Medical Campus, [2]Research Science, Denver VA Medical Center, [3]Department of Psychiatry, University of Colorado Anschutz Medical Campus, Aurora, CO, USA

Background: When presented with different sounds in each ear (dichotic listening), healthy subjects typically show a preference for stimuli heard in the right ear, an effect termed "right ear advantage". Previous studies examining right ear advantage in schizophrenia have been inconsistent, showing either decreased or increased advantage relative to comparison subjects. Given evidence for enhanced semantic processing in schizophrenia, some of this inconsistency may be due to the type of stimuli presented (words or syllables). The present study examined right ear advantage in patients and controls using both words and syllables as stimuli.

Methods: Right ear advantage was compared between 20 patients with schizophrenia and 17 healthy controls. Two versions of the task were used, ie, a consonant-vowel pairing task and a fused rhymed words task.

Results: A significant group × task interaction was observed. Relative to healthy controls, patients showed a greater difference on the syllable-based task compared with the word-based task. The number of distractors marked during the syllable-based task was inversely correlated with score on the Global Assessment of Function Scale.

Conclusion: The findings are consistent with a left hemisphere dysfunction in schizophrenia, but also suggest that differences may be stimulus-specific, with a relative sparing of the deficit in the context of word stimuli. Performance may be related to measures of social, occupational, and psychological function.

Keywords: schizophrenia, right ear advantage, dichotic, distraction

Introduction

Dichotic listening tasks, in which two different stimuli are simultaneously presented to the two ears, typically show a right ear advantage (REA) in healthy adults. This finding is hypothesized to be indicative of left-lateralized language/speech perception in a network of brain regions, including temporal, prefrontal, and inferior parietal cortices.[1]

The prominence of auditory processing abnormalities in schizophrenia has prompted interest in the neurobiology of dichotic listening in the illness. However, previous dichotic listening studies have reported widely variable findings, including reduced, enhanced, or no difference in hemispheric lateralization during dichotic listening in schizophrenia. Using either fused rhymed words or consonant-vowel paired syllables, studies have found reduced REA in patients with schizophrenia.[2–7] Conversely, other studies have reported enhanced REA in patients with paranoid but not undifferentiated schizophrenia,[8] enhanced REA in male patients,[9] and enhanced

Correspondence: Jason Tregellas
Department of Psychiatry, University of Colorado Anschutz Medical Campus, Aurora, CO 80045, USA
Tel +1 303 724 4420
Fax +1 303 724 6227
Email jason.tregellas@ucdenver.edu

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REA in both paranoid and nonparanoid patients.[10] Two other studies have found no differences in REA between patients and controls.[11,12]

Sources of variability in these findings include heterogeneity in the pathological processes and associated symptoms underlining individual illness as well as differences in the methodology (eg, sample size, sample population, performance indices). However, a key factor that may explain some of this variability may be the use of word versus nonword stimuli, given that syllable-based studies consistently show reduced REA in patients,[3–7] whereas the results of word-based studies are more variable,[2,8–12] often finding a relative preservation or even enhancement of REA in patients. The possibility of word/nonword effects is supported by studies of semantic priming, which suggest a facilitation of automatic semantic processing in schizophrenia.[13,14] As such, it is possible that enhanced processing of word stimuli may counter REA deficits observed in dichotic listening tasks that use nonword stimuli. In the present study, we studied subjects with schizophrenia and healthy comparison subjects with two versions of a dichotic listening task, one using words as stimuli and one using syllables. We hypothesized that dichotic listening using words may result in a relative preservation or even enhancement of REA in schizophrenia, whereas dichotic listening using nonword stimuli would show a relative REA deficit in the illness. An additional goal of the study was to relate performance differences to quality of life in patients, as measured by the Global Assessment of Functioning (GAF) scale.

Materials and methods

This study was approved by the Colorado multiple institutional review board. Only decisionally capable subjects with schizophrenia were eligible for study participation. Informed consent was obtained from all study participants.

Subjects

Participants consisted of 20 individuals who met the Diagnostic and Statistical Manual Fourth Edition criteria for schizophrenia, as determined by an interview with a clinician. There were 13 males and seven females, of mean age 40 ± 11 (range 22–56) years and 17 healthy comparison subjects recruited from the local community, comprising five males and 12 females, of mean age 31 ± 10 (range 19–57) years. The groups were significantly different with respect to gender ($U = 113$, $P = 0.02$) and age ($t = 2.56$, $P = 0.01$). Exclusion criteria included a current diagnosis of major depression, substance abuse, neurological disorders, or head trauma. Healthy comparison subjects underwent the Structured Clinical Interview and were excluded for Axis I disorders including schizophrenia, bipolar disorder, depression, anxiety, and lifetime substance dependence as well as a first-degree family history of psychosis. All participants were right-handed as determined by self-report. During screening, patients were also administered the 20-point Brief Psychiatric Rating Scale (average score 28.31 ± 6.56). Patient scores on the GAF scale were also collected during initial Diagnostic and Statistical Manual Fourth Edition diagnosis. One patient was unmedicated, three patients were being treated with first-generation antipsychotics, and the remaining patients were being treated with second-generation antipsychotics.

Procedures

All subjects initially underwent a hearing test to ensure they did not have a substantial difference (>10 dB) in hearing between each ear. The word-based and syllable-based versions of the dichotic listening task each consisted of four sets of 15 pairs of stimuli, for a total of 120 stimuli per version. Stimulus duration was 350 msec, and waveforms for sound pairs were adjusted to have the same onset. Stimuli were delivered every 4 seconds at 70 dB with Bose Acoustic Noise Cancelling® headphones. A 2-minute rest period was given between each set. The sets were presented to subjects in a pseudorandomized, counterbalanced design, such that approximately half of all subjects completed the word version first and half completed the syllable version first.

For the fused rhymed word task, a list of paired rhyming words (eg, pig, dig, see Supplementary Table 1) was generated and matched for frequency of appearance in the English language using the Hyperspace Analogue to Language norms in the English Lexicon Project.[15] Words with emotional connotations were discarded, resulting in 15 pairs. Subjects were asked to cross out the word they heard from a list that included the word played in each ear and two distractors, ie, words that rhymed with the stimuli but were not presented in either ear. Audio pronunciations of the rhyming word pairs were created with the VoiceOver synthesizer (the native voice synthesizer in Macintosh operating system computers). Track volume was equalized and mixed in Adobe SoundBooth.

For the syllable-based task, consonant-vowel pairs using one of the six stop consonants (b, d, g, k, p, t) and a vowel (a) were created and mixed as above. Subjects were asked to cross out which syllable they heard from a list of all six possible consonant-vowel pairs (/ba/, /da/, /ga/, /ka/, /pa/, and /ta/).

Data analysis

REA was calculated using the adjusted laterality index, defined as:

[(Number of Right Ear Words Marked − Number of Left Ear Words Marked) ÷ (Number of Right Ear Words Marked + Number of Left Ear Words Marked)] × 100.

Using this index, values greater than zero imply a REA, values less than zero imply a left ear advantage, and a value of zero implies no laterality.

Laterality index data were analyzed using a repeated-measures analysis of variance, with task type (word-based or syllable-based) as a within-subjects factor, group (patient or control) as a between-subjects factor, and the group × task interaction as the contrast of interest. Using an independent t-test, gender was not found to be significantly associated with either word or syllable laterality. Using regression, age was also not found to be significantly associated with either word or syllable laterality. Thus, age and gender were not considered in the final design. Nonparametric Mann–Whitney tests were used to explore differences in distractors marked between patients and control in each task. The SPSS statistical program (SPSS Inc, Chicago, IL) was used for all analyses.

Results

Behavioral data are presented in Table 1 and Supplementary Table 2. Repeated-measures analysis of variance for REA revealed a significant group × task interaction [$F(1,36) = 3.97$, $P = 0.05$], with patients showing a greater deficit on the syllable-based task than the word-based task.

Patients marked significantly more distractors in the word-based version ($U = 107$, $P = 0.03$, df = 36). A marginally significant increase was also observed in patients for the syllable-based version ($U = 114$, $P = 0.06$, df = 36). No correlation between GAF score and distractors marked in

Table 1 Mean LI's and distractors marked for each task

	Control	Patient	
LI (word-based task)	28.6 ± 4.8	20.3 ± 6.0	]*
LI (syllable-based task)	39.3 ± 7.9	18.7 ± 7.8	
Distractors marked (word-based task)	2.6 ± 0.59	6.2 ± 1.1#	
Distractors marked (syllable-based task)	13.9 ± 1.97	25.7 ± 4.7	

Notes: ± signs are followed by the standard error of the mean; *Significant group × task interaction [$F(1,36) = 3.97$, $P = 0.05$]; #Significant group difference ($U = 107$, $P = 0.03$, df = 36).

the word-based version [$R = 0.09$, $F(1,36) = 0.13$, $P = 0.72$] was observed. A marginally significant inverse correlation was observed between GAF score and number of distractors marked in the syllable-based version [$R = 0.42$, $F(1,36) = 3.44$, $P = 0.08$]. To examine the possibility that the significant difference in distractors marked in the word-based task contributed to laterality index results, the relationship between distractors marked and laterality index for the word-based task was examined and not found to be significant [$R = 0.21$, $F(1,36) = 1.63$, $P = 0.21$].

Discussion

In support of our hypothesis, a significant group × task interaction of REA was observed, showing a greater reduction among REA in patients compared with controls on the syllable-based task compared with the word-based task. This finding suggests that the degree of REA deficits between patients and controls is task-dependent. In addition, patients marked significantly more distractors on both versions of the task. The number of distractors marked on the syllable-based task showed a marginally significant negative correlation with GAF score.

As hypothesized, no significant difference in REA was observed between patients and controls in the word-based task. We propose that this relative preservation of REA in the word-based task may be due to greater automatic processing of word stimuli in patients. Previous studies have reported enhanced semantic processing and associated neural activity in schizophrenia. Behaviorally, patients show increased spreading of semantic associations[16] and enhanced semantic priming under low-relatedness conditions.[17] Neurophysiologically, increased N400 amplitude after sentence presentation,[18] increased activation of temporal and prefrontal cortex in response to indirectly related word pairs,[13] and enhanced activity in fusiform and superior temporal gyri during automatic semantic processing[14] has been observed. These findings suggest that semantic processing may be enhanced in schizophrenia, and may attenuate deficits in REA during word-based dichotic listening tasks.

A marginally significant association between number of distractors marked on the syllable-based task and GAF score in patients was observed. To our knowledge, our study is the first to report a possible association of GAF score with performance on a dichotic listening task in schizophrenia. Importantly, low GAF scores have previously been associated with aberrant auditory processing in schizophrenia.[19–22] These abnormalities may contribute significantly to impairments in

selective and sustained attention that have long been considered hallmarks of the disorder.[23–25] The possible association between distractors marked and poor GAF scores suggest that deficits in concentration may affect global functioning in schizophrenia.

Several limitations of the present study limit the interpretability of the findings. Subjects were not age-matched and gender-matched between groups. Although no significant effect of age, gender, or laterality index was observed, future studies with larger sample sizes and more balanced demographic ratios will be needed to examine further the effect of age and gender on REA in word-based and syllable-based dichotic listening paradigms. The present pilot study may also have been underpowered to ascertain with certainty whether REA was preserved in patients on the word-based but not the syllable-based tasks. Additionally, determination of hemispheric dominance was limited to self-reporting. Finally, as evidenced by the low number of distractors marked in the word-based task, we cannot rule out the possibility that a ceiling effect contributed to the present findings.

In conclusion, this pilot study suggests that patients with schizophrenia show a significantly greater reduction in REA in a syllable-based dichotic listening task compared with a word-based task. The relative preservation of REA in the word-based-task may reflect greater semantic processing observed in schizophrenia. Performance on the task may also be related to measures of normal everyday function.

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Disclosure

The authors report no conflicts of interest in this work.

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Supplementary tables

Table S1 List of paired rhyming words used in this study, and corresponding distractors

Word 1	Word 2	Distractor 1	Distractor 2
boon	dune	tune	june
bake	cake	take	make
ball	tall	call	wall
gong	tong	long	pong
bale	gale	tail	nail
batch	patch	catch	match
dig	pig	gig	jig
pin	tin	bin	win
cat	pat	bat	hat
coat	goat	boat	quote
gong	pong	long	tong
deer	gear	tear	year
core	door	bore	four
dug	tug	bug	rug
cold	told	hold	bold

Table S2 Mean words and syllables marked for each ear

	Control (mean ± SEM)	Patient (mean ± SEM)
Words marked, right ear	75.4 ± 2.8	68.6 ± 3.6
Words marked, left ear	41.9 ± 2.8	45.2 ± 3.3
Syllables marked, right ear	74.2 ± 4.1	56.9 ± 5.2
Syllables marked, left ear	31.9 ± 3.7	37.4 ± 4.0

Abbreviation: SEM, standard error of the mean.