
Reduced Communication Between Frontal and Temporal Lobes During Talking in Schizophrenia

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Background: *Communication between the frontal lobes, where speech and verbal thoughts are generated, and the temporal lobes, where they are perceived, may occur through the action of a corollary discharge. Its dysfunction may underlie failure to recognize inner speech as self-generated and account for auditory hallucinations in schizophrenia.*

Methods: *Electroencephalogram was recorded from 10 healthy adults and 12 patients with schizophrenia (DSM-IV) in two conditions: talking aloud and listening to their own played-back speech. Event-related electroencephalogram coherence to acoustic stimuli presented during both conditions was calculated between frontal and temporal pairs, for delta, theta, alpha, beta, and gamma frequency bands.*

Results: *Talking produced greater coherence than listening between frontal-temporal regions in all frequency bands; however, in the lower frequencies (delta and theta), there were significant interactions of group and condition. This finding revealed that patients failed to show an increase in coherence during talking, especially over the speech production and speech reception areas of the left hemisphere, and especially in patients prone to hallucinate.*

Conclusions: *Reduced fronto-temporal functional connectivity may contribute to the misattribution of inner thoughts to external voices in schizophrenia. Biol Psychiatry 2002;51:485–492 © 2002 Society of Biological Psychiatry*

Key Words: Schizophrenia, self-monitoring of speech, EEG coherence

Introduction

Connection between frontal and temporal cortical areas via the arcuate fasciculus provides a pathway by which frontal speech production areas can prime the auditory cortex for impending speech (Creutzfeldt et al 1989; Paus et al 1996b; Petrides and Pandya 1988). Dysfunction of this connection might be responsible for “failure to integrate perception and action,” (Friston and Frith 1995; Weinberger and Lipska 1995) “splitting of mental faculties,” (Bleuler 1911/1950) and may underlie some of the positive symptoms of schizophrenia.

Priming of the auditory cortex by the frontal lobes may occur through the action of a “corollary discharge.” Although originally described in the visual system as a mechanism to control flight in the horsefly, corollary discharge has been used to describe a mechanism in the auditory system that allows self-monitoring of the spoken word. Such a mechanism might serve speech acquisition during infancy and our ability to distinguish between our own and others’ utterances throughout life. Thus, corollary discharge might be a key mechanism for monitoring our own speech, thoughts, and behaviors. An example of corollary discharge relevant to speech perception is the inhibition of auditory cortical responsiveness during phonation. In subhuman primates, about 50% of call-responsive neurons, identified by response to prerecorded cells, are inhibited during phonation (Muller-Preuss and Ploog 1981). In humans, preoperative intracranial recordings show a reduction in responsiveness of neurons in the middle temporal gyrus, starting 100 msec before and continuing during the patient’s speech, but not occurring when another person speaks to the patient (Creutzfeldt et al 1989).

Disrupted connectivity between frontal and temporal lobes (Friston and Frith 1995) is consistent with the hypothesis that a defective corollary discharge mechanism in schizophrenia causes the misperception of thoughts as voices (Feinberg 1978; Feinberg and Guazzelli 1999; Frith 1995). While corollary discharges are hypothesized to accompany inner speech and thoughts, our most complex motor acts (Jackson 1958), their effects on auditory cortex

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should be particularly evident during speech production which, normally involves differential perception and processing of self-generated auditory input such as vocalizations. Accordingly, we assessed fronto-temporal functional connectivity in controls and patients with schizophrenia during speaking aloud relative to simply hearing playback of speech. The speech statements employed were typical in content and form to those reported by patients experiencing auditory hallucinations (Nayani and David 1996).

Connectivity between brain regions can be assessed using various brain imaging techniques. Those based on hemodynamic responses (e.g., functional magnetic resonance imaging [fMRI] and positron emission tomography [PET]) provide relatively good spatial but poor temporal resolution of cortical activity. Those based on electrophysiological responses (e.g., electroencephalogram [EEG] and Magnetoencephalogram [MEG]) provide limited spatial resolution, but excellent (e.g., millisecond) temporal resolution. Using fMRI or PET, investigators may infer functional relationships between disparate cortical areas coactivated by the same task conditions (Fletcher et al 1998), but little can be concluded about the relative time course of these activations or the degree to which their neural activity is temporally coupled. Using EEG, investigators may calculate the relationship between electrophysiological signals recorded from two different cortical areas and make inferences about their interconnection. This can be done using a variety of techniques including cross-covariance calculations (Gevins et al 1987), wavelet transformations (Nikolaev et al 2001), and coherence calculations (Thatcher et al 1986), the most common of which is coherence.

Coherence is a frequency-dependent measure of the degree of relatedness between EEG recorded over two different brain areas. High coherence between two brain areas indicates that their amplitudes at a given frequency *and* their associated phase angles are correlated across time epochs (Lachaux et al 1999). When coherence is low, it indicates that across time epochs, the relationship between power in the two signals and/or the relative phase difference between them is inconsistent. Moreover, the coherence measure does not allow specification of whether the relationship between the two signals is stronger in terms of relative phase or power (Lachaux et al 1999). Coherence can range from zero to one, and it does not distinguish positive from negative correlations between frequency amplitudes across time. Accordingly, it can reflect either inhibition or excitation of connected areas (Manganotti et al 1998). In any case, high levels of coherence between EEG recorded from noncontiguous electrodes reflect interdependence between brain regions (Lachaux et al 1999) due to anatomical connections (Fein

et al 1988), functional coupling (Thatcher et al 1986), "perceptual binding," (Gray and Singer 1989) and/or associative learning (Miltner et al 1999).

Electroencephalogram coherence can be calculated in passive, unstimulated, task-free conditions and also during cognitively engaging tasks. Patients with schizophrenia show decreases in delta and theta coherence over the left frontal lobes in a task-free condition (Tauscher et al 1998), reduction of bilateral anterior activation during frontal lobe tasks (Morrison-Stewart et al 1996), a reduced level of focal activation of left frontal areas during left hemisphere activation tasks (Morrison-Stewart et al 1991), and reductions in frontal-temporal alpha band coherence in patients with reality distortion during performance of a mathematical task (Norman et al 1997).

Electroencephalogram coherence can also be calculated when subjects are processing external stimuli, from which event-related brain potentials (ERPs) can be derived. A recent study (Muller et al 1999) reported increased delta and theta coherence when normal subjects were processing names compared with nouns. Using event-related coherence analysis, investigators (Rappelsberger et al 1994) have reported increased event-related alpha band coherence between premotor and motor areas. Furthermore, event-related coherence is useful in attempting to understand the temporal relationships between *averaged* ERPs recorded over different cortical areas (Leocani et al 1997). To date, studies of event-related EEG coherence have not been reported in patients with schizophrenia.

To understand the temporal relationships between averaged ERPs to acoustic probes during speaking, we calculated event-related coherence from single trials recorded over frontal and temporal areas. Using these same data, we have previously shown that the averaged ERP N1 component to acoustic probes is differentially sensitive to schizophrenia during talking and listening (Ford et al 2001c). To understand whether this reflects a reduction in temporal communication between frontal and temporal areas, we assess the temporal synchrony of single-trial EEG recorded over frontal and temporal cortical areas by calculating the coherence of the EEG signals. Our predictions were that theta would show increased fronto-temporal coherence during speaking relative to listening to speech in controls, but not in patients. Furthermore, this lack of coherence during speech in patients would be most evident in those most prone to auditory hallucinations. Such a finding would reflect normal functional connectivity between speech production and perception areas during speech and its disruption in schizophrenia. We also expected these effects to be stronger over the left than right hemisphere, and strongest over lateral frontal and posterior temporal areas involved in speech production and reception, respectively.

Methods and Materials

Subjects

Event-related brain potentials data from this experiment are presented elsewhere (Ford et al 2001c). Data from 10 healthy adults (nine males and one female) and 12 patients with schizophrenia (11 males and one female) are presented here. All gave written informed consent after the procedures had been fully described. Normal controls ranged in age from 30 to 52 years (mean = 44.5, SD = 7.2) and patients ranged in age from 24 to 53 years (mean = 39.5, SD = 7.1), a nonsignificant difference ($p = .12$). Years of education were higher in controls (mean = 15.3, SD = 1.3) than in patients (mean = 12.7, SD = 1.0), a significant difference ($p < .0001$). Controls were recruited by newspaper advertisements and by word of mouth; were screened by telephone using the psychiatric screening questions from the Structured Clinical Interview for DSM-IV (SCID) (First et al 1995); and were excluded for any significant history of Axis I psychiatric illness.

Patients were recruited from community mental health centers, as well as from inpatient and outpatient services of the Veterans Affairs Palo Alto Health Care System. All patients met DSM-IV criteria for schizophrenia (six undifferentiated, four paranoid, one disorganized, and one residual), based either on the diagnosis from a SCID interview conducted by a psychiatrist or psychologist, or by consensus of a SCID interview conducted by a trained research assistant and a clinical interview by a psychiatrist or psychologist. In two cases, a psychiatrist confirmed the clinical diagnosis by patient chart review. Nine of the patients were taking atypical and three were taking typical antipsychotic medications. Prospective patient and control participants were excluded for recent (within 30 days before study) alcohol or drug abuse. Four patients with less recent histories of alcohol dependence ($n = 1$), drug abuse ($n = 1$) or drug dependence ($n = 2$) were included. In addition, patient and control participants were excluded for significant head injury (loss of consciousness greater than 30 min or resulting in neurologic sequelae) or neurologic or other medical illnesses compromising the central nervous system. All of the normal controls and all but two of the schizophrenic patients were right handed.

Patient symptoms were assessed by at least two trained raters (including a psychiatrist or clinical psychologist) administering the 18 item Brief Psychiatric Rating Scale (BPRS) (Hedlund and Vieweg 1980). This was done during a semi-structured interview conducted on the same day ($n = 10$), within 2 days ($n = 1$), or within 1 week ($n = 1$) of ERP testing. Ratings were averaged over two raters. The mean BPRS total from the 12 patients was 38.5 (SD = 10.6; range = 21–52.5). In addition, the Schedule for Assessment of Positive Symptoms (SAPS) (Andreasen et al 1995) was administered in the same rating session as the BPRS. The patient group was subdivided into hallucinators (rating of 5, 6, or 7 on the Hallucinatory Behavior item on the BPRS, $n = 7$) and nonhallucinators (rating of 1 or 2 on the Hallucinatory Behavior item on the BPRS, $n = 5$) for exploratory analyses. Of the four patients with histories of substance abuse or dependence, two were hallucinators and two were nonhallucinators. All three of the patients taking typical antipsychotic medications were nonhallucinators.

Experimental Procedure

Before electrodes were attached, the subjects were asked to read aloud from a sheet of paper containing seven hallucinatory statements, such as “That was really stupid,” or “Why are you trying to annoy me?” Statements were recorded and the loudness of each was digitally adjusted by a technician to match that of a target sentence, recorded from another speaker. Playback intensity of the target sentence was then individually adjusted to match each subject’s speech comprehension threshold. For the Listening Condition, the prerecorded hallucinatory statements were played back 25 dB above the individual subject’s threshold, a comfortable listening level, approximately 70–75 dB SPL (C scale). For the Talking Condition, participants were asked to speak at an equivalent loudness to the played back sentences (i.e., in his or her natural talking voice), neither shouting nor whispering. Throughout both Listening and Talking conditions, probes (noise, speech syllable, and checkerboard) were presented. Event-related potentials to the probes are presented elsewhere (Ford et al 2001c). This report presents coherence only for EEG following the speech syllable.

Listening and Talking Condition

The first prerecorded hallucinatory statement was repeated back to the subject for 30 sec (about seven repetitions). Next, the subject repeated the same statement aloud for another 30 sec. This Listen/Talk sequence was repeated for each of the seven hallucinatory statements, for a total of 7 min. About one third of the subjects had to be reminded to speak louder or softer at the beginning of the Talking condition. Before the Listening and Talking conditions, subjects listened silently to the probes. Event-related brain potentials results from that condition are described elsewhere (Ford et al 2001c).

The probe sequence was presented to subjects continuously during both Listening and Talking conditions. It consisted of a series of three equiprobable stimuli: speech sound ([ba], 250 msec duration), noise (broadband, 250 msec duration), and square checkerboard (5×5 degrees of visual angle, 250 msec duration), every 0.8, 1.0, or 1.2 sec. Loudness of auditory probes was constant between Talking and Listening conditions.

EEG Recording and Screening

For this analysis, we report EEG recorded from frontal (F3, F4, F7, F8) and temporal sites (T3, T4, T3L, T4L, C3P, C4P, T5, T6, P3, P4) following the stimulus [ba]. T3L and T4L were located at the midpoint between T3 and T5, and T4 and T6. Vertical electro-oculogram (VEOG) was recorded from electrodes placed above and below the right eye, and horizontal (HEOG) from electrodes placed at the outer canthus of each eye. Electroencephalogram and EOG were sampled at 500 Hz continuously and band pass filtered between .05 and 40 Hz. Epochs of 1 sec duration were corrected for the effects of eye blinks and eye movements based on correlations of the VEOG and HEOG with the EEG recorded at each electrode site (Gratton et al 1983) and rejected if voltages exceeded $\pm 100 \mu\text{V}$. All remaining samples were subjected to visual screening by the investigators to eliminate any artifacts introduced by talking. For controls, 10.1%

of samples and for patients, 11.3% of samples failed the computer and investigator criteria. Data from eight other patients and seven other controls had to be excluded from these analyses because of insufficient numbers of trials. The included and excluded patients did not differ in clinical symptomatology (total BPRS: $t(18) = 1.0, p = .33$).

Analysis of EEG Coherence

To translate data from the time domain to the frequency domain, a Fast Fourier Transform (FFT) was calculated on all points. Coherence was calculated for each frequency band of interest (delta: 1–3 Hz; theta: 4–7 Hz; alpha: 8–12 Hz; beta: 13–20 Hz; gamma: 30–50 Hz). Coherence is the spectral cross-correlation between two electrodes normalized by their power spectra (NeuroscanLabs 1999).

Coherence was calculated between the following electrode pairs, sorted according to hemisphere (right and left) and frontal region (frontal middle or frontal lateral) for each of the temporal lobe sites:

Left, midfrontal (F3) to left temporal: F3-T3, F3-T3L, F3-C3P, F3-T5, F3-P3.

Left, lateral-frontal (F7) to left temporal: F7-T3, F7-T3L, F7-C3P, F7-T5, F7-P3.

Right, midfrontal (F4) to right temporal: F4-T4, F4-T4L, F4-C4P, F4-T6, F4-P4.

Right, lateral-frontal (F8) to right temporal: F8-T4, F8-T4L, F8-C4P, F8-T6, F8-P4.

The coherence values for each electrode pair were averaged across the single trials. The resulting average event-related coherence values for each electrode pair were the dependent variables in the analyses of variance (ANOVA).

Analysis of EEG Power

The power (μV^2) for each frequency band at each electrode site was calculated and log transformed to normalize the distributions. Because our focus is on coherence and not power, only theta power is reported here because of its possible contribution to coherence.

Statistical Analyses

A six-way ANOVA was performed on the average event-related coherence values for the specific frontal-temporal electrode pairs listed above. There was one between-subjects factor (Group) and five repeated factors (Condition, Hemisphere, Frequency Band, Frontal Region, Temporal Site). Analysis proceeded in a hierarchical fashion, with higher order interactions being parsed to identify the simple main effect of Condition (Keppel 1973). To simplify the presentation of the data, only interactions involving Group and Condition are parsed and described. We also conducted an exploratory Group \times Condition analysis with three groups: controls, hallucinators, and nonhallucinators. Probability levels less than .05 were considered statistically significant. Huyn-Feldt epsilon corrections were used to evaluate all F ratios for effects involving two or more degrees of freedom. In addition, we compared theta coherence during Talking and Listening for each electrode pair using *t* tests.

Results

EEG Coherence

While the ANOVA revealed a main effect of Condition ($F[1,20] = 26.28, p < .0001$) indicating greater coherence during talking than listening, the Condition effect interacted with all the other variables resulting in a six-way interaction (Group \times Condition \times Hemisphere \times Frontal Region \times Temporal Site \times Frequency Band: $F[6,320] = 2.12, p < .05$), which was further analyzed by assessing the five-way interaction for each band separately. Only theta and delta bands showed significant five-way interactions (Group \times Condition \times Hemisphere \times Region \times Site: Theta ($F[4,80] = 3.10, p = .03$); Delta ($F[4,80] = 4.80, p = .002$). These interactions were parsed hierarchically to find a simple main effect of Condition, proceeding only if the highest order interaction was significant in the intermediate ANOVA (from four-way, to three-way, to two-way). A two-way Group \times Condition interaction was significant for theta ($F[1,20] = 4.62, p < .05$) over the left hemisphere between lateral frontal (F7) and posterior temporal sites (P3). A similar Group \times Condition interaction was significant for delta ($F[1,20] = 4.48, p < .05$) over the left hemisphere between lateral frontal (F7) and posterior temporal sites (T5). Finally, at the single factor level, a simple main effect of Condition was observed for controls in both bands (Theta: $F[1,9] = 17.17, p = .0025$; Delta: ($F[1,9] = 5.05, p = .05$), but not for patients (Theta: $F[1,11] = 3.28, p = .10$; Delta: ($F[1,11] = 4.04, p = .07$). Thus, for controls but not patients, coherence between lateral frontal and posterior temporal sites was greater during Talking than Listening in the theta and delta bands.

Because the effects were stronger for theta than delta, additional analyses focused on this frequency band. We subdivided patients into hallucinators and nonhallucinators (see Methods) and found a significant Condition \times Group interaction for theta coherence ($F[2,19] = 4.14, p = .03$) in which coherence was greater during Talking than Listening for controls ($F[1,9] = 17.17, p = .0025$), tended to be greater for nonhallucinators ($F[1,4] = 7.10, p = .056$), but was not for the hallucinators ($F[1,6] = .069, p = .80$). Thus, the failure to increase theta coherence during talking in schizophrenia is primarily observed in the hallucinators as can be seen in Figure 1, which shows mean coherence values between F7 and P3 for the three groups.

We compared theta coherence during Talking and Listening for each electrode pair. The resulting *t* values and probability levels are portrayed graphically in Figure 2. In controls, coherence during Talking was greater than during Listening for all 20 of the electrode pairs. In patients, this was true for only two of the pairs.

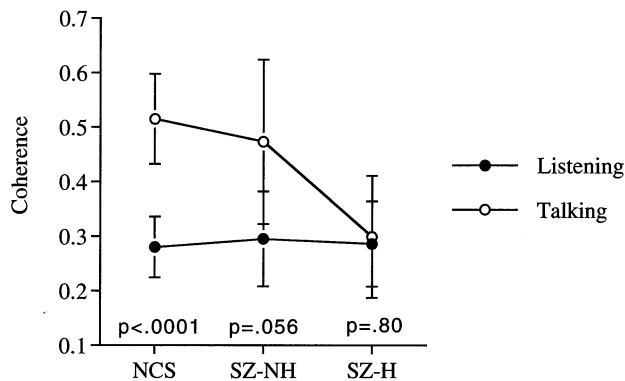


Figure 1. Theta band coherence between left lateral frontal (F7) and left posterior temporal (P3) areas. Theta band coherence plotted separately for talking and listening conditions for normal controls (NCS), nonhallucinating schizophrenic patients (SZ-NH) and hallucinating schizophrenic (SZ-H) patients, illustrating the Group \times Condition interaction ($p = .03$) described in the text.

As mentioned above, coherences during Talking were higher than during Listening in the alpha, beta, and gamma bands. Because there were no Condition \times Group interactions, these effects will not be described.

EEG Power

Power was greater during Talking than Listening (Condition: $F[1,20] = 22.34, p < .0001$) and greater at frontal than temporal sites (Site: $F[6,120] = 20.85, p < .0001$); however both of these effects are tempered by the presence of a four-way interaction (Group \times Condition \times Hemisphere \times Site: ($F[6,120] = 2.547, p = .04$). We parsed this interaction using the strategy described above

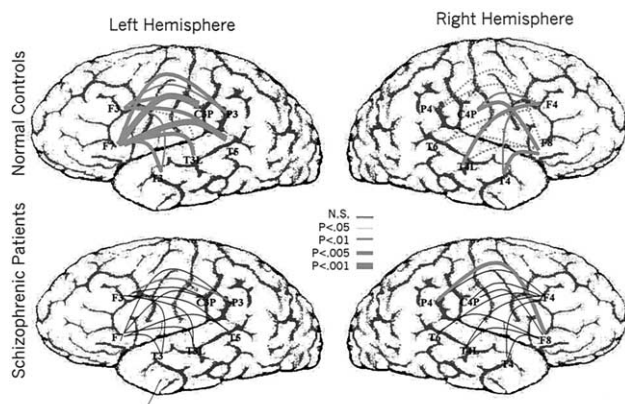


Figure 2. Probability levels for *t* tests showing greater fronto-temporal EEG coherence during Talking than during Listening superimposed on lateral view of right and left hemispheres for normal controls and schizophrenic patients. EEG = electroencephalogram.

and found significant Condition \times Site interactions at both hemispheres, despite the fact that the Condition effect was significant at each site at both hemispheres (significance levels ranging from $p = .0015$ to $p < .0001$). Only on the right was there a Group \times Condition \times Site interaction; although there was a Group \times Condition interaction at T4L ($p = .04$), Condition was significant for both controls ($p = .001$) and patients ($p = .04$). Thus, despite interactions, at every site, over both hemispheres, in both groups, power was greater during Talking than Listening.

Discussion

Using EEG coherence as a measure of functional connection between frontal and temporal brain areas, our results corroborate other functional brain imaging reports of a disconnection between frontal and temporal areas in schizophrenia (Fletcher et al 1999; Friston and Frith 1995; Friston et al 1995; Norman et al 1997). The greater frontal-temporal coherence during talking than listening in controls may reflect the action of a corollary discharge from frontal brain structures preparing temporal lobe structures for speech. Indeed, 100 msec before speech is initiated, the spontaneous firing rate of neurons in the middle temporal gyrus diminishes (Creutzfeldt et al 1989). Increased coherence during talking implies a continuous dialogue between neural systems responsible for producing speech and those involved in perceiving its effects, and this increase is not seen in patients with schizophrenia in the theta and delta bands. Furthermore, this effect in the theta band was stronger in patients who hallucinated than those who did not. This would suggest that a “break” in the frontal-temporal circuit during the act of overt speech, and perhaps covert speech, is associated with the pathophysiology of auditory verbal hallucinations, possibly because corollary discharge mechanisms normally subserved by this circuitry are compromised. Failures of such mechanisms during covert or inner speech could lead to misattribution of self-generated thoughts to external sources, contributing to the phenomenon of auditory verbal hallucinations (Feinberg and Guazzelli 1999).

Greater communication between frontal and temporal lobes during talking than listening is consistent with the literature on language activation tasks (Demonet et al 1992; Warburton et al 1996) in which acoustic analysis of verbal stimuli engages primary and association auditory cortex bilaterally with little frontal activation, and verb generation tasks engage both frontal and temporal lobe structures. Other functional imaging studies have produced results consistent with this interpretation (Paus et al 1996a; Paus et al 1996b). In our study, increased coherence during talking compared with listening may reflect

some kind of coordination between speech generation and speech perception. Although coherence was stronger on the left than the right, even on the right, there were significant increases in coherence during talking compared with listening. Although left hemisphere structures are more involved than right in generation of verbal thoughts and speech, the right hemisphere is typically engaged as well (Sperry 1950; Warburton et al 1996), especially during repetition of material and listening to repetitive material (Ingvar and Schwartz 1974; Roland 1984; Roland et al 1981).

While coherence is typically interpreted as a reflection of communication between two different brain areas, it can also result from a single deep source and be volume conducted to two distant electrodes (Mima and Hallett 1999); however, volume conduction is an unlikely explanation for our data given the lack of correspondence between the degree of coherence and electrode distances. Also, coherence can be artificially enhanced by high levels of coherence in the reference, a linked mastoid in our case, which would affect coherence symmetrically. Such an explanation would not be consistent with the condition by hemispheric differences in coherence observed here. Coherence effects could also be affected by N1 and P2 amplitudes to the acoustic probes; however, N1 and P2 amplitudes and coherences were affected differently by group and condition: in controls, coherence was greater during talking than listening, but N1 was not (Ford et al 2001c); and in patients, N1 was greater during talking than listening, but coherence was not. P2 was not affected differentially by talking and listening, nor was it affected by schizophrenia. Although the calculation of coherence normalizes for power, this may not remove the influence of power completely because combinations of coherent and incoherent theta sources may be present; however, the effects of our variables on theta power and coherence differed.

This study of EEG coherence, directly demonstrating reduced coupling between the frontal and temporal regions during talking in patients compared with controls, augments our earlier ERP analysis (Ford et al 2001c) that we interpreted as reflecting failed corollary discharge from the frontal to the temporal lobes. In addition, it extends other ERP findings in which we have compared cortical responsiveness during directed inner (covert) speech and listening (Ford et al 2001b) and compared responsiveness to vowels, as they were being spoken, to those same vowels played back (Ford et al 2001a). Data from these three studies all suggest that both overt and covert speech reduce auditory cortical responsiveness in controls, but not in patients. We have suggested that this reduction in controls could be due to the action of a corollary discharge from frontal to temporal lobes, which is dysfunctional in

the patients (Feinberg and Guazzelli 1999). The current coherence data are consistent with these ERP reports and augment them by suggesting that there is an interdependence between these areas during talking that is somewhat disrupted in patients, especially those prone to auditory hallucinations. Unanswered is whether this is due to faulty pathways connecting frontal and temporal lobes or to faulty synchronization of the neural impulses traveling along the pathways, or both. Although it may reflect a tendency, or trait, to hallucinate, we have reason to think that it does not reflect ongoing state of hallucinations since most patients report not hearing “voices” while they themselves are talking. One limitation of this study is the fact that our small sample of patients with schizophrenia precluded any assessment of effects of medication type and dose. In addition, all patients were clinically stable at the time of testing, further dampening the severity of hallucinations even among those prone to them.

Friston and Frith (1995) distinguish between first- and second-order pathology. First-order pathology would be revealed in deficits within a region, while second-order pathology would be revealed as deficits in the connections or communication between two areas. The neurophysiological data presented here suggest second-order pathology in schizophrenia revealed in the EEG coherence, or functional disconnectivity, between the frontal and temporal regions during talking compared with listening. Our data are consistent with a recent suggestion that the core pathology in schizophrenia is one of abnormal temporal integration of brain networks, or “dysmetria” (Andreasen et al 1998).

This work was supported by grants from National Institute of Mental Health (MH40052, MH 58262) and by the Department of Veterans Affairs.

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