Journal of Abnormal Psychology
2003, Vol. 112, No. 4, 623–632

0021-843X/03/$12.00 DOI: 10.1037/0021-843X.112.4.623

Lateralized Lexical Decision in Schizophrenia: Hemispheric Specialization and Interhemispheric Lexicality Priming

Katherine L. Narr, Michael F. Green, Linda Capetillo-Cunliffe, Arthur W. Toga, and Eran Zaidel
University of California, Los Angeles

Reports of left-hemisphere dysfunction and abnormal interhemispheric transfer in schizophrenia are mixed. The authors used a unified paradigm, the lateralized lexical decision task, to assess hemispheric specialization in word recognition, hemispheric error monitoring, and interhemispheric transfer in male, right-handed participants with schizophrenia ($n = 34$) compared with controls ($n = 20$). Overall, performance and error monitoring were worse in patients. However, patients like controls showed left-hemisphere superiority for lexical processing and right-hemisphere superiority for error monitoring. Only patients showed selective-interhemispheric lexicality priming for accuracy, in which performance improved when the lexical status of target and distractor stimuli presented to each hemifield was congruent. Results suggest that schizophrenia is associated with impaired monitoring and with increased interhemispheric automatic information transfer rather than with changed hemispheric specialization for language or error monitoring.

To assess the presence of disturbed functional lateralization and altered callosal connectivity in schizophrenia, we used a lateralized lexical decision paradigm that has been well validated in controls and split-brain participants (Iacoboni, Rayman, & Zaidel, 1997; Iacoboni & Zaidel, 1996; Zaidel, 1995; Zaidel, Clarke, & Suyenobu, 1990). In this experiment, word targets or pronounceable nonword targets and distractors are presented tachistoscopically to each visual hemifield. In each trial, only one of the lexical stimuli presented simultaneously to each hemifield is underlined. Participants must decide whether the underlined target is a word or a nonword. Hemispheric capabilities for (a) processing language-related stimuli, (b) semantic and phonological processing (made possible by manipulating the stimulus characteristics of word targets), and (c) error monitoring (made possible by examining the correctness of previous trial decisions) may be evaluated with this paradigm. Additionally, the bilateral lexical decision experiment allows the examination of interhemispheric transfer under conditions of maximum hemispheric independence (made possible because a different target stimulus and distractor stimulus are presented simultaneously to each hemifield). The bilateral lexical decision experiment may thus provide a survey of both disturbed lateralization and altered callosal connectivity in schizophrenia compared with nonschizophrenia.

Functional Lateralization

Disturbances in normal functional and structural lateralization are frequently reported in schizophrenia where the left hemisphere (LH) appears more widely implicated. For example, LH deficits for language processing and reductions in perisylvian asymmetries, brain regions believed to subserve language functions, are reported, although not always replicated, in individuals with schizophrenia (Gur & Chin, 1999; Kwon et al., 1999; Narr et al., 2001; Petty, 1999; Sakuma, Hoff, & DeLisi, 1996). Deficits in emotional perception (Lior & Nachson, 1999), recognition memory for faces (Gruzelier, Wilson, & Richardson, 1999), some motor functions (Spivak et al., 2000), and deficits in the processing of Gestalt aspects of stimuli (Goodarzi, Wykes, & Hemsley, 2000), however, suggest some right hemisphere (RH) specific deficits in individuals with schizophrenia.

In the lateralized lexical decision paradigm, hemispheric effects observed in healthy individuals may be compared with those observed in patients to directly confirm whether functional asymmetries are altered in schizophrenia. In healthy individuals, hemispheric effects typically observed include (a) a right visual field advantage (RVFA), (b) an advantage for word decisions compared with nonword decisions, and (c) a wordness by visual field interaction, in which the advantage for processing words relative to nonwords is greater in the right visual field (RVF) than in the left visual field (LVF) (Iacoboni & Zaidel, 1996; Measso & Zaidel, 1990; Weekes, Capetillo-Cunliffe, Rayman, Iacoboni, & Zaidel, 1999; Zaidel et al., 1990). Previous studies using lateralized tasks have shown alterations in the normal RVFA for lexical stimuli and a reduced normal right ear advantage for dichotic auditory stimuli in schizophrenia (Gur, 1978, 1979; Mozley, Gur, Gur, Mozley, & Alavi, 1996; Sakuma et al., 1996). Although in different sensory modalities, these findings suggest that LH deficits exist in

---

Katherine L. Narr, Linda Capetillo-Cunliffe, and Arthur W. Toga, Department of Neurology, University of California, Los Angeles; Michael F. Green, Department of Psychiatry and Biobehavioral Sciences, University of California, Los Angeles, and Veterans Affairs Greater Los Angeles Healthcare System, Los Angeles, California; Eran Zaidel, Department of Psychology, University of California, Los Angeles.

This work was supported by National Institute of Mental Health Grant MH-43292 to Michael F. Green and by National Institutes of Health Grant NS-20187 to Eran Zaidel. This work was also supported by research grants from the National Library of Medicine (LM/MH05639) and the National Institute of Neurological Disorders and Stroke (NS38253) and by a T32 training grant.

Correspondence concerning this article should be addressed to Katherine L. Narr, University of California, Los Angeles, Department of Neurology, 710 Westwood Plaza, Room 4238, Los Angeles, California 90095-1769. E-mail: narr@loni.ucla.edu

temporo–parietal brain regions important for language processing. Several studies of lexical processing in schizophrenia, however, fail to support altered hemispheric specialization in schizophrenia (Magaro & Chamrad, 1983; Mohr, Pulvermueller, Cohen, & Rockstroh, 2000; Pic'l, Magaro, & Wade, 1979).

Interhemispheric Transfer

Reports of interhemispheric transfer and corpus callosum structural abnormalities are similarly mixed in schizophrenia. Deficits in interhemispheric cooperation and increased interhemispheric facilitation (and/or interference) are documented in schizophrenia (David, 1987; Mohr et al., 2000; Spivak et al., 2000; Woodruff, Phillips, Rushe, & Wright, 1997). Likewise, increases as well as decreases in midsagittal callosal areas have been reported in patients compared with controls (Narr et al., 2000; Woodruff, McManus, & David, 1995). In the bilateral lexical decision experiment, interhemispheric effects are indexed by an improvement in performance when the target and distractor stimuli, presented to opposite visual fields, are of the same lexical category (i.e., word–word or nonword–nonword) compared with when they are of opposite categories (i.e., word–nonword). This is called the *lexicality priming effect* and it measures increased susceptibility to automatic interference or facilitation between the hemispheres (Iacoboni & Zaidel, 1996; Zaidel, Iacoboni, Laack, Crawford, & Rayman, 1998). Lexicality priming, however, is sensitive to lexical variables (Iacoboni & Zaidel, 1996; Zaidel et al., 1998), to task difficulty, and to individual differences (Weekes et al., 1999).

At least two published studies using lateralized tasks have documented abnormalities of callosal transfer in schizophrenia. Using a redundant bilateral lexical decision paradigm, in which words or phonologically regular nonwords were presented to one visual field (unilateral conditions) or simultaneously to both visual fields (bilateral condition), the controls, but not patients, exhibited a redundant bilateral word advantage, suggesting a lack of cooperation between the hemispheres in schizophrenia (Mohr et al., 2000). In contrast, when color and word stimuli presented simultaneously to each visual field were congruent compared with incongruent (Stroop effect from the lateralized Stroop paradigm), increased interhemispheric facilitation was observed in schizophrenia (David, 1993; Phillips, Woodruff, & David, 1996; Woodruff et al., 1997). These two experimental paradigms, however, may engage different types of information transfer that rely on the integrity of different callosal fibers (Aboitiz, Scheibel, Fisher, & Zaidel, 1992). The isthmus, for example, which connects posterior language regions and auditory association areas, reportedly transmits auditory (dichotic) and semantic information from the posterior superior temporal gyrus (Zaidel, Aboitiz, & Clarke, 1995). Tactile information is primarily transmitted by the body of the callosum, and phonetic information by the anterior callosal region (Clarke, McCann, & Zaidel, 1998; Clarke & Zaidel, 1994). Given that deficits in the cross-transfer of visual (David, 1987), tactile (Dimond, 1980; Spivak et al., 2000), and auditory (Green & Kotenko, 1980) information have been reported in schizophrenia, the transfer of primary sensory processes and controlled information processes (e.g., the transfer of skill) are predicted to elicit interhemispheric transfer deficits in individuals with schizophrenia. Patients, however, are expected to show benefits for the callosal transfer of automatic attentional information (Woodruff et al., 1997).

Semantic and Phonological Processing

Hemispheric differences in psycholinguistic processing strategies are measured in the bilateral lexical decision experiment by examining hemispheric capabilities for processing semantic and phonological aspects of the target word stimuli presented to each hemifield. According to the dual-route model of word recognition, both hemispheres possess a lexical–semantic route, whereas only the LH possesses a nonlexical–phonological route (Chase & Tallal, 1991; Paap, Noel, & Johansen, 1992; Weekes et al., 1999; Zaidel, Aboitiz, Clarke, Kaiser, & Matteson, 1995). Word frequency is an index of lexical processing, and indeed, in controls both visual fields are superior for discriminating high-frequency words (e.g., *sun*) compared with low-frequency words (e.g., *orchid*). Regularity of grapheme–phoneme translation is an index of nonlexical processing, and the LH (RVF) is found to be selectively sensitive to the regularity of word grapheme–phoneme correspondences, although some studies indicate that the RH does possess a phonological component (Iacoboni & Zaidel, 1996; Weekes et al., 1999). This evidence notwithstanding, when processing resources are taxed, the LH typically shows superiority for processing regular words (e.g., *stop*) versus irregular words (e.g., *yacht*).

Phonological processing deficits, reflecting largely LH competence, are reported in schizophrenia (Gur, 1978). Deficits in semantic retrieval as observed from verbal fluency experiments (Goldberg et al., 1998) and for the naming of familiar items versus unfamiliar items (frequency effects) also suggests that patients possess impairments in semantic storage and access (Laws, Al-Uzri, & Mortimer, 2000). Semantic priming abnormalities are further reported in schizophrenia, most typically in thought disorder individuals, in which automatic priming effects for associated semantic stimuli appear increased relative to healthy individuals (Henik, Nissimov, Priel, & Umansky, 1995; Kwapil, Hegley, Chapman, & Chapman, 1990; Manschreck, Maher, Milavetz, & Ames, 1988; Spitzer, 1997; Spitzer, Braun, Hermle, & Maier, 1993). This "hyperpriming" effect is thought to index an impaired inhibition of spreading of activation in associative semantic networks. Moreover, when examined in each hemisphere separately, indirectly related words appear to activate RH regions in healthy individuals (Kiefer, Weisbrod, Kern, Maier, & Spitzer, 1998) but LH regions in schizophrenia patients (Weisbrod, Maier, Harig, Himmelsbach, & Spitzer, 1998). However, intact and reduced semantic priming has also been observed in schizophrenia at short (indexing automatic processing) and longer stimulus onset asynchronies (controlled attentional processing; Barch et al., 1996; Blum & Freides, 1995; Henik, Priel, & Umansky, 1992; Ober, Vinogradov, & Shenaut, 1997). Differences in results may depend on response slowing (Chapman, Chapman, Curran, & Miller, 1994; Ober et al., 1997; Vinogradov, Poole, Willis-Shore, Ober, & Shenaut, 1998), on the stimulus onset asynchronies used (Moritz et al., 2001), or on disturbances in attentional control (Barch et al., 1996). Differences in semantic, repetition, and negative priming in schizophrenia (Baving, Wagner, Cohen, & Rockstroh, 2001; Fuller, Frith, & Jahanshahi, 2000; Moritz et al., 2001; Spitzer, 1997), however, suggest that these individuals rely on automatic retrieval strategies selectively influenced by low signal-to-noise ratios, whether intra- or interhemispheric (Spitzer, 1997).

Error Monitoring

Schizophrenia patients have long been reported to display deficits in action monitoring (e.g., Malenka, 1986), although this is denied by some (e.g., Kopp & Rist, 1994). This deficit appears enhanced in patients with delusions of control (Frith, Blakemore, & Wolpert, 2000; Frith & Done, 1989) and positive symptoms (Stirling, Hellewell, & Ndlovu, 2001). Frith et al. (2000) attributed this monitoring deficit to a cortical–cortical disconnection between the representations of the current and predicted state of the motor system in parietal cortices, on the one hand, and the representations of intended actions in prefrontal and premotor cortices. Claims of deficits in action monitoring are usually based on tasks that call for explicit error correction without external sensory feedback. However, a more critical test of failure of self-monitoring may be provided by implicit error monitoring in a discrete-trial cognitive experiment. Here the effects of erroneous responses on subsequent trials gauge effectiveness of self-monitoring. Importantly, the task is cognitive rather than sensorimotor. Second, the monitoring is implicit rather than explicit. Third, monitoring applies to strategic adjustment across trials rather than within a trial.

Several hemifield tachistoscopic behavioral laterality experiments have suggested a special role for the RH in implicit monitoring of language-related tasks (Iacoboni et al., 1997; Luh & Levy, 1995), and this has been specifically demonstrated with the bilateral lexical decision task used in our study. That is, in healthy individuals, Iacoboni et al. (1997) found that erroneous trials are followed by slower and more accurate decisions of targets in the LVF. Thus, whereas the LH is specialized for lexical decision proper, the RH seems specialized for monitoring the correctness of decisions. To investigate potentially disturbed hemispheric roles in implicit, automatic error-monitoring in schizophrenia, we used the same lexical decision paradigm as that used by Iacoboni et al. (1997).

Hypotheses

Although existing results are mixed concerning altered hemispheric competence for lexical processing in schizophrenia, we hypothesized, on the basis of the large literature supporting altered lateralization in schizophrenia, that patients would show decreased hemispheric specialization in lexical processing compared with control groups. We also specifically hypothesized that the LH in particular would be compromised and that patients would show significantly reduced word regularity effects and differences in word frequency effects supporting disturbances in both semantic and phonological processing systems. We further hypothesized that interhemispheric transfer, as indexed by lexicality priming, would be increased in patients with schizophrenia compared with controls, given that increased priming has been shown for automatic information processes and callosal transfer. Concerning monitoring, we predicted, first, a reduced monitoring competence in patients and, second, in line with reduced overall lateralization in schizophrenia, that patients would display a reduced RH specialization for implicit error monitoring.

Method

Participants

Participants included 34 medicated male outpatients with schizophrenia (mean age = 44.7 years ± 9.1; mean duration of illness = 13.5 years ± 8.7; mean months of hospitalization over past year = 0.9 ± 1.2) recruited from clinics at the VA Greater Los Angeles Healthcare System. Comparison participants included 20 male control participants (mean age = 36.5 years ± 9.4) recruited through flyers placed at the UCLA and VA Medical Centers. All patients received a diagnostic interview with the Structured Clinical Interview for *DSM–IV* (SCID–P; First, Spitzer, Gibbon, & Williams, 1997) and symptom ratings with the Expanded Brief Psychiatric Rating Scale (BPRS; Ventura, Green, Shaner, & Liberman, 1993) and the Scale for the Assessment of Negative Symptoms (Andreasen, 1984). Diagnostic interviewers were trained to a minimum kappa of .80 for rating psychotic and mood symptoms by the Diagnostic and Psychopathology Unit of the UCLA Clinical Research Center for the Study of Schizophrenia (R. P. Liberman, Principal Investigator). The mean BPRS Thinking Disturbance (hallucinations, unusual thought content, and conceptual disorganization) cluster score was 8.45 (*SD* = 3.45), and the Withdrawal/Retardation (blunted affect, emotional withdrawal, and motor retardation) cluster score was 6.55 (*SD* = 2.46). Controls received a diagnostic interview for Axis I disorders with the SCID–P and a diagnostic interview for Axis II disorders with the SCID–II (First, Spitzer, Gibbon, Williams, & Benjamin, 1994). Exclusion criteria for patients included head trauma, an identifiable neurological disorder, or drug or alcohol dependency in the last 6 months. Controls were excluded for any neurological condition, history of recurrent depression, bipolar disorder, substance dependence, or any diagnosis in the schizophrenia spectrum. In addition, controls were excluded if they had a first-degree relative with schizophrenia. All participants gave informed written consent and were paid for participation. Patients and controls were all native English speakers and comparable in education (mean years of education = 13.3 ± 1.2 and 12.9 ± 1.6 for controls and patients, respectively). All participants were strongly right handed according to the Edinburgh Handedness Inventory (Oldfield, 1971).

Procedure

Participants sat 22 in. from a Macintosh computer screen with their chins in a chinrest and their eyes at the same height as the center of the screen. Participants were required to maintain fixation on a central cross that remained on the screen for the duration of the bilateral lexical decision experiment. A warning tone sounded 750 ms prior to stimulus presentation. Letter strings that were either word targets or pronounceable nonword targets or distractors were presented simultaneously to each visual field for a period of 120 ms. The letter strings were in Helvetica font and were aligned horizontally in lowercase black on a gray background with the innermost edge at 1.5° to the right or left of the fixation cross and subtending from 1.5° to 3° of visual angle. Target letter strings were underlined in black. Participants were required to decide whether the underlined stimulus appearing randomly on either side of the central cross was a word or a nonword. Participants were asked to respond as quickly and accurately as possible using a switch box and a unimanual button press. Responding hands were switched during each block of the task. There were four blocks of stimulus presentation, each consisting of 192 trials, and the order of stimulus presentation was counterbalanced.

Stimuli were 240 letter strings from three to five letters long. Half of the stimuli were words that differed in frequency (high-frequency words >160 per million, low-frequency words <20 per million) and regularity (regular vs. irregular grapheme-to-phoneme correspondences). Half of the stimuli were orthographically regular nonwords matched in length to words. Stimuli were derived from the lexical lists composed by Seymour, Bunce, and

Evans (1992). All stimulus variables were balanced between subjects and visual fields by creating four different lists.

Experimental Design

Three mixed between and within analyses of variance (ANOVAs) with repeated measures were performed with accuracy or latency as the dependent variable to assess diagnostic group differences in hemispheric specialization for lexical variables, psycholinguistic processing, error monitoring, and interhemispheric transfer. The first ANOVA used a Group (patients; controls) × Target Wordness (word; nonword) × Distractor Wordness (word; nonword) × Visual Field (left; right) design to examine group differences in hemispheric superiority for lexical processing and interhemispheric lexicality priming effects. *D*-prime and beta were calculated to evaluate signal-detection sensitivity and response bias. The second ANOVA used a Group (patients; controls) × Word Frequency (high; low) × Word Regularity (regular; irregular) × Visual Field (left; right) design to examine group differences in psycholinguistic processing strategies for word targets. The last ANOVA assessed group differences in hemispheric error monitoring using a Group (patients; controls) × Previous Trial Correctness (correct; incorrect) × Previous Target Visual Field (left; right) × Current Target Visual Field (left; right) design.

Omnibus analyses were followed by planned comparisons only when appropriate, to protect against an inflated Type I error rate. The predicted Wordness × Visual Field interaction from the first ANOVA, however, was assessed separately in both groups even in the absence of a significant diagnosis effect to further clarify subtle differences in lexical processing based on a priori hypotheses. An alpha level of $p < .05$ (two-tailed) was used as a criterion for significance. Corrections for multiple comparisons were not used given that hemispheric effects are well established for lexical decision and one-directional hypotheses concerning the alterations of these patterns were established a priori. Finally, for significant diagnostic group effects, speed and accuracy relationships were evaluated using Pearson's correlation coefficients and speed–accuracy functions plotted to ensure that relationships, if present, did not differ between groups.

Results

A main effect of group was present for accuracy, in which participants with schizophrenia were significantly less accurate than were controls, $F(1, 52) = 4.71$, $p < .03$ (mean percentage correct ± *SD* for patients: 69 ± 17; for controls: 75 ± 16). Mean latencies (in ms), although not significantly different between diagnostic groups, were greater in patients (for patients: 884.5 ± 133.2; for controls: 807.4 ± 123.9, $p > .4$).

Hemispheric Specialization

A significant main effect of visual field was present for accuracy but not for latency, showing the predicted RVFA for lexical processing, $F(1, 52) = 34.97$, $p < .0001$. Critically, this effect did not differ between diagnostic groups (mean percentage correct ± *SD,* RVF: for controls: 78 ± 14; for patients: 73 ± 17; LVF: for controls: 71 ± 17; for patients: 66 ± 16). A main effect of wordness was present for latency but not for accuracy, in which mean latency (in ms) was reduced for word decisions, $F(1, 52) = 37.73$, $p < .0001$ (for words: 807.35 ± 127.93; for nonwords: 884.48 ± 133.20). A significant Target Wordness × Visual Field interaction was present for both accuracy, $F(1, 52) = 23.14$, $p < .0001$, and latency, $F(1, 52) = 19.27$, $p < .0001$. Even though these effects were significant in both patients and controls, means comparisons were assessed separately in each subgroup to identify subtle diagnostic differences in lexical processing. In both diagnostic groups, words in the RVF were processed more accurately (for patients, $F(1, 33) = 35.3$, $p < .0001$; for controls, $F(1, 19) = 22.8$, $p < .0001$) and more quickly (for patients, $F(1, 33) = 15.6$, $p < .0004$; for controls, $F(1, 19) = 10.6$, $p < .004$) than words in the LVF. No visual field advantage was observed for the processing of nonwords in either subgroup. In the RVF only, words were processed more accurately (for patients, $F(1, 33) = 13.9$, $p < .0007$; for controls, $F(1, 19) = 17.0$, $p < .0006$) and quickly (for patients, $F(1, 33) = 76.1$, $p < .0001$; for controls, $F(1, 19) = 163.0$, $p < .0001$) than nonwords. In the LVF, nonwords compared with words were processed more quickly by patients, $F(1, 33) = 14.6$, $p < .0006$, and controls, $F(1, 19) = 64.2$, $p < .0001$, although they were processed more accurately by patients only, $F(1, 33) = 4.9$, $p < .03$. Target Wordness × Visual Field interactions for accuracy and latency are shown in each diagnostic group in Figure 1.

Finally, *d*-prime showed a trend toward a main effect of diagnosis, $F(1, 52) = 3.43$, $p > .07$, that was higher for controls (1.50 ± 0.75) compared with patients (1.17 ± 0.73). The sensitivity in the RVF (1.56 ± 0.77) was higher than the LVF (1.03 ± 0.62), $F(1, 52) = 38.27$, $p < .0001$, but did not interact with diagnostic group. Both patients, $F(1, 33) = 28.69$, $p < .0001$, and controls, $F(1, 19) = 12.90$, $p < .002$, showed this visual field effect within groups. Beta showed a bias for saying "word" in the RVF and for saying "nonword" in the LVF, which again did not interact with diagnosis, $F(1, 52) = 0.63$, $p > .43$.

Interhemispheric Effects (Lexicality Priming)

A significant Target Wordness × Distractor Wordness interaction was present for accuracy, $F(1, 52) = 7.92$, $p < .006$, that was

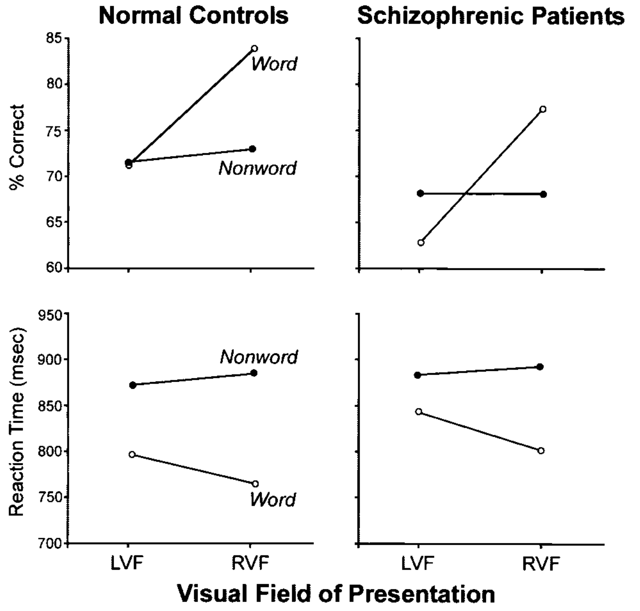

Figure 1. Target Wordness × Visual Field interactions for lexical decision. Mean accuracy data (percentage correct) are presented above, and mean reaction time data (ms) are presented below in individuals with schizophrenia (right) and control subjects (left). LVF = left visual field; RVF = right visual field. ms = milliseconds.

significantly different across diagnosis, $F(1, 52) = 3.81$, $p < .05$. This effect was present in schizophrenia patients, $F(1, 33) = 22.70$, $p < .0001$, but not in controls, $F(1, 19) = 0.19$, $p > .69$. Means comparisons, shown in Figure 2 (top) for patient and control groups separately, revealed significant lexicality priming in patients only when targets and distractors were of the same stimulus class (both words or nonwords) compared with incongruent (word, nonword): target and distractor nonword versus target nonword, distractor word, $F(1, 33) = 12.23$, $p < .001$; target and distractor word versus target word, distractor nonword, $F(1, 33) = 10.50$, $p < .01$; target and distractor word versus target nonword, distractor word, $F(1, 33) = 26.44$, $p < .0001$; target and distractor nonword versus target word, distractor nonword was not significant, $F(1, 33) = 2.57$, $p > .10$.

An overall significant Target Wordness × Distractor Wordness interaction was also present for latency, $F(1, 52) = 5.60$, $p < .02$: target and distractor nonword versus target nonword, distractor word, $F(1, 52) = 4.15$, $p < .04$; target and distractor word versus target nonword, distractor word, $F(1, 52) = 255.42$, $p < .0001$; target and distractor nonword versus target word, distractor nonword, $F(1, 52) = 159.61$, $p < .0001$; target and distractor word versus target word, distractor nonword, $p > .10$. However, although similar response-time patterns were exhibited in both diagnostic groups, when assessed in each subgroup separately, a significant Target Wordness × Distractor Wordness interaction was present in control participants only, $F(1, 19) = 10.0$, $p < .005$. Means for this interaction are also shown in Figure 2 (bottom) within each group separately.

To ensure that overall response slowing did not contribute to the lexicality priming effect observed in patients for accuracy, we correlated lexicality priming scores with overall reaction times and found no significant relationships (Pearson's $r = .15$, $p < .29$) for either patients (Pearson's $r = .09$, $p < .38$) or controls ($r = .26$, $p < .64$). Furthermore, we plotted the speed–accuracy functions of both groups by partitioning the response time distribution into 100-ms bins after pruning responses shorter and longer than 3 *SD*s away from the group mean. The curves displayed mostly a no-tradeoff function that was identical in patients and in controls.

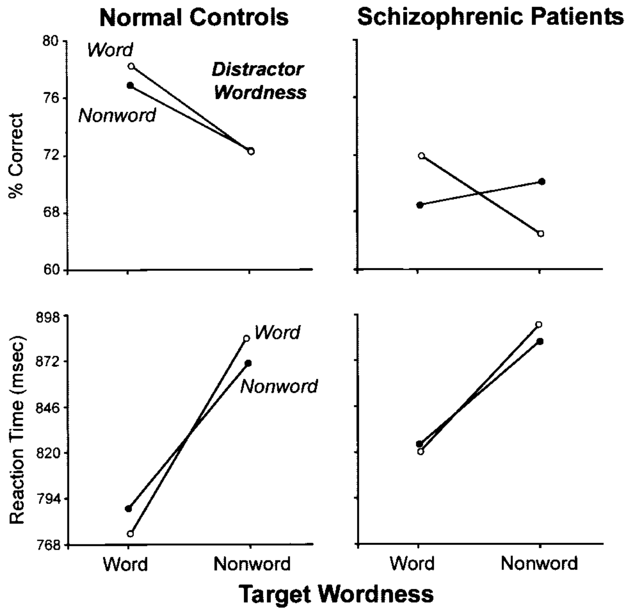

Figure 2. Target Wordness × Distractor Wordness interactions showing the percentage of correct trials (top) and mean reaction times (bottom) in individuals with schizophrenia (right) and control subjects (left). A significant diagnostic group interaction is present for accuracy only when individuals with schizophrenia exhibit enhanced lexicality priming compared with controls. ms = milliseconds.

Psycholinguistic Variables

A main effect of word frequency was present for accuracy, $F(1, 52) = 64.06$, $p < .0001$, and for latency, $F(1, 52) = 55.28$, $p < .0001$, in which high-frequency words were processed faster and more accurately than low-frequency words (high-frequency words mean accuracy: 77 ± 20; low-frequency words mean accuracy: 68 ± 18; high-frequency words mean latency [in ms]: 792.17 ± 130.72; low-frequency mean latency: 838.63 ± 147.61). A significant Word Frequency × Word Regularity interaction was present for latency, $F(1, 52) = 4.66$, $p < .03$. Overall, high-frequency regular words, $F(1, 52) = 21.76$, $p < .0001$, and high-frequency irregular words, $F(1, 52) = 59.59$, were processed more quickly than low-frequency words; and regular low-frequency words were processed more quickly than irregular low-frequency words, $F(1, 52) = p < .01$. Although this interaction did not differ significantly across diagnostic groups, when assessed within each group, this effect was significant in the patient subgroup only, $F(1, 33) = 6.0$, $p < .02$. Mean latencies for the Word Frequency × Word Regularity interactions are plotted in Figure 3.

A Word Regularity × Visual Field interaction was also present for latency, $F(1, 52) = 4.32$, $p < .04$. Decisions were faster for regular words, $F(1, 52) = 37.39$, $p < .0001$, and irregular words, $F(1, 52) = 10.07$, $p < .002$, in the RVF compared with the LVF. In the RVF only, regular word decisions were faster than those for irregular words $F(1, 52) = 4.98$, $p < .03$. Again, although not significantly different between diagnostic groups, this effect was significant in patients only $F(1, 33) = 4.1$, $p < .05$ (see Figure 4).

Error Monitoring and Momentum

The same main effects for target visual field and diagnosis were observed for accuracy as described above. There was also significant interaction between previous trial visual field and current trial visual field, $F(1, 51) = 58.2$, $p < .001$, such that congruent visual fields yielded better performance. This effect did not differ between diagnostic groups ($p > .45$) and was significant within each diagnostic subgroup independently: for patients, $F(1, 33) = 26.86$, $p < .0001$; for controls, $F(1, 19) = 46.88$, $p < .0001$.

The latency ANOVA showed the expected RVFA. Again, there was a significant interaction of previous target visual field and current target visual field, $F(1, 51) = 36.8$, $p < .001$, showing speeding up for congruent pairs, and again, this did not interact with diagnosis, with both patients, $F(1, 33) = 21.05$, $p < .0001$, and controls, $F(1, 19) = 19.66$, $p < .0003$, showing this effect separately. Means from the previous target visual field and current target visual field interactions for accuracy (top) and latency (bottom) are plotted in Figure 5, showing similar visual field momentum or priming effects within both diagnostic groups.

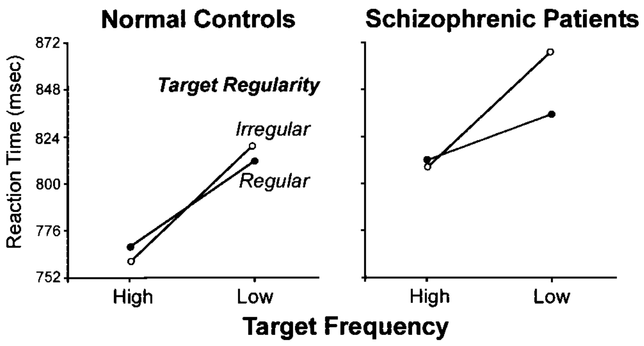

Figure 3. Word Frequency × Word Regularity interactions for reaction times (ms) presented within each diagnostic group. ms = milliseconds.

A significant two-way interaction between previous trial correctness and diagnosis was observed for latency, $F(1, 51) = 4.64$, $p < .036$, showing that controls slowed down after errors, whereas patients speeded up (see Figure 6). Finally, there was a significant two-way interaction between previous trial correctness and target visual field, $F(1, 51) = 4.28$, $p < .043$, showing an adaptive slowing down in the LVF following errors, $F(1, 51) = 4.02$, $p < .05$, but a nonadaptive speeding up in the RVF following errors, $F(1, 51) = 24.31$, $p < .0001$. This effect did not interact with diagnosis ($p > .46$) but reached statistical significance within the patients only, $F(1, 33) = 6.12$, $p < .02$. In summary, participants with schizophrenia appeared to show impaired overall metacognition but no change in hemispheric roles in error monitoring.

Discussion

Hemispheric Specialization

Several language-related deficits are reported in schizophrenia (e.g., DeLisi et al., 1997; Ragland, Gur, Klimas, McGrady, & Gur, 1999; Thomas, Kearney, Napier, & Ellis, 1996). Our results, however, support that hemispheric abilities for lexical processing are similar in schizophrenia compared with controls. Rather than showing a selective LH deficit as originally hypothesized, the overall performance deficit exhibited by schizophrenia patients may instead suggest that both hemispheres are equally compromised. Specifically, patients showed the same LH superiority for lexical decisions as did controls, including an overall RVFA (LH superiority), an advantage for word versus nonword decisions, and an RVFA for processing words.

Although one study reported an LVF (as opposed to an RVF) advantage for processing consonant–vowel–consonant syllables in

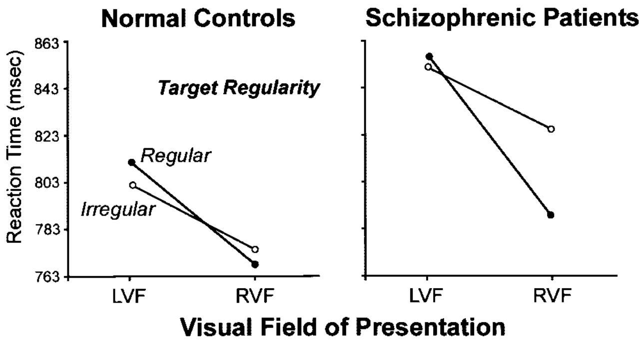

Figure 4. Word Regularity × Visual Field interactions for reaction times (ms) presented within each diagnostic group. LVF = left visual field; RVF = right visual field. ms = milliseconds.

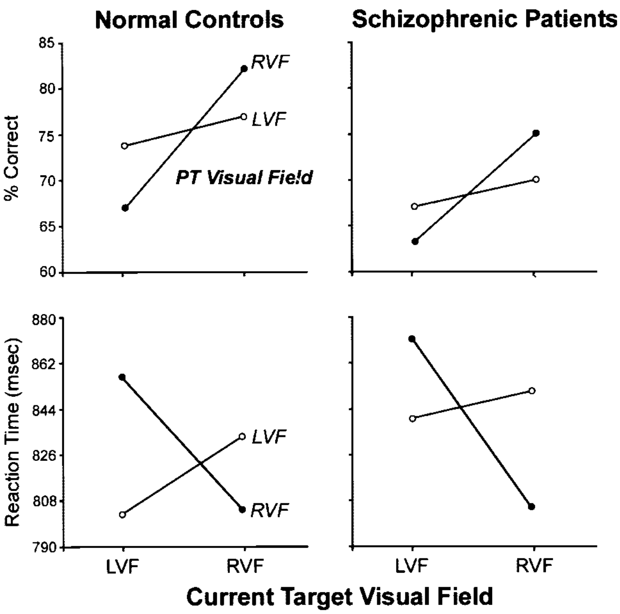

Figure 5. Previous target visual field and current target visual field interactions for accuracy (top) and latency (bottom) presented within each diagnostic group. LVF = left visual field; RVF = right visual field. ms = milliseconds.

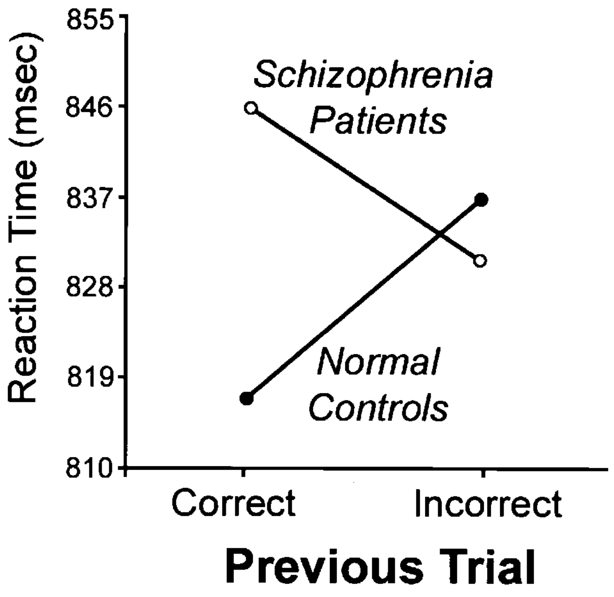

Figure 6. Previous Trial Correctness × Diagnostic Group interaction for reaction time (ms). Controls slow down after errors, whereas individuals with schizophrenia speed up. ms = milliseconds.

schizophrenia (Gur, 1978), other studies have failed to replicate this result (Magaro & Chamrad, 1983; Pic'l et al., 1979). Moreover, a recent study sharing some stimulus parameters with the present experiment showed a significant RVFA for word processing in both patients and controls, consistent with our results (Mohr et al., 2000). In contrast to our study, however, Mohr and colleagues also observed an RVFA for the processing of nonwords, whereas we found no significant visual field advantage for nonword processing in either diagnostic group (see Figure 1). Our study, however, used distractors presented simultaneously to the opposite hemifield, thus maximizing independent hemispheric processing (Iacoboni & Zaidel, 1996; Zaidel et al., 1990). Overall, lateralized lexical decision effects support the conclusion that nonwords may be processed equally well by either hemisphere but that the LH has a distinct advantage for processing word stimuli in both patient and control groups.

Interhemispheric Transfer

Schizophrenia patients showed enhanced interhemispheric cooperation compared with controls, as indexed by increased lexicality priming for accuracy. The significant lexicality priming effects for latency did not interact with diagnostic group, although this effect failed to reach statistical significance within the patient subgroup. Although accuracy and response time are regarded as equivalent and interchangeable indices of performance, accuracy is a more sensitive measure of laterality (Zaidel et al., 1990). In control groups, Iacoboni and Zaidel (1996) found lexicality priming in reaction time but not in accuracy, although a more focused study found this effect in accuracy but not latency (Zaidel et al., 1998). A more robust lexicality priming effect, however, is expressed in both dependent variables.

The overall performance advantage observed in controls may suggest that the lexical decision task was less difficult and less taxing on processing resources in controls compared with patients. Results from experiments manipulating task complexity indicate that processing resources in the two hemispheres are more likely to be shared, resulting in increased callosal exchange, when task difficulty is increased (Zaidel et al., 1990). Interhemispheric cooperation for accuracy may thus be enhanced in patients if they experience more difficulty with the bilateral lexical decision task. However, it is not the case that patients exhibited increased lexicality priming in accuracy simply because they had slower overall reaction times. First, there was no main effect of diagnosis for latency. Second, there was no significant relationship between lexicality priming and overall reaction time in either diagnostic group. Furthermore, speed–accuracy relationships showed no tradeoff functions and were identical in patient and control study groups.

Differences in subject variables such as gender, handedness, and potentially, age, may additionally influence interhemispheric transfer (Zaidel et al., 1990) and thus lexicality priming (Weekes & Zaidel, 1996). Experimental and control groups were matched on the critical variables of gender, handedness, and education, although patients were older on average than controls. There is evidence that callosal connectivity for inhibitory control signals remains static or increases with age (Reuter-Lorenz & Stanczak, 2000). Transfer of other types of information, particularly for sensorimotor signals, however, may decrease with age (Jeeves & Moes, 1996; Moes, Jeeves, & Cook, 1995). Although there are no data to clarify the effects of age on lexicality priming, lexicality priming is likely to be mediated by language-specific lexical signals (Iacoboni & Zaidel, 1996), and we do not expect this effect to increase with age.

If we view lexicality priming as occurring at the lexical level of representation, then increased lexicality priming in schizophrenia is consistent with spreading activation increases in semantic networks (Ober et al., 1997). Alternatively, lexicality priming may reflect a difficulty in suppressing irrelevant information (i.e., the distractor) in the opposite visual field and thus may be related to deficits in the control of attention in schizophrenia (Barch et al., 1996). Previous research has shown, in turn, impaired callosal transfer, supporting a "disconnection syndrome" (Biswas, Haque-Nizamie, Pandey, & Mandal, 1996; Dimond, 1980; Green, 1978; Mandal, Singh, Asthana, & Srivastava, 1992) as well as facilitation of information processing between the hemispheres in schizophrenia. Facilitation is typically observed in selective attention tasks such as the lateralized Stroop paradigm (David, 1993; Phillips et al., 1996; Woodruff et al., 1997). These findings are consistent with our observations of increased lexicality priming in schizophrenia, as both tasks involve automatic responses for lexical information that are likely subserved by similar callosal channels. Our results, however, appear inconsistent with those reporting a lack of interhemispheric cooperation for the bilateral presentation of redundant stimuli (Mohr et al., 2000). Different types of priming effects, mediated by different callosal channels, however, may contribute to discrepancies between results. That is, redundant bilateral presentations may facilitate processing at an earlier stage than do lexical distractors, and the former may engage more posterior callosal channels. Moreover, the priming effect observed by Mohr et al. (2000) may have been due to intrahemispheric facilitation subsequent to sensory interhemispheric transfer. This possibility may not be excluded because there is no control condition with redundant presentations in each VF. In contrast, our paradigm has been shown to yield lexicality priming only in the interhemispheric condition (Zaidel et al., 1998).

Psycholinguistic Processing

Patients in our study failed to exhibit significant differences in phonological and semantic processing strategies compared with controls. Both diagnostic groups exhibited significant word frequency effects, in which performance was better for high- compared with low-frequency words. This effect did not differ across visual fields, confirming that both hemispheres are sensitive to word frequency effects. Groups also did not differ significantly in their hemispheric superiority for processing regular words, in which regular words in the RVF were processed more quickly than irregular words, supporting the model that only the LH has a nonlexical route (Zaidel, 1998). This finding is contrary to that of Gur (1978), in which patients showed an LVFA for recognizing consonant–vowel–consonants. In fact, within groups, only the patients showed the standard Word Frequency × Word Regularity interaction, with a significant advantage for regular words over irregular words only for low-frequency words. This confirms normal psycholinguistic strategies in schizophrenia patients.

Error Monitoring

Our results showed that previous-trial correctness interacts with previous-trial visual field (in the LVF, a previous correct trial increases accuracy on the current trial; in the RVF, it reduces it) in both diagnostic groups. However, for latency, a previous-trial correctness by diagnostic group interaction was observed, in which controls slowed down after an incorrect trial whereas patients speeded up (see Figure 6). Again there was an interaction between previous-trial correctness and current-trial visual field, such that in the LVF, responses for targets slowed down after an error whereas in the RVF, responses for targets speeded up. This indicates that the RH is a better implicit error monitor, but again, this effect is not different in diagnostic groups. In sum, patients overall are poorer monitors. Also, the LH is a poor monitor, but this is just as true for patients as it is for controls. Thus, here too the laterality effect is similar in schizophrenia. Our observation of a monitoring deficit in lexical decision making in schizophrenia extends previous results on explicit error monitoring during a sensorimotor task to (a) implicit error monitoring of (b) a cognitive task resulting in the adjustment of processing strategies (c) across trials. It follows that the neural basis for the schizophrenia deficit in error monitoring cannot be solely a parietal–frontal disconnection of sensorimotor circuits (Frith et al., 2000).

Conclusion

Our results support that LH superiority for language processing and RH superiority for error monitoring are not altered in chronic schizophrenia, although patients continue to show global deficits in information processing that may reflect impairments in the processing capabilities of both hemispheres. Our results do not contradict findings of specific language-related deficits in schizophrenia but instead suggest that LH dominance for lexical processing and RH superiority for error monitoring do not differ from those of healthy individuals.

Our results further support that schizophrenia is associated with increased automatic interhemispheric transfer during language tasks. Increased interhemispheric priming in schizophrenia is consistent with hypotheses that assume that excessive connectivity exists between the two hemispheres in individuals with schizophrenia (Randall, 1983). Indeed, a model of integrated brain functioning (Miran & Miran, 1984) supports this position, suggesting that schizophrenia neuropathology, rather than being localized in one hemisphere, arises from the disorganization of information processing between the hemispheres and between cortical and subcortical regions. Furthermore, increased lexicality priming may result from similar mechanisms as those responsible for the increased semantic, repetition, negative, and categorical priming effects observed in individuals with schizophrenia (Baving et al., 2001; Fuller et al., 2000; Moritz et al., 2001; Spitzer, 1997). Specifically, it has been suggested that increased indirect semantic priming reflects a passive spreading of associational activation for lexical access in which the threshold for related information is lowered in individuals with schizophrenia (Neely, 1991; Spitzer, 1997). Discrepancies in results from earlier studies suggest, however, that information transfer abnormalities are sensitive to the stimulus parameters used in the task and depend on the information transferred and callosal channel engaged. Further experiments in schizophrenia are thus needed to systematically assess hemispheric asymmetries in different modules and transfer in different callosal channels to clarify why patients show both deficits and facilitation in interhemispheric transfer.

References

Aboitiz, F., Scheibel, A. B., Fisher, R. S., & Zaidel, E. (1992). Fiber composition of the human corpus callosum. *Brain Research, 598*(1–2), 143–153.

Andreasen, N. C. (1984). *The Scale for the Assessment of Negative Symptoms (SANS).* Iowa City: The University of Iowa.

Barch, D. M., Cohen, J. D., Servan-Schreiber, D., Steingard, S., Steinhauer, S. S., & van Kammen, D. P. (1996). Semantic priming in schizophrenia: An examination of spreading activation using word pronunciation and multiple SOAs. *Journal of Abnormal Psychology, 105*, 592–601.

Baving, L., Wagner, M., Cohen, R., & Rockstroh, B. (2001). Increased semantic and repetition priming in schizophrenic patients. *Journal of Abnormal Psychology, 110,* 67–75.

Biswas, A. K., Haque-Nizamie, S., Pandey, R., & Mandal, M. K. (1996). Bilateral transfer deficit in schizophrenia: A trait marker. *Psychiatry Research, 64*(2), 115–120.

Blum, N. A., & Freides, D. (1995). Investigating thought disorder in schizophrenia with the lexical decision task. *Schizophr Research, 16,* 217–224.

Chapman, L. J., Chapman, J. P., Curran, T. E., & Miller, M. B. (1994). Do children and the elderly show heightened semantic priming? How to answer the question. *Developmental Review, 14*(2), 159–185.

Chase, C. H., & Tallal, P. (1991). Cognitive models of developmental reading disorders. In J. E. Obrzut & G. W. Hynd (Eds.), *Neuropsychological foundations of learning disabilities: A handbook of issues, methods, and practice* (pp. 199–240). San Diego, CA: Academic Press.

Clarke, J. M., McCann, C. M., & Zaidel, E. (1998). The corpus callosum and language: Anatomical-behavioral relationships. In E. Mark Beeman & E. Christine Chiarello (Eds.), *Right hemisphere language comprehension: Perspectives from cognitive neuroscience* (pp. 27–50). Mahwah, NJ: Erlbaum.

Clarke, J. M., & Zaidel, E. (1994). Anatomical-behavioral relationships: Corpus callosum morphometry and hemispheric specialization. *Behavioral Brain Research, 64*(1–2), 185–202.

David, A. S. (1987). Tachistoscopic tests of colour naming and matching in schizophrenia: Evidence for posterior callosum dysfunction? *Psychological Medicine, 17,* 621–630.

David, A. S. (1993). Callosal transfer in schizophrenia: Too much or too little? *Journal of Abnormal Psychology, 102,* 573–579.

DeLisi, L. E., Sakuma, M., Kushner, M., Finer, D. L., Hoff, A. L., & Crow, T. J. (1997). Anomalous cerebral asymmetry and language processing in schizophrenia. *Schizophrenia Bulletin, 23,* 255–271.

Dimond, S. J. (1980). Some failures of intermanual and cross-lateral transfer in chronic schizophrenia. *Journal of Abnormal Psychology, 89,* 505–509.

First, M. B., Spitzer, R. L., Gibbon, M., & Williams, J. B. W. (1997). *Structured Clinical Interview for DSM–IV Axis I disorders: Patient edition.* New York: New York State Psychiatric Institute.

First, M. B., Spitzer, R. L., Gibbon, M., Williams, J. B. W., & Benjamin, L. (1994). *Structured Clinical Interview for DSM–IV Axis II personality disorders (Version 2.0).* New York: New York State Psychiatric Institute.

Frith, C. D., Blakemore, S.-J., & Wolpert, D. M. (2000). Explaining the symptoms of schizophrenia: Abnormalities in the awareness of action. *Brain Research Review, 31,* 357–363.

Frith, C. D., & Done, D. J. (1989). Experiences of alien control in schizophrenia reflect a disorder in the central monitoring of action. *Psychological Medicine, 19,* 359–363.

Fuller, R., Frith, C. D., & Jahanshahi, M. (2000). Reduced negative priming does indicate reduced cognitive inhibition in schizophrenia. *Cognitive Neuropsychiatry, 5*(1), 21–35.

Goldberg, T. E., Aloia, M. S., Gourovitch, M. L., Missar, D., Pickar, D., & Weinberger, D. R. (1998). Cognitive substrates of thought disorder: I. The semantic system. *American Journal of Psychiatry, 155,* 1671–1676.

Goodarzi, M. A., Wykes, T., & Hemsley, D. R. (2000). Cerebral lateralization of global-local processing in people with schizotypy. *Schizophrenia Research, 45,* 115–121.

Green, P. (1978). Defective interhemispheric transfer in schizophrenia. *Journal of Abnormal Psychology, 87,* 472–480.

Green, P., & Kotenko, V. (1980). Superior speech comprehension in schizophrenics under monaural versus binaural listening conditions. *Journal of Abnormal Psychology, 89,* 399–408.

Gruzelier, J., Wilson, L., & Richardson, A. (1999). Cognitive asymmetry patterns in schizophrenia: Retest reliability and modification with recovery. *International Journal of Psychophysiology, 34,* 323–331.

Gur, R. E. (1978). Left hemisphere dysfunction and left hemisphere overactivation in schizophrenia. *Journal of Abnormal Psychology, 87,* 226–238.

Gur, R. E. (1979). Cognitive concomitants of hemispheric dysfunction in schizophrenia. *Archives of General Psychiatry, 36,* 269–274.

Gur, R. E., & Chin, S. (1999). Laterality in functional brain imaging studies of schizophrenia. *Schizophrenia Bulletin, 25,* 141–156.

Henik, A., Nissimov, E., Priel, B., & Umansky, R. (1995). Effects of cognitive load on semantic priming in patients with schizophrenia. *Journal of Abnormal Psychology, 104,* 576–584.

Henik, A., Priel, B., & Umansky, R. (1992). Attention and automaticity in semantic processing of schizophrenic patients. *Neuropsychiatry, Neuropsychology, & Behavioral Neurology, 5*(3), 161–169.

Iacoboni, M., Rayman, J., & Zaidel, E. (1997). Does the previous trial affect lateralized lexical decision? *Neuropsychologia, 35,* 81–88.

Iacoboni, M., & Zaidel, E. (1996). Hemispheric independence in word recognition: Evidence from unilateral and bilateral presentations. *Brain Language, 53,* 121–140.

Jeeves, M. A., & Moes, P. (1996). Interhemispheric transfer time differences related to aging and gender. *Neuropsychologia, 34,* 627–636.

Kiefer, M., Weisbrod, M., Kern, I., Maier, S., & Spitzer, M. (1998). Right hemisphere activation during indirect semantic priming: Evidence from event-related potentials. *Brain Language, 64,* 377–408.

Kopp, B., & Rist, F. (1994). Error-correcting behavior in schizophrenic patients. *Schizophrenia Research, 13,* 11–22.

Kwapil, T. R., Hegley, D. C., Chapman, L. J., & Chapman, J. P. (1990). Facilitation of word recognition by semantic priming in schizophrenia. *Journal of Abnormal Psychology, 99,* 215–221.

Kwon, J. S., McCarley, R. W., Hirayasu, Y., Anderson, J. E., Fischer, I. A., Kikinis, R., et al. (1999). Left planum temporale volume reduction in schizophrenia. *Archives of General Psychiatry, 56,* 142–148.

Laws, K. R., Al-Uzri, M., & Mortimer, A. M. (2000). Lexical knowledge degradation in schizophrenia. *Schizophrenia Research, 45,* 123–131.

Lior, R., & Nachson, I. (1999). Impairments in judgment of chimeric faces by schizophrenic and affective patients. *International Journal of Neuroscience, 97*(3–4), 185–209.

Luh, K. E., & Levy, J. (1995). Interhemispheric cooperation: Left is left and right is right, but sometimes the twain shall meet. *Journal of Experimental Psychology: Human Perception & Performance, 21,* 1243–1258.

Magaro, P. A., & Chamrad, D. L. (1983). Information processing and lateralization in schizophrenia. *Biological Psychiatry, 18,* 29–44.

Malenka, R. C. (1986). Central error-correcting behavior in schizophrenia and depression. *Biological Psychiatry, 21,* 263–273.

Mandal, M. K., Singh, S. K., Asthana, H. S., & Srivastava, P. (1992). Bilateral transfer deficit in schizophrenia. *Comprehensive Psychiatry, 33,* 319–324.

Manschreck, T. C., Maher, B. A., Milavetz, J. J., & Ames, D. (1988). Semantic priming in thought disordered schizophrenic patients. *Schizophrenia Research, 1,* 61–66.

Measso, G., & Zaidel, E. (1990). Effect of response programming on hemispheric differences in lexical decision. *Neuropsychologia, 28,* 635–646.

Miran, M., & Miran, E. (1984). Cerebral asymmetries: Neuropsychological measurement and theoretical issues. *Biological Psychology, 19,* 295–304.

Moes, P., Jeeves, M. A., & Cook, K. (1995). Bimanual coordination with aging: Implications for interhemispheric transfer. *Developmental Neuropsychology, 11*(1), 23–40.

Mohr, B., Pulvermueller, F., Cohen, R., & Rockstroh, B. (2000). Interhemispheric cooperation during word processing: Evidence for callosal transfer dysfunction in schizophrenic patients. *Schizophrenia Research, 46,* 231–239.

Moritz, S., Mersmann, K., Kloss, M., Jacobsen, D., Andresen, B., Krausz, M., et al. (2001). Enhanced semantic priming in thought-disordered schizophrenic patients using a word pronunciation task. *Schizophrenia Research, 48,* 301–305.

Mozley, L. H., Gur, R. C., Gur, R. E., Mozley, P. D., & Alavi, A. (1996). Relationships between verbal memory performance and the cerebral distribution of fluorodeoxyglucose in patients with schizophrenia. *Biological Psychiatry, 40,* 443–451.

Narr, K. L., Thompson, P. M., Moussai, J., Zoumalan, C., Rayman, J., & Toga, A. W. (2001). 3D mapping of gyral shape and cortical surface asymmetries in schizophrenia: Gender effects. *American Journal of Psychiatry, 158,* 244–255.

Narr, K. L., Thompson, P. M., Sharma, T., Moussai, J., Cannestra, A., & Toga, A. W. (2000). Mapping morphology of the corpus callosum in schizophrenia. *Cerebral Cortex, 10*(1), 40–49.

Neely, J. H. (1991). Semantic priming effects in visual word recognition: A selective review of current findings and theories. In D. Besner & G. W. Humphreys (Eds.), *Basic processes in reading: Visual word recognition* (pp. 264–336). Hillsdale, NJ: Erlbaum.

Ober, B. A., Vinogradov, S., & Shenaut, G. K. (1997). Automatic versus controlled semantic priming in schizophrenia. *Neuropsychology, 11,* 506–513.

Oldfield, R. C. (1971). The assessment and analysis of handedness: The Edinburgh Inventory. *Neuropsychologia, 9*(1), 97–113.

Paap, K. R., Noel, R. W., & Johansen, L. S. (1992). Dual-route models of print to sound: Red herrings and real horses. In R. Frost & L. Katz (Eds.), *Orthography, phonology, morphology, and meaning* (pp. 293–318). Amsterdam: North-Holland.

Petty, R. G. (1999). Structural asymmetries of the human brain and their disturbance in schizophrenia. *Schizophrenia Bulletin, 25,* 121–139.

Phillips, M. L., Woodruff, P. W. R., & David, A. S. (1996). Stroop interference and facilitation in the cerebral hemispheres in schizophrenia. *Schizophrenia Research, 20,* 57–68.

Pic'l, A. K., Magaro, P. A., & Wade, E. A. (1979). Hemispheric functioning in paranoid and nonparanoid schizophrenia. *Biological Psychiatry, 14,* 891–903.

Ragland, J. D., Gur, R. E., Klimas, B. C., McGrady, N., & Gur, R. C. (1999). Neuropsychological laterality indices of schizophrenia: Interactions with gender. *Schizophrenia Bulletin, 25,* 79–89.

Randall, J. H. (1983). *Morphological structure and language acquisition.* Boston: University of Massachusetts.

Reuter-Lorenz, P. A., & Stanczak, L. (2000). Differential effects of aging on the functions of the corpus callosum. *Developmental Neuropsychology, 18*(1), 113–137.

Sakuma, M., Hoff, A. L., & DeLisi, L. E. (1996). Functional asymmetries in schizophrenia and their relationship to cognitive performance. *Psychiatry Research, 65*(1), 1–13.

Seymour, P. H. K., Bunce, F., & Evans, H. M. (1992). A framework for orthographic assessment and remediation. In C. Sterling & C. Robson (Eds.), *Psychology, spelling, and education.* Clevedon, England. Multilingual Matters.

Spitzer, M. (1997). A cognitive neuroscience view of schizophrenic thought disorder. *Schizophrenia Bulletin, 23,* 29–50.

Spitzer, M., Braun, U., Hermle, L., & Maier, S. (1993). Associative semantic network dysfunction in thought-disordered schizophrenic patients: Direct evidence from indirect semantic priming. *Biological Psychiatry, 34,* 864–877.

Spivak, B., Elimelech, D., Ocring, R., Mester, R., Kotler, M., & Weizman, A. (2000). Hemispheric function in disorganized type schizophrenia: Performance on the Quality Extinction Test. *European Psychiatry, 15,* 402–406.

Stirling, J. D., Hellewell, J. S. E., & Ndlovu, D. (2001). Self-monitoring dysfunction and the positive symptoms of schizophrenia. *Psychopathology, 34*(4), 198–202.

Thomas, P., Kearney, G., Napier, E., & Ellis, E. (1996). Speech and language in first onset psychosis differences between people and schizophrenia, mania, and controls. *British Journal of Psychiatry, 168,* 337–343.

Ventura, J., Green, M. F., Shaner, A., & Liberman, R. P. (1993). Training and quality assurance with the Brief Psychiatric Rating Scale: “The Drift Busters.” *International Journal of Methods in Psychiatric Research, 3,* 221–224.

Vinogradov, S., Poole, J. H., Willis-Shore, J., Ober, B. A., & Shenaut, G. K. (1998). Slower and more variable reaction times in schizophrenia: What do they signify? *Schizophrenia Research, 32,* 183–190.

Weekes, N. Y., Capetillo-Cunliffe, L., Rayman, J., Iacoboni, M., & Zaidel, E. (1999). Individual differences in the hemispheric specialization of dual route variables. *Brain Language, 67*(2), 110–133.

Weekes, N. Y., & Zaidel, E. (1996). The effects of procedural variation on lateralized Stroop effects. *Brain and Cognition, 31,* 308–330.

Weisbrod, M., Maier, S., Harig, S., Himmelsbach, U., & Spitzer, M. (1998). Lateralised semantic and indirect semantic priming effects in people with schizophrenia. *British Journal of Psychiatry, 172,* 142–146.

Woodruff, P. W. R., McManus, I. C., & David, A. S. (1995). Meta-analysis of corpus callosum size in schizophrenia. *Journal of Neurology, Neurosurgery & Psychiatry, 58,* 457–462.

Woodruff, P. W. R., Phillips, M. L., Rushe, T., & Wright, I. C. (1997). Corpus callosum size and inter-hemispheric function in schizophrenia. *Schizophrenia Research, 23,* 189–196.

Zaidel, E. (1995). Interhemispheric transfer in the split brain: Long-term status following complete cerebral commissurotomy. In R. J. Davidson & K. Hugdahl (Eds.), *Brain asymmetry* (pp. 491–532). Cambridge, MA: MIT Press.

Zaidel, E. (1998). Language in the right hemisphere following callosal disconnection. In B. Stemmer & H. Whitaker (Eds.), *Handbook of neurolinguistics* (pp. 369–383). New York: Academic Press.

Zaidel, E., Aboitiz, F., & Clarke, J. M. (1995). Sexual dimorphism in interhemispheric relations: Anatomical-behavioral convergence. *Biological Research, 28,* 27–43.

Zaidel, E., Aboitiz, F., Clarke, J., Kaiser, D., & Matteson, R. (1995). Sex differences in interhemispheric relations for language. In L. Frederick & E. Kitterle (Eds.), *Hemispheric communication: Mechanisms and models* (pp. 85–175). Hillsdale, NJ: Erlbaum.

Zaidel, E., Clarke, J. M., & Suyenobu, B. (1990). Hemispheric independence: A paradigm case for cognitive neuroscience. In A. B. Scheibel & A. F. Wechsler (Eds.), *Neurobiology of higher cognitive function* (pp. 297–355). New York: Guilford Press.

Zaidel, E., Iacoboni, M., Laack, K. A., Crawford, B. T., & Rayman, J. (1998). Implicit interhemispheric lexicality priming in lateralized lexical decision. *Brain Language, 65,* 102–105.

Received August 1, 2001
Revision received September 1, 2002
Accepted April 28, 2003 ■