

**THE EFFECTS OF ATTENTION ON LANGUAGE LATERALITY
IN SCHIZOPHRENIA**

by

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ABSTRACT

Language lateralization is reduced in schizophrenia patients relative to healthy individuals. It remains unclear whether these findings are moderated by the impaired attentional processes seen in the disorder. This study investigated whether patients increase their right ear advantage with the aid of a tone cue to systematically control for the effects of decreased alertness. Eighteen right-handed patients with schizophrenia or schizoaffective disorder and 18 right-handed healthy controls matched on age, gender, and parental education, completed a traditional dichotic listening task and a second dichotic task in which a binaural tone was presented prior to each stimulus pair. It was hypothesized that patients would demonstrate a stronger REA in the tone condition, and would benefit more from the tone than controls. Results revealed similar lateralization between groups in both conditions, and thus did not support the hypotheses. Nonetheless, results also suggested that the tone decreased attentional resource demands during dichotic monitoring.

DEDICATION

To my parents, Alfred and Lois Boudreau, for their unfailing support and encouragement throughout all these years. Your love and devotion have truly inspired me.

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INTRODUCTION

Since Emile Kraepelin began studying “Dementia Praecox” in the late 19th century, researchers have been interested in the cognitive deficits seen in what is now known as schizophrenia (Heinrichs & Zakzanis, 1998; Liddle, 1987a; McCarley et al., 1999). Past research has shown that patients with this disorder tend to exhibit impairment in a number of cognitive domains, such as general intelligence (Goldberg, Gold, Greenberg, & Griffin, 1993), memory (Aleman, Hijman, de Haan, & Kahn, 1999), attention (Braff, 1993), and executive function (Morice & Delahunty, 1996). Not only are such deficits consistently reported in the literature, but they have also been shown to predate the commencement of medication treatment (Saykin et al., 1994), as well as the onset of clinical symptoms, albeit with significant attenuation (Green, 1998).

Language is another cognitive function that is often impaired in schizophrenia, as evidenced by moderate to large effect sizes, and is comparable to other common domains of cognitive deficit (Berlim, Mattevi, Belmonte-de-Abreu, & Crow, 2003; Heinrichs & Zakzanis, 1998). More specifically, it has been shown that patients tend to have both expressive and receptive language deficits (DeLisi et al., 1997). Moreover, symptoms of poverty of speech can be seen as a failure for verbal fluency, whereas auditory hallucinations and formal thought disorder can be viewed as deviations from organized speech (Crow, 1997).

One aspect of language functioning that is of particular interest in schizophrenia is the lateralization of verbal abilities. In fact, some researchers have argued that schizophrenia itself develops from abnormal laterality due to a failure for hemispheric dominance for language (Crow, 1997). It is important to note, however, that there are

some healthy individuals with bilateral language dominance (Hugdahl, 2003; McKeever, Seitz, Krusch, & Van Eys, 1995), and thus unusual laterality alone cannot be a basis for schizophrenia. Nevertheless, researchers have attempted to quantify language laterality in individuals with schizophrenia in order to better comprehend the degree and impact of aberrant lateralization. The present study aims to further elucidate language laterality in schizophrenia by systematically investigating the effects of attention on language lateralization.

Structural Abnormalities

Interestingly, studies investigating the anatomical structures involved in language have demonstrated abnormal cerebral volumes and asymmetry in patients with schizophrenia (Petty, 1999; Wright et al., 2000). In healthy individuals, language areas in the temporal lobe, including the planum temporale, are generally significantly larger in the left hemisphere of the brain (Jancke & Steinmetz, 2003). This finding is independent of gender and handedness, although females and right-handed adults tend to have a relatively larger left planum temporale than males and left-handers, respectively (Shapleske, Rossell, Woodruff, & David, 1999). Conversely, patients with schizophrenia generally have enlarged lateral ventricles and reduced temporal lobe volumes, particularly in the left hemisphere, which cannot be solely accounted for by overall reduction in brain volume (Petty, 1999; Shenton, Dickey, Frumin, & McCarley, 2001). Neuroimaging and post-mortem studies have revealed reduced left superior temporal gyrus volume, an area that contains the planum temporale, which is implicated in language processing (Highley, McDonald, Walker, Esiri, & Crow, 1999; Shenton et al., 2001; Wright et al., 2000). The reduction in superior temporal gyrus volume is specific to

this area and cannot be accounted for by an overall decrease in left hemisphere volume (Wright et al., 2000). A review of magnetic resonance imaging (MRI) findings has also revealed a reduction in normal asymmetry of the planum temporale in schizophrenia that results from a somewhat larger right planum temporale volume than in healthy controls, rather than a significantly reduced left planum temporale volume in patients (Shapleske et al., 1999).

These findings have generally been shown to be independent of gender and handedness (Bryant, Buchanan, Vadar, Breier, & Rothman, 1999; Shapleske et al., 1999; Sommer, Aleman, Ramsey, Bouma, & Kahn, 2001a; Wright et al., 2000). Moreover, similar results have been found in studies examining temporal lobe volumes in patients with first-episode schizophrenia and in individuals with schizotypal personality disorder, a less severe spectrum disorder. Consequently, the above cerebral abnormalities are not due to chronic illness or medication (Dickey et al., 1999; McCarley et al., 1999; Shenton et al., 2001). A review of post-mortem neurohistological and structural imaging studies revealed that volume reductions of the superior temporal gyrus were found in schizophrenia, but not in mood disorder, further highlighting the specificity of such cerebral abnormalities in schizophrenia (Baumann & Bogerts, 1999).

Functional Asymmetry

In addition to anatomical asymmetries in the brain, evidence suggests that functional differences exist between the two cerebral hemispheres in healthy individuals. More specifically, verbal material is more efficiently processed in the left hemisphere of the brain, whereas nonverbal material is more efficiently processed in the right hemisphere (Geschwind, 1972; Humphrey & Zangwill, 1952; Kimura, 1966; McFie,

Piercy, & Zangwill, 1950). Such specialization of cerebral function is defined as laterality.

Of particular interest to the present study is the left hemisphere's specialization for language processes. The most commonly used technique to investigate language lateralization is the dichotic listening task (Kimura, 1961b). In this task, participants are presented with two different lists of stimuli spoken simultaneously, one to each ear. The majority of right-handed adults identify verbal stimuli presented to the right ear more accurately than those delivered to the left ear (Kimura, 1966). Based on evidence that the contralateral connections from ear to cerebral cortex are more efficiently processed than the ipsilateral pathways (Kimura, 1961a), it is generally concluded that this right ear advantage (REA) is due to the left hemisphere's specialization for verbal functions. The reader is referred to Appendix A for an overview of the psychometric properties of the dichotic listening technique.

Despite some negative findings (e.g., Hatta, Ayetani, & Yoshizaki, 1984; Hugdahl et al., 2003; Oie, Rund, Sundet, & Bryhn, 1998), the majority of past studies have revealed reduced, and at times, even reversed language lateralization in patients with schizophrenia when compared to healthy individuals (e.g., Harrison, 1999; Kircher et al., 2002; Loberg, Hugdahl, & Green, 1999; Sommer et al., 2001a; Sommer, Ramsey, & Kahn, 2001b). Relevant to dichotic listening tasks, these patients typically have significantly lower REAs or, less often, a left ear advantage (LEA) (Malaspina et al., 2000; Sommer et al., 2001a).

Moreover, research has shown that patients with schizophrenia have lower REAs than other psychiatric patients with depression and schizoaffective disorder (Bruder et al., 1995; Wexler, Giller, & Southwick, 1991). In addition, manic patients with reduced

REAs have been found to be more likely to exhibit symptoms of thought disorder than mood disturbances, whereas manic patients with relatively higher REAs have been shown to have less thought disorder (Wexler et al., 1991). Healthy relatives of patients with schizophrenia also tend to exhibit lower REAs than controls for verbal material, although their REAs are still higher than those found in schizophrenia (Grosh, Docherty, & Wexler, 1995). It has been further demonstrated that patients with schizophrenia have similar reductions in REA regardless of whether they are medicated or unmedicated with antipsychotic drugs (Bruder et al., 1995). Past research using fMRI has also revealed similar decreases in language lateralization for both male and female patients with schizophrenia (Sommer, Ramsey, Mandl, & Kahn, 2003). Thus, such findings of abnormal perceptual asymmetry in schizophrenia cannot be solely explained by the presence of psychiatric symptoms in general, medication, or gender. It is important to note, however, that some studies have shown a relative normalization in the REA with symptom remission (Loberg, Jorgensen, & Hugdahl, 2002; Shukla, Behere, & Mandal, 1993; Wexler & Heninger, 1979), which may explain some findings of normal language lateralization in schizophrenia.

Many researchers have attempted to elucidate the mechanisms underlying the decreased language lateralization in schizophrenia by using functional brain imaging. Some researchers have argued that abnormal language lateralization is the result of a dysfunctional left hemisphere (Gur & Chin, 1999), whereas others claim that it results from a failure to inhibit an overactivated right hemisphere (Malaspina et al., 2000; Sommer et al., 2001a). It has also been hypothesized that abnormal lateralization in schizophrenia is due to a failure for hemispheric dominance for language (Crow, 1997). And still others have suggested the possibility of aberrant callosal transfer between the

two hemispheres (Jancke, Buchanan, Lutz, & Shah, 2001). Thus, despite consistent findings of reduced perceptual asymmetry for language in schizophrenia, explanations vary with regards to its underlying mechanisms.

Attention Impairment in Schizophrenia

Attention is a complex function to define, as it refers to a multitude of cognitive processes. Given that a thorough review of the various types and models of attentional processes is beyond the scope of the current study, it will instead briefly describe some of the most relevant functions. Alertness, for example, is one of the most basic forms of attention and generally refers to a state of optimal sensitivity to respond to external stimuli, whereas vigilance, or sustained attention, is known as the ability to maintain this sensitivity over time (Posner & Boies, 1971). Selective attention generally refers to the ability to focus on one source of information rather than others, and has been previously explained by filtering mechanisms that block irrelevant information due to limited processing capacity (Broadbent, 1958; Treisman, 1969). Moreover, limited processing capacity has been further linked to divided attention, or dual tasking, where attentional resources must be simultaneously allocated to two or more streams of information (Friedman, Polson, Dafoe, & Gaskill, 1982).

Patients with schizophrenia have been shown to exhibit deficits in a number of attentional processes, with moderate to large effect sizes when compared to healthy controls (Heinrichs & Zakzanis, 1998). Specifically, schizophrenia has been shown to be associated with deficits in alertness, as evidenced by decreased sensitivity to external stimuli (Cornblatt, Lenzenweger, & Erlenmeyer-Kimling, 1989). Patients with schizophrenia also have difficulty selectively attending to one stream of information while

ignoring others (Brazo et al., 2002; Iwanami, Kanamori, Isono, Okajima, & Kamijima, 1996; Loberg et al., 1999; Wexler et al., 1991), as well as dividing attention across two streams of information (Hatta et al., 1984; Loberg et al., 1999). Moreover, these individuals have also been shown to have difficulty sorting attended information for further processing, which may thus affect its encoding (Calev, 1999). Schizophrenia has been further associated with impaired information processing speed, as well as limited attentional or processing resources (Gourovitch & Goldberg, 1996; Nuechterlein & Dawson, 1984).

Influence of Attention on Laterality

Past research has also suggested that attentional processes may interact with and subsequently obscure laterality effects, as measured by conventional dichotic listening techniques (Hugdahl, 2000; Hugdahl & Andersson, 1986). Specifically, patterns of language lateralization are known to result from a dynamic interaction between bottom-up and top-down attentional processing (Hugdahl, 2000). Bottom-up, or stimulus-driven, laterality reflects a more “automatic” process where the hemispheres are specialized for processing specific types of stimuli, whereas top-down, or instruction-driven, laterality reflects a more “controlled” ability to modulate stimulus effects in lateralization by shifting attention to either ear. Given Kinsbourne’s (1970) contention that the anticipation of incoming verbal material automatically primes the left hemisphere, and thus the right ear, for processing stimuli, some researchers have attempted to design alternative approaches to laterality testing that aim to provide a less attention-biased laterality estimate (Hugdahl & Andersson, 1986).

One alternative approach that was designed to control for potential selective attention confounds is a modified version of the dichotic listening task, which investigates the interaction between stimulus-driven and instruction-driven laterality effects by having participants selectively attend to and report from only one ear at a time (Asbjornsen & Hugdahl, 1995; Hugdahl & Andersson, 1986). Specifically, participants are generally instructed to listen for six target consonant-vowel (CV) syllables and then to report the syllable they heard best on each trial by either repeating the syllable aloud or by pointing to the syllable on a sheet in front of them that lists all possible responses vertically. Participants are first required to complete one condition, in which no instructions are given concerning which ear to attend to (i.e., non-forced condition: NF), followed by a forced-right (FR) condition, in which participants are instructed to attend to and report from only the right ear, and a forced-left (FL) condition, in which they are required to attend to and report from only the left ear. The latter technique is generally known as the “forced-attention paradigm”.

Previous studies that have examined the effects of attention on laterality via the forced-attention paradigm have generally found that one can increase or decrease the normal, stimulus-driven REA by having participants selectively attend to a specific ear. Specifically, the REA in healthy individuals is generally increased in the FR condition, whereas it is decreased, and sometimes reversed, in the FL condition (Asbjornsen & Hugdahl, 1995; Hugdahl, 2003). Such changes in the REA result primarily from a suppression of intrusions from the left and right ears (i.e., unattended ears), respectively, as well as a secondary increase in correct reports from the attended ear in each condition.

Although attempts have also been made to more accurately estimate language lateralization in schizophrenia via the forced-attention paradigm, past researchers have found inconsistent evidence as to whether attentional cueing moderates language laterality in these individuals. Some studies have found that patients with schizophrenia have difficulty modifying their performance on forced-attention tasks with verbal material in both the FR and FL conditions when compared to controls (Green, Hugdahl, & Mitchell, 1994; Loberg et al., 1999). In other words, not only do these individuals exhibit impaired language lateralization in the left hemisphere, but they also have difficulty modifying their laterality performance by shifting their attention to either the left or right ear. Such impairment in both stimulus-driven and instruction-driven processes has been referred to as a “dual deficit” in language lateralization, reflecting deficits in both automatic and controlled processing skills (Loberg et al., 1999). In contrast, Hugdahl et al. (2003) found that patients with schizophrenia were able to modify their performance on the FR condition, but not on the FL condition. It is important to note, however, that the patients in Hugdahl et al.’s (2003) study were drawn from a much less chronic sample of outpatients and inpatients than those in Green et al. (1994) and Loberg et al. (1999). Moreover, Hugdahl et al.’s (2003) sample was comprised of almost all paranoid patients, and thus results are consistent with studies that have found an increased REA in these individuals (Bruder, 1988; Friedman et al., 2001; Romney, Mosley, & Addington, 2000), which would also explained their relative difficulty suppressing their right ear in the FL condition.

Furthermore, the patients in past forced-attention studies were given verbal instructions to selectively attend to either the left or right ear during the forced-attention conditions. Given that chronic patients with schizophrenia have significant difficulties

with both attention and verbal memory (Heinrichs & Zakzanis, 1998), it seems plausible that they may have difficulty allocating attentional resources or remembering to selectively attend to one ear throughout the entire testing condition. In addition, these patients can be cognitively inflexible, and may thus have difficulty voluntarily shifting attention to a different ear following the first forced-attention condition. Although Loberg et al. (1999) attempted to control for such cognitive difficulties by counterbalancing the forced-attention conditions and by placing arrows in front of the patients to remind them which ear they were instructed to attend to, such reminders rely on controlled, instruction-driven processing skills, and may therefore not be sufficient in directing the patients' attention. Such an interpretation is supported by studies of visual attention using push cues (Yantis & Jonides, 1990). Specifically, push cues are those cues that indicate the location where the stimulus will appear, but are not actually situated in that location (e.g., an arrow), and must therefore be consciously processed in order to direct attention.

But perhaps a more basic attentional difficulty is underlying past findings of reduced language lateralization in schizophrenia. It seems plausible that patients are simply not sufficiently alert while completing dichotic listening tasks, and that their level of alertness may further decrease over extended periods of time. If this were the case, then it would be expected that these patients would have difficulty attending to stimuli regardless of whether they were presented in the traditional dichotic listening paradigm or in the forced-attention paradigm. The consequences of decreased alertness may therefore be obscuring past findings of abnormal language laterality in schizophrenia. If a patient's level of alertness, for example, is below some optimal level of alertness for laterality, it seems plausible that they may not hear the presented stimuli, which would

encourage guessing on a subset of trials and result in lower overall accuracy, thus leading to lower laterality estimates¹. It therefore remains unclear the degree to which abnormal language lateralization in schizophrenia is a function of alertness relative to significant language impairment.

Past studies of visual attention have shown that cueing can increase alertness and facilitate cognitive processing in patients with schizophrenia (Frecska, Symer, White, Piscani, & Kulcsar, 2004; Hirt & Pithers, 1990; Liotti, Dazzi, & Umiltà, 1993). For example, Liotti et al. (1993) employed peripheral cues in a visual attention task in patients with schizophrenia and healthy controls. These types of cues are known as pull cues, and they can be distinguished from push cues in that they appear in the location of the upcoming stimulus and therefore rely on more automatic processes to direct attention (Yantis & Jonides, 1990), which may be relatively more preserved in schizophrenia. These researchers found that patients showed reduced costs of invalid cueing (i.e., a lower increase in reaction time) and greater benefits of valid cueing (i.e., a greater decrease in reaction time), relative to the performance found in healthy controls. The authors suggested that the peripheral cues may have served as a warning signal that increased the patients' arousal and further helped to sustain their attention throughout the task, which would also explain their greater benefit of cueing when compared to controls, given the latter group's more robust cognitive resources. Other studies of visual attention have similarly found a differential increase in the benefits of

¹ The standard formula for calculating the laterality effect is $[(\text{Right Ear} - \text{Left Ear}) / (\text{Right Ear} + \text{Left Ear})]$, where the ear scores correspond to the number correctly reported for that ear. Increased guessing would move laterality effect scores toward chance, as the number correct for both the right and left ears would be expected to increase equally since the probability of correctly reporting stimuli from either ear is equal by chance. This would result in a lower laterality effect score.

cueing in patients with schizophrenia by utilizing centralized warning cues to improve their level of alertness to target stimuli, without directing attention to a particular area in space (e.g., Hirt & Pithers, 1990).

The benefits of cueing have also been demonstrated in other populations and modalities. Reaction time studies employing either lateralized monaural cues (i.e., tone cues presented to one ear only) or non-directional binaural cues (i.e., tone cues presented to both ears simultaneously, thus appearing centralized) prior to the presentation of target stimuli have also demonstrated faster reaction times in healthy individuals, without a reduction in accuracy (Niemi & Naatanen, 1981; Rodway, 2004; Simon & Craft, 1970; Spence & Driver, 1997). Also, Whyte, Fleming, Polansky, Cavallucci, and Coslett (1997) examined the effects of centralized auditory tone cues on reaction time in a visual go/no go task in healthy controls and in patients who had a recent traumatic brain injury (TBI). Results revealed that TBI patients and controls demonstrated equivalent benefit from the auditory warning cues, as evidenced by reduced reaction time and increased accuracy when presented with a warning cue than when the trials were uncued. The authors concluded that the auditory tone cues were effective in activating and orienting the patients' level of arousal, and subsequently in aiding their performance on the task. Although similar studies, to the author's knowledge, have not been conducted in patients with schizophrenia, such findings of improved cognitive performance due to auditory tone cueing in patients with attentional difficulties are nevertheless encouraging and appear worthy of further investigation.

With regards to dichotic listening performance, Mondor and Bryden (1991) have previously examined the effects of attention on language laterality in healthy individuals by presenting a lateralized tone cue to a target ear, which varied between trials, just prior

to the onset of each stimulus. Participants were required to report the stimulus that was presented to the ear with the preceding tone cue on each trial. The authors demonstrated that the magnitude of the REA in healthy individuals could be altered with the use of lateralized tone cues, therefore suggesting that tone cueing can effectively direct attention in dichotic listening tasks. Although the current study is interested in the effects of increasing one's level of alertness while completing dichotic listening tasks, and not in directing attention to a specific ear, these findings nevertheless suggest that the REA in healthy individuals can be altered with orienting auditory tone cues.

The use of a pull cue, such as a tone, to help increase alertness in patients with schizophrenia has not, to the author's knowledge, been used to examine the effects of alertness on language lateralization. Given that past research has revealed that the presentation of tone cues is useful in activating the arousal level of TBI patients during a visual attention task, as well as in directing attention in healthy controls during a dichotic listening task, it seems plausible to infer that patients with schizophrenia may also benefit from the presentation of tone cues to help alert them to the stimuli in dichotic listening tasks. This procedure would utilize more automatic processes to help improve their ability to attend to dichotic stimuli than previous studies in this area, and should thus yield a laterality effect that better controls for confounding cognitive difficulties, such as decreased alertness. If diminished alertness is a critical determinant of lower REAs in schizophrenia, then the laterality effect obtained should be a more accurate index of language lateralization for patients with the disorder, thus helping to elucidate patterns of language lateralization in these individuals.

Symptom Dimensions and Laterality

Such findings of abnormal language lateralization are further complicated by the fact that patients with schizophrenia exhibit a variety of symptom patterns (Frith, 1992; Liddle, 1987b). It has been suggested that there are two types of symptoms expressed in this disorder (Crow, 1980). In addition to positive symptoms that comprise excesses such as delusions, hallucinations, and disorganized speech, there exist negative symptoms (i.e., psychomotor poverty) that consist of deficits involving flat affect, poverty of speech, decreased spontaneous movement, and loss of drive. More recent research has expanded this taxonomy by subdividing positive symptoms into two factors, one for delusions and hallucinations (i.e., reality distortion), and one for symptoms of disorganization, such as thought disorder and bizarre behaviour (Liddle, 1987b).

Neuroimaging studies that have used fMRI and SPECT to investigate the relationship between symptom dimensions and language lateralization have generally revealed that reduced perceptual asymmetry in patients with predominant psychomotor poverty results from left hemisphere dysfunction, whereas reality distortion is related to a failure to inhibit the right hemisphere (Malaspina et al., 2000; Sommer et al., 2001b). Moreover, it appears that patients with primary symptoms of reality distortion, particularly those with hallucinations, have lower REAs than those with psychomotor poverty (Green et al., 1994; Levitan, Ward, & Catts, 1999; Malaspina et al., 2000; Romney et al., 2000; Sommer et al., 2001b).

Despite recent suggestions regarding the utility of a three-symptom dimension approach, relatively fewer studies have investigated the presence of differences in language lateralization among the three symptom patterns. Nevertheless, studies have

shown that thought disorder, which is a symptom of disorganization, has been associated with reduced (Rossi et al., 1994) and even reversed planum temporale asymmetry (Petty et al., 1995), reversed language lateralization (Kircher et al., 2002), and increased non-right-handedness, as compared to other symptom dimensions and controls (Dollfus, Buijsrogge, Benali, Delamillieure, & Brazo, 2002; Manoach, 1994). It is important to note that individuals who are not right-handed tend to be less consistently lateralized for verbal material in the left hemisphere (Jancke & Steinmetz, 2003). However, findings of diminished or reversed language lateralization in patients with thought disorder cannot be explained by handedness alone, given that a decreased REA is found regardless of the patient's hand of preference and/or proficiency (Dollfus et al., 2002; Kircher et al., 2002).

Study Objectives

As previously mentioned, past research has shown relatively consistent reductions in language laterality in patients with schizophrenia (Harrison, 1999; Kircher et al., 2002; Loberg et al., 1999; Sommer et al., 2001a; Sommer et al., 2001b), as well as reduced planum temporale asymmetry and decreased left superior temporal gyrus volume, which are areas important in language functions (Highley et al., 1999; Shapleske et al., 1999; Shenton et al., 2001; Wright et al., 2000). These patients also have difficulties modifying their performance on forced-attention tasks (e.g., Loberg et al., 1999), further highlighting the existence of impaired language processes. However, it seems plausible that decreased alertness may also play a role in findings of reduced language lateralization, and it therefore remains unclear the degree to which aberrant

language laterality in schizophrenia is a function of decreased alertness relative to significant language impairment.

The present study thus aims to systematically investigate the effects of attention on language lateralization in schizophrenia by controlling for potential confounds of previous research in this area. This study differs from past research in that it will present a centralized binaural tone (BT) cue prior to the onset of the stimulus, in addition to instructions to attend to upcoming stimuli, in order to help increase the patients' alertness by utilizing both automatic and controlled processes. If diminished alertness is a critical determinant of reduced language laterality, and if the tone cue acts to equate alertness between patients and healthy controls, then the latter procedure should yield a laterality effect that is a more accurate index of language lateralization in patients with schizophrenia. If diminished alertness is not a critical determinant of reduced language laterality in schizophrenia, then the present results will further support previous research showing significant abnormalities in language lateralization that cannot be accounted for by decreased alertness. Taken together, this study should indicate the degree to which abnormal language lateralization in schizophrenia is a function of alertness relative to significant language impairment. The present findings should also help to elucidate whether patients are able to modify their low REA with the aid of additional cognitive support. Finally, this study will explore the presence of differential patterns of language lateralization in patients with various symptom presentations.

Hypotheses

1. To replicate previous findings of reduced language laterality in schizophrenia, it is hypothesized that patients will demonstrate a significantly lower REA in the traditional uncued (UC) condition when compared to healthy controls.
2. Given the additional use of a tone cue in the BT condition, it is hypothesized that patients with schizophrenia will be more alert while completing the dichotic listening task. Relative to the UC condition, it is therefore hypothesized that the REA will be strengthened in the BT condition.
3. It is further hypothesized that patients will benefit more from the use of a tone cue as compared to healthy controls, given that the latter group possesses more robust cognitive resources, which are likely to attenuate the benefits of cueing that are necessary to complete the task. With the additional aid of a tone cue, patients with schizophrenia should demonstrate a relative normalization of the REA in the BT condition compared to controls. This relative normalization pattern would suggest that past findings of aberrant language laterality in these patients overestimated the degree of impairment of laterality effects due to the presence of confounding cognitive difficulties in attention.

Secondary Investigations

1. Past studies have shown that patients with schizophrenia are less able to correctly identify dichotic stimuli when compared to healthy controls (Loberg et al., 1999; Hugdahl et al., 2003; Wexler & Heninger, 1979). It thus seems plausible that, with the aid of the tone cue, the patients will be better able to

attend to the CV syllables presented on each trial, thereby improving their overall accuracy. It is therefore predicted that the overall accuracy score in the BT condition will be significantly greater than the overall accuracy score in the UC condition.

2. The potential attentional contribution to language lateralization in these patients will be examined by evaluating the presence of a relationship between attention and performance on the dichotic listening conditions. It is expected that a relationship may exist between attention and the UC condition, but not with the BT condition. Moreover, the present study will examine the presence of attentional difficulties over time by evaluating the attenuation of the REA over time. It would thus follow that, if the ability to sustain attention is an important factor mediating language lateralization in patients with schizophrenia, then the REA will be greater in the initial third of the UC condition than in the final third of the task. It is also predicted that their differential performance between the first and last thirds of the UC condition will be significantly attenuated in the BT condition, thus confirming the use of attentional cues to increase one's level of alertness.
3. Researchers have shown that patients with predominant psychomotor poverty have relatively less impaired perceptual asymmetries, as well as a higher REA than other patients with the disorder (Green et al., 1994; Levitan et al., 1999; Malaspina et al., 2000; Romney et al., 2000; Sommer et al., 2001b). Moreover, patients with thought disorder have more aberrant planum temporale asymmetry than patients with psychomotor poverty and reality distortion (Petty et al., 1995; Rossi et al., 1994) as well as reduced language lateralization in the left

hemisphere (Kircher et al., 2002). However, past studies examining language lateralization in patients with schizophrenia have not employed tone cues to help increase their alertness. It therefore remains unclear how their performance on this condition may vary among patients with predominant psychomotor poverty, reality distortion, or disorganization symptoms. Findings of differential language lateralization in patients with varying symptoms may thus also help to elucidate the controversy regarding the underlying mechanisms involved in abnormal language lateralization in schizophrenia. The present study will thus explore the presence of differential patterns of language lateralization in patients with various symptomatologies.

METHOD

Participants

The number of participants required to achieve a power of approximately .80 was calculated using Cohen's (1977) power tables for F tests on means in the Analysis of Variance and Covariance, with an $\alpha=.05$ and a $u=1$ (i.e., number of means in analysis minus one). The effect size estimate ($d=.48$) used in this table was obtained from a meta-analysis performed by Sommer et al. (2001a), who calculated the average effect size for reduced language lateralization in patients with schizophrenia relative to healthy controls, using dichotic listening tasks with fused words and CV syllables. Given the hypothesized normalization of the REA with the aid of the tone cue in patients with schizophrenia relative to controls, it would be expected that the increase in the REA in patients in the BT condition relative to the UC condition, when compared to controls, would be of a similar magnitude (i.e., $d=.48$).

Subsequently, 18 right-handed inpatients that have received the diagnosis of either schizophrenia or schizoaffective disorder by their treating physician were recruited from a tertiary psychiatric hospital in Coquitlam, Canada. Given that affective symptoms have been shown to modify patterns of language laterality (Wexler et al., 1991), schizoaffective patients were screened for evidence of current affective symptoms. Specifically, psychiatric charts were reviewed prior to testing to ensure that the patients were not currently experiencing either a manic or depressive episode. Testable patients were then assessed using two rating scales that measure affective symptomatology, one for depression and one for mania. Patients continued with testing only if they met cutoff

scores indicating that they were not currently depressed or manic (described below).

Potential patients were also excluded if they: 1) had a history of head injury with loss of consciousness for more than five minutes; 2) were being treated for a neurological illness (e.g., epilepsy, diabetes, HIV, hepatitis C, hypothyroidism); 3) had an additional Axis I diagnosis (e.g., anxiety disorder, active substance abuse); 4) had an Axis II diagnosis of mental retardation and/or a pervasive developmental disorder (e.g., asperger's, autism); and 5) had known hearing difficulties.

Eighteen right-handed healthy controls matched on sex, age, and mean parental education, were recruited from the community via advertisements posted at Riverview Hospital, or on approach by a researcher involved with the study. As with the patients, controls were excluded if they met any of the above criteria, including a diagnosis of schizophrenia or schizoaffective disorder. All participants were fluent in English.

Materials

Symptoms

Symptom dimensions were assessed using the Signs and Symptoms of Psychotic Illness rating scale (SSPI; Liddle, Ngan, Duffield, Kho, & Warren, 2002). This scale comprises 20 items designed to measure the severity of symptoms of psychotic illness. The three symptom dimensions of schizophrenia were assessed using the following items from the SSPI: Underactivity, Flattened Affect, and Poverty of Speech for psychomotor poverty; Delusions and Hallucinations for reality distortion; and Inappropriate Affect and Disordered Form of Thought for symptoms of disorganization.

Depression

The Calgary Depression Scale (CDS; Addington, Addington, & Maticka-Tyndale, 1993) was used to assess the presence of depression. This measure is a nine item structured interview scale, with a four-point rating of each item, which was specifically developed to assess depression in schizophrenia in both acute and residual stages. Of particular importance, the CDS distinguishes depressed schizophrenic patients from those who are not depressed on the basis of emotional features and excludes an examination of vegetative symptoms, as they may overlap with and be confounded by symptoms of psychomotor poverty and extrapyramidal side effects. Moreover, the CDS was further used to identify and subsequently exclude schizoaffective patients that were experiencing a depressive episode at the time of testing in order to ensure that the laterality effects obtained were representative of schizophrenia and not depressive symptoms. Item 8, which measures suicidal ideation and behaviours, was eliminated from the questionnaire, as it was felt that this item could not be thoroughly evaluated by the research assistants. Consequently, a cutoff score often used in the literature (e.g., Lancon, Auquier, Reine, Bernard, & Addington, 2001; Tugal, Yazici, Yagcioglu, & Gogus, 2004) was recalculated to maintain the same percentage of items endorsed (i.e., ratio of the individual's score over the total possible score). Subsequently, scores equal to or less than five on the CDS were required for inclusion in the study. Interrater reliability was measured using an intraclass correlation (ICC). The ICC for the CDS was 0.970.

Mania

The Clinician-Administered Rating Scale for Mania (CARS-M; Altman, Hedeker, Janicak, & Peterson, 1994) was used to assess the presence and severity of mania in the patients. This measure is a 15 item structured interview scale that focuses on symptoms experienced during the previous seven days, and uses a six-point rating for most items. The CARS-M was further used to identify and subsequently exclude schizoaffective patients that were experiencing a manic episode at the time of testing in order to ensure that the laterality effects obtained were representative of schizophrenia and not affective symptoms. Scores equal to or less than seven on Subscale 1 were required for inclusion in the study (Altman, Hedeker, Peterson, & Davis, 2001). Interrater reliability for the CARS-M was measured using an ICC, and was found to be 0.867.

Handedness

The Edinburgh Handedness Inventory (Oldfield, 1971) was used to measure hand preference. This questionnaire consists of 10 items concerning hand preference for specific activities. It generates laterality quotients, or handedness scores, ranging from 0 (completely left-handed) to 100 (completely right-handed). Scores equal to or above 70 were considered to reflect right-handedness.

The Grooved Pegboard Test (Reitan & Davison, 1974) was used to measure manual proficiency. This task requires participants to place 25 small pegs into a set of randomly oriented holes with each hand separately. Performance time is recorded for each hand. A laterality quotient was computed by dividing the time required to complete the task with the left hand from the total time for both hands (i.e., L/R+L). Scores above

.50 indicate right-handedness, whereas scores below .50 indicate left-handedness.

Participants were required to meet the criteria for right-handedness on both handedness measures.

Measures that Tax Selective Attention

Selective attention was operationalized as the ability to attend to a task without distraction from the environment. The Digit Span, Digit Symbol Coding, and Symbol Search subtests of the Wechsler Adult Intelligence Scale, 3rd edition (WAIS-III; Wechsler, 1997) were chosen, as these tasks require adequate selective attention in order to be completed successfully. The Digit Span subtest requires participants to repeat a sequence of digits presented orally, both in the same order as well as backwards. The Digit Symbol Coding subtest involves copying a series of symbols that correspond to specific numbers as quickly as possible. The Symbol Search subtest requires participants to quickly scan groups of symbols and to decide whether or not target symbols are presented in each of the groups.

Moreover, tasks of working memory, or the ability to temporarily maintain the memory representation of a stimulus “on line” in order to use, process, or manipulate it mentally (Green, 1998), require adequate attention in order to be successfully completed. Thus, the present study also assessed working memory by employing the Letter-Number Sequencing subtest of the WAIS-III (Wechsler, 1997). This test requires participants to order sequentially a series of letters and numbers that are presented orally.

Hearing Acuity

Participants were screened for differences between the ears in hearing acuity using the method of ascending and descending limits. Specifically, they were required to listen to 500, 1000, 2000, and 4000 Hz frequencies to determine the hearing threshold for each ear. Individuals were excluded from the study if they had average threshold differences between the ears that were greater than 10 dB on any of the frequencies (Absjornsen & Hugdahl, 1995; Malaspina et al., 2000; Zatorre, 1989). Subsequently, the data for one healthy control were excluded.

Phoneme Discrimination Test

Participants were further screened for impaired ability to discriminate phoneme sounds using the Phoneme Discrimination Test (Benton, Sivan, Hamsher, Varney, & Spreen, 1994). Specifically, they were required to listen to a series of stimulus pairs (e.g., loo-loo; aksan-aksad) that were presented on a cassette tape and then to report on each trial whether the pair of sounds was the same or different. As suggested by Benton et al. (1994), individuals with a score below 22 on this test were excluded from the study. All participants met criterion for inclusion on this test.

Dichotic Listening Task

Both dichotic listening conditions included six CV syllables, *ba*, *da*, *ga*, *ka*, *pa*, and *ta*, that were digitized and stored as separate sound files on a standard microcomputer (obtained from Hugdahl, 2003). The CV sounds were pronounced by a male speaker, and were equated to a length of 350 msec and an intensity of 70 dB, with an intertrial interval of 4 sec. On each trial, one syllable was presented to each ear in

such a way that all possible dichotic pairings of the syllables resulted in 36 combinations, including homonymic pairs. The homonymic pairs were included in the administration of the test as test trials, but will be excluded from the statistical analyses. In the BT condition, a 100 msec, 600 Hz tone was presented to the both ears prior to the onset of each CV pair, with an SOA of 150 msec. All stimuli were edited using standard audio editing software, then recorded on a compact disk (CD), and played through headphones on a standard portable CD player.

Additional Measures

Intellectual ability was assessed using the Kauffman Brief Intelligence Test-Second Edition (KBIT-II; Kaufman & Kaufman, 2004). This test yields an overall estimate of intelligence, as well as verbal and nonverbal ability scores. The Trailmaking Test A and B (Reitan & Wolfson, 1985) were administered to examine visual scanning speed, motor sequencing skills, and attentional shifting. A health questionnaire was completed in order to identify any health related difficulties or concerns. This information was further supplemented by a review of hospital charts.

Procedure

Participants were tested individually in a quiet room on two separate sessions. On the first session, they were required to complete the handedness measures at the beginning of the testing session to ensure right-handedness. Participants then completed either the UC or the BT dichotic listening condition. On the second session, they were required to complete the Digit Symbol Coding and Symbol Search tests, followed by either the UC or the BT dichotic listening condition. The presentation order

of the dichotic listening conditions was counterbalanced, and participants were randomly assigned to a specific presentation order. The remaining tests were completed following the dichotic listening condition on either of the sessions.

For both dichotic listening conditions, participants were instructed to listen for all the six CV syllables and to report the syllable they heard best on each trial by either repeating the syllable aloud or by pointing to the syllable on a sheet in front of them that lists all six possible responses vertically. In the BT condition, participants were also informed that they would hear a tone just prior to the presentation of each sound to alert them of the upcoming trial. The examiner recorded all responses on a separate response sheet. The reader is referred to Appendix B for the instructions of the dichotic listening conditions.

Participants were required to complete five practice trials, followed by 3 blocks of 36 randomized experimental trials (total of 108 trials) for each condition. The approximate duration of the trials for each condition was 12 minutes. To counterbalance any effects due to the possibility that the sound coming out of the left and right headphones may vary in intensity, half the participants completed the tasks with the right headphone on the right ear, while the other half performed the task with the left headphone on the right ear.

Data Analyses

Data analyses involved three distinct approaches. First, a 2 x 2 x 2 Mixed-Design ANOVA was computed with Condition (UC/BT) and Ear (right/left) as the within-subject factors, Group (patients/controls) as the between-subjects factor, and accuracy as the dependent variable. In accordance with the main hypotheses, it was predicted that a

Condition x Ear x Group interaction would demonstrate a greater increase in the REA in patients than in controls when completing the BT condition relative to the UC condition. Moreover, it was predicted that a Condition x Ear interaction would indicate that the REA was strengthened in the BT condition when compared to the UC condition, and that an Ear x Group interaction would signify that the patients have a significantly lower REA than healthy controls. An additional analysis to investigate the role of attention in language lateralization in schizophrenia was conducted using an attention composite score as a covariate in the main analysis. All tests were two-tailed, with the exception of the Ear x Group interaction, which was one-tailed.

Second, the presence of attentional difficulties over time was examined by computing a $3 \times 2 \times 2 \times 2$ Mixed-Design ANOVA, with Trials (initial third/middle third/final third) and Condition (UC/BT) and Ear (right/left) as the within-subject factors, Group (patients/controls) as the between-subjects factor, and accuracy as the dependent variable, in order to determine whether there was a decline in either the REA or in accuracy over time.

Third, Pearson product moment correlations were computed between performance on the dichotic listening conditions and symptoms of illness to explore the presence of differential patterns of language lateralization and accuracy in patients with schizophrenia. Specifically, symptom-rating scores were correlated with the total accuracy scores and the derived laterality effects scores $[(\text{Right Ear} - \text{Left Ear}) / (\text{Right Ear} + \text{Left Ear}) \times 100]$ in the dichotic listening conditions.

RESULTS

Demographic Characteristics

Demographic information for both the patient and healthy control samples are presented in Table 1. The two groups were matched on age, $t(34) = 1.28, p = .208$, gender, $\chi^2(1, N = 36) = 0.11, p = .738$, parental education, $t(33) = -0.24, p = .814$, and handedness, $t(34) = 1.18, p = .247$. However, the control group was significantly more educated, $t(34) = -3.25, p = .003$ than the patients, and there was a significantly higher number of patients who were smokers than controls, $\chi^2(1, N = 36) = 13.49, p < .001$.

Table 1:

Demographic Characteristics of the Participants.

Variable	Patients (n=18)	Controls (n=18)
Age (years)	35.61 (10.98)	31.44 (8.31)
Gender (male:female)	8:10	9:9
Education (years)	11.67 (1.82)	13.67 (1.88)**
Parental Education (years)	12.18 (2.30)	12.36 (2.31)
Handedness Questionnaire Laterality Quotient	92.64 (5.97)	89.86 (8.02)
Smoker (yes:no)	15:3	4:14***
Less than 1 cigarettes/day (n)	0	1
1-10 cigarettes/day (n)	4	2
11-20 cigarettes/day (n)	3	1
1-2 packs/day (n)	8	0
More than 2 packs/day (n)	0	0

Note: Figures indicate mean (SD) unless otherwise specified.

* $p < .05$

** $p < .01$

*** $p < .001$

Clinical Characteristics

The reader is referred to Table 2 for a summary of the clinical characteristics of the patient sample.

Table 2:

Clinical Characteristics of the Patients.

Variable	N	Mean (SD)	Minimum	Maximum
Diagnosis				
Schizophrenia	9			
Schizoaffective	9			
Illness Duration (yrs)	18	12.39 (9.86)	3	38
CPZ Equivalents	14	990.24 (547.61)	255	2000
SSPI Ratings				
PP	18	1.78 (1.44)	0	4
RD	18	4.56 (2.62)	0	8
DS	18	1.11 (1.78)	0	6
CDS	18	2.28 (1.78)	0	5
CARS-M	18	1.94 (1.73)	0	5

Note: Chlorpromazine (CPZ) equivalents were not available for four patients.

SSPI = Signs and Symptoms of Psychotic Illness rating scale; PP = psychomotor poverty; RD = Reality Distortion; DS = Disorganization; CDS = Calgary Depression Scale; CARS-M = Clinician-Administered Rating Scale for Mania.

Cognitive Measures

In addition to the dichotic listening conditions, the participants completed a number of cognitive tasks to measure attention, working memory, visual scanning and motor sequencing speed, handedness, and phoneme discrimination. Differential performance on these tasks was examined using independent-samples *t*-tests, and is shown below in Table 3.

Table 3:

Mean (SD) Performance on Cognitive Measure for Patients and Controls.

Variable	Patients	Controls	Cohen's <i>d</i>
KBIT-II Verbal IQ (VIQ)	90.17 (10.68)	106.11 (12.32)	-1.38**
KBIT-II Nonverbal IQ (PIQ)	90.11 (10.38)	105.89 (10.85)	-1.49**
KBIT-II General IQ	89.61 (8.95)	106.83 (11.11)	-1.71**
Digit Span	9.11 (2.85)	12.22 (2.18)	-1.23*
Letter-Number Sequencing	8.24 (3.40)	11.83 (1.98)	-1.29*
Symbol Search	7.00 (3.03)	12.28 (2.24)	-1.98**
Digit Symbol Coding	6.39 (2.12)	11.06 (3.19)	-1.72**
Trails A	36.89 (13.99)	25.39 (9.09)	-0.97*
Trails B	123.72 (89.36)	52.67 (18.62)	-1.10*
Grooved Pegboard Laterality Quotient	0.56 (0.03)	0.54 (0.03)	+0.67
Phoneme Discrimination	28.17 (1.51)	29.33 (0.91)	-0.93*

Note: Trails A and B are measured in completion time, and therefore a higher score denotes poorer performance. KBIT = Kaufman Brief Intelligence Test

t(34), except for Letter-Number Sequencing, *t*(33)

* *p* < .01

** *p* < .001

As shown above, the patients performed significantly worse on measures of intelligence, attention, working memory, phoneme discrimination, and visual scanning and motor sequencing speed, when compared to healthy controls. Laterality quotients for hand proficiency were similar in both groups.

Dichotic Listening Performance

The obtained mean percentage of correct responses and standard deviations for the ear performances of patients and controls in both the UC and BT conditions are presented in Table 4.

Table 4:

Mean (SD) Percentage of Correct Responses and Laterality Effects for Patients and Controls in the UC and BT Conditions.

	Right Ear	Left Ear	Total	Laterality Effect
UC Condition				
Patients	41.05 (9.70)	30.68 (6.88)	71.73 (9.62)	13.86 (18.30)
Controls	47.04 (6.65)	32.41 (6.54)	79.44 (6.60)	18.52 (13.68)
Total	44.04 (8.74)	31.54 (6.67)		
BT Condition				
Patients	40.43 (5.86)	30.68 (5.59)	71.11 (5.82)	13.77 (14.64)
Controls	43.95 (9.61)	32.22 (7.64)	75.90 (9.67)	15.13 (17.21)
Total	42.19 (8.04)	31.45 (6.64)		

Note: Laterality Effect = $[(\text{Right Ear} - \text{Left Ear}) / (\text{Right Ear} + \text{Left Ear}) \times 100]$. Scores above 0 denote increasingly greater REA; scores below 0 represent increasingly greater LEA.

To investigate the main hypotheses, a 2 x 2 x 2 Mixed-Design ANOVA was computed with Condition (UC/BT) and Ear (right/left) as the within-subjects factor, Group (patients/controls) as the between-subjects factor, and accuracy as the dependent

variable.² Of interest, patients did not demonstrate a greater increase in the REA than controls when completing the BT condition relative to the UC condition, as evidenced by a nonsignificant Condition x Ear x Group interaction, $F(1,34) = 0.52, p = .476$. There was also no significant Condition x Ear interaction, $F(1,34) = 1.24, p = .274$, indicating that the REA was not strengthened in the BT condition when compared to the UC condition. Moreover, patients did not demonstrate a significantly lower REA than healthy controls, given the nonsignificant Ear x Group interaction $F(1,34) = 0.64, p = .214$.

In addition to the main hypotheses, results did not reveal either a Condition x Group interaction, $F(1,34) = 1.06, p = .310$, or a main effect of Condition, $F(1,34) = 2.27, p = .141$, indicating similar total accuracy on the UC and BT conditions for both patients and controls. There was, however, a main effect of Group, $F(1,34) = 7.45, p = .010$, demonstrating that the control participants ($M = 77.67, SD = 7.31$) were more accurate than patients ($M = 71.42, SD = 6.80$) in identifying dichotic stimuli. There was also a main effect of Ear, $F(1,34) = 35.86, p < .001$, indicating that participants showed a REA (see Table 1).

Further statistical analyses in the above Mixed-Design ANOVA model, but with Diagnosis (schizophrenia/schizoaffective) as the between-subjects factor instead of Group, revealed similar accuracy and REAs in patients with schizophrenia and those with schizoaffective disorder in both the UC and BT conditions, $F(1,16) = 0.44, p = .519$, and no significant two-way interactions or main effects (all p -values $>.05$). There was also no difference in accuracy and REAs between males and females in both the UC

² The absence of UC-BT order effects and their interactions was verified (all p -values > 0.05), and the order term was dropped from all subsequent analyses.

and BT conditions for either the patient or control groups, $F(1,32) = 0.00$, $p = .998$, and no significant two-way interactions or main effects (all p -values $> .05$).

Attentional Contribution to Dichotic Listening Performance

The overall purpose of the tone cue in the BT condition was to increase the patients' alertness in order to control for potential confounds related to decreased arousal. To evaluate the role of selective attentional resources, an attention composite score was entered as a covariate in a $2 \times 2 \times 2$ Repeated Measures ANCOVA with Condition (UC/BT) and Ear (right/left) as the within-subjects factors, Group (patients/controls) as the between-subjects factor, and accuracy as the dependent variable. The composite score was computed by combining standardized z-scores for the attention-related measures given in the neuropsychological test battery. The reader is referred to Appendix C for the intercorrelations of these measures. Sphericity and homogeneity of regression slopes were tested and assumptions were met. Results revealed a significant Condition x Attention Composite interaction, $F(1,33) = 5.38$, $p = .027$. Follow-up simple regression analyses between the attention composite and accuracy for the UC and BT conditions revealed a significant relationship between the attention composite and accuracy for both conditions (Table 5). Nonetheless, the Condition x Attention Composite indicates that the regression slopes of the covariate in the UC and BT conditions are different. The attention composite did not interact with Ear on any of the three-way or two-way interactions (all p -values > 0.05).

Table 5:
Regression Analyses for the Attention Composite and General IQ Predicting Accuracy.

Condition	<i>B</i>	<i>SE B</i>	<i>β</i>
Attention Composite			
UC	7.634	1.354	.695**
BT	3.850	1.586	.384*
General IQ			
UC	.415	.093	.608**
BT	.324	.091	.521*

Note: * $p < .05$
 ** $p < .001$

To ensure that the above findings were related to attention specifically and not to general cognitive functioning, an ANCOVA was computed with general IQ as a covariate. Results revealed a nonsignificant Condition x General IQ interaction, $F(1,33) = 0.18, p = .673$, indicating that the effects of general intelligence on accuracy were similar in the UC and BT conditions (Table 5).

Attentional Difficulties Over Time and Dichotic Listening Performance

To evaluate for an attenuation of the REA over time, a $3 \times 2 \times 2 \times 2$ Repeated Measures ANOVA was computed with Trials (initial third/middle third/final third), Condition (UC/BT), Ear (right/left) as the within-subject factors, Group (patients/controls) as the between-subjects factor, and accuracy as the dependent variable. Results revealed similar REAs over time for patients and controls in both the UC and BT conditions, as evidenced by a nonsignificant Trials x Condition x Ear x Group interaction, $F(1,34) = 0.20, p = .823$. There were no significant three-way or two-way interactions

and no main effect related to a change in the REA or in accuracy over time (all p -values $>.05$).

Symptom Dimensions and Dichotic Listening Performance

Given that total accuracy and laterality effects for patients did not differ between the two dichotic listening conditions, Pearson product moment correlations were computed between symptoms ratings and both total accuracy and laterality effect scores for the UC and BT conditions combined. By combining the data, the total accuracy and laterality effect scores should be more reliable. Bonferroni corrections were applied so that the probability of making a Type I error would be maintained at 0.05, and thus the significance level for the first-order correlations was subsequently adjusted to $p = .01$ and the significance level for the partial correlations was adjusted to $p = .017$, for both overall accuracy and laterality effects.

With regards to the three symptom dimensions of schizophrenia, results are suggestive of an association between higher DS and lower total accuracy, as well as an association between higher PP and reduced lateralization, but correlations did not meet the Bonferroni-corrected significance level. Reality Distortion was not associated with dichotic listening performance. Moreover, correlations between affective ratings and task performance are also suggestive of an association between higher mania and increased laterality, but did not meet significance levels. After controlling for the effects of mania and depression, results suggested a similar pattern of association between higher DS and lower total accuracy and some relationship between higher PP and reduced laterality was apparent, although again these correlations did not meet the Bonferroni-corrected significance level. Table 6 presents the first-order correlations

between symptoms and task performance, as well as partial correlations between psychotic symptoms and performance, while controlling for the effects of mania and depression.

Table 6:

Correlations Between Symptom Dimensions and Dichotic Listening Performance.

Variable	Total Accuracy	p-value	Laterality Effect	p-value
First-Order Correlations				
PP	-0.03	.898	-0.50*	.034
RD	0.18	.464	0.05	.849
DS ³	-0.58*	.012	0.06	.813
CDS	0.03	.905	0.39	.110
CARS-M	0.34	.175	0.41*	.094
Partial Correlations⁴				
PP	-0.02	.949	-0.48*	.058
RD	0.08	.782	-0.01	.963
DS	-0.50*	.050	0.28	.298

Note: Laterality Effect = [(Right Ear - Left Ear) / (Right Ear + Left Ear) x 100]. PP = psychomotor poverty; RD = reality distortion; DS = disorganization; CDS = Calgary Depression Scale; CARS-M = Clinician-Administered Rating Scale for Mania.

³ Due to the abnormal distribution of DS ratings, Spearman's rho was also computed between DS and total accuracy, $r = -0.46$, $p = .054$, and laterality, $r = -0.18$, $p = .464$.

⁴ Only mild modifications were noted when the effects of mania and depression were controlled for separately. Of interest, controlling for mania resulted in a correlation between PP and the laterality effect of $r = -0.51$, $p = .038$ and controlling for depression resulted in a correlation of $r = -0.47$, $p = .058$.

DISCUSSION

The Effects of Attention Manipulation on Language Laterality

The overall purpose of the present study was to investigate language lateralization in schizophrenia by systematically controlling for potential cognitive confounds of attention through the use of cues to help alert the patients to upcoming stimuli in the dichotic listening task. Contrary to predictions, patients with schizophrenia did not demonstrate a significantly lower REA in the traditional UC condition when compared to healthy controls. Moreover, neither the patients nor the controls demonstrated a significant change in their REA in the BT condition despite being given an auditory warning cue prior to the onset of the dichotic stimuli. Thus, patients with schizophrenia did not exhibit the expected normalization in language laterality with the aid of cognitive support that was given in the form of an alerting tone cue.

The present study aimed to address a practical question regarding the role of alertness in language lateralization in schizophrenia. This investigation was important, as past estimates of aberrant laterality in schizophrenia may have been obscured by decreased alertness in these patients, rather than accurately representing significant language impairment. Results revealed that in this sample of participants, alertness was not a critical determinant of language lateralization.

However, the schizophrenia patients in this sample did not demonstrate a significantly reduced REA in the traditional UC condition when compared to healthy controls, and thus the role of alertness in language laterality estimates could not be

adequately evaluated. It seems plausible that the patients, like healthy controls, may have already possessed the adequate attentional resources to complete the dichotic listening conditions successfully, given their normal REA, and therefore did not stand to benefit from the additional cognitive support of the tone cue. Thus, the benefits of cueing to improve alertness in laterality estimates for schizophrenia patients with diminished REAs remain unclear.

To explore this possibility in the current sample, data for schizophrenia patients were dichotomised into a low laterality group and a high laterality group, based on the laterality effects derived from the traditional UC condition. Results revealed that the laterality effect scores in the low laterality group increased from -0.26 (12.62) in the UC condition to 6.68 (14.87) in the BT condition, $d = 0.50$, whereas the laterality effect scores in the high laterality group decreased from 27.99 (10.19) in the UC condition to 20.87 (11.00), $d = 0.67$. Although these data are preliminary and quite limited given the small sample size, they support the possibility that the benefits of tone cueing may only exist for those with already diminished REAs. Further clarification on this issue thus appears warranted in future research.

Nevertheless, further analyses revealed that attentional processing differentially predicted accuracy in the UC and BT conditions for both patients and controls. More specifically, measures that heavily taxed selective attention were stronger predictors of total accuracy in identifying dichotic stimuli in the UC condition than they were in the BT condition. This suggests that the tone cue used to manipulate the participants' level of alertness in the BT condition had the expected impact, as accuracy was less associated with selective attention resources in the BT condition. However, neither total accuracy nor the degree to which the participants were lateralized for language processing were

improved by the tone cue. Thus, although the tone cue appeared to attenuate attentional demands (i.e., alertness) during dichotic listening, it did not moderate accuracy or lateralization in this sample of participants. However, alertness did not appear to be a critical factor in moderating the accuracy or laterality patterns in this sample, perhaps given that the patients already possessed a normal REA, and therefore the tone cue would not have been expected to ameliorate accuracy or laterality.

It is also important to recognize the possibility that alertness may not moderate patterns of language lateralization. More specifically, it may be the case that the inability to strengthen the REA with the aid of the tone cue is due to significant language impairment in schizophrenia that is unrelated to one's level of alertness. This explanation is further supported by previous findings of structural abnormalities in language areas of the brain in patients with schizophrenia (Highley et al., 1999; Shapleske et al., 1999; Shenton et al., 2001; Wright et al., 2000). Future research should help to clarify the nature of laterality deficits in these patients by further elucidating the potential role of alertness.

The Influence of Attentional Difficulties Over Time on Dichotic Listening Performance

Contrary to expectations, patients with schizophrenia did not demonstrate a decrease in their REA nor in their total accuracy over time in either of the dichotic listening conditions. This finding is consistent with past Continuous Performance Test research showing well-established deficits on this task in patients with schizophrenia but no differences in performance over time relative to controls (Cornblatt et al., 1989). It has thus been suggested that these patients differ on overall sensitivity (i.e., their ability

to respond to target stimuli but not to non-targets) on this test rather than on sustained attention (Green, 1998).

However, it is important to acknowledge the limitations of the current findings given certain methodological issues in the dichotic listening conditions employed in this study. More specifically, participants were required to complete three blocks of 36 trials each (total of 108 trials), where each block lasted for approximately three minutes with a brief break in between each block to repeat the instructions. Although administering trials in blocks during dichotic listening conditions is not uncommon, it seems likely that these breaks, as well as the constant, predictable intertrial intervals, supported the alertness of the participants, thus limiting the extent that sustained attention was taxed. It therefore remains unclear whether individuals with schizophrenia would demonstrate differential performance over time when cued versus uncued if the conditions were more taxing on their attentional processes.

The Relationship Between Symptom Dimensions of Schizophrenia and Language Lateralization and Accuracy

The current study also explored the existence of potential relationships between symptom dimensions of schizophrenia and both language laterality and overall accuracy in dichotic listening performance. Although there were no findings of differential performance between the UC and BT conditions, there were some interesting patterns that emerged between symptoms of psychosis and both language lateralization and overall accuracy.

Specifically, there was an association between increasing levels of DS and lower overall accuracy in dichotic listening performance. This finding is consistent with past

research demonstrating cognitive deficits in patients with predominant symptoms of DS, particularly in areas of distractibility, information processing, attention, and language functions (Basso, Nasrallah, Olson, & Bornstein, 1998; Cuesta & Peralta, 1995; Eckman & Shean, 2000; Strauss, Buchanan, & Hale, 1993). It seems surprising, however, that patients with higher levels of DS in this sample did not demonstrate lower language lateralization than patients with other symptoms dimensions given past findings of relatively more aberrant planum temporale asymmetry in these patients (Petty et al., 1995; Rossi et al., 1994) as well as reduced language lateralization in the left hemisphere (Kircher et al., 2002). However, the current finding is likely due to the small sample size and subsequent restricted variability of DS ratings. Specifically, 55.6% (10 / 18) of the patients in this sample received a DS rating of 0 and only 11.1% (2 / 18) received a score greater than 2 (total possible score on the DS rating equals 8). Conclusions regarding symptoms of DS and language lateralization in this sample therefore cannot be reliably drawn.

Interestingly, there was an association between increasing levels of PP and decreased laterality. This finding is surprising given that patients with predominant symptoms of PP have generally been shown to have a relatively higher REA than patients with other symptom types (Green et al., 1994; Levitan et al., 1999; Malaspina et al., 2000; Romney et al., 2000; Sommer et al., 2001b). This finding does, however, support previous neuroimaging studies that have revealed reduced perceptual asymmetry in patients with predominant psychomotor poverty related to left hemisphere dysfunction (Malaspina et al., 2000; Sommer et al., 2001b). Moreover, past research has also shown that verbal memory impairment is selectively associated with predominant symptoms of PP (Aleman et al., 1999; Green, 1998; O'Leary et al., 2000),

further highlighting the contention of an existing relationship between higher PP and a dysfunctional left hemisphere. Past fMRI research in healthy individuals has further shown that performance on dichotic listening tasks is associated with activations in the bilateral inferior frontal gyrus and the left middle frontal gyrus regions of the brain, in addition to language areas in the temporal lobes (Jancke & Shah, 2002). Of interest, PP has been shown to be associated with both decreased prefrontal gray matter and orbitofrontal regions and decreased frontal lobe functioning (Andreasen et al., 1992; Baare et al., 1999; Chua & McKenna, 1995), and it therefore seems possible that this might further affect their performance on dichotic listening tasks.

The current findings did not reveal an association between RD and the degree of language lateralization in patients with schizophrenia. These findings are inconsistent with past studies that have revealed an association between current auditory hallucinations and reduced language laterality in schizophrenia (Bruder et al., 1995; Green et al., 1994; Levitan et al., 1999; Sommer et al., 2001b). Given that RD includes ratings of other types of symptoms, such as visual hallucinations and delusions, data for patients who were currently hallucinating were further explored. Correlational analysis between ratings of hallucinations and laterality effects, however, did not reveal the existence a relationship, $r = 0.17$, $p = .493$, and thus the inclusion of other symptoms in the RD rating cannot account for the lack of an association between RD and language laterality in this study. The distribution of RD ratings was also normal, and therefore it does not appear as though these findings are due to a lack of variability in the data on these ratings. On the other hand, the current findings are consistent with the many studies showing that RD is generally not associated with cognitive deficits (Basso et al., 1998; Brazo et al., 2002; Moritz et al., 2001; O'Leary et al., 2000). The nature of the

relationship between RD and language lateralization in schizophrenia should be further clarified in future studies.

Limitations of the Current Study

Sample Size and Characteristics

Although there were some significant patterns of performance that emerged regarding differential relationships between selective attention measures and performance in the UC and BT conditions, as well as varying patterns in performance related to symptom presentation, the sample sizes were small and it is likely that there was insufficient power to detect other existing population differences. Despite the small sample, it is important to note that there was virtually no difference in the laterality effects between the two conditions for the patients, and thus null findings for the main questions of interest regarding the use of tone cueing in this sample do not appear to be the result of insufficient power.

Given the small sample size, there was also some restriction in the variability of data in certain measures, particularly in the symptom rating scales. Although there was a normal distribution of scores for ratings of RD, depression, and mania, there was less variability in both PP and DS ratings. It is therefore possible that more revealing associations between symptom patterns and differential task performance may have emerged with a larger sample size and more variability in the ratings.

Choice of Task

As previously mentioned, it seems likely that the dichotic listening conditions used in the present study were too supportive of the participants' attentional processes, thus limiting its ability to properly examine the presence of attentional difficulties over time. Future research using dichotic listening procedures that are more taxing on the patients' attentional processes may therefore help to clarify whether patients would exhibit differential performance over time when cued versus uncued. Although this would be interesting, it would not explain the reduced REA found in past studies, given that dichotic listening tasks are generally not designed to purposely tax the cognitive functions (i.e., sustained attention) of the participants.

The dichotic listening tests were administered by means of a standard portable CD player, and it was therefore not possible to collect reaction time data to investigate whether the tone cues would decrease the time required to respond to dichotic stimuli. This was not pursued here because such an endeavour would require the use of computerized stimulus presentation and data recording, which would subsequently require the use of a target detection task in which participant are required to report whether or not a specified target stimulus was presented on each trial. Although this is an appropriate method to examine language lateralization, the majority of past studies in schizophrenia have employed more free recall based dichotic listening methods in which participants are required to report whichever stimulus they heard best on each trial. Given that the current study aimed to investigate the potential benefits of tone cueing as compared to the more commonly employed dichotic listening methods in schizophrenia research, it was decided that a free recall based test of dichotic listening would be more appropriate for this study.

Tone Cue

Despite evidence that the tone cue decreased attentional resource demands during the dichotic listening task, there is some evidence that a longer SOA between 400 msec to 600 msec may have produced an even more beneficial response (Posner & Boies, 1971; Whyte et al., 1997). However, it is important to note that the 150 msec SOA used in the current study appears to be within the range of appropriate SOAs employed in previous research. For example, Hirt and Pithers (1990) investigated arousal and maintenance of a heightened attentional state in patients with schizophrenia by using a range of SOAs between 0 and 4000 msec. Although they found that reaction time was fastest for patients when given an SOA of 400 msec, results also revealed that reaction times obtained at SOAs between 10 to 3000 msec did not significantly differ from the reaction time obtain at 400 msec, and therefore concluded that the entire range of SOAs was appropriate for alerting patients to target stimuli. Thus, the SOA used in the present study appears to be effective at improving alertness in schizophrenia.

Concluding Statements

Overall, there is evidence that employing tone cues just prior to the onset of stimuli in verbal dichotic listening tasks reduces attentional demands. However, these cues do not appear to moderate the degree to which individuals are lateralized for language. Future research, however, should clarify whether the use of auditory warning cues in dichotic listening tasks would be helpful in schizophrenia patients with known reductions in REA, as they may be in more need of the additional cognitive support.

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APPENDICES

Appendix A: Overview of the Psychometric Properties of the Dichotic Listening Task

On average, dichotic listening tasks produce moderate reliability estimates of approximately 0.70 (Voyer, 1998). After partitioning the effects of test stimuli, the reliability of tasks employing either fused-words or consonant-vowel (CV) syllables increase to approximately 0.80, with CV syllables having the highest reliability (Voyer, 1998). Although dichotic listening tasks have been shown to reliably demonstrate a REA in about 80% of right-handers, a REA in left-handers occurs in only about 65% of cases (Hugdahl, 1995). This is not surprising given that non-right-handed adults tend to be less lateralized for language in the left hemisphere, and previous findings of language lateralization in these individuals have been inconsistently reported (Jancke & Steinmetz, 2003). It is for this reason that many studies employing the dichotic listening task only test individuals who are right-handed.

The validity of this technique has been examined using more direct measures of cerebral lateralization. For example, Zatorre (1989) directly examined the relationship between language lateralization on the dichotic listening task and speech lateralization using the carotid sodium amytal test in individuals with epilepsy. Results revealed a near perfect classification of the dichotic listening task, as compared to the carotid sodium amytal test, that could not be accounted for by handedness, family handedness, sex, or side of epileptic lesions. Moreover, a study investigating language lateralization with functional MRI (fMRI) and a dichotic listening task in 17 right-handers and 17 left-

handlers demonstrated an overall agreement of lateralization between the two techniques of 97.1% (Hund-Georgiadis, Lex, Friederici, & von Cramon, 2002).

In an attempt to investigate the mechanisms underlying the dichotic listening task in healthy individuals, Davidson and Hugdahl (1996) examined the relationship between performance on a CV syllable dichotic listening task and baseline asymmetry of electrophysiological activation using an electroencephalogram (EEG). Results revealed that individuals with greater activation in the left posterior temporal and parietal lobe regions had a larger REA. However, it is also important to note that these researchers, as well as others (Jancke & Shah, 2002), have found additional involvement in prefrontal regions of the brain, thus indicating that dichotic listening procedures likely activate more complex frontotemporal circuits related to language processing, rather than isolated temporal lobe functioning.

Appendix B: Instructions for the Dichotic Listening Tasks

UC Condition:

"You should listen to the six different sounds which are given on this page (*show the examinee the sheet with the dichotic list*). After each presentation, you should repeat whichever sound you hear. Say the sound loud and clear directly after it has been presented. Sometimes it will seem as if you hear two different sounds at the same time. Don't worry about this, but say the sound you seemed to hear **best** or most clearly. Don't spend time thinking, but just repeat the sound as soon as it has been presented. Try to respond to each trial. There are many trials, but try your best on all trials."

BT Condition:

"You should listen to the six different sounds which are given on this page (*show the examinee the sheet with the dichotic list*). After each presentation, you should repeat whichever sound you hear. Say the sound loud and clear directly after it has been presented. Sometimes it will seem as if you hear two different sounds at the same time. Don't worry about this, but say the sound you seemed to hear **best** or most clearly. Don't spend time thinking, but just repeat the sound as soon as it has been presented. You will also hear a tone in both ears just before the presentation of each of these sounds (*point to the sheet with the dichotic list*). This is to help alert you to the upcoming trial. Try to respond to each trial. There are many trials, but try your best on all trials."

Appendix C:
Intercorrelations of Measures that Tax Selective Attention

Variable	Letter-Number Sequencing	Digit Symbol Coding	Symbol Search	Trails A	Trails B
Digit Span	0.68***	0.51**	0.54**	-0.33*	-0.63***
Letter-Number Sequencing		0.58***	0.70***	-0.63***	-0.70***
Digit Symbol Coding			0.81***	-0.56***	-0.55**
Symbol Search				-0.69***	-0.71***
Trails A					0.61***

Note: Trails A and B are measured in completion time, and therefore a higher score denotes poorer performance

N = 36, except for Letter-Number Sequencing, *N* = 35

* *p* < .05

** *p* < .01

*** *p* < .001