Language context processing deficits in schizophrenia: The role of attentional engagement

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ABSTRACT

Individuals with schizophrenia exhibit problems in language comprehension that are most evident during discourse processing. We hypothesized that deficits in cognitive control contribute to these comprehension deficits during discourse processing, and investigated the underlying cognitive-neural mechanisms using EEG (alpha power) and ERPs (N400). N400 amplitudes to globally supported or unsupported target words near the end of stories were used to index sensitivity to previous context. ERPs showed reduced sensitivity to context in patients versus controls. EEG alpha-band activity was used to index attentional engagement while participants listened to the stories. We found that context effects varied with attentional engagement in both groups, as well as with negative symptom severity in patients. Both groups demonstrated trial-to-trial fluctuations in alpha. Relatively high alpha power was associated with compromised discourse processing in participants with schizophrenia when it occurred during any early portion of the story. In contrast, discourse processing was only compromised in controls when alpha was relatively high for longer segments of the stories. Our results indicate that shifts in attention from the story context may be more detrimental to discourse processing for participants with schizophrenia than for controls, most likely due to an impaired ability to benefit from global context.

1. Introduction

Individuals with schizophrenia have a variety of cognitive impairments that are resistant to standard treatments, and are related to functional outcomes (Carter, 2006; Green et al., 2000, 2004; Green and Nuechterlein, 1999). Language processing is one area in which abnormalities have consistently been observed in the disorder, in both speech production and comprehension (Bleuler, 1950; Kraepelin, 1971; Kuperberg, 2010; Kuperberg and Caplan, 2003). Recent studies of language comprehension have found that individuals with schizophrenia tend to exhibit the most pronounced impairment at the discourse (multi-sentence) level, when demands on controlled processing are high (Ditman and Kuperberg, 2007; Swaab et al., 2013). This pattern of impairment has been related to more general context processing and cognitive control deficits that are often observed in schizophrenia (see Boudewyn et al., 2012a for a review).

Our goal in this study was to investigate the extent to which individuals with schizophrenia use context in language to guide processing of incoming words. Participants listened to cartoon-style stories, in which inanimate objects (e.g., a peanut) were described as animate protagonists. This allowed us to examine how listeners process incoming words as a function of the local context (e.g., The peanut was elated/salted) and as a function of knowledge from the global context that the object had animate characteristics. Previous work has demonstrated that healthy adults quickly develop discourse representations and that these global representations can facilitate processing of incoming words that violate local animacy constraints (e.g. a singing, dancing inanimate peanut in a cartoon) (Nieuwland and Van Berkum, 2006). Our overarching hypothesis is that individuals with schizophrenia are impaired in their use of global context as they process incoming words due to general context processing deficits. Numerous studies suggest that these deficits form a core impairment in schizophrenia (Barch et al., 2003; Carter et al., 2012; Lesh et al., 2011). We were further interested in the role of attentional engagement during listening as a contributing factor in whether or not context is used in processing incoming words. Below, we introduce previous research on language and context processing deficits in schizophrenia and then provide a brief introduction to previous work that has linked changes in alpha-band EEG activity to attention. Finally, we describe our experimental manipulation and predicted results.

1.1. Language and context processing deficits in schizophrenia

Previous studies have documented significant deficits in language in schizophrenia. In speech production, a number of commonly observed abnormalities have been reported at the discourse level. For example, speech that is characterized by disjointed slips from one topic to another is captured by the clinical term *derailment*, and is one feature of the disorganized speech that is often seen in the disorder (Andreasen, 1979a, 1979b). Several studies have provided evidence for discourse-level impairments in language comprehension, as well (Ditman and Kuperberg, 2007; Swaab et al., 2013). The results of these studies indicate that individuals with schizophrenia are limited in their ability to benefit from context when processing incoming words and phrases (Boudewyn et al., 2012a; Gernsbacher et al., 1999; Kuperberg, 2010).

Previous studies suggest that individuals with schizophrenia tend to show the most marked language comprehension impairments when these cognitive control functions are taxed. For example, individuals with schizophrenia do not benefit from discourse organization to the same extent as control participants, showing limited improvements in text recall with increased text coherence (Levy and Maxwell, 1968; Maher et al., 1980). Individuals with schizophrenia also demonstrate deficits in the ability to draw inferences using available context compared to control participants (Ditman and Kuperberg, 2007). Further, we recently found that participants with schizophrenia showed a context effect during the processing of incoming words only when primed by an immediately preceding cue word (Swaab et al., 2013).

Lexical ambiguity provides another example of a language processing situation in which cognitive control functions are engaged. When ambiguous words such as *bridge* are encountered in discourse, both meanings (e.g. *card-game* and *architectural structure*) are initially activated and then context is used to select the appropriate meaning and suppress the inappropriate one (e.g. The guests were playing….-*bridge*; suppress *architectural structure*). In contrast to healthy controls, individuals with schizophrenia are impaired at suppressing the context-irrelevant meaning of an ambiguous word in favor of the context-relevant meaning one (Sitnikova et al., 2002). Results such as these have led to the hypothesis that many language impairments in schizophrenia may be related to an underlying deficit in cognitive control (Boudewyn et al., 2012a).

1.2. Attention, alpha-band activity and language processing

Readers and listeners must sustain attention to incoming words and phrases in order to construct an accurate and coherent discourse representation. This is especially true during listening comprehension, due to the fleeting nature of the speech signal. However, attention during discourse processing typically waxes and wanes: some studies estimate that individuals spend between 30–50% of the time off-task during language processing (Franklin et al., 2011; Giambra, 1995; Smallwood et al., 2008; Uzzaman and Joordens, 2011). Lapses of attention during comprehension lead to impaired comprehension performance. Smallwood et al. (2008) found that increases in the number of attentional lapses that were reported while reading a detective story were associated with poorer comprehension on a subsequent multiple-choice comprehension test.

Attention engages numerous neural substrates, and there is no straightforward neural signature to indicate when an individual is off-task. However, neuroimaging studies have linked attentional lapses to activity in the default mode network, a large-scale neural network in which activity appears to be suppressed during active task engagement in numerous fMRI studies (Allen et al., 2013; Andrews-Hanna et al., 2014; Christoff et al., 2009; Dumontheil et al., 2010; Kucyi et al., 2013; Mason et al., 2007; Mittner et al., 2014; Stawarczyk et al., 2011). In EEG, changes in attentional focus have been linked to changes in alpha-band (~8–12 Hz) activity. For example, alpha activity increases

when the eyes are closed compared to when they are open (e.g. Adrian and Matthews, 1934), and tends to decrease as task difficulty increases (e.g. Gevins et al., 1997; Van Winsum et al., 1984). There are several theories as to the functional significance of alpha activity, including that it reflects a "cortical idling" signal (Pfurtscheller et al., 1996), the active inhibition of sensory stimuli (Klimesch, 2012; Klimesch et al., 2007; Roux and Uhlhaas, 2014), and that it is modulated in concert with activity in other bands to facilitate the processing of sensory input (Arnal and Giraud, 2012; Samaha et al., 2015).

One reliable finding is that increases in alpha are associated with the direction of attention inward, away from external stimuli, in scalp-recorded EEG (Jensen et al., 2002; Jensen and Mazaheri, 2010; Mazaheri and Jensen, 2010; Roux and Uhlhaas, 2014). This does not necessarily equate increases in alpha with attentional lapses, as that depends on the nature of the task. For example, a shift of attention inward toward internal representations and away from external stimuli may optimize task performance during the delay period of a working memory task, when a memory set must be maintained prior to recall. Indeed, increases in alpha accompany increases in memory load during such tasks (Jensen et al., 2002). In other tasks, however, such as language comprehension, shifts of attention away from the auditory or visual input are not likely to promote optimal task performance, since information relevant to comprehension may be missed. In this case, increases in alpha may indicate shifts in attention away from the task that may be detrimental to task performance. In line with this reasoning, we recently found that relative increases in alpha power when critical information was presented during story listening predicted individuals' later ability to access that information (Boudewyn et al., 2015).

The engagement of attention has typically been studied separately from language processing in schizophrenia. However, deficits in sustained attention and vigilance have consistently been demonstrated in individuals with the disorder (e.g. Liu et al., 2002; Nestor et al., 1990; Nuechterlein et al., 2015). In addition, there is some indication that individuals with the disorder may be more prone to attentional lapses during cognitive tasks than are control participants, which may partially drive differences in performance (Barch et al., 2012). In the current study, we examined how fluctuations in attention during language processing influence discourse comprehension. Specifically, we used changes in alpha power as an index of attentional engagement as participants listened to cartoon-style stories for comprehension.

1.3. Current study

The goal of this study was to examine whether individuals with schizophrenia use global discourse representations of cartoon-like stories to override local animacy violations (e.g., a singing peanut). Specifically, EEG was recorded while participants listened to cartoon-style stories featuring an inanimate character (see Table 1 for a sample story set; see Appendix 1 for additional sample stories). The stories introduced an inanimate object in the first sentence as an animate character. Its animacy was established by using language that is normally reserved for animate agents (e.g. references to the character having a big smile on his face). In the animate condition, a critical target word in the fourth sentence (e.g. *elated*) was used that requires

Table 1
Sample stimulus set in both conditions (Animate, Inanimate). All stimuli were presented in the auditory modality in this experiment.

Sentence 1: A lucky peanut had a big smile on his face.
Sentence 2: The peanut was amazed about his good fortune.
Sentence 3: Just now he had won the jackpot of two million dollars.
Sentence 4: The peanut was elated[ANIMATE] / salted[INANIMATE], and who could blame him.
True/False: The peanut won the jackpot.