Language Context Processing Deficits in Schizophrenia: The Role of Attentional Engagement

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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.

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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$^{\text{ANIMATE}}$ / salted$^{\text{INANIMATE}}$, and who could blame him.
True/False: The peanut won the jackpot.

an animate object as one of its thematic roles. In the inanimate condition, this word was replaced by a target word (e.g. *salted*) that was inappropriate in the global context but typically takes an inanimate object as one of its thematic roles in the real world (e.g., peanuts are often salted). Thus, context-appropriate processing of the critical target word requires having developed a representation of the inanimate object as an animate protagonist in the global context, sufficient to render a local animacy violation acceptable by the fourth sentence. We hypothesized that participants with schizophrenia would be impaired at this task compared to control participants, such that they would continue to show a local animacy violation effect on the critical target word even though the global context licensed treatment of the character as animate.

In order to test this hypothesis, we examined the N400 elicited by critical target words. The N400 is a negative-going ERP waveform that is reduced in amplitude as a function of semantic fit and lexical properties (see Swaab et al., 2012, p. for a review). Previous studies have demonstrated that healthy adult readers and listeners are rapidly sensitive to the currently developing discourse context, showing reduced N400 amplitudes to target words that are context-appropriate compared to context-inappropriate (Boudewyn et al., 2012b; Camblin et al., 2007; Van Berkum et al., 1999). Previous work in healthy adults has also shown that, in cartoon contexts similar to those used in the current study, N400 effects at the target words are influenced by the current discourse context, such that "the peanut was *elated*" yields a reduced N400 amplitude compared to "the peanut was *salted*" (Nieuwland and Van Berkum, 2006). We predicted that a similar pattern would be observed in the healthy control group. In contrast, we predicted that context processing deficits in individuals with schizophrenia would lead to reduced N400 effects of discourse context.

We also hypothesized that the extent to which processing of the critical target words was guided by context would vary across individuals in both groups. To examine individual differences in the ERP effects, all participants completed three behavioral tasks in addition to the EEG task: the Listening Span task, the AX version of the Continuous Performance Task (AX-CPT), and the Nelson-Denny vocabulary test. The Listening Span task was included as a measure of working memory span, which has been related to the ability to use language context in previous ERP studies (e.g. Boudewyn et al., 2013; Nakano et al., 2010; Van Petten et al., 1997). Thus, performance on the Listening Span task may be predictive of the N400 context effect. The AX-CPT has been used in previous studies to examine individual differences in the ability to maintain and use context during the performance of cognitive tasks (Cohen et al., 1999), and therefore may also be predictive of the N400 context effect in the current study. A measure of vocabulary size was included because this measure accounts for more variation in language comprehension ability than individual differences in other linguistic and cognitive abilities (Blozis and Traxler, 2007; Hamilton et al., 2013; Long et al., 2006). We used a multiple regression approach to determine whether performance on the Listening Span task, the AX-CPT, and the vocabulary test were unique in predicting variation in the N400 context effect.

Finally, we used EEG activity in the alpha frequency band in order to examine the relation between shifts in attention to the external stimulus (the story) and language context effects at the critical target words in the fourth sentence of each story. In previous work, we have investigated the role of attention during language comprehension by examining individual differences in alpha power changes during language processing and relating those changes to ERP effects (Boudewyn et al., 2015). Here, we adopted a similar approach, but focused on within-participant (trial-to-trial) fluctuations in alpha-band activity, measured while participants listened to the story context preceding the critical words to which ERPs were time-locked. We predicted that N400 amplitude to the critical target words in sentence 4 would be modulated by condition (Animate, Inanimate) and by alpha power. Specifically, we predicted that higher alpha power would be associated with a reduced N400 effect.

2. Methods

2.1. Participants

Thirty individuals with schizophrenia or a schizophrenia-spectrum disorder and 27 healthy controls completed the study. All participants provided informed consent prior to enrollment, with the approval of the Institutional Review Board at the University of California, Davis. All participants were compensated at a rate of $15 per hour for EEG and behavioral testing; patient participants were compensated $25 for completion of a clinical interview and symptom ratings session. Participants with schizophrenia were within 5 years of the onset of their psychotic symptoms, and were recruited through the Early Diagnosis and Preventive Treatment of Psychosis (EDAPT) clinic at the University of California, Davis Medical Center.

Four participants in the schizophrenia (SZ) group and three HC were ultimately excluded from all analyses due to the presence of excessive artifacts in their EEG data (see EEG Recording & Processing section below for details). Thus, the SZ group included 26 individuals and the HC group included 23 individuals. Participants with schizophrenia ranged in age from 18 to 30 years (mean: 22.6); 81% were male. HC ranged in age from 18 to 29 years (mean: 22); 74% were male. All participants were recruited with the following exclusion criteria: (1) IQ below 70, as measured by the Wechsler Abbreviated Scale of Intelligence or Wechsler Test of Adult Reading; (2) history of neurological illness, including head injury; (3) substance-related disorder in the previous six months; (4) uncontrolled medical illness; (5) history of electro-convulsive therapy. Twenty-four of the 26 participants with schizophrenia were right-handed (92.3%), and 21 of the 23 HC were right-handed (91.3%). HC were evaluated using the Structured Clinical Interview for DSM-IV-TR (SCID) (First, 2005) to exclude those with a history of an Axis 1 disorder or first-degree relatives with a psychotic disorder. All participants tested negative on a urine drug screen test immediately prior to completion of the study. See Table 2 for additional demographic information.

2.2. Clinical and functional characteristics

Clinicians conducted all diagnostic evaluations, and diagnoses were confirmed by consensus conference. All clinicians had demonstrated reliability, defined by $>.8$ intra-class correlation-coefficients for continuous measures, and kappa $>.7$ for categorical measures; all participated in monthly reliability checks to prevent drift from these standards. Clinical symptom scores were measured using the Scales for the Assessment of Positive and Negative Symptoms (SAPS and SANS) (Andreasen, 1981, 1984).

2.3. EEG task stimuli

The stimuli consisted of 80 story sets. A set was comprised of two

Table 2
Demographic, symptom severity and daily functioning information for all participants. Significance levels reflect *t*-tests between HC and SZ groups. $^{**}p < .01$.

	Control participants (N =23)		*Participants with schizophrenia (N =26)*	
Demographics	*Mean*	*SD*	*Mean*	*SD*
Age	22	2.9	22.6	3.1
Participant education (years)	15	2	13.5**	1.2
Parental education (years)	15.7	2.9	15.1	2.1
Symptom ratings	*Mean*	*SD*	*Min*	*Max*
SAPS total	3.2	2.8	0	10
SANS total	8.9	3.9	1	15

conditions of the same story: Animate and Inanimate. Stories were translated from Dutch to English and adapted for the purposes of the current study from those used in Nieuwland and Van Berkum (2006). Each story contained 4 sentences. For all stories, an inanimate, cartoon-like character was introduced in the first sentence (e.g. a peanut that is described as happy and smiling). The passages were written so that each sentence reinforced that the normally inanimate object (e.g., the peanut) served as an animate character in this context. This was accomplished by references in the first three sentences to the character using pronouns reserved for animate characters (he/she), and by the use of verbs and descriptions likewise reserved for animate characters (e.g. the peanut had a big smile…; the peanut was amazed…). Then, in sentence 4, the character was described using a critical word that requires an animate or inanimate object to fill one of its thematic roles. This critical word was therefore consistent with either the immediately preceding context (cartoon-style context-Animate critical word), or inconsistent (cartoon-style context-Inanimate critical word). Inanimate critical words were chosen to be consistent with the most typical, non-cartoon-style meaning of the inanimate objects that served as the animate character. See Table 1 for an example.

The critical words (e.g. elated, salted) were matched in lexical frequency, length and number of syllables across conditions.[1] To measure lexical frequency, we used LG10CD values from the SUBTLEXus database (http://expsy.ugent.be/subtlexus). The average LG10CD lexical frequency value for critical words in the Animate condition was 1.94 (SD: .62), and 1.8 (SD: .66) in the Inanimate condition. Critical words were also matched in length and number of syllables. The average length of Animate critical words was 7.9 characters (SD: 1.7), and 7.5 (SD: 1.9) for Inanimate critical words. The average number of syllables of Animate critical words was 2.6 (SD: .8), and 2.4 (SD: .84) for Inanimate critical words.

Stimuli were recorded for auditory presentation by a female speaker, using a natural inflection and speaking rate. The first three sentences of each passage, which comprised the discourse context for the fourth sentence (which contained the critical words), were recorded separately from the critical fourth sentences. The onset and offset of all critical words were determined by visual inspection of the speech waveform and by listening to the waveforms using speech-editing software (Audacity, by Soundforge). The average duration of the critical words was 637.6 ms (range: 366–974 ms); the critical words did not differ in duration between conditions (p=.4).

One hundred and sixty filler stories of comparable length and structure were also included. These served as experimental stories for a separate study, and also consisted of spoken 4-sentence stories, but did not feature cartoon-style protagonists. Instead, the filler stories featured canonically animate protagonists in non-anomalous scenarios (e.g. a seamstress mending clothes). These stories included a syntactic manipulation in which a prepositional phrase in the fourth sentence attached to the main verb or attached to the direct object (e.g. repaired the sock with the thread/hole). Comprehension questions followed all stories (experimental items and fillers). The correct answer to half of the questions was true, whereas the correct answer to the other half was false. Stimuli were divided into four lists for presentation, such that each list contained 40 stories in each condition (Animate, Inanimate), and no list contained both conditions of the same item.

2.4. Stimuli for behavioral tasks

In addition to the EEG task, participants completed three behavioral tasks designed to assess vocabulary, working memory, and cognitive control (the Nelson-Denny vocabulary test, Listening Span, and the AX-CPT, respectively).

All participants completed the vocabulary section of the Nelson-Denny Reading Test, a standardized paper and pencil multiple-choice assessment. Participants were allotted 15 min to complete the section. Vocabulary is strongly predictive of language comprehension abilities (Long et al., 2008) and was employed in this study to examine individual variation in the ERP/EEG data that may be due to variability in verbal ability. Nelson-Denny vocabulary scores were calculated as the total percent correct for the vocabulary section, Form G (out of 80 possible).

The Listening Span task was adapted from Daneman and Carpenter (1980) and consisted of 25 sets of sentences ranging from two to six sentences per set; there were five sets of each set size. Participants were instructed to listen to all sentences within each set for comprehension and then to indicate whether each sentence was true or false immediately after hearing it. In addition, participants were instructed to remember the final word of each sentence in the set and were asked to recall them in any order after the whole set was presented. There was a 1500 ms pause between each sentence during which participants made their true/false response. Presentation of sets was random. Each correct response (accurate final word recall) was scored as one point, for a maximum of 100 points.

The AX-CPT was designed to assess cognitive control mechanisms, specifically the ability to maintain task goals and task-relevant context (Cohen et al., 1999). The version used here was developed as part of the CNTRACS (Cognitive Neuroscience Test Reliability and Clinical applications for Schizophrenia) initiative, and is freely available via the CNTRACS website (http://cntracs.ucdavis.edu/task/dpx). In this task, participants respond to a series of letters via key press. They are told to respond with their index finger only to the letter X (target) and only when the X is preceded by the letter A (cue); they are asked to respond with a middle finger button press to all other letters. A-X cue-probe target sequences are frequent (70%) and set up a tendency to make a target response when the letter X occurs. Therefore, participants often make errors when the letter X appears, but was not preceded by an A (e.g., X preceded by the letter B). Good performance involves the ability to attend to the context in which the letter X occurs and to maintain the task goal throughout processing. D-prime values were computed as a measure of context processing (Cohen et al., 1999), using accuracy on AX trials, controlling for errors on BX trials. This provides a measure of the ability to maintain context (having just seen an A) in order to correctly respond to the target (X), taking into account false alarms to BX trials (d' context = z(AX accuracy) - z(BX error)).

2.5. Procedure

Stimuli were presented through Beyer dynamic headphones using Presentation software (Neurobehavioral Systems). Trials began with a white fixation marker at the center of the screen. The fixation marker was present from 1000 ms before stimulus onset and remained on the screen throughout presentation of the story. Following story offset, the fixation marker remained on the screen for 1000 ms, and was then replaced by a true/false comprehension question. Questions never queried information from the fourth sentence, which contained the critical target words. Participants were asked to make a true/false response via button press. Comprehension questions remained on the screen until participants responded.

Each stimulus list was divided into 20 blocks for presentation. Participants completed the 20 blocks from one list over two EEG sessions. Each session began with a practice block consisting of 8 stories. Lists and blocks were presented in counterbalanced order across participants. Participants completed the behavioral tasks after the second EEG session.

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[1] It was not possible to match critical words across conditions on all lexical properties (e.g. concreteness norming data was not available for the majority of critical words). Thus, there is the potential for some variance across lexical items. However, as noted above, critical words were carefully matched across conditions on lexical frequency, length, and number of syllables.

2.6. EEG recording and processing

EEG was recorded from 29 tin electrodes fitted in an elastic cap (ElectroCap International). The right mastoid electrode was used as the recording reference for all electrodes except those used to measure eye-movements. For these, electrodes above and below the left eye were referenced to each other and used to measure blinks; in addition, two electrodes at the outer canthi of each eye were referenced to each other and used to measure other eye-movements. Recordings from a left mastoid electrode were also obtained, and used for later re-referencing offline to the algebraic average of both mastoids. EEG was recorded using a Neuroscan Synamps 2 system, and digitized at a rate of 500 Hz, with half-amplitude cutoffs of .05–100 Hz. Electrode impedances were kept below 5 kΩ.

MATLAB (Mathworks) was used to process and analyze data, with the EEGlab toolbox (Delorme and Makeig, 2004) and ERPlab plugin (Lopez-Calderon and Luck, 2014), along with custom MATLAB code. Independent component analysis (ICA) was used to correct for artifacts caused by blinks, and single-trial waveforms were additionally screened for horizontal eye-movements, and any remaining blinks or movement-related artifacts. These artifact correction and rejection procedures were performed using epochs of 1200 ms for ERP analysis time-locked to the critical words (−200–1000 ms with respect to critical word onset). Baseline correction was performed using a −200–0 ms window relative to critical word onset. Average ERPs were computed using artifact-free trials in each of the two conditions. Four participants in the schizophrenia group and three in the healthy control group were excluded from all analyses because too few artifact-free trials (< 20 per condition) remained following artifact correction and rejection procedures. The remaining participants in the HC group (N=23) had an average of 33 artifact-free Animate trials (SD: 5.1) and 32 artifact-free Inanimate trials (SD: 5.5). The remaining participants in the SZ group (N=26) had an average of 31 artifact-free Animate trials (SD: 5.8) and 30 artifact-free Inanimate trials (SD: 5.8). There were no statistically significant differences between groups in the number of trials included. All ERPs were filtered off-line using a Gaussian low-pass filter (25 Hz half-amplitude cutoff). Statistical analyses were conducted using the filtered data.

For EEG analysis, epochs of 7300 ms were used (−1800–5550 ms with respect to 1st and 2nd sentence onset). EEG spectral power was calculated using the EEGlab toolbox, by convolving single-trial epochs with seven-cycle complex Morlet wavelets. Power for 52 log-spaced frequencies from 4 to 30 Hz was calculated for all trials and log-transformed. The alpha frequency band was defined as 8–12 Hz.

3. Results

3.1. Behavior

On average, individuals in the HC group were more accurate than individuals in the SZ group on the comprehension questions that followed the stories ($p < .05$). Average accuracy was 93% (range: 82.5–98.8%) in the HC group, compared to 89% (range: 73.8–98.8%) in the SZ group. Neither the HC nor the SZ group showed differences in accuracy across conditions.

3.2. ERP data: animate vs. inanimate critical words

To examine processing of the critical words in the fourth sentence, we focused on the N400 response. As in our previous work on discourse processing in schizophrenia, we conducted a repeated measures ANOVA on the mean amplitude of the N400 using the 350–650 ms time window relative to critical word onset, for the midline, medial, and lateral electrode columns. This time window was chosen following from our previous work examining the N400 effect in the same patient population as the current study (Swaab et al., 2013). Animacy (Animate, Inanimate) was included as a within-participants factor, and Group (SZ, HC) was included as a between-participants factor. To capture potential differences in distribution across the scalp, within-participants topographic factors were included for each column. For the midline column (electrodes Fz, Cz, Pz, PoZ), Electrode Site was included as a factor. For the medial (electrodes FC1, FC2, C3, C4, CP1, CP2) and lateral columns (electrodes F3, F4, FC5, FC6, CP5, CP6, P3, P4), two within-subjects topographic factors were included instead of Electrode Site: Hemisphere (Left, Right), and Anteriority (Medial: Fronto-Central, Centro-Parietal, Parietal; Lateral: Frontal, Fronto-Central, Centro-Parietal, Parietal). The Greenhouse-Geisser correction was applied to F tests with more than one degree of freedom in the numerator. Significant interactions with group were followed up with rANOVAs for each group separately. Results are summarized in Tables 3, 4. ERP waveforms for each group are plotted in Fig. 1.

Table 3
Group level rANOVA results for Animate vs. Inanimate N400 effect. ^$p < .1$, *$p < .05$; **$p < .01$.

	df	*Midline*		*Medial*		*Lateral*	
		F	*p*	*F*	*p*	*F*	*p*
Animacy	(1,47)	9.9	**	4.5	*	2.5	ns
Animacy X group	(1,47)	4	*	1.3	ns	1.2	ns
Animacy X electrode	(3,141)	4.5	*				
Animacy X electrode X group	(3,54)	< 1	ns				
Animacy X hemisphere	(1,47)			< 1	ns	2.9	ns
Animacy X hemisphere X group	(1,47)			1.3	ns	3.6	^
Animacy X Anteriority	Medial: (2,94);			5.2	*	4.2	^
Animacy X Anteriority X Group	Lateral: (3,141)			< 1	ns	< 1	ns
Animacy X Hemi X Anteriority X Group				1.1	ns	2	ns

The analyses yielded an effect of Animacy that significantly interacted with Group at the midline electrode column ($p < .05$; η^2=.04). Follow-up analyses showed that the effect of Animacy was significant in HC at midline ($p < .05$; η^2=.09) and medial columns ($p < .05$; η^2=.08). This is consistent with the typical central-posterior maximum of the N400 effect. In contrast, the effect of Animacy in the SZ group was less robust, and only significant at a subset of electrodes in the medial (p

Table 4
Follow-up rANOVA results for Animate vs. Inanimate N400 effect, for each group. ^$p < .1$, *$p < .05$; **$p < .01$.

	df	*Midline*		*Medial*		*Lateral*	
Control participants (N=23)		*F*	*p*	*F*	*p*	*F*	*p*
Animacy	(1,22)	16.3	**	5.7	*	3.5	^
Animacy X electrode	(3,66)	1.8	ns				
Animacy X hemisphere	(1,22)			< 1	ns	< 1	ns
Animacy X Anteriority	Medial: (2,44);			1.3	ns	2.2	ns
Animacy X Hemi X Anteriority	Lateral: (3,66)			< 1	ns	2.3	ns

	df	*Midline*		*Medial*		*Lateral*	
Participants with Schizophrenia (N=26)		*F*	*p*	*F*	*p*	*F*	*p*
Animacy	(1,25)	< 1	ns	< 1	ns	< 1	ns
Animacy X electrode	(3,75)	3.3	^				
Animacy X hemisphere	(1,25)			2.2	ns	6	*
Animacy X anteriority	Medial: (2,50);			5.6	*	2.1	ns
Animacy X hemi X anteriority	Lateral: (3,75)			< 1	ns	< 1	ns

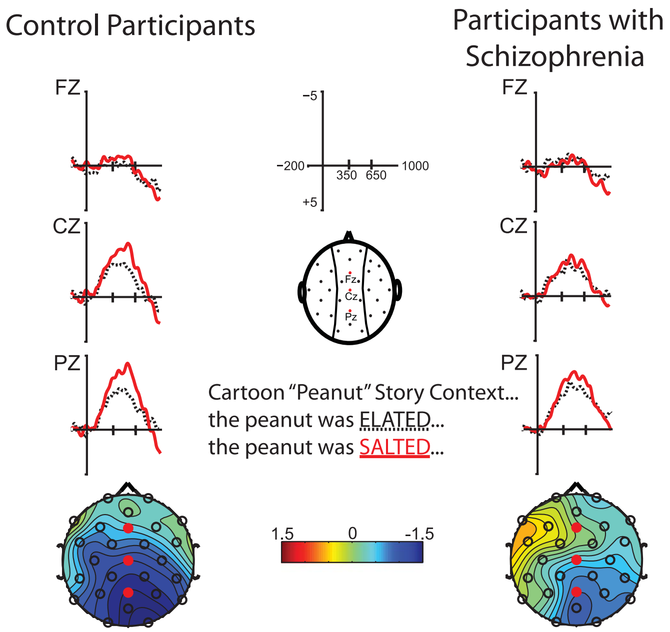

Fig. 1. Displayed are ERP waveforms comparing animate (dotted lines) vs. inanimate (solid lines) critical target words in Sentence 4. ERPs for control participants are plotted on the left and ERPs for participants with schizophrenia are plotted on the right. Topographic maps displaying the posterior distribution of the effect (Inanimate minus Animate, 350–650 ms time window post critical word onset) are plotted below ERP waveforms for each group. The displayed electrodes (Fz, Cz, Pz) are highlighted in gray on the topographic maps. Negative voltage is plotted up.

$< .05$; $\eta^2=.01$) and lateral columns ($p < .05$; $\eta^2=.01$), as evidenced by interactions of Animacy with the topographic factors Anteriority and Hemisphere.

3.3. Predictors of the ERP context effect: behavior and symptoms

To investigate how individual differences in our behavioral and symptom severity measures related to the ERP effects (Animate vs. Inanimate critical words), we first calculated simple correlations for these measures for each group separately. We then used a multiple regression approach, which allowed us to determine the unique contribution of each predictor in accounting for variance in the dependent measure (the ERP context effect). This approach also allowed us to include interactions with group in the same regression model. The ERP context effect was defined in these analyses as the difference in mean amplitude between the Animate and Inanimate conditions (Inanimate minus Animate) in the N400 time window (350–650 ms) at electrode Pz. Results are summarized in Tables 5, 6.

The Pearson's correlation results for the behavioral measures showed that Vocabulary and AX-CPT D-prime were significantly correlated with the N400 effect in HC (*p*s < .05). In the SZ group, there was a trend toward a significant correlation between Vocabulary and the N400 context effect (p=.09). Thus, Vocabulary and AX-CPT D-prime, along with their interaction term and interactions with group were entered into a stepwise multiple regression model. Results showed that only Vocabulary significantly predicted the N400 context effect, such that higher Vocabulary scores predicted larger N400 context effects ($p < .05$), with the overall model significant at trend level (R^2 =.2, $F(5,42)$=2.1, p=.086). Fig. 2 plots the N400 context effect as a function of Vocabulary score.

The Pearson's correlation results for the symptom severity measures showed that only negative symptom severity (SANS total score) was correlated with the N400 context effect ($p < .05$), such that higher negative symptom severity scores were associated with smaller N400 context effects. Positive symptom severity was not significantly correlated with the N400 context effect (p=.1). Fig. 3 plots the N400 context effect for individuals with schizophrenia as a function of negative symptom severity.

Table 5
Simple Pearson's correlation results for ERP Context effect (Animate vs. Inanimate critical words) and behavioral Measures (Vocabulary, Listening Span, AX-CPT D-prime). Note that larger N400 Context effects are reflected by more negative values. ^$p < .1$; *$p < .05$; **$p < .01$.

Control participants (N=23)	N400 context effect	Vocabulary	Listening span	D-prime
N400 context effect				
Vocabulary	−.48*			
Listening span	−.226	.53**		
D-prime	−.435*	.314	.361^	
Participants with schizophrenia (N=26)	**N400 context effect**	**Vocabulary**	**Listening span**	**D-prime**
N400 Context Effect				
Vocabulary	−.339^			
Listening Span	−.95	.451*		
D-prime	−.12	.21	.293	

Table 6
Multiple regression results with five predictors of the N400 context effect: Vocabulary, D-prime, Vocabulary By Group Interaction, D-prime by Group interaction, and Vocabulary by D-prime interaction. Unstandardized (b) and standardized (β) partial coefficients and probability levels (p) are shown. *$p < .05$.

N400 context effect Predictor	b	β	p
Constant	6.373		
Vocabulary	−.074	−.407	.018*
D-prime	−2.612	−.251	ns
Group X Vocabulary	.017	.308	ns
Group X D-prime	−1.631	−.308	ns
Vocabulary X D-prime	.008	.893	ns

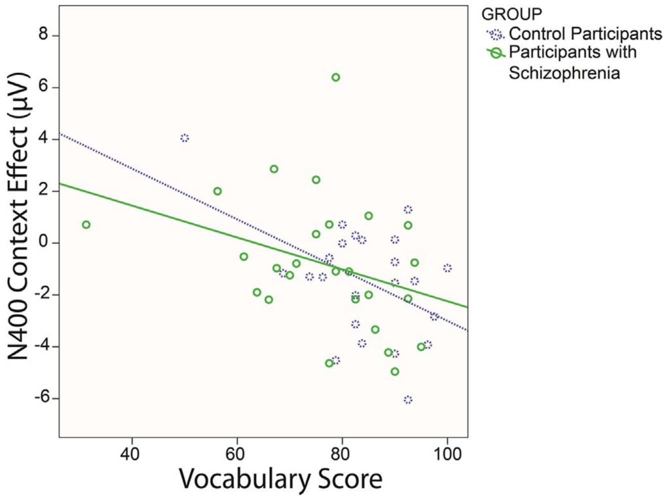

Fig. 2. Displayed is the single regression correlation between the N400 context effect (Inanimate minus Animate) and Vocabulary score. On the Y-axis is the N400 context effect; note that larger *negative* values denote larger effect sizes due to the negative-going nature of the N400 waveform. On the X-axis is Vocabulary score. Group status (Control or Patient) is denoted by dotted (Control Participant) or solid (Participants with Schizophrenia) circles; best fit lines are fitted for each group.

3.4. ERP context effect and attention

3.4.1. Alpha activity during sentence 1

In order to investigate within-participant (trial-to-trial) fluctuations

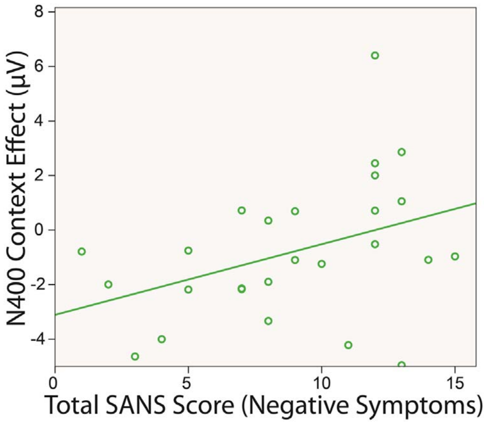

Fig. 3. Displayed is the single regression correlation between the N400 context effect (Inanimate minus Animate) and SANS total score (negative symptom ratings) for participants with schizophrenia. On the Y-axis is the N400 context effect; note that larger *negative* values denote larger effect sizes due to the negative-going nature of the N400 waveform. On the X-axis is SANS total score.

in alpha-band activity, we first obtained single-trial alpha power estimates, measured when participants were listening to sentence 1 of each story. For each participant, these estimates were divided into high and low alpha trials, using a median split (based on each individual's median alpha value during sentence 1). Single-trial mean amplitude measures in the N400 time window for the critical words on the corresponding trials (which end in the same stories, 3 sentences later) were calculated, for electrode Pz (where the N400 effects were maximal). These were analyzed using a repeated measures ANOVA as a function of condition (within-participants factor of Animacy) and Alpha (within-participants factor of High/Low Alpha power), and using the between-participants factor of Group (HC, SZ). Significant interactions with group were followed up with rANOVAs for each group separately. As this analysis entailed using longer epochs than in the ERP analyses described above, one additional participant in each group was excluded for excessive artifacts in the long-epoch ERP data. Thus, N=22 in the HC group and N=25 in the SZ group for this analysis. Results are summarized in Table 7.

Results showed a significant main effect of Animacy ($p < .01$; η^2=.06), characterized by a significant three-way interaction of Alpha X Animacy X Group ($p < .05$; η^2=.03). Follow-up analyses showed a main effect of Animacy in the HC group ($p < .01$; η^2=.13), but no main effect of alpha on N400 amplitude nor any significant interactions with Alpha. For the SZ group, Alpha and Animacy significantly interacted ($p < .01$; η^2=.11). Simple effects comparisons for the SZ group showed that the N400 effect of Animacy was only significant for Low Alpha trials ($p < .01$; η^2=.3). These results are plotted in Fig. 4.

3.4.2. Alpha activity during sentence 2

In order to determine whether the relation between alpha activity and the N400 effect at Sentence 4 was specific to alpha activity at the beginning of the stories (Sentence 1), we conducted an analogous analysis using alpha activity measured during Sentence 2. Results are summarized in Table 8.

We found a significant main effect of Animacy ($p < .001$; η^2=.09), characterized by a marginal Animacy X Group interaction p=.059; η^2=.02) and a significant interaction of Animacy X Alpha ($p < .05$; η^2=.02). Follow-up analyses showed a main effect of Animacy in the HC group ($p < .001$; η^2=.18), and no main effect of alpha on N400 amplitude nor any significant interactions with Alpha. For the SZ group, Alpha and Animacy significantly interacted ($p < .05$; η^2=.05). Simple effects comparisons for the SZ group showed that the N400 effect of Animacy was only significant for Low Alpha trials ($p < .01$; η^2=.29). These results replicate the pattern found in the Sentence 1 analyses above, and are plotted in Fig. 5.

Table 7
rANOVA results for mean amplitude in the N400 context effect time window as a function of Alpha Power (measured during sentence 1 of each story), Animacy and Group. ^$p < .1$; *$p < .05$; **$p < .01$.

Group level results			
	df	F	p
Alpha	(1,45)	< 1	ns
Alpha X group	(1,45)	< 1	ns
Animacy	(1,45)	10.6	**
Animacy X group	(1,45)	2.3	ns
Alpha X animacy	(1,45)	3.9	^
Alpha X animacy X group	(1,45)	5.4	*
Results by group			
Control participants (N=22)	df	F	p
Alpha	(1,21)	< 1	ns
Animacy	(1,21)	9.6	**
Alpha X animacy	(1,21)	< 1	ns
Participants with schizophrenia (N=25)	df	F	p
Alpha	(1,24)	< 1	ns
Animacy	(1,24)	1.7	ns
Alpha X animacy	(1,24)	10	**
Simple effects results for SZ group			
Participants with schizophrenia (N=25)	df	F	p
Low alpha: animate vs. inanimate	(1,24)	10.2	**
High alpha: animate vs. inanimate	(1,24)	2.1	ns

3.4.3. Alpha activity across both sentence 1 and 2

Finally, in order to examine whether relatively high alpha activity across multiple sentences influenced the N400 effect, we conducted an analysis in which High Alpha and Low Alpha trials were defined using both Sentence 1 and 2 alpha estimates. In this analysis, High Alpha trials were defined as those trials on which alpha measured during *both* Sentence 1 and Sentence 2 was above the respective median alpha estimates for S1 and S2. Likewise, Low Alpha trials were trials on which alpha measured during Sentence 1 was below the median Sentence 1 alpha value, *and* on which alpha measured during Sentence 2 was below the median Sentence 2 alpha value. Results are summarized in Table 9.

Results showed a significant interaction of Animacy X Alpha ($p < .05$; η^2=.04); no other effects were significant in the omnibus rANOVA. Follow-up analyses showed a main effect of Animacy for Low S1/S2 Alpha trials ($p < .05$; η^2=.12), but not for High S1/S2 Alpha trials; this effect did not interact with group. These results are plotted in Fig. 6.

4. Discussion

Our primary goal in this study was to investigate the role of attentional engagement in accounting for language processing deficits in comprehension. Participants listened to stories in which cartoon-like inanimate objects were established as main characters through the use of language normally reserved for animate protagonists (e.g. *The lucky peanut had a big smile on his face*....). In the final sentence of these stories, listeners encountered critical words that either constituted local animacy violations given the typical meaning of the inanimate object (Animate condition; *the peanut was <u>elated</u>*...), or constituted canonical descriptors of the inanimate object (Inanimate condition; *the peanut was <u>salted</u>*...). Importantly, target words in the Animate condition were supported by global context given the cartoon-like

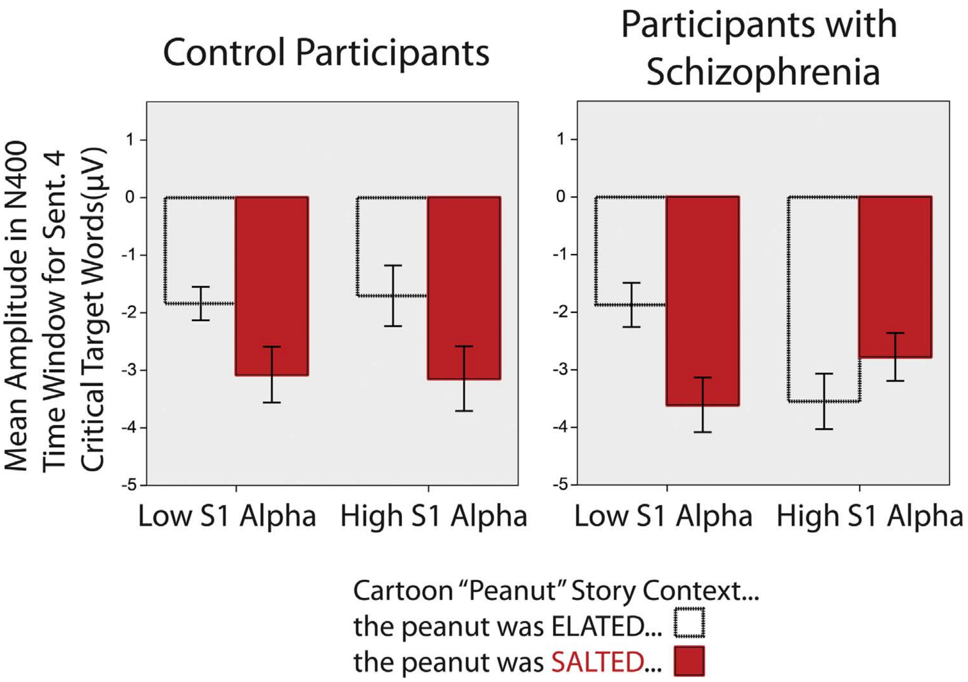

Fig. 4. Displayed is mean amplitude in the N400 time window following critical target words in Sentence 4, as a function of condition (Animate, Inanimate) and alpha power level measured during Sentence 1 of each trial (High, Low). On the Y-axis is mean N400 amplitude for sentence 4 critical target words; note that larger *negative* values denote larger effect sizes due to the negative-going nature of the N400 waveform. On the X-axis is Sentence 1 alpha level. Results for control participants are plotted on the left, and results for participants with schizophrenia are plotted on the right. Animate critical target words are displayed with dotted/open bars and Inanimate critical target words are displayed with solid/gray bars.

Table 8
rANOVA results for mean amplitude in the N400 context effect time window as a function of Alpha Power (measured during sentence 2 of each story), Animacy and Group. ^$p < .1$; *$p < .05$; **$p < .01$; ***$p < .001$.

Group level results			
	df	*F*	*p*
Alpha	(1,45)	1.1	ns
Alpha X group	(1,45)	< 1	ns
Animacy	(1,45)	15	***
Animacy X group	(1,45)	3.8	^
Alpha X animacy	(1,45)	4.2	*
Alpha X animacy X group	(1,45)	< 1	ns
Results by group			
Control participants (N=22)	df	*F*	*p*
Alpha	(1,21)	< 1	ns
Animacy	(1,21)	14.8	***
Alpha X animacy	(1,21)	< 1	ns
Participants with schizophrenia (N=25)	df	*F*	*p*
Alpha	(1,24)	< 1	ns
Animacy	(1,24)	2.1	ns
Alpha X animacy	(1,24)	5.2	*
Simple effects results for SZ group			
Participants with schizophrenia (N=25)	df	*F*	*p*
Low alpha: animate vs. inanimate	(1,24)	9.6	**
High alpha: animate vs. inanimate	(1,24)	< 1	ns

nature of the stories, whereas target words in the Inanimate condition were unsupported given the global context.

We found that both participants with schizophrenia and control participants showed an N400 effect of context, such that the N400 response to globally supported (Animate) target words was reduced compared to globally unsupported (Inanimate) words in both groups. However, this effect was significantly weaker in participants with schizophrenia compared to control participants. In addition, higher scores on a vocabulary test predicted larger ERP context effects in both the patient and control groups. In the patient group, higher negative symptom severity scores predicted smaller ERP effects. Most importantly, we found that whether or not processing of the critical target words was affected by global context depended on EEG alpha power measured on a trial-by-trial basis at earlier points in the stories. The relation between alpha power and the N400 effect at Sentence 4 varied as a function of group. Control participants did not show N400 effects when alpha activity was high across both Sentence 1 and Sentence 2 of the stories, but did show significant effects when alpha was only high during one of those sentences. In contrast, participants with schizophrenia showed N400 effects when alpha activity was low across Sentence 1 and also when it was low across Sentence 2. We discuss each of these findings in turn.

4.1. N400 context effect: basic ERP findings and relation to behavior and symptoms

Our results showed a significantly weaker context effect in participants with schizophrenia than in control participants. This is consistent with previous studies that have demonstrated impaired discourse-level processing in schizophrenia (Ditman and Kuperberg, 2010; Swaab et al., 2013). However, participants with schizophrenia still showed some sensitivity to context, albeit not to the same extent as participants in the control group. Thus, it was not the case that processing of the critical target words in patients was completely uninfluenced by the preceding discourse, or that processing was completely influenced by lower-level effects.[2] If that had been the case, participants in the

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[2] We attribute the N400 effect in the current study to the influence of discourse-level context on the processing of incoming words. It should be noted, however, that critical words differed across conditions; thus, it is possible that subtle changes in pronunciation based on particular upcoming critical words (coarticulation) could have contributed to

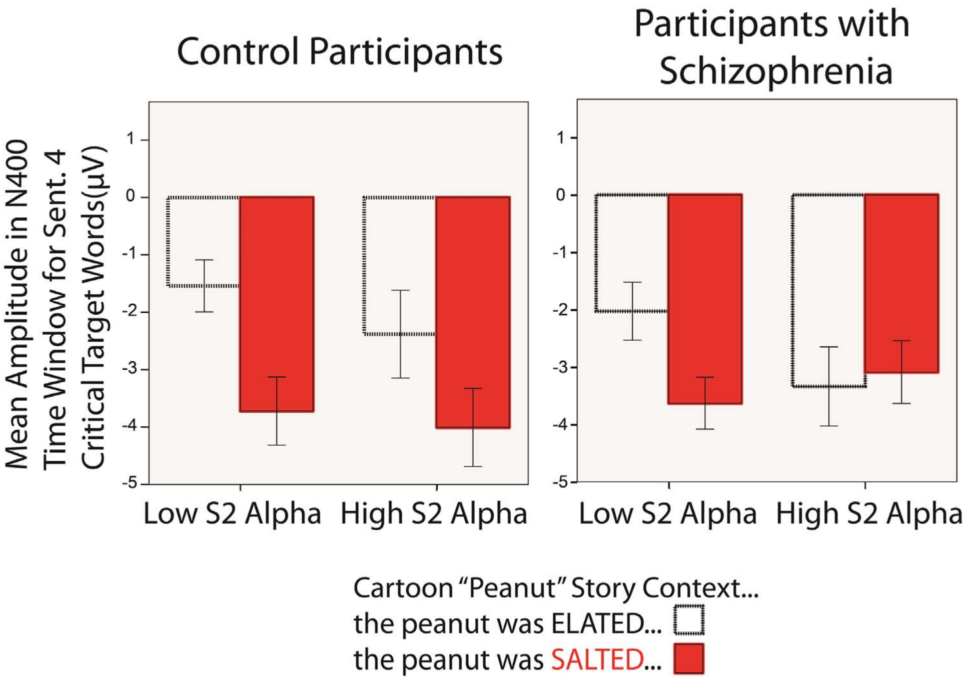

Fig. 5. Displayed is mean amplitude in the N400 time window following critical target words in Sentence 4, as a function of condition (Animate, Inanimate) and alpha power level measured during Sentence 2 of each trial (High, Low). On the Y-axis is mean N400 amplitude for sentence 4 critical target words; note that larger *negative* values denote larger effect sizes due to the negative-going nature of the N400 waveform. On the X-axis is Sentence 2 alpha level. Results for control participants are plotted on the left, and results for participants with schizophrenia are plotted on the right. Animate critical target words are displayed with dotted/open bars and Inanimate critical target words are displayed with solid/gray bars.

Table 9
rANOVA results for mean amplitude in the N400 context effect time window as a function of Alpha Power (measured based on Sentence 1 and Sentence 2 of each story), Animacy and Group. ^$p < .1$; *$p < .05$; **$p < .01$; ***$p < .001$.

Group level results			
	df	*F*	*p*
Alpha	(1,45)	< 1	ns
Alpha X group	(1,45)	< 1	ns
Animacy	(1,45)	< 1	ns
Animacy X group	(1,45)	1.5	ns
Alpha X animacy	(1,45)	5.8	*
Alpha X animacy X group	(1,45)	< 1	ns
Results by alpha level			
Low alpha	df	*F*	*p*
Animacy	(1,45)	5.9	*
Animacy X group	(1,45)	< 1	ns
High alpha	df	*F*	*p*
Animacy	(1,45)	1.1	ns
Animacy X group	(1,45)	1.3	ns

schizophrenia group would have demonstrated a reversal of the N400 effect relative to control participants, such that target words in the globally unsupported condition would have shown reduced N400 amplitude compared to the globally supported condition (which would normally be a local anomaly). Instead, the ability of participants in the schizophrenia group to override previous expectations (namely, that animate descriptors do not apply to inanimate objects) varied across individuals as a function of vocabulary and negative symptom severity, and varied within individuals as a function of attention to the story context.

Indeed, the influence of context on the processing incoming words varied in both groups as a function of vocabulary. Individuals with larger vocabularies tended to show stronger effects of context. This is consistent with our previous work in which individuals with larger vocabularies tended to show stronger referential ambiguity effects, which rely on accurate representations of preceding context (Boudewyn et al., 2015). This pattern is likely driven by the strong relation between the depth and breadth of vocabulary and general verbal ability (Long et al., 2006). Vocabulary is associated with a number of factors related to language comprehension ability, but is particularly related to print exposure, how much time individuals spend reading (Hamilton et al., 2013; Long et al., 2006). Our results extend previous research to show that vocabulary performance is associated with increased sensitivity to context not just in control participants but in participants with schizophrenia as well.

For participants with schizophrenia, negative symptom severity also contributed to variability in sensitivity to global context. Negative symptoms include several that are related to language and motivated behavior, such as poverty of speech (brief, unelaborated responses to questions), poverty of content of speech (responses conveying very little information), and inattentiveness (either social disengagement or lack of attention to clinician's testing) (Andreasen, 1981, 1982). Individuals with high scores on these and similar symptoms tended to show reduced context effects in this study. Relatively high negative symptom severity has also been shown to correlate with reduced use of language context in a previous behavioral study (Kuperberg et al., 1998). Furthermore, negative symptoms have been associated with deficits in selective attention (Nuechterlein et al., 1986) and performance on a variety of other cognitive tasks (Addington et al., 1991; Andreasen et al., 1990).

(*footnote continued*)
these effects. As coarticulation would represent one type of contextual information embedded in spoken discourse, this would not change the interpretation of our findings: that the patient group was less sensitive to context during comprehension than the control group.

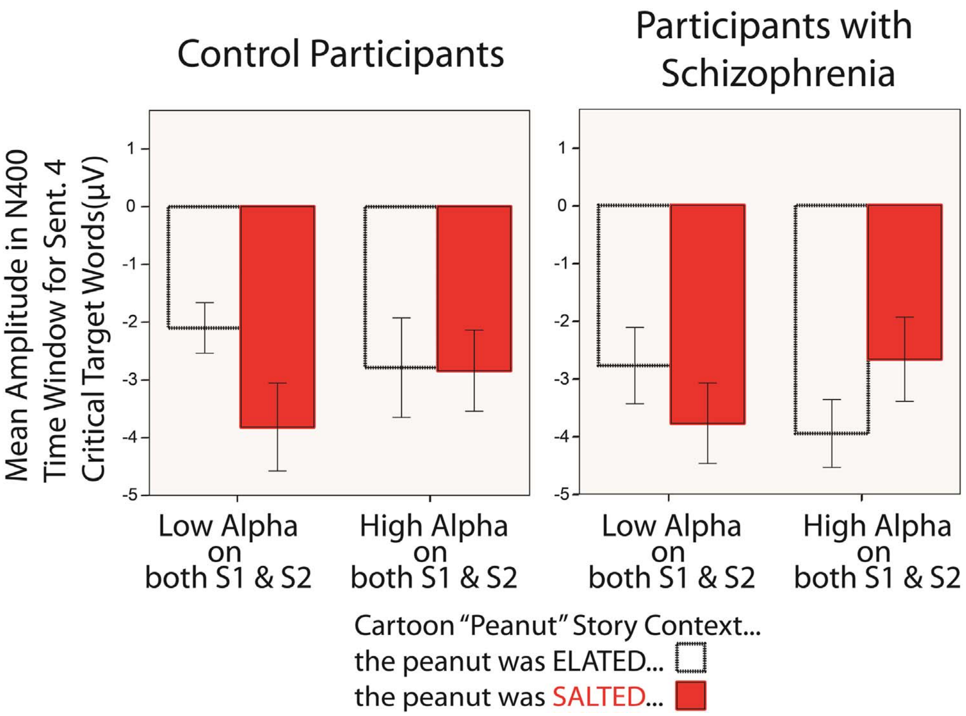

Fig. 6. Displayed is mean amplitude in the N400 time window following critical target words in Sentence 4, as a function of condition (Animate, Inanimate) and alpha power level measured using both Sentence 1 and Sentence 2 of each trial (High, Low). On the Y-axis is mean N400 amplitude for sentence 4 critical target words; note that larger *negative* values denote larger effect sizes due to the negative-going nature of the N400 waveform. On the X-axis is S1/S2 alpha level. Results for control participants are plotted on the left, and results for participants with schizophrenia are plotted on the right. Animate critical target words are displayed with dotted/open bars and Inanimate critical target words are displayed with solid/gray bars.

4.2. Sentence 4 N400 context effect and attention

The nature of context processing deficits in the schizophrenia group is informed by our oscillatory results. Although participants with schizophrenia showed weaker context effects overall, patients were sensitive to prior discourse in some conditions. Specifically, we found the strongest context effects when participants with schizophrenia were attentionally engaged in the stories, as indexed by relatively low alpha activity measured on a trial-by-trial basis, but that the context effect was not present when alpha activity during either Sentence 1 or Sentence 2 of the stories was relatively high. This pattern stands in contrast to that observed in control participants, who demonstrated significant context effects at Sentence 4 even when alpha activity was relatively high in Sentence 1 or Sentence 2. Context effects were diminished in this group only when alpha activity was high during *both* Sentence 1 and Sentence 2.

We argue that high alpha activity reflects a partial shift in attention away from the external stimulus (the story). The alpha results indicate that control participants did not require full attention to the entirety of the short stories in order to establish a contextual representation that was sufficient to render the Sentence 4 target words appropriate given the context. Instead, control participants who "missed" a small portion of the stories as indicated by high alpha activity (Sentence 1 or 2, but not both) established representations of the context that were sufficient to influence the N400 effect at the end of the story. This is consistent with previous studies that have shown that healthy adults develop and use prior context rapidly to guide the processing of incoming words, after even a single sentence of establishing context (e.g. Nieuwland and Van Berkum, 2006; Van Berkum et al., 1999).

The difference between the patient and control groups with respect to how attentional disengagement from the story affects language processing has important implications for understanding comprehension deficits in schizophrenia. Overall, patients showed reduced sensitivity to context (reflected in a reduced N400 context effect) compared to control participants. This is consistent with previous work which has found limitations in the ability to benefit from context when processing incoming words and phrases in schizophrenia (Boudewyn et al., 2012a; Ditman and Kuperberg, 2007, 2010; Levy and Maxwell, 1968; Maher et al., 1980; Sitnikova et al., 2002; Swaab et al., 2013).

The extent to which patients showed the ERP effect depended on their allocation of attention earlier in the story. When alpha activity during either of the first two sentences of the stories was relatively high, the ERP effect was diminished. Our interpretation of this pattern of results depends on our assumption that alpha activity correlates with the focus of attention, specifically the degree to which attention is directed toward an external stimulus. As discussed in the introduction, this is a reasonable assumption given prior research linking shifts in attention away from external stimuli to increases in alpha activity (Jensen et al., 2002; Jensen and Mazaheri, 2010; Mazaheri and Jensen, 2010; Roux and Uhlhaas, 2014). Based on this assumption, we suggest that the context processing deficits observed in the schizophrenia group may be secondary to deficits in attention to the stories. Participants in both groups had changes in alpha activity across trials that we suggest correspond to changes in attention to the external stimulus (i.e. both groups have trials with relatively low alpha activity and trials with relatively high alpha activity). However, these trial-by-trial fluctuations in alpha activity had the most pronounced influence on context effects in the schizophrenia group. In other words, full attention to the first two sentences of the stories was necessary for participants with schizophrenia to show context effects at the critical target words in Sentence 4. In contrast, control participants showed context effects even when they did not fully attend to a portion of the stories. When control participants "missed" one of the available opportunities to establish the inanimate object as a cartoon-style protagonist, their representation was still sufficient to produce the N400 effect later in the story.

This pattern of results suggests that inattention or shifts in attention away from the story context had a greater influence on discourse processing in participants with schizophrenia than in control participants. We suggest that the negative influence of lapses in attention on comprehension in schizophrenia is influenced by an already weakened ability to use context representations and/or a delayed time-course in the construction of such representations. These results highlight how attentional control failures in schizophrenia may contribute to impairments in language comprehension tasks in which attention over time is required to construct accurate, high-quality discourse representations. Language comprehension may be disrupted more by momentary lapses in attention among individuals with schizophrenia than among healthy adults, in that it may represent a case of "adding insult to injury". Namely, the cost of even brief lapses in attention to the developing discourse representation may be particularly pronounced in schizophrenia given existing impairments in establishing and making use of contextual representations.

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