Published in final edited form as:
J Neurolinguistics. 2010 May 1; 23(3): 254–269. doi:10.1016/j.jneuroling.2009.03.003.

Building coherence: A framework for exploring the breakdown of links across clause boundaries in schizophrenia

Tali Ditman[§,*] and **Gina R Kuperberg**[§,*]

[§] Department of Psychology, Tufts University, Medford, MA 02155

[*] Department of Psychiatry and Athinoula A. Martinos Center for Biomedical Imaging, Massachusetts General Hospital, Bldg 149, 13th Street, Charlestown, MA 02129, USA

Abstract

Clinically, patients with schizophrenia show prominent abnormalities at the discourse level, with production characterized by tangential and illogical relationships between ideas and unclear references. Despite these clinical manifestations, most studies of language in schizophrenia have focused on semantic relationships between single words and the build-up of meaning within single-clause sentences. The present paper discusses the few studies that have gone beyond clause boundaries to fully understand language impairments in schizophrenia. We also give an overview of a relevant literature that considers the neurocognitive mechanisms by which coherence links are established across clauses in healthy adults, providing a framework that may guide future research in this area.

Keywords

schizophrenia; discourse; ERP; fMRI; language; inferences; N400; pragmatics; right hemisphere; semantics; reference; sentences

Introduction

Schizophrenia is a neuropsychiatric disorder characterized by heterogeneous symptoms and neurocognitive dysfunction across multiple domains. Positive thought disorder has long been considered a cardinal clinical feature (Bleuler, 1911/195; Kraeplin, 1971). Thought disorder is most apparent in the disorganized and sometimes unintelligible language produced by some patients (DSM-IV, American Psychiatric Association, 1990). However, language impairments in schizophrenia are not confined to production. Although, from a clinical perspective, abnormalities of comprehension are more subtle than those of production, there is evidence that patients show selective cognitive impairments on a variety of language processing paradigms (Kuperberg, Ditman, Kreher, & Goldberg, in press). These abnormalities can be linked not only to disorganized speech, but also to other aspects of psychotic thought and behavior in schizophrenia, including delusions (e.g. Holt, Titone, Long, Goff, Cather, Rauch, Judge, & Kuperberg, 2006), hallucinations (e.g. Ditman & Kuperberg, 2005), non-goal-

Correspondence should be addressed to: Tali Ditman or Gina Kuperberg, Tufts University, Psychology Building, 490 Boston Ave, Medford, MA 02155, tditman@nmr.mgh.harvard.edu or kuperber@nmr.mgh.harvard.edu.

directed behavior (Sitnikova, Goff, & Kuperberg, in press), and negative symptoms (Kuperberg, Kreher, Swain, Goff, & Holt, in press). Studying the language processing system in schizophrenia can, therefore, give important insights into the neuropathology of schizophrenia as a whole (Bleuler, 1911/1950).

There have been two main approaches to studying language abnormalities in schizophrenia. The first, inspired by observations that some patients produce strings of semantic associations (Bleuler, 1911/1950), focuses on semantic associative processing outside a sentence or discourse context. The second seeks to link impairments at the sentence and discourse levels with more general working memory or executive dysfunction. Both of these approaches have yielded valuable information. There is evidence that schizophrenia patients show abnormal semantic memory function as indexed using several different tasks and paradigms (for a review, see Kuperberg, Ditman, Kreher, & Goldberg, in press). There is also evidence that both severity of thought disorder and referential communication impairments (discussed further below) correlate with poor performance on various neuropsychological tasks indexing attention (Docherty, Hawkins, Hoffman, Quinlan, Rakfeldt, & Sledge, 1996; Docherty, 2005), distractibility (Hotchkiss & Harvey, 1990; Docherty & Gordinier, 1999), working memory (Kerns, 2007; Docherty & Gordinier, 1999; Docherty, 2005) and other executive functions (Kerns & Berenbaum, 2002).

Alone, however, these two approaches may be too limited. This is because they have generally been considered in isolation of one another and outside psycholinguistic models of normal language processing. Building a gestalt meaning through language requires us not only to match input with prior-stored associations, but also to combine words together (through syntactic and semantic mechanisms) in order to construct the meaning of individual clauses (Chomsky, 1980; Jackendoff, 2002), and then to integrate such clauses together to form a mental model (or 'situation model') (Johnson-Laird, 1983; van Dijk & Kintsch, 1983; Zwaan & Radvansky, 1998). Determining which of these integrative mechanisms are spared and which are impaired is essential for understanding how thought and communication break down in schizophrenia. This review focuses on the few studies that have explored integrative processes *across* individual clauses in schizophrenia, and their interactions with lexical and associative processes. We discuss these studies with reference to a relevant literature in healthy adults which addresses the cognitive mechanisms by which coherence links are established across clause boundaries, thus providing a framework that may guide future research in this area. (Mechanisms by which meaning is built within clauses in schizophrenia by assigning syntactic and thematic relationships are discussed elsewhere, see Kuperberg, Ditman, Kreher, & Goldberg, in press; Kuperberg, Kreher, & Ditman, in press.)

Establishing Coherence across Clauses

The establishment of discourse coherence requires us to maintain logical consistency -- i.e. physical, motivational, and psychological continuity and causal linkage -- between the events, actions, and states described in individual clauses (Fletcher & Bloom, 1988; Schank & Abelson, 1977; Trabasso & van den Broek, 1985; Trabasso, van den Broek, & Suh, 1989; van den Broek, 1990; van den Broek, Virtue, Everson, Tzeng, & Sung, 2002). This is clearly essential for the effective communication of ideas to others (language production), as well as for the accurate interpretation of incoming information (language processing). One tool that may help comprehenders establish coherence is cohesion markers, or explicit linguistic devices that link information across clauses (cf. Graesser, McNamara, Louwerse, & Cai, 2004).

The coherence of language output in schizophrenia—*Interviewer: "How have you been feeling today?" Patient: "Well, in myself I have been okay what with the prices in the shops being what they are and my flat is just round the corner. I keep a watch for the arbiters*

most of the time since it is just round the corner. There is not all that much to do otherwise." This is a transcript of a conversation with a patient with schizophrenia. It is clear that, although the patient starts to answer the interviewer's question, he/she quickly goes off on a tangent and the relationship between the ideas across the individual clauses is illogical. These types of failures to establish coherence across clauses are well documented in the language output of some schizophrenia patients (Schneider 1959; Andreasen 1979). Indeed, 'tangentiality' (responding to questions with an irrelevant response) and 'derailment' (spontaneous speech with tangential associations between ideas) are among the most common phenomena documented in thought disordered speech (Andreasen 1979; Earle-Boyer, Levinson, Grant, & Harvey, 1986; Mazumdar, Chaturvedi, & Gopinath, 1995).

There have been several attempts to characterize these types of coherence failures more systematically than through clinical ratings. Early studies focused on the predictability of upcoming words in speech using cloze procedures (Taylor, 1953). Salzinger, Portnoy, and Feldman (1964) reported that healthy individuals were less likely to accurately predict missing words in transcripts of speech produced by patients than by controls. Moreover, when more context was provided, it proved easier to predict upcoming words in controls' speech, but harder to make such predictions in patients' speech (Salzinger, Pisoni, Portnoy, & Feldman, 1970; Salzinger, Portnoy, & Feldman, 1979). Later studies suggested that such unpredictability was most characteristic of speech produced by patients who had been clinically characterized as thought disordered (Hart & Payne, 1973; Manschreck, Maher, Rucklos, & White, 1979).

A second approach has been to examine the overall discourse structure of speech produced by patients. In healthy adults, discourse can be organized into a systematic tree structure with a central proposition from which other propositions branch out. In a series of studies, Hoffman and colleagues used transcripts of speech acquired from patients with schizophrenia, mania, and healthy adults to examine their discourse structures. The transcripts of patients with schizophrenia revealed more disorganized tree structures than those of controls and manic patients (Hoffman, Kirstein, Stopek, & Cicchetti, 1982; Hoffman, 1986).

A third and more recent approach has examined patients' language output in relation to the co-occurrence or associations between its individual words, characterized using computational models. This approach may be particularly informative given the classic observations that, in some patients, incoherence appears to arise because they are preoccupied with relationships between individual words (Bleuler 1911/1950; Chaika, 1974). For example, in the following speech sample (quoted by Maher, 1983), the associations between the individual words are clear; however, the overall message that the patient wishes to convey is incoherent: *"If you think you are being wise to send me a bill for money I have already paid, I am in nowise going to do so unless I get the whys and wherefores from you to me. But where the fours have been, then fives will be, and other numbers and calculations and accounts to your no-account…."* Although most patients' speech is not so obviously dominated by such lexico-semantic associations, studying such lexical relationships may give important clues as to how incoherence arises.

Maher, Manschreck, Linnet, & Candela (2005) examined transcripts of patients' descriptions of pictures with reference to the Computed Associations in Sequential Text (CAST). CAST quantifies the number of associations within specific units of text that are input into the model. For example, if five words are put into the model, it determines whether the first word (i.e., the index word) is associated to any of the subsequent four words by checking a word association database. Results demonstrated that, overall, patients produced a greater number of associations than healthy adults. This difference was more pronounced when larger units of text (greater than fifteen words) were input, suggesting that associations between words exerted their influence for longer periods of time in patients than in controls.

Another computational model that has been used to examine speech output in schizophrenia is Latent Semantic Analysis (LSA) (Landauer & Dumais, 1997; http:lsa.colorado.edu). LSA is derived from a large corpus of texts and determines the *co-occurrence* between individual words in a given discourse context. While co-occurrence is not synonymous with lexico-semantic associations, words within the same context usually have stronger semantic associations than words from different contexts. Elvevag, Foltz, Weinberger, & Goldberg (2007) used LSA to explore lexical co-occurrence within transcriptions of speech produced by patients during an interview. Lower LSA scores were taken to indicate "looser", or more unusual, associations between words. More severely thought-disordered patients (as assessed by a high global score on the Scale for the Assessment of Thought, Language, and Communication; TLC; Andreasen & Grove, 1986) had lower LSA scores than less thought-disordered patients or healthy adults. In addition, the authors employed a 'moving window' analysis in which they examined LSA scores at various distances between an interviewer's original question and a participant's response (from 2–8 words following the question). LSA scores increased with increasing window sizes in all three groups. However, with a window size of 8 words, LSA scores of more thought-disordered patients did not increase to the same degree as that of the less thought-disordered patients and healthy controls.

All the approaches described above rely on examining the transcripts of patients' speech. A fourth powerful way of probing mechanisms that underlie discourse incoherence in schizophrenia is to examine speech as it is produced in real time. Few researchers have taken this approach, but one interesting study by Spitzer, Beuckers, Beyer, Majer, & Hermle (1994) examined the patterns of pauses and hesitations during a picture description task employed to elicit spontaneous speech production in healthy adults and patients. Spitzer et al. defined a context-expected word as a noun that was frequently employed across all participants' speech samples as it referenced a highly visible object within the picture that was being described. Words were considered contextually unpredictable if they were used only once across all participants' speech samples. Healthy adults tend to pause for slightly longer durations just before producing a relatively contextually unpredictable (vs. predictable) word in discourse (e.g., Butterworth, 1980). Spitzer et al. (1994) found that this was also true of non-thought-disordered patients. However, in thought-disordered patients, there was no difference in pause duration between the predictable and non-predictable words. This was interpreted as suggesting that patients are less able to use discourse context to selectively activate contextually appropriate words during speech production.

Overall, these findings corroborate clinical observations of coherence failures in patients. Specifically, these studies demonstrate that patients' speech is less predictable and organized than that of healthy controls. In addition, word selection appears to be less constrained by the global discourse context.

Establishing coherence during language processing in schizophrenia

An insensitivity to discourse context in schizophrenia: Just as early studies of language output in schizophrenia focused on the predictability of speech output, early studies of language processing examined patients' ability to predict upcoming words in discourse produced by healthy individuals. In healthy adults, the more context provided, the better their accuracy in predicting missing words. De Silva and Hemsley (1977) found that giving chronic schizophrenia patients more context did not improve their predictive ability, and, in acutely ill patients, led to an even worse performance. This was interpreted as suggesting that patients are relatively insensitive to discourse context, not only during production, but also during processing. A similar insensitivity to discourse context was also reported in memory paradigms in which patients were asked to recall spoken discourse (Maher, Manschrek, & Rucklos, 1980; Hotchkiss & Harvey, 1990). Whereas memory performance in healthy adults improved

when, during encoding, sentences were organized into a coherent discourse, compared with random presentation, schizophrenia patients derived no benefits from the meaningful organization of encoded material (Harvey, Earle-Boyer, Wielgus, & Levinson, 1986; Speed, Shugar, & Di Gasbarro, 1991).

Although these studies suggest that patients are relatively insensitive to discourse context, they provide little information about whether such insensitivity occurs as context is being built up, word-byword, or whether it emerges at a later stage of processing. Online techniques such as event-related potentials (ERPs), which provide a direct measure of neural processing with excellent temporal resolution, can address this issue. One particular waveform, the N400, has provided much information about the semantic integration of words into a preceding context (Kutas & Hillyard, 1980; 1984). The amplitude of the N400 is modulated by the ease or difficulty of mapping the meaning of an incoming word on to the meaning of its preceding context (word, sentence or discourse), with respect to our semantic memory structures (Federmeier & Kutas, 1999), and our real-world knowledge (Hagoort, Hald, Bastiaansen, & Petersson, 2004). In schizophrenia, most studies of the N400 have focused on semantic relationships between individual words and on incongruities within clauses (reviewed by Kuperberg, Kreher, & Ditman, in press). Recently, however, Ditman and Kuperberg (2007) examined the modulation of the N400 in a discourse context. Patients and healthy controls read three-sentence discourse scenarios in which the final sentence was highly causally related (e.g., James was practicing piano for months. He won first prize in the competition. He took the medal with pride), intermediately related (e.g., James was practicing piano for months. He played his best in the competition. He took the medal with pride), or unrelated (e.g., Fred had never had the measles. He caught the infection in day care. He took the medal with pride) to its preceding context. Importantly, in isolation, the final sentences in all three conditions were locally coherent. While healthy controls showed a robust N400 effect to critical words (e.g. 'medal' in the example above) within final sentences that were completely unrelated and intermediately related (vs. highly related) with their preceding two-sentence contexts, patients failed to show these N400 effects.[1] This finding suggests that patients are unable to construct coherence links across individual sentences to build up overall global context during the earliest phases of discourse comprehension.

Layered models of processing: at what level of representation does an insensitivity to discourse context in schizophrenia arise?: While the studies reviewed above suggest that patients are relatively insensitive to a wider discourse context, an important question is how and at what level of representation such insensitivity arises. Normal models of discourse processing emphasize the idea that the representations built during comprehension are multi-layered (Kintsch, 1988, 1992; van Dijk & Kintsch, 1983). For rich comprehension, we must go beyond the precise wording of the input, including its lexical and semantic relationships (the surface structure), and even beyond its component propositions (propositional structure) to extract the overall message of the discourse – the 'situation model'. Recent evidence suggests that this situation model is represented or embodied at perceptual and motor levels, rather than at more abstract levels (e.g., Glenberg & Kaschak, 2002; Yaxley & Zwaan, 2007; however, for an amodal perspective, see Fodor, 1987). Comprehenders not only track information along causal, temporal, spatial, and emotional dimensions, but also represent characters' goals, motivations (Zwaan, Magliano & Graesser, 1995), and even sensori-motor perspectives on objects (e.g., Brunyé, Ditman, Mahoney, Augustyn, & Taylor, 2009; Glenberg & Kaschak, 2002; Yaxley & Zwaan, 2007). In theory, failures to establish discourse coherence in schizophrenia might arise at the level of the situation model, the propositional structure, the

[1]Note that the N400 effect in schizophrenia is often normal to semantic incongruities (vs. congruities) within single sentences, so long as such critical words are not lexico-semantically related to preceding words (e.g. Kuperberg, Sitnikova, et al., 2006; Sitnikova et al., 2002).

surface structure, and/or in the interactions between these levels. Below we describe studies that have explored each of these levels of representations, and their interactions, in schizophrenia.

A classic way of examining the situation model – the global discourse message extracted from the input – is through story recall. In an important early study, Bransford and Franks (1971) presented healthy adults with groups of sentences in random order, e.g., “The ants were in the kitchen. The ants ate the jelly. The jelly was sweet.” On a later memory test, participants misremembered (as measured by confidence ratings) encoding larger sentences, e.g. “The ants in the kitchen ate the sweet jelly”. In other words, participants integrated the individual propositions to create a global representation or ‘gist’ of the discourse. In an early examination of whether patients with schizophrenia were able to similarly extract this gist, Knight and Sims-Knight (1979) found that patients with a history of poor functioning (compared with controls and patients with relatively good premorbid histories) performed poorly on this task. However, a subsequent study using the gist paradigm by Grove and Anderson (1985) failed to find group differences between healthy adults, patients with mania, and schizophrenia patients.

Another study by Leroy, Pezard, Nandrino, & Beaune (2005) focused on the propositional level of representation, again using story recall. In healthy adults, the global discourse topic, or macrostructure, constrains the more local structure of clauses and sentences, or microstructure (Kintsch & van Dijk, 1978) such that irrelevant information is deleted to make generalizations. Thus, examining the types of propositions produced, and their relationships, can provide important information about how patients develop and maintain a discourse plan. Leroy et al. (2005) asked healthy adults and patients with schizophrenia to read a story aloud and then, immediately after, to produce discourse in which they described the contents of the story. Patients were selected based on their ability to recall enough information (i.e., linguistically skilled). Recalled micro-propositions (propositions with story details) and macro-propositions (propositions related to the global discourse topic) were examined. Results showed that both groups of participants produced similar numbers of micro- and macro-propositions. However, schizophrenia patients were more likely than healthy adults to connect micro-propositions, These results were interpreted as suggesting a failure of patients to delete story details and maintain the overall global discourse topic.

Finally, there have been some studies examining interactions between lexical relationships (within the surface structure) and the build-up of the situation model through the establishment of causal links between clauses. Given the findings discussed above that increased lexical association or co-occurrence are associated with positive thought disorder (Elvevag et al., 2007; Maher et al., 2005), studying such interactions may be particularly relevant to understanding the mechanisms leading to coherence breakdown in schizophrenia.

In healthy individuals, lexico-semantic relationships between words within the surface structure are thought to influence discourse comprehension though an automatic ‘resonance’ with information stored within long term semantic memory (Albrecht & O’Brien, 1993; Dell, McKoon, & Ratcliff, 1983; Kintsch, 1988, 1992; Sanford & Garrod, 1981; Cook, Halleran, & O’Brien, 1998; Myers & O’ Brien, 1998; Myers, O’Brien, Albrecht, & Mason, 1994). When such resonance conflicts with discourse coherence at the level of the situation model, there are costs in processing (McKoon and Ratcliff, 1986; Myers & O’Brien, 1998; O’Brien, Cook, & Peracchi, 2004; O’Brien & Albrecht, 1992; & O’Brien, Rizzella, Albrecht, & Halleran, 1998), and higher-level processes will ultimately override such lower-level lexical influences (cf. Zwaan & Radvansky, 1998) based on a reader’s standard of coherence (cf. van den Broek, Rapp, & Kendeou, 2005;van den Broek, Virtue, Everson, Tzeng, & Sung, 2002). One way in which lexical information and the situation model have been pitted directly against one another is through the use of homonyms. For example, to correctly interpret the word *“pen”* in the

second clause of this sentence, *"When the farmer bought a herd of cattle, he needed a new pen"*, one must integrate the meaning of the first clause such that the inappropriate dominant meaning of 'pen' (a writing instrument) is inhibited, and the contextually appropriate subordinate meaning is selected (a place where animals live).

There have been several studies using homonyms to examine the relationship between lexical processing and the integration of information across clauses in schizophrenia. In an early study, Chapman, Chapman, and Miller (1964) asked healthy adults and schizophrenia patients to indicate the meaning (by selecting a response from several choices) of homonyms within two-clause sentences, similar to the sentence given above. Patients were more likely than healthy adults to misinterpret homonyms in terms of their dominant meanings, suggesting that they failed to use the meaning of the first clause to inhibit the prepotent response and to select the most appropriate meaning (see also Benjamin & Watt, 1969). These results were supported by a study by Bazin, Perruchet, Hardy-Bayle and Feline (2000) who found that, during sentence completion, thought-disordered patients were more likely than healthy controls and patients without thought disorder to use the dominant meaning of lexically ambiguous words, despite the meaning of the first clause biasing toward their subordinate meanings. A third study by Titone, Levy, and Holzman (2000) introduced the homonyms at the end of two-clause sentences and asked participants to make lexical decisions to probe-words that followed each sentence. This study reported, that when the meaning of the first clause *strongly* biased towards the subordinate meaning of the homonym (e.g. Because the musicians were great, we really enjoyed the *jam*), patients, like healthy adults, were able to suppress the dominant meaning of the homonym, 'jam', and access its subordinate meaning It was only when the meaning of the first clause moderately biased towards the subordinate interpretation (e.g., Because it was extremely loud, we really enjoyed the *jam*) that patients, unlike controls, were unable to inhibit the dominant meaning of 'jam'.

Finally, an ERP study by Sitnikova, Salisbury, Kuperberg, and Holcomb (2002) extended these findings to online neural processing. In this study, the homonyms appeared at the end of the first clause of the two-clause sentence that was linked by the word 'because'. The words of the first clause biased towards either the dominant meaning (e.g., *"Diving was forbidden from the bridge…")* or the subordinate meaning (e.g., *"The guests played bridge…")* of the homonym. The second clause contained a critical word that was always semantically associated with the dominant meaning of the homonym (e.g., *"…because the river had rocks in it").* As expected, healthy adults produced an N400 effect to contextually inappropriate critical words (e.g. to *"river"* when the initial context was *"the guests played bridge"):* the incoherence of the situation model overrode the strong lexico-semantic relationships between the individual words, leading to a cost in neural processing. Schizophrenia patients, however, showed an attenuated N400 effect, suggesting that they failed to use context to inhibit the dominant meaning of the homonym *("bridge")* that primed *"river"*. Critically, the same patients showed a normal N400 effect to unambiguously contextually incongruous (vs. congruous) words that, in half the sentences, were introduced towards the end of the second clause (e.g. *"cracks"* in *"…because the river had cracks in it.").*

Taken together, these observations suggest that patients are able to use the lexico-semantic relationships between individual words within two-clause sentences, but that they have specific difficulty in integrating meaning across clauses. Thus, lexical information exerted an inappropriate influence on processing and the balance of interactions between the surface structure and the situation model was disrupted. Interestingly, a similar inappropriate influence of lexico-semantic relationships in schizophrenia has been described at the level of single clauses where such associations can, under some circumstances, override the syntactically-determined build-up of meaning (see Kuperberg, Sitnikova, Goff, & Holcomb, 2006; Kuperberg, Kreher, & Ditman, in press).

Establishing Coherence through the Use of Referential Cohesion Markers

One way of establishing coherence across clauses is through the use of referential cohesion markers. This involves linking one word – the *anaphor* – with a previously presented word in the discourse (e.g., linking 'he' in "John went to the store because he needed to buy milk" with 'John') or with an object or person in the real world (e.g., linking 'that' in "Look at that" with the thing the speaker is looking at) – the *referent*. We discuss abnormal use of these referential cohesion markers in patients with schizophrenia as well as impairments in interpreting or resolving these cohesion markers, resulting in an impaired ability to establish referential coherence.

Using referential cohesion markers during language production in schizophrenia—The first systematic examination of referential coherence in schizophrenic speech came from Rochester and Martin (1979) who reported that patients failed to use cohesion markers to the same degree as healthy controls. These problems were observed both in patients who had been clinically characterized as thought-disordered as well as those without thought disorder. Relative to healthy individuals, non-thought-disordered patients were more likely to use semantically-rich anaphors than pronouns to refer to a referent, even when pronouns would have been more appropriate; patients with thought-disorder were more likely to use pronouns to refer to referents that had not previously been presented.

Findings of impaired use of cohesion markers in schizophrenia speech have been replicated and described in more detail by other researchers (e.g., Docherty, Hawkins, Hoffman, Rakfeldt, & Sledge, 1996; Noel-Jorand, Reinert, Giudicelli, & Dassa, 1997). For example, Docherty and colleagues have developed a comprehensive measure that captures a range of referential communication failures including vague (e.g., "We had to go to court and other bad *things*"), confused (e.g., "The supervisor was so jealous because bosses liked me because I was a very good and hard worker, that *they* didn't like *that*, so they plotted against me," in which "they" could plausibly refer to either "supervisors" or "bosses), and missing ("I designed the American first rockets, and *the cars* and *the boats*;" "They let **him**/George go, so why not me?" with no prior mention of a specific male person or of a man named George) references. Once again, these abnormalities have been observed not only in clinically thought-disordered speech, but also in the language output of non-thought-disordered patients. Indeed, there is evidence that some types of cohesion impairments may be trait markers of schizophrenia: for example, they can be stable over time (Docherty, Cohen, Nienow, Dinzeo, & Dangelmaier, 2003), and they are evident to a greater degree in first-degree family members of patients than of controls (Docherty, Rhinewine, Labhart, & Gordinier, 1998; Docherty & Gottesman, 2000).

Referential coherence during language processing in schizophrenia—Despite the careful characterization of how referential cohesion markers are used in the speech produced in schizophrenia, there has been little study of the cognitive processes engaged as patients attempt to establish referential coherence, across clauses during processing.[2]

Below we consider some of the relevant mechanisms in healthy individuals and discuss ways in which they could be probed in schizophrenia

Consider the following passage:

> *"You know," Rahim Khan said, "one time, when you weren't around, your father and I were talking. And you know how he always worried about you in those days. I remember he said to me, 'Rahim, a boy who won't stand up for himself becomes a*

[2]The assumption here is that patients with schizophrenia fail to use cohesion markers to the same degree as healthy adults because they have a relatively relaxed standard of coherence.

> *man who won't stand up for anything.' I wonder, is that what you've become?"* (The Kite Runner by Khaled Hosseini, p. 221)

Although the comprehension of this passage appears effortless, it places many demands on the processing system. First, content words that can function as potential referents (e.g., *father*) must each be maintained online, sometimes across long delay periods, even as new information is being processed. Second, when a potential anaphor is subsequently encountered (e.g., *he*), it must be linked back to the most appropriate referent (e.g., Haviland & Clark, 1974). An anaphor often has several possible referents – in the above passage, he could refer to any previously introduced male character such as 'Rahim Khan' (the speaker) or the 'father'. To resolve this inherent ambiguity and determine what anaphor to link back to what referent, we use multiple types of cues. These cues include low-level information such as gender and number agreement (Cacciari, Carreiras, & Cionini, 1997; Rigalleau, Caplan, & Baudiffier, 2004). For example, we know that *he* must refer to one male character. They also include higher-level information such as the surrounding sentence and/or discourse context (Ditman, Holcomb, & Kuperberg, 2007; Nieuwland, Otten, & Van Berkum, 2007), and real-world knowledge (e.g., Almor, 1999; Gernsbacher, 1991). For example, in the above passage, one uses the real-world knowledge to infer that the speaker (Rahim Khan) would not refer to himself in the third-person and thus is most likely not the referent for the pronoun *he*. In theory, an impairment in establishing referential coherence in schizophrenia might arise because patients are unable to maintain multiple referents online for later resolution, or because they are unable to use contextual information or real-world knowledge to link the correct anaphor with the correct antecedent.

To determine whether patients are able to use context in order to appropriately resolve an anaphor, we have manipulated the nature of the context and examined processing to a reinstated referent after the anaphor. For example, in a recent study in healthy individuals, Ditman, Holcomb, and Kuperberg (2007) used ERPs to determine how lexico-semantic and discourse context influenced the resolution of categorical anaphors (e.g., whether 'alcohol' refers to 'beer' or 'champagne' at a ballgame). Participants read five-sentence scenarios in which the first three sentences explicitly introduced potential referents (champagne, beer, cake) in their appropriate contexts (e.g., Champagne is served at a New Year's party. Beer is served at a ballpark. Cake is served at a birthday party), a fourth sentence introduced a context with an anaphor describing a particular category (e.g., At the New Year's party, Bill took a sip of the alcohol). One of the referents was then reinstated in the fifth sentence and ERPs were measured to this word. The reinstatement was either correct (e.g., *The champagne* was good), incorrect but an exempler of the category depicted by the anaphor (e.g., *The beer* was good), or incorrect and unrelated to the anaphor (e.g., *The cake* was good). We found that the ERP response to the reinstatement was modulated by both discourse cues and lexico-semantic relationships; the largest amplitude N400 was evoked to incorrect and lexico-semantically unrelated critical words (*cake*), followed by a medium-sized amplitude N400 to incorrect but lexico-semantically related critical words (*beer*), and the smallest amplitude N400 was elicited by correct and lexico-semantically related critical words (*champagne*). We have recently carried out this paradigm in schizophrenia patients and our findings suggest that patients and controls show a similar pattern of ERP activity (Ditman & Kuperberg, 2008). These data suggest that, at least when the context is explicitly provided, patients are able to use it appropriately to resolve anaphors during online processing. While it is encouraging that there may be some conditions that promote accurate linking across sentences in schizophrenia, future studies are needed to determine the boundary of this effect.

Neuroanatomical Underpinnings

Another reason why it is important to explore abnormalities in the use of cohesion markers and the establishment of coherence in schizophrenia within normal frameworks of discourse

processing is that it allows the design of tightly-controlled cognitive neuroscience paradigms that use functional neuroimaging techniques to elucidate their neuroanatomical bases. Below we discuss the possible roles of neuroanatomical regions engaged during normal discourse processing, and speculate how these may be abnormally modulated in schizophrenia.

In healthy individuals, the establishment of causal coherence across sentences is associated with the recruitment of a widespread brain network distributed across temporal, frontal and parietal cortices (Mason & Just, 2004; Kuperberg, Lakshmanan, Caplan, & Holcomb, 2006; Virtue, Haberman, Clancy, Parrish, Jung Beeman, 2006); sometimes more rostral superior frontal and medial frontal cortices are also engaged (Ferstl & von Cramon, 2001; Ferstl & von Cramon, 2002; Ruby, Sirigu, & Decety, 2002; Xu, Kemeny, Park, Frattali, & Braun, 2005; Kuperberg, Lakshmanan, et al., 2006). The precise roles of each of these different regions is unclear, but it has been suggested that the modulation of temporal and inferior frontal cortices reflects the activation and retrieval of stored semantic information, while more superior and medial prefrontal regions may be involved in a more directed and explicit search for meaning, possibly through attempts to establish temporal, sequential relationships between clauses (Ferstl & von Cramon, 2001; Ferstl & von Cramon, 2002; Ruby et al., 2002; Kuperberg, Lakshmanan, et al., 2006).

There has been less work examining the neuroanatomical regions engaged in establishing referential coherence in healthy individuals, but there is some indication that both superior/medial prefrontal cortices and superior/medial parietal cortices may play a role: in comparison with pronoun anaphors that are easily linked with their preceding referents, noun-phrase anaphors that refer inappropriately to a repeated name referent lead to increased activity within superior and medial parietal cortices (Almor, Smith, Bonilha, Fridriksson, & Rorden, 2007), while pronouns that refer inappropriately to one of two ambiguous referents are associated with increased activity within both superior/medial parietal and frontal cortices (Nieuwland, Petersson, & Van Berkum, 2007).

If, as some of the evidence discussed in this review suggests, patients are inappropriately dependent on lexical and semantic relationships in establishing coherence across clauses, they may show abnormally increased activity within temporal cortices to discourse with related (vs. unrelated) lexico-semantic relationships (cf. Kuperberg, Deckersbach, Holt, Goff, & West, 2007); in contrast, a failure to establish full coherence or cohesion at the level of the situation model, particularly when this contradicts lexical and semantic associative relationships, might be associated with abnormally reduced recruitment of superior frontal and parietal cortices. Although these hypotheses have not yet been tested at the level of discourse in schizophrenia, one recent study at the sentence level does describe a dissociation across patients and controls in the modulation of superior fronto-parietal regions and the temporal/inferior frontal cortices when integration demands are increased (Kuperberg, West, Lakshmanan, & Goff, 2008).

A second important issue that functional neuroimaging studies of discourse in schizophrenia can address relates to the role of the right hemisphere. One interesting hypothesis is that language dysfunction in schizophrenia is associated with a redistribution of function between the left and right hemispheres, whereby the right hemisphere mediates tasks that, in healthy individuals, are typically subserved by the left-hemisphere. This reorganization, in turn, is believed to compromise traditional right-hemisphere functions (Mitchell & Crow, 2005). Indeed, Crow (2000) has speculated that a failure to establish dominance for language in schizophrenia may reflect a byproduct of the evolution of language itself.

As yet, there is little direct evidence either supporting or refuting these ideas – neuroimaging studies in schizophrenia have not revealed any systematic relationship between abnormal laterality and language processing: although there have been some reports of abnormal

lateralization (Kircher, Bulimore, Brammer, Williams, Broome, Murray, et al., 2001; Kircher, Liddle, Brammer, Williams, Murray, & McGuire, 2002; Artiges, Martinot, Verdys, Attar-Levy, Mazoyer, Tzourio, et al., 2000; for a review, see Crow, 1997), other studies do not report clear between-group differences in relative activity across right and left hemispheres during language processing or production (e.g., Han, Nestor, Hale-Spencer, Cohen, Niznikiewicz, McCarley, & Wible, 2007; Kuperberg, Deckersbach, Holt, Goff, & West, 2007).

This heterogeneity in findings across studies is not surprising: different studies of language in schizophrenia use very different paradigms and tap into different aspects of language processing. Also, most of these studies have used single word or sentence stimuli. It is possible that studying the neuroanatomical correlates of specific cohesion and coherence processes will yield more insights into the relationship between right hemisphere function and language in schizophrenia. This is because the right hemisphere has been directly implicated in these types of discourse-level processes: patients with right-hemisphere lesions sometimes produce speech that is socially inappropriate with tangential relationships between sentences, even when other aspects of their language comprehension and production are normal (Joanette, 1990). As pointed out by Mitchell and Crow (2005), this is reminiscent of the type of thought-disordered speech produced by some schizophrenia patients, although, to our knowledge, there have been no systematic phenomenological comparisons between the language produced by right-hemisphere and schizophrenia patients. Patients with right hemisphere lesions also show abnormal function on a number of discourse-level comprehension tasks, such as causal inferencing (Beeman 1993; Brownell, Potter, Bihrle, & Gardner, 1986) – the types of operations that may also be impaired in schizophrenia.

These types of similarities between right-hemisphere patients and schizophrenia patients are certainly intriguing. However, there are important caveats in interpreting such comparisons. Patients with left hemisphere lesions (Zaidel, Kasher, Soroker, & Batori, 2002) and frontal lesions (Ferstl, Guthke, & von Cramon, 2002) can sometimes perform just as badly as patients with right hemisphere lesions on so-called ‘right hemisphere’ tasks; in healthy individuals, evidence from divided visual field studies (Long & Baynes, 2002; Long, Baynes, & Prat, 2005) and neuroimaging studies (e.g., Eviatar & Just, 2006; Kuperberg, Lakshmanan, et al., 2006) suggests that both hemispheres are involved in extracting the discourse-level interpretation. Taken together, these studies suggest that, while there may be some segregation in function between the two hemispheres (Jung-Beeman, 2005; Tompkins, Fassbinder, Lehman-Blake, & Baumgaertner (2002); Johns, Tooley, & Traxler, 2009), the right hemisphere does not act alone to establish discourse coherence or cohesion. It therefore seems unlikely that neuroimaging studies in schizophrenia will reveal any simple or single relationship between laterality and discourse function. However, the use of tightly controlled cognitive neuroscience paradigms will allow specific patterns of right/left hemisphere modulation to be linked to the specific types of neurocognitive operations that establish coherence and cohesion across clauses.

Links with Other Domains of Function

Throughout this paper, we have highlighted places in which we believe that the study of language impairments in schizophrenia would benefit from a systematic examination within a framework of normal discourse processing. Once such specific impairments are better defined in controlled experimental settings, we may be in a better position to determine whether or how they are linked with dysfunction in other cognitive domains.

One important question is whether impairments in operations that establish coherence across clauses can be explained by the types of general working memory impairments that are well established in schizophrenia (Lee & Park, 2005). This is certainly a possibility: in healthy adults, individual differences in general working memory function (usually assessed using

complex span tasks, such as the reading span) account for some variability in language function at both the sentence (Caplan & Waters, 1999; Just & Carpenter, 1992; Van Petten, Weckerly, McIsaac, & Kutas, 1997) and discourse levels (Singer & Ritchot, 1996; Virtue, Parrish, & Jung-Beeman, 2008). On some accounts of how referential coherence is resolved during normal communication (Almor, 1999), an individual's working memory capacity places constraints on the type of anaphor used to refer to an entity introduced earlier in discourse: when a noun-phrase referent is easily accessible within working memory, it is more appropriate to refer to it using a pronoun as opposed to a repeated noun-phrase anaphor. Impairments in working memory capacity in schizophrenia may therefore contribute to the use of anaphors with an inappropriate amount of semantic content (e.g., repeated noun-phrases), as has been observed in patients without clinical thought-disorder (Rochester & Martin, 1979).

There is also evidence that our ability to maintain multiple references online during comprehension may be dependent on general working memory capacity. In order to understand sentences such as "John went to the store because he needed to buy milk," the pronoun 'he' can only refer to one potential antecedent, 'John.' However, if two male characters were introduced (John and Tim) in the example above, at the point of encountering 'he', it would be impossible to know whether this pronoun was referring to John or Tim. Thus, resolving this pronoun would involve maintaining two potential referents online until disambiguation is possible. In healthy adults, encountering a pronominal ambiguity results in longer sentence processing times (Stewart, Holler, & Kidd, 2007). In addition ERP studies report a frontal negativity referred to as an Nref, to such ambiguous, relative to unambiguous, pronouns (van Berkum, Zwitserlood, Bastiannsen, Brown, & Hagoort, 2004). This component has been interpreted as reflecting the costs of attempting to disambiguate the two referents (i.e., John, Tim) and recent evidence suggests that its amplitude is correlated with working memory performance across healthy individuals (Nieuwland & van Berkum, 2006). Future studies might apply this paradigm to study referential processing in schizophrenia. If patients fail to maintain both referents online during processing, they should not incur this neural cost in processing and the amplitude of the Nref should be reduced. Moreover, if this impairment in patients can be accounted for by general working memory deficits, then, within the patient group, the Nref amplitude should correlate with patients' performance on more general WM tasks.

Another important question is whether certain discourse-level impairments in schizophrenia can be linked to 'pragmatic' dysfunction. Pragmatics refers to the goals of communication and takes into account assumptions about the speaker's intentions as well as the listener's knowledge. Healthy individuals adhere to several principles of communication to maintain coherence and cohesion, termed Grice's maxims (Grice, 1975). According to these maxims, communicators should relay information that is truthful, relevant, as informative as possible (but not over-informative), and clear (unambiguous). However, under some circumstances, healthy adults will violate these norms. For example, although the response *"Is the Pope Catholic?"* to the question *"Did Mike get drunk last night?"* violates the maxim of relevance, it conveys the speaker's view on Mike's drinking habits and, in healthy individuals, is generally interpreted as coherent. There is some evidence that schizophrenia patients have difficulty in interpreting sentences that violate these maxims (Tényi et al., 2002), and future studies should determine whether such difficulties can be linked to specific types of cohesion or coherence abnormalities in schizophrenia.

One way of exploring the role of pragmatic factors in schizophrenia patients would be to use experimental paradigms that study naturalistic communication. For instance, in a clever study, Brown-Schmidt & Tanenhaus (2006) examined speech planning as pairs of healthy adults engaged in an interactive conversation in which one person (the speaker) had to explain to the other (the addressee) which of several given pictures was the target on a given trial. On critical

trials, the speaker had to communicate information about the target's size in order to differentiate between the target and a similar, but differently-sized, distractor. Eye movements measured during conversations determined the time at which the speaker noticed the distractor item. The amount of time between this point and the point at which the speaker produced an utterance was used to determine the amount of time required for speech planning. Results demonstrated that when speakers noticed the distractor early on, they were able to modify their initial utterances (e.g., the triangle) with a pre-nominal modifier in order to disambiguate the target (e.g., "the small triangle"). However, when the distractor was noticed later, speakers modified their initial utterances with a post-nominal modifier (e.g., "the triangle… small one"). These findings suggest that our pragmatic knowledge of what information a listener might need for comprehension is very tightly linked to our choice of words during speech output. If patients with schizophrenia fail to use such pragmatic cues to disambiguate a referenced object (Rochester & Martin, 1979), then they should fail to show any such temporal association between their eye-movements and their language output. If, on the other hand, they are able to take into account the needs of the listener, but show more global deficits in speech planning, one might predict the same pattern of findings as in controls, but longer overall latencies between eye movements to the referenced object and speech output.

In this article, we have mainly considered paradigms examining processing across single clauses and sentences. However, in the future, it will also be important to use even more naturalistic stimuli, such as longer paragraphs and ultimately even entire written texts and spoken discourse. By further increasing working memory demands as well as the amount of pragmatic and contextual information available, the use of such materials will allow for an even more rigorous examination of the factors influencing the establishment of coherence in schizophrenia. In addition, the use of ecologically valid materials allows researchers to determine how patients' language impairments affect their real-world functioning.

Conclusions

Converging behavioral and neural evidence suggests that schizophrenia patients show impairments in establishing coherence across clauses during both the production and comprehension of language. Although these types of deficits can be, in part, attributed to abnormal semantic memory function (for a review, see Kuperberg, Ditman, & Kreher, in press) and working memory or executive function (Docherty, 2005; Docherty & Gordinier, 1999; Kerns & Berenbaum, 2002; Kerns, 2007), we have argued that it is also important to define and study these abnormalities within frameworks of normal discourse processing. This can allow the study of interactions between lexical and semantic information in the surface structure and the establishment of discourse-level coherence in the situation model, giving a more complete picture of how communication breaks down in schizophrenia patients. This psycholinguistic approach is also necessary for the design of cognitive neuroscience paradigms that can probe the time-course and neuroanatomical basis of coherence abnormalities in schizophrenia.

Acknowledgments

The authors are supported by NIMH (R01 MH071635) and NARSAD (with the Sidney Baer Trust). Tali Ditman is also supported by an Advanced Multimodal Neuroimaging Grant from Mass. General Hospital (grant #1R90DA023427).

References

DSM-IV: Diagnostic and Statistical Manual of Mental Disorders. Washington, DC: American Psychiatric Press; 1990.

Albrecht JE, O'Brien EJ. Updating a mental model: Maintaining both local and global coherence. Journal of Experimental Psychology: Learning, Memory, and Cognition 1993;19:1061–1070.

Allen HA. Positive and negative symptoms and the thematic organisation of schizophrenic speech. British Journal of Psychiatry 1984;144:611–617. [PubMed: 6743926]

Almor A. Noun-phrase anaphors and focus: the informational load hypothesis. Psychological Review 1999;106:748–765. [PubMed: 10560327]

Almor A, Smith DV, Bonilha L, Fridriksson J, Rorden C. What is in a name? Spatial brain circuits are used to track discourse references. Neuroreport 2007;18:1215–1219. [PubMed: 17632270]

Andreasen NC. Thought, language and communication disorders. II. Diagnostic significance. Archives of General Psychiatry 1979;36:1325–1330. [PubMed: 496552]

Andreasen NC, Grove WM. Thought, language, and communication in schizophrenia: diagnosis and prognosis. Schizophrenia Bulletin 1986;12:348–359. [PubMed: 3764356]

Artiges E, Martinot JL, Verdys M, Attar-Levy D, Mazoyer B, Tzourio N, Giraud MJ, Paillere-Martinot ML. Altered hemispheric functional dominance during word generation in negative schizophrenia. Schizophrenia Bulletin 2000;26:709–721. [PubMed: 10993408]

Bazin N, Perruchet P, Hardy-Bayle MC, Feline A. Context-dependent information processing in patients with schizophrenia. Schizophrenia Research 2000;45(1–2):93–101. [PubMed: 10978877]

Beeman M. Semantic processing in the right hemisphere may contribute to drawing inferences from discourse. Brain and Language 1993;44(1):80–120. [PubMed: 8467379]

Bleuler, E. Dementia Praecox, or the Group of Schizophrenias. New York: International Universities Press; 1911/1950.

Bransford JD, Franks JJ. The abstraction of linguistic ideas. Cognitive Psychology 1971;2:331–350.

Brown-Schmidt S, Tanenhaus MK. Watching the eyes when talking about size: An investigation of message formulation and utterance planning. Journal of Memory and Language 2006;54:592–609.

Brownell HH, Potter HH, Bihrle AM, Gardner H. Inference deficits in right brain-damaged patients. Brain and Language 1986;27:310–321. [PubMed: 3955344]

Brunyé TT, Ditman T, Mahoney CR, Augustyn JS, Taylor HA. When you and I share perspectives: Pronouns and perspective-taking during narrative comprehension. Psychological Science 2009;20:27–32. [PubMed: 19076318]

Butterworth, B. Evidence from pauses in speech. In: Butterworth, B., editor. Language Production Volume 1. Speech and Talk. London: Academic Press; 1980. p. 155-176.

Cacciari C, Carreiras M, Cionini CB. When words have two genders: Anaphor resolution for Italian functionally ambiguous words. Journal of Memory and Language 1997;37:517–532.

Caplan D, Waters GS. Verbal working memory and sentence comprehension. Behavioral and Brain Sciences 1999;22(1):77–94. [PubMed: 11301522]

Chaika E. A linguist looks at 'schizophrenic' language. Brain and Language 1974;1:257–276.

Chapman, LJ.; Chapman, JP.; Miller, GA. A theory of verbal behaviour in schizophrenia. In: Maher, BA., editor. Progress in Experimental Personality Research. Vol. 1. San Diego, CA: Academic Press; 1964. p. 49-77.

Chomsky, N. Lectures on Government and Binding. Foris; Dordrecht: 1981.

Cook AE, Halleran JG, O'Brien EJ. What is readily available during reading? A memory-based view of text processing. Discourse Process 1998;26:109–129.

Crow TJ. Schizophrenia as failure of hemispheric dominance for language. Trends in Neuroscience 1997;20:339–343.

Crow TJ. Schizophrenia as the price that Homo sapiens pays for language: A resolution of the central paradox in the origin of the species. Brain Research Reviews 2000;31:118–129. [PubMed: 10719140]

de Silva WP, Hemsley DR. The influence of context on language perception in schizophrenia. British Journal of Social and Clinical Psychology 1977;16:337–345. [PubMed: 588889]

Dell GS, McKoon G, Ratcliff R. The activation of antecedent information during the processing of anaphoric inference in reading. Journal of Experimental Psychology: Learning, Memory, and Cognition 1983;22:121–132.

Ditman T, Holcomb PJ, Kuperberg GR. The contributions of lexico-semantic and discourse information to the resolution of ambiguous categorical anaphors. Language and Cognitive Processes 2007;22:793–827.

Ditman T, Kuperberg GR. A source-monitoring account of auditory verbal hallucinations in patients with schizophrenia. Harvard Review of Psychiatry 2005;13:280–299. [PubMed: 16251167]

Ditman T, Kuperberg GR. The time course of building discourse coherence in schizophrenia: an ERP Investigation. Psychophysiology 2007;44:991–1001. [PubMed: 17666031]

Ditman, T.; Kuperberg, GR. An ERP examination of lexico-semantic and contextual influences across sentence boundaries in schizophrenia. Annual meeting of the Cognitive Neuroscience Society; 2008.

Docherty NM. Cognitive impairments and disordered speech in schizophrenia: Thought disorder, disorganization, and communication failure perspectives. Journal of Abnormal Psychology 2005;114:269–278. [PubMed: 15869357]

Docherty NM, Cohen AS, Nienow TM, Dinzeo TJ, Dangelmaier RE. Stability of formal thought disorder and referential communication disturbances in schizophrenia. Journal of Abnormal Psychology 2003;112:469–475. [PubMed: 12943025]

Docherty NM, Gottesman II. A twin study of communication disturbances in schizophrenia. Journal of Nervous and Mental Disease 2000;188:395–401. [PubMed: 10919696]

Docherty NM, Gordinier SW. Immediate memory, attention and communication disturbances in schizophrenia patients and their relatives. Psychological Medicine 1999;29(1):189–197. [PubMed: 10077307]

Docherty NM, Hawkins KA, Hoffman RE, Rakfeldt J, Sledge WH. Working memory, attention, and communication disturbances in schizophrenia. Journal of Abnormal Psychology 1996;105:212–219. [PubMed: 8723002]

Docherty NM, Rhinewine JP, Labhart RP, Gordinier SW. Communication disturbances and family psychiatric history in parents of schizophrenic patients. Journal of Nervous and Mental Disease 1998;186:761–768. [PubMed: 9865814]

Earle-Boyer EA, Levinson JC, Grant R, Harvey PD. The consistency of thought disorder in mania and schizophrenia. II. An assessment at consecutive admissions. Journal of Nervous and Mental Disease 1986;174:443–447. [PubMed: 3734766]

Elvevag B, Foltz PW, Weinberger DR, Goldberg TE. Quantifying incoherence in speech: An automated methodology and novel application to schizophrenia. Schizophrenia Research 2007;93:304–316. [PubMed: 17433866]

Eviatar Z, Just MA. Brain correlates of discourse processing: An fMRI investigation of irony and conventional metaphor comprehension. Neuropsychologia 2006;44(12):2348–2359. [PubMed: 16806316]

Federmeier KD, Kutas M. A rose by any other name: long-term memory structure and sentence processing. Journal of Memory and Language 1999;41:469–495.

Ferstl EC, von Cramon DY. The role of coherence and cohesion in text comprehension: An event-related fMRI study. Cognitive Brain Research 2001;11:325–340. [PubMed: 11339984]

Ferstl EC, von Cramon DY. What does the frontomedian cortex contribute to language processing: coherence or theory of mind? Neuroimage 2002;17:1599–1612. [PubMed: 12414298]

Ferstl EC, Guthke T, von Cramon DY. Text comprehension after brain injury: Left prefrontal lesions affect inference processes. Neuropsychology 2002;16:292–308. [PubMed: 12146677]

Fletcher CR, Bloom CP. Causal reasoning in the comprehension of simple narrative texts. Journal of Memory and Language 1988;27(3):235–244.

Fodor, JA. Psychosemantics: The Problem of Meaning in the Philosophy of Mind. Cambridge, Massachusetts: MIT Press; 1987.

Gernsbacher MA. Comprehending conceptual anaphors. Language and Cognitive Processes 1991;6(2): 81–105.

Glenberg AM, Kaschak MP. Grounding language in action. Psychonomic Bulletin & Review 2002;9:558–565. [PubMed: 12412897]

Graesser AC, McNamara DS, Louwerse M, Cai Z. Coh-Matrix: Analysis of text on cohesion and language. Behavior Research Methods, Instruments, & Computers 2004;36:193–202.

Grice, P. Logic and conversation. New York: Academic Press; 1975.

Grove WM, Andreasen NC. Language and thinking in psychosis: Is there an input abnormality? Archives of General Psychiatry 1985;42:26–32. [PubMed: 3966850]

Hagoort P, Hald L, Bastiaansen M, Petersson KM. Integration of word meaning and world knowledge in language comprehension. Science 2004;304:438–441. [PubMed: 15031438]

Han SD, Nestor PG, Hale-Spencer M, Cohen A, Niznikiewicz M, McCarley RW, Wible C. Functional neuroimaging of word priming in males with chronic schizophrenia. Neuroimage 2007;35:273–282. [PubMed: 17215145]

Hart DS, Payne RW. Language structure and predictability in overinclusive patients. British Journal of Psychiatry 1973;123(577):643–52. [PubMed: 4772305]

Harvey PD, Earle-Boyer EA, Wielgus MS, Levinson JC. Encoding, memory, and thought disorder in schizophrenia and mania. Schizophrenia Bulletin 1986;12:252–261. [PubMed: 3715419]

Haviland SE, Clark HH. What's new? Acquiring new information as a process in comprehension. Journal of Verbal Learning and Verbal Behavior 1974;13:512–521.

Hoffman RE. Tree structures, the work of listening, and schizophrenic discourse: A reply to Beveridge and Brown. Brain and Language 1986;27(2):385–92. [PubMed: 3955346]

Hoffman RE, Kirstein L, Stopek S, Cicchetti DV. Apprehending schizophrenic discourse: a structural analysis of the listener's task. Brain and Language 1982;15:207–233. [PubMed: 7074342]

Hoffman RE, Stopek S, Andreasen NC. A comparative study of manic vs schizophrenic speech disorganization. Archives of General Psychiatry 1986;43:831–838. [PubMed: 3753163]

Holt DJ, Titone D, Long S, Goff DC, Cather C, Rauch SL, Judge A, Kuperberg GR. Misattributions of salience in delusional patients with schizophrenia. Schizophrenia Research 2006;83:247–256. [PubMed: 16540291]

Hosseini, K. The Kite Runner. New York, NY: Riverhead Books; 2003.

Hotchkiss AP, Harvey PD. Effect of distraction on communication failures in schizophrenic patients. American Journal of Psychiatry 1990;147:513–515. [PubMed: 2316742]

Jackendoff, R. Foundations of Language. Brain, Meaning, Grammar, Evolution. New York: Oxford University Press; 2002.

Joanette, Y. Pragmatics. In: Joanette, Y.; Goulet, P.; Hannequin, D., editors. Right hemisphere and verbal communication. New York, NY: Springer-Verlag; 1990. p. 160-187.

Johns CL, Tooley KM, Traxler MJ. Discourse impairments following right hemisphere brain damage: A critical review. Language and Linguistics Compass 2008;2/6:1038–1052.

Johnson-Laird, PN. Mental models: Toward a cognitive science of language, inference, and consciousness. Cambridge, MA: Harvard University Press; 1983.

Jung-Beeman M. Bilateral brain processes for comprehending natural language. Trends in Cognitive Sciences 2005;9:512–518. [PubMed: 16214387]

Just MA, Carpenter PA. A capacity theory of comprehension: Individual differences in working memory. Psychological Review 1992;99(1):122–149. [PubMed: 1546114]

Kerns JG. Verbal communication impairments and cognitive control components in people with schizophrenia. Journal of Abnormal Psychology 2007;116:279–289. [PubMed: 17516761]

Kerns JG, Berenbaum H. Cognitive impairments associated with formal thought disorder in people with schizophrenia. Journal of Abnormal Psychology 2002;111:211–224. [PubMed: 12003444]

Kintsch W. The role of knowledge in discourse comprehension: a construction–integration model. Psychological Review 1988;95:163–182. [PubMed: 3375398]

Kintsch, W. How readers construct situation models for stories: The role of syntactic cues and causal inferences. In: Healy, AE.; Kosslyn, SM.; Shiffrin, RM., editors. From learning processes to cognitive processes. Essays in honor of William K. Estes. Vol. 2. Hillsdale, NJ: Erlbaum; 1992. p. 261-278.

Kircher TT, Bulimore ET, Brammer MJ, Williams SCR, Broome MR, Murray RM, McGuire PK. Differential activation of temporal cortex during sentence completion in schizophrenic patients with and without formal thought disorder. Schizophrenia Research 2001;50:27–40. [PubMed: 11378312]

Kircher TT, Liddle PF, Brammer MJ, Williams SC, Murray RM, McGuire PK. Reversed lateralization of temporal activation during speech production in thought disordered patients with schizophrenia. Psychological Medicine 2002;32:439–449. [PubMed: 11989989]

Knight RA, Sims-Knight JE. Integration of linguistic ideas in schizophrenics. Journal of Abnormal Psychology 1979;88(2):191–202. [PubMed: 447902]

Kraepelin, E. Dementia Praecox and Paraphrenia. New York: Krieger; 1971.

Kuperberg G, Deckersbach T, Holt D, Goff D, West WC. Increased temporal and prefrontal activity to semantic associations in schizophrenia. Archives of General Psychiatry 2007;64:138–151. [PubMed: 17283282]

Kuperberg, GR.; Ditman, T.; Kreher, DA.; Goldberg, T. Approaches to understanding language dysfunction in neuropsychiatric disorders: Insights from the study of schizophrenia. In: Wood, S.; Allen, N.; Pantelis, C., editors. Handbook of Neuropsychology of Mental Illness. Cambridge University Press; in press

Kuperberg GR, Kreher DA, Swain A, Goff DC, Holt DJ. Selective emotional processing deficits to social vignettes in schizophrenia: An ERP study. Schizophrenia Bulletin. in press.

Kuperberg GR, Lakshmanan BM, Caplan DN, Holcomb PJ. Making sense of discourse: An fMRI study of causal inferencing across sentences. NeuroImage 2006;33:343–361. [PubMed: 16876436]

Kuperberg GR, Sitnikova T, Goff D, Holcomb PJ. Making sense of sentences in schizophrenia: Electrophysiological evidence for abnormal interactions between semantic and syntactic processing. Journal of Abnormal Psychology 2006;115:243–256.

Kuperberg GR, West WC, Lakshmanan BM, Goff DC. fMRI reveals neuroanatomical dissociations during semantic integration in schizophrenia. Biological Psychiatry 2008;64:407–418. [PubMed: 18504037]

Kutas M, Hillyard SA. Reading senseless sentences: Brain potentials reflect semantic incongruity. Science 1980;207:203–205. [PubMed: 7350657]

Kutas M, Hillyard SA. Brain potentials during reading reflect word expectancy and semantic anomalies. Nature 1984;307:161–163. [PubMed: 6690995]

Landauer TK, Dumais ST. A solution to Plato's problem: the latent semantic analysis theory of acquisition, induction, and representation of knowledge. Psychological Review 1997;104:211–240.

Lee J, Park S. Working memory impairments in schizophrenia: A meta-analysis. Journal of Abnormal Psychology 2005;114(4):599–611. [PubMed: 16351383]

Leroy F, Pezard L, Nandrino JL, Beaune D. Dynamical quantification of schizophrenic speech. Psychiatry Research 2005;133:159–171. [PubMed: 15740992]

Long DL, Baynes K. Discourse representation in the two cerebral hemispheres. Journal of Cognitive Neuroscience 2002;14:228–242. [PubMed: 11970788]

Long DL, Baynes K, Prat CS. The propositional structure of discourse in the two hemispheres. Brain and Language 2005;95:383–394. [PubMed: 16298668]

Maher, BA. A tentative theory of schizophrenic utterences. In: Maher, BA.; Maher, WB., editors. Progress in Experimental Personality Research. San Diego, C.A: Academic Press; 1983.

Maher BA, Manschreck TC, Linnet J, Candela S. Quantitative assessment of the frequency of normal associations in the utterances of schizophrenia patients and healthy controls. Schizophrenia Research 2005;78:219–224. [PubMed: 16005190]

Maher BA, Manschreck TC, Rucklos ME. Contextual constraint and the recall of verbal material in schizophrenia: the effect of thought disorder. British Journal of Psychiatry 1980;137:69–73. [PubMed: 7459542]

Manschreck TC, Maher BA, Rucklos ME, White MT. The predictability of thought disordered speech in schizophrenic patients. British Journal of Psychiatry 1979;134:595–601. [PubMed: 476370]

Mason RA, Just MA. How the brain processes causal inferences in text. Psychological Sciemce 2004;15:1–7.

Mazumdar PK, Chaturvedi SK, Gopinath PS. A comparative study of thought disorder in acute and chronic schizophrenia. Psychopathology 1995;28:185–189. [PubMed: 7480574]

McKoon G, Ratcliff R. The automatic activation of episodic information in a semantic memory task. Journal of Experimental Psychology: Learning, Memory, and Cognition 1986;12:108–115.

Mitchell RL, Crow TJ. Right hemisphere language functions and schizophrenia: The forgotten hemisphere? Brain 2005;128:963–978. [PubMed: 15743870]

Myers JL, O'Brien EJ. Accessing the discourse representation during reading. Discourse Processes 1998;26:131–157.

Myers JL, O'Brien EJ, Albrecht JE, Mason RA. Maintaining global coherence during reading. Journal of Experimental Psychology: Learning, Memory, and Cognition 1994;20:876–886.

Nieuwland MS, Petersson KM, van Berkum JJ. On sense and reference: examining the functional neuroanatomy of referential processing. Neuroimage 2007;37:993–1004. [PubMed: 17611124]

Nieuwland MS, Otten M, van Berkum JJ. Who are you talking about? Tracking discourse-level referential processes with ERPs. Journal of Cognitive Neuroscience 2007;19:1–9. [PubMed: 17214558]

Nieuwland MS, van Berkum JJ. Individual differences and contextual bias in pronoun resolution: Evidence from ERPs. Brain Research 2006;1118:155–167. [PubMed: 16956594]

Noel-Jorand MC, Reinert M, Giudicelli S, Dassa D. A new approach to discourse analysis in psychiatry, applied to a schizophrenic patient's speech. Schizophrenia Research 1997;25:183–198. [PubMed: 9264174]

O'Brien EJ, Albrecht JE. Comprehension strategies in the development of a mental model. Journal of Experimental Psychology: Learning, Memory, and Cognition 1992;18:777–784.

O'Brien EJ, Cook AE, Peracchi KA. Updating situation models: A reply to Zwaan and Madden. Journal of Experimental Psychology: Learning, Memory, and Cognition 2004;30:289–291.

O'Brien EJ, Rizzella ML, Albrecht JE, Halleran JG. Updating a situation model: A memory-based text processing view. Journal of Experimental Psychology: Learning, Memory, and Cognition 1998;24:1200–1210.

Rigalleau F, Caplan D, Baudiffier V. New arguments in favour of an automatic gender pronominal process. The Quarterly Journal of Experimental Psychology 2004;57A(5):893–933. [PubMed: 15204122]

Rochester, S.; Martin, JR. Crazy Talk: A Study of the Discourse of Schizophrenic Speakers. New York: Plenum Press; 1979.

Ruby P, Sirigu A, Decety J. Distinct areas in parietal cortex involved in long-term and short-term action planning: A PET investigation. Cortex 2002;38:321–339. [PubMed: 12146659]

Salzinger K, Pisoni DB, Portnoy S, Feldman RS. The immediacy hypothesis and response-produced stimuli in schizophrenic speech. Journal of Abnormal Psychology 1970;76:258–264. [PubMed: 5483373]

Salzinger K, Portnoy S, Feldman RS. Verbal behavior of schizophrenic and normal subjects. Annals of the New York Academy of Sciences 1964;105:845–860. [PubMed: 14212839]

Salzinger K, Portnoy S, Feldman RS. The predictability of speech in schizophrenic patients [letter]. British Journal of Psychiatry 1979;135:284–287. [PubMed: 486857]

Sanford, AJ.; Garrod, SC. Explorations of comprehension beyond the sentence. Chichester: Wiley; 1981. Understanding written language.

Schank, RC.; Abelson, RP. Scripts, plans, goals, and understanding: An inquiry into human knowledge structures. Hillsdale, NJ: Lawrence Erlbaum Associates; 1977.

Schneider, K. Clinical Psychopathology. New York: Grune and Stratton; 1959.

Singer M, Ritchot KFM. The role of working memory capacity and knowledge access in text inference processing. Memory and Cognition 1996;24:733–743.

Sitnikova T, Goff D, Kuperberg GR. Abnormalities in conceptual processing dissociate disorganization and negative symptomatology during real-world behavior in schizophrenia. Journal of Abnormal Psychology. in press.

Sitnikova T, Salisbury DF, Kuperberg GR, Holcomb PJ. Electrophysiological insights into language processing in schizophrenia. Psychophysiology 2002;39:851–860. [PubMed: 12462512]

Speed M, Shugar G, Di Gasbarro I. Thought disorder and verbal recall in acutely psychotic patients. Journal of Clinical Psychology 1991;47:735–744. [PubMed: 1757575]

Spitzer M, Beuckers J, Beyer S, Majer S, Hermle L. Contextual insensitivity in thought-disordered schizophrenic patients: Evidence from pauses in spontaneous speech. Language and Speech 1994;37(2):171–185. [PubMed: 7837903]

Stewart A, Holler J, Kidd E. Shallow processing of ambiguous pronouns: Evidence for delay. Quarterly Journal of Experimental Psychology 2007;60:1680–1696.

Taylor WL. Cloze procedure: A new tool for measuring readability. Journalism Quarterly 1953;30:415–433.

Tenyi T, Herold R, Szili IM, Trixler M. Schizophrenics show a failure in the decoding of violations of conversational implicatures. Psychopathology 2002;35(1):25–7. [PubMed: 12006745]

Titone D, Levy DL, Holzman PS. Contextual insensitivity in schizophrenic language processing: evidence from lexical ambiguity. Journal of Abnormal Psychology 2000;109:761–767. [PubMed: 11196002]

Tompkins, CA.; Fassbinder, W.; Lehman-Blake, MT.; Baumgaertner, A. The nature and implications of right hemisphere language disorders: Issues in search of answers. In: Hillis, A., editor. Handbook of adult language disorders: Integrating cognitive neuropsychology, neurology, and rehabilitation. New York, NY: Psychology Press; 2002. p. 429-448.

Trabasso T, van den Broek P. Causal thinking and the representation of narrative events. Journal of Memory and Language 1985;24(5):612–630.

Trabasso T, van den Broek P, Suh SY. Logical necessity and transitivity of causal relations in stories. Discourse Processes 1989;12:1–25.

van Berkum, JJ.; Zwitserlood, P.; Bastiannsen, MCM.; Brown, CM.; Hagoort, P. So who's "he" anyway? Differential ERP and ERSP effects of referential success, ambiguity and failure during spoken language comprehension. Annual meeting of the Cognitive Neuroscience Society; 2004.

van den Broek, P. The causal inference maker: Towards a process model of inference generation in text comprehension. In: Balota, DA.; Flores d'Arcais, GB.; Rayner, K., editors. Comprehension processes in reading. Hillsdale, NJ: Erlbaum; 1990. p. 423-445.

van den Broek P, Rapp DN, Kendeou P. Integrating memory-based and constructionist approaches in accounts of reading comprehension. Discourse Processes 2005;39:299–316.

van den Broek, P.; Virtue, S.; Everson, M.; Tzeng, Y.; Sung, Y. Comprehension and memory of science texts: Inferential processes and the construction of a mental representation. In: Otero, J.; Leon, JA.; Graesser, C., editors. The psychology of science text comprehension. Mahweh, NJ: Erlbaum; 2002. p. 131-154.

van Dijk, TA.; Kintsch, W. Strategies of discourse comprehension. New York: Academic Press; 1983.

Van Petten C, Weckerly J, McIsaac HK, Kutas M. Working memory capacity dissociates lexical and sentential context effects. Psychological Science 1997;8(3):238–242.

Virtue S, Haberman J, Clancy Z, Parrish T, Jung-Beeman M. Neural activity of inferences during story comprehension. Brain Research 2006;1084:104–114. [PubMed: 16574079]

Virtue S, Parrish T, Jung-Beeman M. Inferences during story comprehension: Cortical recruitment affected by predictability of events and working memory capacity. Journal of Cognitive Neuroscience 2008;20(12):2274–2284. [PubMed: 18457505]

Xu J, Kemeny S, Park G, Frattali C, Braun A. Language in context: emergent features of word, sentence, and narrative comprehension. Neuroimage 2005;25:1002–1015. [PubMed: 15809000]

Yaxley RH, Zwaan RA. Simulating visibility during language comprehension. Cognition 2007;105:229–236. [PubMed: 17070792]

Zaidel E, Kasher A, Soroker N, Batori G. Effects of right and left hemisphere damage on performance of the ''right hemisphere communication battery''. Brain and Language 2002;80:510–35. [PubMed: 11896655]

Zwaan RA, Magliano JP, Graesser AC. Dimensions of situation model construction in narrative comprehension. Journal of Experimental Psychology: Learning, Memory, and Cognition 1995;21:386–397.

Zwaan RA, Radvansky GA. Situation models in language comprehension and memory. Psychological Bulletin 1998;123:162–185. [PubMed: 9522683]