

## LANGUAGE DYSFUNCTION IN SCHIZOPHRENIA

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### A REVIEW OF LANGUAGE DYSFUNCTION IN SCHIZOPHRENIA

Abnormalities in language are central to psychosis, particularly the schizophrenic syndrome. This chapter first discusses one clinical manifestation of abnormal language in schizophrenia: 'thought disorder'. We then give a framework for understanding normal language structure and processing. Within this framework, we review studies of language processing in schizophrenia. Finally, we review some recent neuroimaging and electrophysiologic studies that have attempted to examine the neural correlates of language abnormalities in schizophrenia.

### THOUGHT DISORDER

Perhaps the most extreme and obvious manifestation of a language disorder in schizophrenia is the abnormal speech produced by some patients. This disturbance is heterogeneous and has traditionally been termed 'thought disorder'. Positive thought disorder, with disorganized unintelligible speech, is a strong predictor of maladaptive social and vocational functioning (121,141,223). Yet its definition and study has challenged psychopathologists since schizophrenia was first described. In this section, we discuss some of the fundamental questions that have shaped our understanding of thought disorder. First, is it truly a disorder of thought or one of language? Second, is it characterized by problems in the content or the form of speech or both? Third, is it unique to schizophrenia? Fourth, how has it been classified and studied?

#### Thought Versus Language?

The traditional viewpoint of most psychopathologists has been to regard speech disturbances as reflective of an underlying disorder of thinking rather than a primary disorder of

language. For example, Kraepelin (168) attributed abnormal speech of schizophrenic patients to derailments and incoherence in the "train of thought." Bleuler (28) believed that disorders of the association of thoughts were fundamental to schizophrenia but that these disorders did not "lie in the language itself." Indeed, he classified disorders of speech and writing as secondary "accessory symptoms" of schizophrenia. Despite these early attempts to distinguish between thought and language disturbances in schizophrenia, there has been considerable confusion in the terminology used to refer to these phenomena.

It has long been recognized that most disorders of thought can only be deduced from the speech of patients. Rochester and Martin (240) pointed out that, because thought cannot be accessed directly, attributing thought disorder to a speaker is tautologic, i.e., we infer thought disorder based on disordered speech. However, it has also long been acknowledged that there is no simple, one-to-one relationship between the language system, on the one hand, and abnormalities in accomplishing the goals of language use on the other. One patient could theoretically have major problems in his/her thought processes but choose to say nothing. Another patient's thought processes may be intact but he/she may find him/herself unable to use the tools of language to express him/herself. Thus, to some researchers, the term 'thought disorder' refers to subjective changes experienced and reported by a patient. Observed abnormalities of spoken or written language are referred to as speech or language disorders. Other researchers, however, refer to spoken and written language abnormalities as 'thought disorder'.

A second and related source of confusion has arisen because of differing assumptions about what phenomena and processes are classified as thought versus language. This debate has often been at a theoretical and philosophical level, perhaps because the very concept of thought is ill defined. Thought has been studied not just by examining speech, but by assessing logic, problem solving, various nonverbal analogy-making abilities, and so on. Nonetheless, we

still know relatively little about the relationships between thought, knowledge, and language and its expression.

### Content Versus Form of Thought

Traditional psychiatric teaching has distinguished between problems in the *content* and *form* of thought (253). Content has been defined simply as what the patient is talking about (291), whereas form has been defined as the way ideas, sentences, and words are put together.

### Disorders of Content

In psychosis, the most extreme example of a disorder of content is the delusion. Indeed, some psychopathologists narrow their definition of content abnormalities to include only delusions (86). However, the content of speech produced by schizophrenic patients can be distinguished from that of control subjects in ways that do not meet the criteria for a delusion, particularly in terms of the conviction, consistency, and strength with which such beliefs are expressed. The content of schizophrenic speech has been described as deviant in the use of conventional social norms (121,196,241), the degree to which personal themes have an inappropriate impact (122,302), and in how subjects think about or judge events in the real world (33,68). For example, Brown (33) describes a patient who told him that “When I get out of here, I’m going to fly to Scotland where they are making a movie of *Fiddler on the Roof* because I’d really like to try out for the lead.” Brown points out that this patient had incorrect knowledge about the nature of *Fiddler on the Roof*; Scotland was an unlikely venue for it, and the patient was the wrong age to play its leading role. Cutting and Murphy (68) give a similar example of a patient who claimed that “a thermometer made everyone of the age of 21 get either flu or pneumonia.”

Disorders of content such as those described above form essential components of several commonly used rating scales of thought disorder (see below). For example, they are included, by definition, in the Assessment of Bizarre-Idiosyncratic Thinking (195,196). Similarly, criteria such as “queer” responses (expressions and imagery), fabulized combinations (impossible or bizarre), absurd responses, and autistic logic are included in the Thought Disorder Index (150,270).

### Disorders of the Form of Thought

Disorders in the way ideas, sentences, and words are put together in psychotic speech were first codified in the late nineteenth and early twentieth centuries. For example, Schneider (254) described a number of phenomena including *Verschmelzung* (fusion), *Faseln* (muddling), and *Entgleiten* (snapping off). These abnormalities ranged from the use of vague sentences that are difficult to follow, non sequitur re-

sponses to questions, through fragmented incomprehensible speech with neologisms, word approximations, and private word usage.

More recently, many of these phenomena have been included as essential components in the three most commonly used instruments to assess thought disorder: the Scale for Assessment of Thought, Language, and Communication (TLC) (12,15), the Thought Disorder Index (TDI) (150,270), and the Assessment of Bizarre-Idiosyncratic Thinking (195,196). Of these, the 20-item Thought, Language, and Communication scale (12) is notable because, unlike other scales that make assumptions about the nature of thought disorder, it simply describes abnormalities in speech during psychiatric interviews. For example, ‘derailment’ and ‘loss of goal’ would be scored highly on this instrument if a patient’s utterances were either unrelated or only obliquely related to one another, and, as a result, the patient’s discourse ended with something completely unrelated to how it started (e.g., “I always liked geography. My last teacher in that subject was Professor August A. He was a man with black eyes. I also like black eyes. There are also blue and grey eyes and other sorts, too. . .” (28).

Studies using this scale have reported that phenomena occurring at the level of sentences and discourse, such as derailment, loss of goal, perseveration, and tangentiality, are much more common in schizophrenia than phenomena that occur at the level of single words such as neologisms (11,80,200).

### Distinction between Content and Form in Schizophrenia

The distinction between form and content, as defined above, is sometimes blurred. They often co-occur (26), and, in clinical practice, it is sometimes difficult to distinguish the two. For example, a tangential answer to a question (a disorder of form) might arise because a patient is preoccupied with a bizarre belief (a disorder of content). Moreover, in many patients, form and content interact. For example, recent studies have shown that speech becomes more disjointed when patients talk about negative emotional themes (75,117).

### Is Thought Disorder Unique to Schizophrenia?

The question of whether thought disorder is unique to schizophrenia has stimulated extensive debate for two main reasons. First, for many years, it was believed that the identification and characterization of speech disturbances might aid in the differential diagnosis of schizophrenia from other psychoses. Second, many researchers believed that identifying similarities between the speech of patients with schizophrenia and that of patients with identifiable brain damage would give clues about the sites and origins of brain dysfunction in schizophrenia (161).

### *Speech in Schizophrenia Versus Other Psychoses*

Because Bleuler (28) considered thought disorder to be a primary symptom and a core feature of the schizophrenic syndrome, it was once the norm for clinicians to assign a diagnosis of schizophrenia when any kind of thought disorder was present. However, with the development of more stringent diagnostic criteria, it became clear that thought disorder occurred in other psychoses, particularly in mania (10,11,120,150,271). Although several studies have documented overlap in the quantity and quality of thought disorder in schizophrenic and manic patients, some differences have also been highlighted. For example, compared with manic patients, the thought disorder of schizophrenic patients is often more disorganized and confused, with an increased use of peculiar words and phrases (271).

### *Speech in Schizophrenic Versus Brain-Damaged Patients*

The speech of schizophrenic patients has been likened to that produced by two main groups of brain-damaged patients: those with aphasias and those with right-hemisphere lesions.

#### **Aphasias**

The speech of some schizophrenic patients appears, at least superficially, similar to Wernicke's aphasia, i.e., well formed syntactically but giving an overall impression of nonsensical jargon. Like Wernicke's aphasia, it can include paraphasic-like semantic substitutions of words and phrases and a tendency to string words together based on phonologic or semantic relationships rather than whole themes. Moreover, like some patients with Wernicke's aphasia, schizophrenic patients with thought disorder often show little awareness of their speech abnormalities.

These comparisons, however, have been largely based on clinical impression, and there have been few systematic comparisons of these two patient groups. One study reported that only one of five specialist raters was able to differentiate accurately between the speech produced by schizophrenic patients and that produced by aphasic patients (83). Another study, however, identified several differences between the two groups: the speech of eight patients with posterior aphasic syndromes (Wernicke's aphasia, transcortical sensory aphasia and conduction aphasia) tended to show paraphasic errors, whereas the speech of schizophrenic patients was characterized by one or two bizarre themes (100). Studies that have examined the performance of schizophrenic patients on neuropsychological language tasks traditionally used in aphasic patients, such as the Boston Naming Test (109), have identified both differences and similarities between the two groups.

The design and rationale of studies that have compared the speech of schizophrenic and aphasic patients may be inherently flawed: many of these studies failed to take into account the heterogeneity of schizophrenia: only some schizophrenic patients produce abnormal speech. Moreover, the aphasias themselves are syndromes that are relatively broadly defined: the criteria for inclusion of patients in different aphasic groups overlap. For example, phonemic paraphasias are observed in several categories, and anomia is said to occur in almost all categories.

Another reason why comparisons between groups of schizophrenic and brain-damaged patients may not yield useful information about the neural basis of schizophrenic language abnormalities is that the localization of brain lesions in the aphasic syndromes remains controversial (see later).

#### **Right-Hemisphere Patients**

The speech of schizophrenic patients has also been likened to that produced by patients with disorders of hemispheric imbalance, particularly those with isolated right-hemisphere lesions. Like schizophrenic patients, such patients are said to follow "associations that are tangential to the overall meaning of a discourse. . .and are often stuck with, or are satisfied with, a limited and piecemeal understanding, one based on personalization as well as on other inappropriate associations" (34). Right-hemisphere patients also show a range of other deficits including problems with nonliteral language, stories, jokes, and conversations. To our knowledge, there have been no systematic comparisons of the speech of right-hemisphere and schizophrenic patients.

#### **Classifying Thought Disorder**

There have been numerous attempts to classify the phenomena constituting thought disorder. Psychopathologists originally attempted to group these phenomena together on a conceptual basis. More recent studies have examined their co-occurrence in large numbers of patients, classifying patients on this more empirical basis. To the extent that what is usually called 'thought disorder' is manifest in language (see earlier discussion), a third approach is to describe and classify language itself within a framework used by linguists and psycholinguists to describe normal language structure and processing. We adopt this last approach in the following review of studies of language output and processing in schizophrenia.

#### **Conceptual Classification**

In the first half of this century, psychopathologists described a number of deficits that they believed to underlie the abnormal speech produced by many patients with schizophrenia.

These were essentially descriptions of what was inferred about patients' thinking—intrinsic disturbance in thinking or 'dyslogia' (13,14). They included concepts such as "looseness of association" (28), "overinclusive thinking," [a tendency of patients to use concepts beyond their usual boundaries (36,37)], concrete thinking [an inability to think abstractly (108)], and logical deficits (304).

### *Empirical Classification*

With the development and use of scales that rated thought disorder more systematically came an attempt to group together its various phenomena based on the frequency of their co-occurrence. The first widely recognized classification of thought disorder was one that distinguished positive from negative thought disorders, paralleling the traditional distinction between positive and negative symptoms of schizophrenia (65). Positive thought disorder included tangentiality, derailment, neologisms, and several other phenomena that appeared to be highly correlated in patients (11,126,229). Negative thought disorder included phenomena such as "poverty of speech." A distinction between positive and negative thought disorders has been confirmed by several factor analytic studies of speech disturbances in schizophrenia (15,131,233,292). Positive thought disorder is generally associated with acute schizophrenia and often improves with neuroleptic treatment (105). However, it can sometimes persist after the acute phase and become chronic with a poor prognosis (123,200).

Positive thought disorder is now generally conceptualized as part of the disorganization subsyndrome of schizophrenia (79a). It is also termed disorganized speech.

### *Psycholinguistic Classification*

It is clear from the discussions above that there are several problems with the traditional phenomenologic approach to studying thought disorder: there is confusion about terminology, phenomena are often imprecisely defined, and there is no obvious way to link clinical disturbances with dysfunction at the neurocognitive level. One way to overcome these problems is to approach the study of thought disorder in schizophrenia within a framework of psycholinguistics. Such an approach has the advantages of having a sound theoretical basis and of highlighting the close relationship between normal and abnormal processing. This, in turn, encourages the generation of specific hypotheses that can be tested experimentally.

A psycholinguistic approach involves the identification of disturbances in the major components of the language processing system that are present in patients with thought disorder. From a practical point of view, a very detailed taxonomy based on all possible deficits is unrealistic. One way

to approach a psycholinguistic classification is to identify language-processing deficits (e.g., semantic, syntactic) at the three basic levels of the language code: simple words (the lexical level), sentences (the sentential level), and discourse (the discourse level). It is also important to examine how psycholinguistic processes interact with other cognitive processes such as nonverbal semantic processing, attention, and working memory.

We first give an overview of the normal language system, highlighting its essential features and its interaction with other cognitive processes. Within this framework, we then review relevant studies in schizophrenia.

## **NORMAL LANGUAGE: STRUCTURE, REPRESENTATION, AND PROCESSING**

### **Language Structure**

The three basic levels of the language code are simple words (the lexical level), sentences (the sentential level), and discourse (the discourse level).

#### *The Lexical Level*

The lexical level of language consists of simple words. The basic form of a simple word (or lexical item) consists of a phonologic representation that specifies the segmental elements (phonemes) of the word and its organization into metrical structures such as syllables (118). The form of a word can also be represented orthographically (135). In addition, simple words are assigned to different syntactic categories, such as noun, verb, adjective, article, and position. Finally, words are represented at a lexico-semantic level. Each of these lexico-semantic representations is associated with concepts and categories in the nonlinguistic world. Simple words tend to designate concrete objects, abstract concepts, actions, properties, and logical connectives.

#### *The Sentential Level*

The sentential level of language consists of syntactic structures—hierarchical sets of syntactic categories, e.g., noun phrases, verb phrases (50–52), into which words are inserted. The meaning of a sentence, known as its propositional content, is determined by the way the meanings of words combine in syntactic structures. Propositions convey aspects of the structure of events and states in the world. These include information about who did what to whom (thematic roles), which adjectives go with which nouns (attribution of modification), and which words in a set of sentences refer to the same items or actions (the reference of pronouns and other anaphoric elements). For instance,

in the sentence “The big boy told the little girl to wash herself,” the agent of “told” is “the big boy” and its theme is “the little girl”; “big” is associated with “boy” and “little” with “girl,” and “herself” refers to the same person as “girl.” Sentences are a crucial level of the language code because the propositions that they express make assertions about the world. These assertions can be entered into logical systems and can be used to add to an individual’s knowledge of the world.

### *The Discourse Level*

The discourse level constitutes higher-order structures formed by the propositional meanings conveyed by sentences (113,301). Discourse includes information about the general topic under discussion, the focus of a speaker’s attention, the novelty of the information in a given sentence, the temporal order of events, and causation. The structure and processing of discourse involve many nonlinguistic elements and operations, such as logical inferences, as well as more purely linguistic operations. For instance, consider the following set of sentences:

John and Henry went to Peter’s last night. They were very glad they did. They raved about the dessert all the next day.

The reader infers that John and Henry ate dinner at Peter’s. This is an inference that is based on information that is outside the language system. On the other hand, the reader takes the word “They” in the second sentence to refer to John and Henry, not John and Peter, or Henry and Peter, or all three men. This assignment is probably based on the fact that “They” and “John and Henry” are both noun phrases in the subject positions of their sentences—a linguistic fact.

Information conveyed by the discourse level of language serves as a basis for updating an individual’s knowledge of the world and for reasoning and planning action.

### **Representations: Linguistic and Other Types**

Different linguistic representations (e.g., semantics and syntax) have different rules and are generally acknowledged to be independent of one another. It is clear from the above discussion that some linguistic representations cut across the three levels of the language code. For example, meaning—semantics—is represented at the word, sentence, and discourse levels. Similarly, individual words are assigned to specific syntactic categories, but the ways in which they are put together (the syntactic structure) are defined at the sentential level.

The boundary between linguistic representations and other types of representation is not always easy to draw. This

is particularly the case in the study of semantics. One of the reasons for this blurring is inconsistent terminology. In the study of language, the word semantics is generally used as an umbrella term to refer to all aspects of meaning. For example, at the level of single words, it may refer to conceptual associations and groups, whereas at the level of sentences, it refers to propositions that are derived from a combination of word meanings and the syntactic structure. Another source of confusion is that the distinction between amodal semantic representations and lexico-semantic representations is not always specified.

There is also a blurred boundary between the study of semantics and pragmatics. Pragmatics is a widely used term that encompasses our social and real world knowledge—the way people use language in natural settings, particularly in the study of discourse. Some researchers but not others, explicitly exclude pragmatic inferences, discourse context, and knowledge of the world from the study of semantics.

Semantics has not only been studied from the perspective of language but also of memory. Semantic memory is traditionally conceptualized as the component of long-term memory that constitutes representations of objects, facts, concepts, word meanings, and their relationships. This is thought to be distinguishable from episodic memories that are temporally specific for personal events, i.e., the place or time of encoding (298).

### **Language Processing**

The different forms of the language code are thought to be computed by a set of processors whose operations range from conversion of the acoustic signal to speech sounds, through visual word recognition through determination of sentence and discourse structure.

Information-processing models of language often depict a sequence of operations of the different components required to perform a language-related task. These models are based on the results of experimental psychological research in both normal subjects and in patient populations (39,135,181,259). They can become extremely detailed and complex when all the operations and components used in a task are specified. For our current purposes, it is adequate to identify the major components of the language-processing system as those processors that activate units at the lexical, sentential, and discourse levels of the language code.

### *Temporal and Spatial Distinctions*

As noted above, different linguistic representations (e.g., semantic, syntactic) are thought to be independent of one another. A fundamental question is whether these

representational distinctions are respected during language processing, both with respect to the temporal sequence of these processes and their spatial localization in the brain.

The question of relative *timing* of different linguistic processes addresses the extent to which the components of the system operate serially or in parallel. This question remains controversial. At one extreme, serial models hold that processing of one form of linguistic information awaits the completion of processing of another form of linguistic information. Parallel-processing models, in contrast, suggest that processing different types of information occurs at the same time. It is important to note that some parallel models are still consistent with different processes being temporally distinct. For example, cascade models hold that individual processing stages are arranged in a temporal sequence with one stage starting before another, but with information continually flowing in feed-forward fashion. Alternatively, the output of one type of processing may be delayed relative to another type of processing. Strict parallel models, however, assume that all processes are initiated at the same time and that the output of each process is available at the same time. Information about the timing of processes is given by on-line behavioral studies and by event-related potential (ERP) studies (see later discussion).

Information regarding whether different levels of language processing are mediated by distinct neural systems has traditionally come from studies of patients with brain lesions. So-called double dissociations in which one patient performs normally on one task and abnormally on a second task and a second patient shows the opposite pattern, provide evidence of the existence of separate processors, each involved in only one of the two tasks (259). These observations support localizationist theories of brain function.

Another somewhat orthogonal question is whether processing different types of linguistic information is autonomous or interactive. A purely modular view (91) holds that different processing components are each dedicated to activating particular elements of the language code, accepting only particular types of representations as input (encapsulation) and producing only specific types of representations as output (domain specificity). Pure interactionalist models hold that processing different types of linguistic information are dependent on each other (81,197,199).

### *Relationship with Other Cognitive Processes*

Each component of the language-processing system interacts with and can be influenced by *outside* cognitive systems and processes, such as attention, working memory, executive function, and non-linguistic semantic memory.

Researchers have developed a number of theories describing such interactions (38,154,155,259). Some of these processes may be necessary for successful language comprehension. For example, consider the sentence “The daughter of the king’s son shaved himself.” It is relatively easy to understand its individual parts (“The daughter of the king” and “The king’s son shaved himself”), but putting them all together to parse it as “[the daughter of the king]’s son,” i.e., the king’s grandson, may require additional processing resources.

Other cognitive processes may be under strategic control. For example, we exercise control over the entire language-processing system when we decide whether to use language to convey our intentions. We exercise control over the choice of vocabulary elements in our speech based on our estimation of the listeners’ ability to understand different sets of words. We control the rate of our speech, the formality of the vocabulary, and the syntax that we choose.

## **OFF-LINE STUDIES OF LANGUAGE PROCESSING IN PSYCHOSIS**

Neuropsychological profiles of patients with schizophrenia depict deficits across a broad range of cognitive functions. There is some evidence that, among cognitive domains, language processing and verbal memory are particularly susceptible to disruption. For example, in one study, patients performed comparably with controls on a tone serial position task but poorly on an auditory and visual verbal task (283).

In this section, we review studies of language output and processing in schizophrenia. First, we describe studies at the level of single words. These have been conducted mainly from the perspective of the structure and function of semantic memory. Second, we review studies that have examined the meaning of words in relation to their context within sentences and discourse. Third, we discuss studies that have specifically examined syntactic processing in schizophrenia. Finally, we review studies of discourse that have examined the relationships between sentences in schizophrenia.

At each of these levels of processing and/or representation, we consider studies of language production and language processing in turn. Our review of language-processing studies in schizophrenia in this section is limited to those that have used traditional off-line methods. These are methods that do not measure psycholinguistic operations at the time they occur. In most off-line studies, the task is untimed (immediate judgment or immediate/delayed recall or recognition), and the dependent variable is usually accuracy or error type. The interest of the study lies in what linguistic representations a patient can or cannot deal with. Studies

that have made use of so-called on-line methods are reviewed in the next section.

### Single Words

It has long been noted that the speech of some patients with schizophrenia is characterized by a "preoccupation with too many of the semantic features of words" (42). After Bleuler (28) who conceived of schizophrenia as a disorder of association, most studies in schizophrenia at the level of single words have focussed on the structure of and access to semantic memory.

As discussed below, patients with schizophrenia perform poorly on several different verbal semantic tasks including semantic fluency, naming, categorization and recall. Recent studies have suggested that poor performance on some semantic tasks is particularly impaired in patients with thought disorder (104).

Many of these studies of semantic memory in schizophrenia have followed the neuropsychological lesion literature in attempting to distinguish between storage and access/retrieval deficits in semantic memory (259,260). There are said to be five hallmarks of the loss of items in semantic memory:

1. Consistent production of semantic errors on particular items across different inputs (pictures, written words, spoken words),
2. Relative preservation of superordinate information as opposed to information about an item's specific semantic features,
3. Relative preservation of information about higher frequency items,
4. Improvement of performance by priming and cueing,
5. No effect of the rate at which a task is performed on performance.

Disorders of retrieval of items and information from semantic memory are said to be characterized by the opposite effects of these variables on performance. Patients have been described who are said to show characteristics indicating storage versus retrieval deficits and vice versa, but the interpretation of these data remains controversial (39,40). As discussed further below, in schizophrenia, the traditional empirical distinctions between storage and access deficits may be even more blurred because several researchers have proposed that in these patients the semantic memory store may be disorganized rather than degraded (8,231).

### Production of Single Words

#### Word Association Tasks and Verbal Fluency

Early experiments carried out by Bleuler, Jung, and Kraepelin used word-association tasks to show that schizo-

phrenic patients produced more idiosyncratic associations than normal controls (153,273). These findings were confirmed by some later studies (149,157,208,214,217,261,262).

Increased associative word production may be particularly characteristic of positive thought disorder, not only in schizophrenia but also in schizoaffective disorder and mania (182).

The word-association task has inherent limitations: there exist different sets of norms that have changed over the years, and deciding what constitutes a "rare" response is largely subjective. Another paradigm commonly used in schizophrenia research is verbal fluency, otherwise known as the controlled oral association test. The semantic or category fluency version of this task requires subjects to produce words within specific categories (e.g., animals, body parts, furniture) (296). Many researchers using the semantic fluency task have reported that schizophrenic patients generate fewer words in a specified period than controls (2,6,8,23,49,62,103,106,111,115,152,205,231). Such deficits are evident at an early stage of illness (49,231) and are particularly associated with negative symptoms (2,48). They do not increase with increased illness duration (49,103) and cannot be explained by intellectual deficits (62).

Temporal analyses of semantic fluency in schizophrenia suggests that, given enough time, patients do eventually produce the same total number of category exemplars as controls (5,6), suggesting that the deficit is not due to a degradation in knowledge but rather reflects an impairment in access to or retrieval from the semantic system. There have been two studies in which the experimenter provided cues to verbal production, but the results of these studies are difficult to interpret, partly because of ceiling effects in the control groups (103,152).

If the problem is indeed one of retrieval, one question is whether it is specific to retrieval from semantic memory or whether it reflects a general problem in the retrieval of verbal items. Some studies have reported that patients perform selectively poorly on semantic versus letter fluency tasks (84,104,111), suggesting a differential deficit in the semantic system. However, in two other studies, patients produced 60% to 70% of the number of words produced by the controls' on both letter and semantic fluency tasks (23,152).

During semantic fluency, some patients produce words that are inappropriate for a given category. Multidimensional scaling and clustering techniques have been used to examine the relationships between words produced within given categories in more depth (2,8,231). These studies have suggested that patients are less likely than controls to group superordinate exemplars in clusters and are more likely to produce bizarre associations. Whether these patterns reflect a disorganization of the storage of items or specific deficits in the task-appropriate selection of items in semantic memory (see below) requires further investigation.

### **Naming and Repetition Tasks**

Anomia is a characteristic feature of several types of aphasic syndromes and suggests problems in accessing lexical phonologic representations from semantic memory and/or planning speech production. Naming tasks in schizophrenia have usually been administered as part of neuropsychological batteries designed for use with the aphasia syndromes, e.g., the Boston Diagnostic Aphasia Examination (109). Schizophrenic patients perform less well than controls (82) and at times as poorly as fluent aphasic patients (176) and patients with Alzheimer disease (69) on such tasks. This deficit may not, however, be specifically associated with thought disorder (104).

Improved naming with semantic cuing (178,206) suggests problems with access to semantic memory rather than a storage loss (see above), although the questions of whether patients show variability in performance across trials or an effect of familiarity remain controversial (178,206).

### **Comprehension and Memory of Single Words**

#### **Semantic Categorization and Immediate Recall**

Several investigators have reported that patients with schizophrenia are slower and less accurate in classifying words or word pairs as members of conceptual categories (47,53,116). Moreover, in a timed short-term memory recognition task, schizophrenic patients with positive thought disorder failed to use semantic information to (a) improve recall of items that were originally encoded among semantically related words and (b) elicit false recognitions of targets that were semantically related to the originally encoded words (210).

#### **Semantic Categorization and Long-Term Recall**

When normal subjects learn a list of words, their recall is better if the list can be organized into semantic categories than if it consists of a sequence of unrelated words. This is thought to reflect the tendency to organize words in semantic memory during encoding (61,160). An encoding strategy of semantic organization is also reflected by the organization of words at recall (282).

Patients with schizophrenia fail to spontaneously use semantic categorization strategies (201), often producing largely unorganized word lists at recall (32,35,102,146,156,162,177,186,201,243). Nonetheless, most studies (146,163,164,177,243), although not all (102), have reported that, if material is preorganized or if patients are given enough time to organize material during encoding (see above), they have the capacity to use semantic information to improve recall.

One study examined the recall of words whose associative properties were already known. In healthy controls, recall of a particular word was dependent on both its associative strength and the number of associative links within its associative network. In schizophrenic patients, however, cued

recall was impaired, particularly for words of low associative strength (221).

### **Summary**

Most of the studies reviewed above suggest that there is no loss of semantic information in schizophrenia. The problem appears to be one of access/retrieval and of using semantic knowledge effectively. Access and retrieval of items in semantic memory can be subdivided into several subcomponents: successful retrieval (or recovery) involves both the activation and selection of target items in semantic memory (194). Either of these processes could be disturbed in schizophrenia. Moreover, some of the studies described above suggest that schizophrenia may be characterized by a disorganized semantic memory store. This might, in turn, lead to deficits in effective retrieval.

Another important question requiring further study is the degree to which semantic deficits occur specifically at the lexical level as opposed to at an amodal level of semantic representation. Some patients have been shown to perform poorly on nonverbal or cross-modal semantic tasks such as word-to-picture matching and picture classification (205,289), suggesting at least some dysfunction at an amodal level of semantic memory.

### **Words in Sentences and Discourse**

The observation that some patients with schizophrenia produce "sentences according to the semantic features of previously uttered words, rather than according to a topic" (42) has led to several studies investigating the relationship between the meanings of individual words within whole sentences and discourse in schizophrenia.

### **Production of Words in Sentences**

#### **Word Associations in Sentences**

In an elaboration of the free word-association task (discussed above), subjects are asked to place the words that they produced in the context of a sentence (147). In one study using this paradigm, at least 70% of responses by both patients and controls that were judged to be pathologic based on the word-association test alone became meaningful in the context of sentences (110). In a more recent study, however, patients did have difficulty in producing words in the context of sentences: some patients with negative symptoms were unable to put their idiosyncratic associations into meaningful sentences, and patients with positive symptoms were unable to place common associations in meaningful sentences (149).

This method, however, has the same drawbacks as the single word-association tasks in that the decision of whether or not a word is appropriate in the context of a sentence is largely subjective.

### Predictability of Words in Sentences

A more systematic method of examining how well a word fits in with its surrounding context is to determine its predictability or redundancy using the technique of Cloze analysis. Speech is transcribed, and words in the resultant text are periodically omitted. Normal readers are then asked to determine the missing words. In one of the first studies using this technique, judges (healthy individuals) were less able to guess the words omitted from the first 100 words of a schizophrenic patient's transcript than those omitted from the transcript of a control subject (248). Judges performed even more poorly for the second 100 words of the schizophrenic transcript, although, for the control transcript, their judgment actually improved. Further experiments indicated that judges performed differentially poorly on schizophrenic transcripts when lengthy (14 words surrounding the omitted word) as opposed to more immediate contexts (four surrounding words) were provided (249,250). These findings were interpreted as supporting an 'immediacy hypothesis', which proposed that schizophrenic behavior (verbal and non-verbal) was primarily controlled by stimuli immediate to the environment. Later studies, however, failed to replicate these findings (244) and suggested that only patients with thought disorder produced unpredictable speech (124, 189).

### Repetition of Words in Sentences

Another statistical measure of language is the type:token ratio. This is considered a measure of flexibility or variability in the use of words in discourse. It measures the number of different words (types) in relation to the total number of words used (tokens). Several studies have reported that the type:token ratio is generally lower in speech and writing produced by schizophrenic patients than that produced by healthy controls (119,192,232). This is particularly apparent in patients with thought disorder (3,190).

### Comprehension and Memory of Words in Sentences

#### Cloze Technique

Schizophrenic patients do not only produce speech that is relatively hard to predict (as described above), but they also appear to be specifically impaired in their ability to make predictability judgments on normal speech. This has been demonstrated using a reverse Cloze technique in which patients are asked to judge whether a word is appropriate in the context of normal transcribed speech (27,144). Moreover, when levels of context are systematically varied (by deleting words with different periodicity), acute schizophrenic patients not only fail to improve with greater context, but their performance deteriorates (71). These deficits do not appear to be due to differences in verbal IQ (71,269).

### Lexical Ambiguity

The effects of sentential context on the meaning of individual words have been examined in a series of experiments of lexical ambiguity (45). Participants in these studies were asked to use context to judge the meaning of homographs—words with multiple unrelated meanings (e.g., bridge: a structure across a river or a card game). For many homographs, some meaning(s) occur more frequently than others and are referred to as *dominant* and *subordinate*, respectively. To interpret the subordinate meaning of homographs correctly, the surrounding context plays a crucial role. When the homograph and the preceding alternative sentence contexts are presented in the form of a multiple-choice test, schizophrenic patients tend to misjudge the subordinate meanings of the homographs more frequently than controls (24,27,45,285). For example, patients tended to select "writing implement" when given a sentence "When the farmer bought a herd of cattle, he needed a new pen."

### Recall of Words in and out of Context

Just as the recall of words of normal subjects improves if they can be semantically categorized, recall is also better when words are encoded in the context of whole sentences rather than as isolated strings. Indeed, when normal subjects are presented with speech samples varying in their degree of contextual constraint, recall of these samples improves with increasing constraint (211). Findings have been mixed in schizophrenic patients. Some studies have documented that patients are less able to benefit from increasing context than normal controls (179,183,192), whereas others report that only some patients are impaired: chronic but not acute patients (180); thought-disordered but not non-thought-disordered patients (187), and left-handed but not right-handed patients (193). Intriguingly, there appears to be an interaction between the effects of context and the serial position of the word to be recalled (192); schizophrenic patients were able to use contextual constraint to recall words that were recently presented but failed to do so when words were presented in primacy and middle positions.

In most of these studies, contexts were derived statistically (211). Another approach is to use stimuli in which linguistic rules are violated in different ways. For example, in one study, the recall of words encoded in the context of normal sentences was compared with those encoded in the context of semantically anomalous sentences, semantically related word strings, and random word strings (297). Recall of words encoded in the context of real sentences was selectively impaired in the schizophrenic group. This was interpreted as suggesting that schizophrenic patients were unable to use a combination of syntactic and semantic information to improve recall. This interpretation is discussed in more detail below.

### Judgment of Words in and out of Context

Three studies have examined the ability of schizophrenic patients to explicitly judge the acceptability of sentences in which linguistic rules have been violated. In the first study, chronic schizophrenic patients performed normally in judging the acceptability of selection–restriction violations (e.g., animacy, concrete/abstract violations) in sentences (212). In the second and third more recent studies, acutely psychotic patients (9) and thought-disordered patients (169) were relatively impaired in judging the acceptability of semantically anomalous sentences.

### Sentences: Syntax

The extent to which syntactic relationships within sentences break down in schizophrenia is somewhat controversial. Although several classes of syntactic errors have been identified in the speech of a single schizophrenic patient (42), most of these errors can occur in the utterances of normal speakers (97). There have been several formal analyses of the syntactic structure of speech produced by schizophrenic patients and a few studies that have examined speech comprehension by manipulating syntactic parameters. One of the difficulties in using off-line tasks (that do not measure psycholinguistic operations at the time that they occur) to determine whether or not schizophrenic patients are selectively impaired in their use of syntax, is that syntactic structure and the meaning of words are eventually combined. Such tasks may therefore not distinguish between specific deficits in syntactic processing *per se* and deficits in the combination of syntactic with lexico-semantic processes. For example, in the study described above that reported a selective impairment in the ability of patients to recall words encoded in the context of normal sentences versus word strings might suggest either a problem in using syntactic information or in using a combination of syntactic and semantic information to improve recall.

### Production of Syntactic Structure

Formal analyses of the speech produced by schizophrenic patients show that it is more grammatically deviant (139) and less complex than that of controls, as reflected by a higher percentage of simple sentences and, in compound sentences, fewer dependent clauses that are not deeply embedded (95,215). The latter findings are particularly associated with chronicity (158,294), early onset of the illness (216), and negative symptoms (293). A study that used another measure of syntactic complexity (number of clauses and proportion of relative:total clauses), however, reported no differences between patients and controls (251).

### Comprehension of Syntactic Structure

Early studies suggested that schizophrenic patients perform as poorly as many aphasic brain-damaged patients on measures of comprehension (82,236,265). More recent studies have confirmed comprehension deficits in schizophrenic patients (57–59). Although manipulating grammatical structure appears to have no effect on language comprehension (58), when patients are asked to explicitly identify syntactic errors in sentences, their performance is relatively poor (9). This deficit, however, is not as marked as for the identification of semantic errors. Moreover, the identification of syntactic errors, unlike semantic errors, correlates negatively with educational achievement (9).

### Discourse: Relationships between Sentences

Phenomena that are most frequent in schizophrenic thought disorder—tangentiality and derailment—occur primarily at the level of whole discourse. It is not surprising, therefore, that several investigators have attempted to examine discourse structure and the relationships between sentences in the speech produced by schizophrenic patients.

### Production of Discourse

#### Cohesion Analysis

One of the most systematic examinations of schizophrenic discourse is cohesion analysis, first applied by Rochester and Martin (240) who reported that thought-disordered schizophrenic patients used fewer cohesive ties than normal and non-thought-disordered patients. In this first study, three types of cohesive ties were examined: reference (e.g., “I’ve known Bill for years. He is a great guy.”), conjunction (“First I went to school and then I came back.”), and lexical cohesion (“My sister is pretty independent. Independence has always been one of her strengths.”). The finding that schizophrenic patients used abnormally few reference ties has been replicated by several investigators (7,125,129,207,246). Earlier measures have been refined and expanded. For example, the Communication Disturbance Index classifies unclear communication into several subtypes (73). The use of unclear and ambiguous verbal references appears to be a stable trait of schizophrenia (72), although it remains unclear exactly how this trait is linked to the symptom of thought disorder. One study, for example, reported no differences in cohesive elements between segments of speech that did and did not meet criteria for thought disorder as rated by the Thought, Language and Communication scale (129).

### **Predictability of Discourse**

The links between sentences produced by schizophrenic patients have also been examined using measures of predictability. In one experiment, discourse produced by normal controls and schizophrenic patients was transcribed, and judges were asked to arrange groups of randomly arrayed sentences of schizophrenic patients and normal subjects into their correct original sequential order. The correct arrangement of three or more sentences in their original order was achieved more often for normal than for schizophrenic discourse (245). This was also true of transcripts of the conversations of schizophrenic patients with others (246).

### **Structure of Discourse**

Normal discourse exhibits a systematic hierarchical structure in which propositions branch out from a central proposition. This tree structure has been reported to be relatively unconnected in psychotic speech (138,140).

### **Thematic Content of Discourse**

Another approach has been to analyze the thematic content of discourse. In one study, patients were asked to describe pictures, and speech transcripts were decomposed into ideas (individual sentences, semantic propositions, phrases, and words) and then rated according to whether they were thematically appropriate to the picture or inferential. Thought-disordered patients produced significantly fewer inferences than controls, but there was a trend toward an increase in the number of ideas classified as inappropriate (4).

### **Manic Versus Schizophrenic Discourse**

Some of the discourse measures described above have been used to compare the speech produced by schizophrenic and manic patients. Studies that included patients irrespective of their level of thought disorder have failed to detect differences in language coherence between these two groups (72,125,129,130). However, studies that limited comparisons to thought-disordered speech suggest that the discourse of manic patients is more cohesive than that of schizophrenic patients (140,207,310).

### **Comprehension and Memory of Discourse**

There have been relatively few studies examining discourse processing in schizophrenia. An early study suggested that schizophrenic listeners were able to identify referents in the speech of normal controls (54). Later studies have focused on the effects of discourse organization and of the number of propositions during encoding on later recall and recognition.

### **Recall of Sentences in Discourse**

As described above, in healthy individuals the recall of single words is superior if items are organized by semantic cate-

gories or are presented within sentences during encoding. Similarly, whole sentences are better remembered when presented as part of coherent discourse than when presented in random order. Schizophrenic patients may fail to take advantage of the organizational structure of sentences during encoding. In one study, organization of material presented during encoding did not influence organization at recall (127). In this study, even when patients generated their own discourse passages, recall performance remained inferior to that of controls. Intriguingly, thought-disordered patients (schizophrenics and manics) remembered significantly *more* than controls when sentences were presented randomly than when they were presented within a coherent text (272).

A gist paradigm (31) has also been used to study the memory of discourse in schizophrenia. In this task, participants learn four complex ideas from sentences with different numbers of propositions and later complete a recognition test. Normal participants are usually more confident in their recognition of sentences that describe ideas with a greater number of propositions, even when asked to recognize sentences that were not presented during encoding. This response pattern is thought to reflect a tendency of comprehenders to integrate semantic information and to store the meaning of the whole message rather than its verbatim form. The results of two studies using this gist paradigm in schizophrenia have been contradictory: When sentences were presented verbally, a normal pattern of recognition confidence levels in patients was reported (114), but when sentences were presented visually, some patients showed an abnormal response pattern (165).

### **Relationships between Comprehension and Production of Discourse**

Performance on a task that probes the ability to select information relevant to discourse topics has also been examined in schizophrenic patients (19). Participants were given story topics and asked to select five (of 20) pictures that best told the story and to put these pictures in sequential order. Interestingly, within the schizophrenic group, discourse planning performance deficits indexed by this task were selectively correlated with the number of incomplete references (see above) produced in speech.

## **ON-LINE STUDIES OF LANGUAGE PROCESSING AND PRODUCTION IN PSYCHOSIS**

By the mid-1960's, psycholinguistic researchers had begun to use methods that required a subject to make responses to ongoing language stimuli and to respond to a stimulus in a way that did not require conscious consideration of the

representation under investigation. As opposed to ‘off-line’ tasks that can be thought of as tapping into the final representations, these on-line methods probe implicit language processing and index the *intermediate representations* formed as language unfolds. One example of an on-line task is the semantic priming paradigm (with a lexical decision task) used to study the semantic relationships between single words (218,219). Most on-line methods, however, have been used to investigate sentence processing. They include the localization of extraneous noises (clicks) in sentences (99), monitoring for phonemes (94), and more complex tasks such as self-paced reading (pressing a key to call up subsequent words or passages) (159,305).

Researchers have been concerned with the “ecologic validity” of some of the more complex on-line tasks. Monitoring the loci and durations of eye fixations during reading and recording ERPs (see below) does not require subjects to make behavioral responses and may therefore be more naturalistic measures of on-line language processing.

### Characteristics of the Normal Language-Processing System

Studies of on-line processing have established a number of features that characterize the normal language-processing system (39,181,300). First, most processors are obligatorily activated when their inputs are presented to them. For instance, if we attend to a sound that happens to be the word “elephant,” we must hear and understand that word; we cannot hear this sound as just a noise (198). Second, language processors generally operate unconsciously. The unconscious nature of most of language processing can be appreciated by considering that when we listen to a lecture, converse with an interlocutor, read a novel, or engage in some other language-processing task, we usually have the subjective impression that we are extracting another person’s meaning and producing linguistic forms appropriate to our intentions without being aware of the details of the sounds of words or sentence structure. Third, components of the system operate remarkably quickly and accurately. For instance, it has been estimated that spoken words are usually recognized less than 125 ms after their onset, i.e., while they are still being uttered (199,299). This speed is achieved because of the massively parallel functional architecture of the language-processing system, leading to many of its components being simultaneously active.

Normal word production in speech occurs at the rate of approximately three words per second, with an error rate of approximately one per 1,000 words (181). Words that are appropriate to our conceptual preparation must be retrieved from a mental word production dictionary of more than 30,000 items (181). Thus, the ability to use linguistic context on-line is essential in speech production. Higher-order semantic-lexical connections are thought to be reciprocally

interconnected or shared by speech input and output systems (181,213).

On-line methods have begun to be applied to the study of psychiatric disorders. Indeed, some of the earliest on-line studies of language processing were in schizophrenia (41,238), but these were not followed up. The use of these techniques in patient populations is valuable because they can give quite different views of language processing abnormalities than those emerging from off-line studies.

### On-line Studies of lexico-semantic Processing in Schizophrenia

Numerous behavioral studies have shown that a subject’s processing of related targets (e.g., “doctor–nurse”) is enhanced or facilitated compared with naming or making lexical decisions about unrelated targets (e.g., “window–nurse”). Similarly, when subjects are asked to name or make lexical decisions about words in sentences, they respond more quickly to words preceded by a related context than to words preceded by an unrelated context (85,255–257,279–281). This is also true of scripts and texts (46,263,264). This facilitation typically takes the form of faster reaction times and is termed semantic or sentential priming.

There have been several studies of semantic priming in schizophrenia. Some have demonstrated greater priming effects in schizophrenic subjects than in controls (137,177,191,274,277). Furthermore, Spitzer et al. (275) showed that schizophrenics, particularly those who were thought disordered, had greater *indirect* priming effects (i.e., priming when there was a mediating word between prime and target) than normal subjects. These findings are consistent with Maher’s proposal (188) that thought-disordered schizophrenic patients have an activated or disinhibited semantic associative network. Conversely, some groups have shown that priming in schizophrenic subjects is no greater than in normal subjects (20,29,43,44,136,225,303) and may even be reduced (8,21,137,225,303). These contradictory results may be due to a variety of methodologic factors, including the failure to distinguish between thought-disordered and non-thought-disordered schizophrenic patients. However, as discussed above, it may also depend on the particular experimental conditions and the paradigm used (219). Thus, it has been argued that the decreased priming shown by schizophrenic subjects under particular experimental conditions reflects a deficit in conceptually mediated priming that involves controlled rather than automatic mechanisms (20,225,303).

### On-line Studies of Sentence Processing in Schizophrenia

One of the first applications of online techniques to the study of schizophrenia was the use of the ‘click’ paradigm (92,98)

to investigate syntactic processing in sentences. With this technique, a short burst of noise (the click) presented during speech is usually perceived as occurring at, or near, a clause boundary, when, in fact, the click might have occurred somewhere in the middle of the clause. This automatic perceptual displacement of clicks is thought to be due to the operation of syntactic constraints. Three studies in schizophrenia using this paradigm have suggested that patients perceive the click at or near clause boundaries to the same extent as matched controls (41,114,238). These findings suggest that at least some aspects of syntactic processing are intact in schizophrenia.

Online studies examining the use of different contextual constraints in schizophrenia have yielded contradictory findings. In one study, schizophrenic patients were presented with words that were masked to a greater or lesser extent by white noise. The word strings formed grammatical and meaningful sentences, grammatical and meaningless sentences, or were randomized word strings. Schizophrenic patients benefited from increases in sentence cohesion to the same degree as healthy controls (101). In another study that examined the influence of contextual constraints on word perception in both visual and auditory domains, schizophrenic patients were no less sensitive in their detection threshold of words in linguistically anomalous sentences than healthy controls (79).

Other online studies suggest that patients with schizophrenia may be impaired in using contextual constraints during language processing. In one study in which schizophrenic patients shadowed (i.e., listened and repeated each word) texts, their errors tended to be semantically irrelevant more often than the errors of patients with affective disorders and normal controls. This was interpreted as suggesting that schizophrenic patients were impaired in their ability to follow semantic context (235). Another study reported a negative correlation between positive thought disorder and the ability of schizophrenic patients to monitor the level of organization in passages that they were required to shadow under distraction conditions (306).

A third study (169) investigated the use of linguistic context in positively thought disordered schizophrenics by examining their performance on an online word-monitoring task. Controls and non-thought disordered patients took longer to recognize words preceded by linguistic anomalies compared with words in normal sentences. Compared with both other groups, thought disordered schizophrenics showed significantly smaller differences in reaction time, suggesting that they were relatively insensitive to linguistic violations. There appeared to be an inverse relationship between severity of thought disorder and sensitivity to linguistic violations within individual patients over time. This suggested

that the impairment in the use of linguistic context were related to the state, rather than the trait, of thought disorder (171).

### **On-line Language Production in Schizophrenia**

The term on-line is generally reserved for studies of language processing. However, as discussed above, speech production occurs implicitly and extremely fast. A few investigators have begun to investigate implicit processes during speech production in schizophrenia. For example, Spitzer et al. (276) compared the implicit use of context by thought-disordered and non-thought-disordered schizophrenic subjects by examining the distribution of pauses in the speech spontaneously produced by these two patient groups. Whereas the proportion of pauses before words produced in context was smaller than the proportion of pauses before words produced out of context in normal controls and non-thought-disordered patients, no such pattern was observed in thought-disordered schizophrenic patients.

### **RELATIONSHIP BETWEEN LANGUAGE DEFICITS AND OTHER COGNITIVE DEFICITS**

Several investigators have argued that many of the language-processing deficits in schizophrenia arise directly from cognitive deficits outside the language system. These include deficits in selective attention and pigeonholing (134,258), working memory, and updating and retrieval from short-term memory (107,239), using an "internal representation of context" to guide action (55), use of strategy (146), and other executive and frontal lobe functions (138,202). In this section, we review some of the studies cited to support such theories. We first discuss studies that have documented associations between clinical measures of thought disorder and performance of cognitive tasks of attention and working memory. We then review the few studies that have investigated relationships between these more general cognitive functions and some of the measures of language production and processing outlined above.

### **Clinical Measures of Thought Disorder and General Cognitive Deficits**

There is evidence that severity of disorganized speech in schizophrenia correlates with distractibility (76,130), deficits in short-term verbal memory (221), selective attention as

measured by the Stroop task (21), sustained attention as measured by the Continuous Performance Test (224,230,286), measures of executive dysfunction (221), and lower-level information processing deficits such as prepulse inhibition (70,234). The question of whether thought disorder is linked to working memory deficits remains unresolved. On the one hand, there is a modest correlation of thought disorder severity with deficits in verbal working memory (221). On the other hand, although clinical thought disorder generally improves with standard neuroleptic medication treatment and worsens with withdrawal of medication, working memory deficits are usually resistant to neuroleptic treatment (105).

### **Measures of Language Dysfunction and General Cognitive Deficits**

Some of the language deficits described above can theoretically be attributed to cognitive deficits outside the language system. For example, a deficit in rehearsing information (a component of working memory) might prevent deep encoding of semantic information (32). A short-term or working memory deficit might account for the interaction of contextual constraint with word position (primacy or recency) in schizophrenia (192).

At the level of single words, reduced semantic priming does not correlate with impaired performance on the Stroop test (21). Evidence of an association between performance of working memory and language tasks in schizophrenia is strongest at the level of sentences and discourse. Verbal working memory deficits are correlated with language comprehension deficits (58), and referential communication disturbances are associated with poor performance on tasks of immediate auditory memory (76), distractibility (76,128,145), and working memory and attention (74). In a study of written language in schizophrenic patients, syntactic errors were partly explained by deficiencies in working memory and attention, although significant differences between the groups remained (295).

There are several caveats to the interpretation of most of these studies. First, functions such as working memory and attention have been defined very broadly. There is growing recognition of the importance of “fractionating” cognitive systems conceptually and empirically. For example, studies of working memory involve tasks that range from spatial to linguistic domains, with different levels of analysis from behavioral to neuroanatomic. Second, even in healthy volunteers, the precise relationships and interactions between general cognitive processes such as working memory and different types of language processing are not fully understood.

## **THE NEURAL SUBSTRATES OF LANGUAGE PROCESSING IN SCHIZOPHRENIA**

Three different techniques have been used to investigate the neural basis of language deficits in schizophrenia. First, structural imaging studies have reported abnormalities in regions that are known to play an important role in language. Second, functional neuroimaging studies have described abnormal patterns of activation during the presentation of linguistic stimuli (usually at the level of single words). Third, electrophysiologic studies have reported abnormalities of ERP components that are known to be sensitive to Levels of Language processing in schizophrenia, using both single-word and whole-sentence paradigms.

### **Structural Imaging Studies**

Morphometric studies examining cortical gray matter volume in schizophrenia have traditionally focused on specific regions of interest (ROIs) that are usually selected on the basis of lobar neuroanatomy. Such studies have reported small reductions in the volume of several ROIs, particularly within the temporal and prefrontal cortices, in patients with schizophrenia (265a). In addition, there have been attempts to automate the measurement of gray matter volume or density throughout the brain (17,307,37a,295a). Taken together, such studies have confirmed subtle volumetric reductions in multiple anatomical regions within the prefrontal and temporal cortices (145a,265a,267,308). Interestingly, several studies suggest that these structural abnormalities may be more extensive on the left than the right. One study suggested that, within a group of schizophrenic patients, the degree of atrophy within the left temporal cortex was correlated with the severity of thought disorder (266). It is therefore possible that subtle temporal and frontal gray matter atrophy may contribute to some of the abnormalities in semantic and language function discussed in this review.

### **Functional Neuroimaging Studies**

Functional neuroimaging studies in schizophrenia using a wide variety of cognitive paradigms have shown that perturbations of brain activity in schizophrenia are not localized to one brain region but to networks comprising multiple regions, particularly involving the frontal and temporal cortices and subcortical structures such as the cerebellum and thalamus (170).

Most functional neuroimaging studies in schizophrenia that have used linguistic stimuli have been at the level of individual words rather than whole sentences and discourse. Studies that have used tasks such as

verbal fluency (66,88,96,311), semantic categorization (67,148), and the recognition of learned words (64,133) have reported abnormal patterns of activity within both frontal and temporal regions. Some of these studies have also reported relatively increased activity in parietal regions (64,66).

Another approach to investigating localized dysfunction is to examine the relationships between brain regions in schizophrenia. Structural equation modeling (path analysis) of a PET semantic processing study suggested differences between schizophrenic and control groups in interactions among frontal regions, between frontal and temporal regions, and between the lateral, frontal and anterior cingulate cortices (148). An effective connectivity analysis of PET data from a graded memory study suggested that the normal anterior cingulate modulation of frontal-temporal interaction is disrupted in schizophrenia (89,90).

Relative increases in activation of several other regions in patients relative to controls have been described during functional neuroimaging studies of language in schizophrenia. For example, greater activity in the parietal cortex in schizophrenic patients (relative to controls) has been reported in association with covert word production (66) as well as learning and recalling word lists (90). Increased activation of the inferior temporal cortex and/or fusiform cortex has been reported in schizophrenic patients (relative to controls) in association with cued stem recall of semantically encoded words (133), the recognition of novel words (64), the completion of sentences (160a) and during speech production (203,160b).

### Event-Related Potential Studies

ERPs are voltage fluctuations derived from the ongoing electroencephalography that are time locked to specific sensory, motor, or cognitive events (56). Particular regions or temporal windows of the ERP waveform (components) have been differentiated and labeled according to their polarity (positive or negative), peak latency, and/or spatial position on the scalp. Several ERP components have been particularly useful in the study of on-line processes. These components can be measured without subjects having to make an overt response (e.g., pressing a button after each word or sentence), giving them an advantage over the on-line behavioral measures reviewed earlier in this chapter.

The best studied ERP component in schizophrenia is the P300 which is thought to index the process by which contextual information is updated within memory (78). The amplitude of the P300 is reduced in schizophrenic patients; indeed, this is one of the most robust and consistent biologic markers of schizophrenia, although it is not specific to this disorder. In addition, many (although not all) studies have reported an increased latency of the P300 in schizophrenia (93).

More recently, researchers have begun to investigate the use of semantic context in schizophrenia by examining the

N400 ERP component. The N400 is a large, negative-going waveform, peaking at approximately 400 ms that was first described in association with contextually inappropriate words in sentences (172–174) and with unprimed words in word-pair semantic priming paradigms (25,142,143,242). The difference in N400 amplitude to primed and unprimed words was termed the N400 effect.

In many studies of the N400 in schizophrenia, patients showed a relatively intact N400 congruity effect, i.e., with larger amplitude N400 elicited to unprimed than primed words in semantic priming word-pair paradigms (30,112,166,167,228,278) and to words preceded by incongruent than congruent contexts in sentence paradigms (16,220,222,268). Nonetheless, other studies have reported an abnormally reduced N400 effect in both sentence (1,227,247) and word-pair paradigms (60,284). One reason for these contradictory findings may be heterogeneity in the schizophrenic patient samples used in different studies. Consistent with this idea is the finding of an inverse correlation between the N400 effect and severity of thought disorder within a group of schizophrenic patients (16). This supports the behavioral findings described above and suggests that an on-line deficit in using semantic context may be specifically associated with positive thought disorder.

Some of the above studies have reported an increase in the absolute amplitude of the N400 waveform to primed and unprimed words in word-pair paradigms (30) as well as to congruous and incongruous words in sentence paradigms (220,222,227). This has been argued to support the idea that schizophrenic patients have difficulty in processing the meaning of words, regardless of their context.

Modifications of both word and sentence paradigms give additional insights into the nature of on-line language-processing deficits in schizophrenia. In a mediated priming paradigm (18), an N400 congruity effect to target words that were preceded by indirectly related words (e.g., “lion—stripes”—both related to “tiger”) was reported in schizophrenic patients but not in healthy participants (278). This is consistent with the idea that activity spreads abnormally far across interconnected representations in semantic memory in patients, supporting the online behavioral studies using the indirect semantic priming paradigm described earlier in this chapter. In a sentence paradigm, an N400 effect was elicited to words preceded by a semantically associated homonym when the surrounding context suggested the secondary meaning of the homonym in healthy volunteers but not in patients with schizophrenia (268). In other words, in patients, the context of the whole sentence failed to override the semantic associative effects of its individual words. This suggests that sentence and discourse deficits in schizophrenia may be, to some degree, driven by abnormalities in a lexico-semantic network.

Finally, probably the most robust abnormality described across studies is an increased N400 latency. This has

been reported in both word-pair (30,112,167) and sentence (1,16,220,222,228,278) paradigms and suggests that the contextual integration of words may be delayed in schizophrenia.

## CONCLUSIONS

In summary, schizophrenia is a complex disorder that is frequently manifest in language and related cognitive dysfunction. We have reviewed studies that have identified abnormalities in both language output and comprehension in schizophrenic patients. Abnormalities have been described at the level of single words (deficits in the structure and function of lexico-semantic memory), sentences (impaired use of different types of linguistic context) and whole discourse (abnormal relationships between sentences). The neurocognitive basis of language dysfunction in schizophrenia has been investigated using structural and functional neuroimaging as well as electrophysiological techniques. These techniques give complementary information. ERP studies suggest neurophysiological abnormalities in the online use of semantic context, while neuroimaging studies suggest widespread structural and functional neuroanatomical abnormalities, particularly in the temporal and frontal cortices.

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