

## Impairment of the semantic network in schizophrenia

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### Abstract

It is well established that patients with schizophrenia display a variety of language impairments. Despite considerable research, however, the underlying mechanisms of the language deficits in schizophrenia remain unclear. Representations of semantic networks of 56 patients with schizophrenia and 28 normal comparison (NC) subjects of similar ages and educational levels were generated by multidimensional scaling and Pathfinder analyses of their responses on the Animal Fluency Test. On the basis of traditional scoring techniques (i.e., total number of correct animal names generated in 60 s), all patients performed significantly worse than the NC subjects. More detailed analyses of the underlying semantic networks revealed that performance in the patients varied according to age of onset and subtype of schizophrenia. The semantic network of patients with late-onset schizophrenia (i.e., with onset after age 45) was virtually identical to that of the NC group. In contrast, the semantic network of patients with a younger age of onset was disorganized and differed significantly from that of the NC subjects. Findings demonstrated that patients with nonparanoid subtypes displayed greater disorganization in their semantic networks than patients with a paranoid subtype. Although general fluency impairments (e.g., difficulties in initiation, retrieval, and search mechanisms) may be sensitive to schizophrenia, per se, specific deficits in the structure of semantic knowledge may be associated with certain characteristics of individual patients with schizophrenia, such as an earlier age of onset and nonparanoid subtype.

*Keywords:* Language; Neuropsychology; Memory; Nonparanoid subtype

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### 1. Introduction

It is well established that patients with schizophrenia display a variety of cognitive deficits, including language impairments (see Goldberg et al. [1995] for a recent review). Perfor-

mance deficits have been reported for patients with schizophrenia on several language tasks including verbal fluency (Allen et al., 1993; Goldberg et al., 1995), confrontation naming (Barr et al., 1989), definition of vocabulary words (Paulsen et al., 1995), auditory and reading comprehension (Silverberg-Shalev et al., 1981), semantic memory for real world knowledge (Cutting and Murphy, 1988; Tamlyn et al., 1992; Clare et al., 1993), lex-

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ical decision (Manschreck et al., 1988; Chapin et al., 1992), and semantic priming (Chen et al., 1994; Spitzer et al., 1994). In fact, some investigators consider the thought disorder (and subsequent speech abnormalities) typical of schizophrenia to reflect impairments in basic linguistic and/or semantic systems. Despite considerable research, however, the underlying mechanisms of the language deficits in schizophrenia remain unclear.

Several hypotheses have been advanced to explain the language impairments found in patients with schizophrenia. Early speculations included deficiency in deductive reasoning (Von Domarus, 1944), excessive concreteness of thought (Goldstein, 1944), regression (Gardner, 1931; Kasanin, 1944), and associational disorder (Bleuler, 1950). In recent years, several authors have applied methods and models derived from cognitive psychology to investigate the language impairments characteristic of schizophrenia. Although some investigators have examined verbal priming in schizophrenia, to our knowledge no published study has evaluated the integrity of the semantic memory system in schizophrenia using detailed qualitative analyses of clinical data.

Models of semantic memory (e.g., Collins and Loftus, 1975) usually assume that semantic knowledge is organized as a complex network of associated concepts. Within the normal semantic network, concepts that have many attributes in common are more strongly associated than those that share fewer attributes. Specific attributes of a concept serve a dual purpose: (1) they provide a means of grouping concepts into categories; and (2) they distinguish among the various exemplars that constitute a given category. For instance, 'chair' and 'table' are both categorized as furniture because they share attributes such as being made of wood, having legs, and providing a place to sit and eat; they can be distinguished from each other, however, by such attributes as size, shape, and use. According to the network model of semantic memory, each component of a speech utterance activates associated semantic concepts within a neuronal network. The model further asserts that concepts activated in a semantic network facilitate a spread of activation to other related concepts. Activation of semantic units remains for a short

period of time and then either decays or is inhibited (see Neely [1977, 1991]). Using this model, some investigators hypothesize that the incoherent language often found in schizophrenia occurs because of dysfunction in the activation or inhibition pattern that may define the semantic network (Maher et al., 1983, 1988; Spitzer, 1993).

Although several studies have demonstrated primary language deficits in patients with schizophrenia who performed traditional neuropsychological tests (Silverberg-Shalev et al., 1981; Barr et al., 1989; Tamlyn et al., 1992; Allen et al., 1993; Goldberg et al., 1995) and a few investigators have demonstrated impaired semantic activation using priming paradigms (Manschreck et al., 1988; Chapin et al., 1992; Chen et al., 1994; Spitzer et al., 1994), there are a number of shortcomings in the current literature that limit our understanding of language deficits in schizophrenia: (1) Few studies have evaluated language performances in schizophrenia across the life span; most studies have been conducted in young adults. (2) Few studies have considered the clinical heterogeneity in schizophrenia (e.g., age of onset) and its relationship with language performance. (3) We are aware of no published study that has examined the qualitative performances of patients with schizophrenia on language tests or that has evaluated the cognitive map of semantic knowledge in patients with schizophrenia.

Although earlier reports considered cognitive impairment in late-onset schizophrenia to be similar to that in early-onset schizophrenia (e.g., Heaton et al., 1994), further analyses of these two groups of patients have revealed some interesting differences. For instance, Paulsen et al. (1995) found that episodic learning and memory performances were better in schizophrenia with a later age of onset. In addition, Jeste et al. (1995) reported that patients with late-onset schizophrenia had a better premorbid social history, had a greater likelihood of having the paranoid subtype of schizophrenia, and were more likely to achieve a higher level of functional independence than were patients with early-onset schizophrenia.

The purpose of the current study was to compare the organization of semantic memory for the

category ‘animals’ in patients who varied in their ages of onset of schizophrenia. It was assumed that the pattern of responses produced on the Animal Fluency Test would represent the spreading activation within the semantic network. For instance, animals that were highly associated would tend to be grouped closer together within a subject’s sequential responses on the fluency task than animals that were less related. This strategy has been successfully used to evaluate the integrity of the semantic network in several other geriatric and neurologic patient groups (see Salmon and Chan, 1994). We hypothesized that patients with a later age of onset of schizophrenia would demonstrate more intact semantic networks than patients with an earlier age of onset.

## 2. Methods

### 2.1. Subjects

A total of 84 subjects (56 patients with schizophrenia and 28 normal comparison [NC] subjects) participated in this study. Patients with schizophrenia were recruited for research purposes from the San Diego Department of Veterans Affairs (VA) Medical Center, the Mission Valley VA Outpatient Clinic, the University of California at San Diego Medical Center and Psychiatry Outpatient Services, the San Diego County Mental Health Services, and private physicians. The NC subjects were obtained from the community in San Diego and had no history of or current psychiatric disorder. All of the subjects were screened with a medical history questionnaire to exclude the following: (1) history of significant head trauma (i.e., closed head injury with loss of consciousness > 30 min or persisting neurological findings); (2) other major neurological disorder; (3) current alcohol or other substance abuse (i.e., *DSM-III-R* [American Psychiatric Association, 1987] criteria for abuse not met for  $\geq 3$  months); and (4) systemic medical disease likely to affect nervous system function (e.g., chronic obstructive pulmonary disease).

Table 1 summarizes the demographic characteristics of the NC subjects and the patients with schizophrenia. The two groups did not differ

Table 1. Demographic characteristics of the normal comparison subjects and the patients with schizophrenia

Variable	Normal comparison group ( <i>n</i> = 28)	Schizophrenia group ( <i>n</i> = 56)
Age (years)	62.0 (4.38)	59.9 (7.9)
Education (years)	13.8 (2.5)	12.9 (3.1)
Race (% Caucasian)	96	80
Gender (% male)	14.8*	81.8*
Verbal IQ	111.0 (11.4)*	96.1 (18.5)*

Note. The values for continuous variables represent means (with standard deviations). \* $P < 0.001$  (two-tailed *t* test or  $\chi^2$  test).

in mean age, education, or ethnicity. The group of patients had a significantly greater proportion of males (versus females) than the NC group ( $U = 245.0$ ,  $P < 0.001$ ). Subtype diagnoses among the patients were as follows: undifferentiated subtype, 34%; paranoid subtype, 46%; disorganized subtype, 10%; and residual subtype, 10%. As expected, the patients demonstrated lower verbal intelligence as measured by the Wechsler Adult Intelligence Scale-Revised (Wechsler, 1981) than did the NC subjects ( $t = 3.9$ ,  $P < 0.001$ ). Among the group of patients, 20 had late-onset schizophrenia (i.e., age of onset after age 45) and 36 had early-onset schizophrenia.

Table 2 summarizes the demographic, clinical, treatment, and cognitive characteristics of the patients divided by age of onset. The late-onset and early-onset subgroups were similar in mean age, education, neuroleptic dosage, total score on the Abnormal Involuntary Movements Scale (AIMS; National Institute of Mental Health, 1975), and verbal IQ score. The early-onset patients had more negative symptoms and were more likely to be taking anticholinergic medication. The proportion of paranoid subtype was greater in the late-onset subgroup (72%) than in the early-onset subgroup (44%) ( $P < 0.001$ ,  $\chi^2$  test). Given that our own data (e.g., Heaton et al., 1994; Paulsen et al., 1994) as well as those of other investigators (Goldstein and Halperin, 1977; Bornstein et al., 1990) have shown that cognitive ability is less impaired in the paranoid subtype of schizophrenia, patients were also grouped according to paranoid versus non-paranoid subtype distribution for further data

Table 2. Demographic, clinical, and neuropsychological characteristics of the subgroups of schizophrenia

Variable	Age of onset		Subtypes	
	Late ( <i>n</i> = 20)	Early ( <i>n</i> = 36)	Paranoid ( <i>n</i> = 26)	Nonparanoid ( <i>n</i> = 30)
Age (years)	60.9 (7.6)	59.3 (8.1)	59.6 (8.8)	59.8 (7.1)
Education (years)	13.1 (3.7)	12.8 (2.8)	12.9 (3.2)	12.9 (3.1)
Duration of illness (years)	7.9 (9.1)**	33.3 (10.5)**	20.8 (13.8)*	30.8 (15.4)*
Age of onset of illness (years)	53.1 (7.5)**	25.9 (6.8)**	38.7 (12.6)*	28.9 (13.9)*
Daily neuroleptic dose (chlorpromazine equivalent, mg)	159.4 (146.6)	292.1 (438.5)	187.1 (201.9)	330.4 (478.7)
% on anticholinergics	0	20*	4	26*
Verbal IQ	95.5 (11.9)	96.3 (12.3)	96.1 (12.2)	96.1 (12.2)
Brief Psychiatric Rating Scale total score	34.3 (8.0)	29.4 (10.8)	33.0 (11.6)	29.0 (8.3)
Scale for the Assessment of Positive Symptoms score	4.7 (3.6)	3.5 (3.6)	4.4 (3.7)	3.4 (3.7)
Scale for the Assessment of Negative Symptoms score	4.1 (3.1)*	6.7 (4.9)*	6.0 (4.5)	6.0 (4.8)
Hamilton Rating Scale for Depression total score	7.7 (5.7)	6.6 (5.6)	6.8 (4.8)	7.2 (6.4)
Abnormal Involuntary Movement Scale total score	2.3 (4.7)	3.9 (4.9)	3.2 (5.5)	4.1 (4.2)
Mean neuropsychological deficit score	0.89 (0.4)	0.97 (0.6)	0.89 (0.5)	0.97 (0.7)
Animal Fluency Test score	15.8 (4.3)	15.8 (5.3)	15.2 (5.1)	16.4 (4.9)
Intrusions	0.05 (0.23)	0.12 (0.41)	0.04 (0.20)	0.14 (0.46)
Perseverations	0.63 (0.95)	0.62 (0.70)	0.75 (0.67)	0.56 (0.89)

Note. The values for continuous variables represent means (with standard deviations).

\*\**P* < 0.001 (two-tailed *t* test);

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analyses. The subgroups based upon subtype were comparable in mean age, education, daily neuroleptic dosage, verbal IQ, AIMS total score, and severity of psychopathology. The paranoid patients had a shorter duration of illness and an older age of onset and were less likely to be taking anticholinergic medication.

## 2.2. Procedure

The diagnosis of schizophrenia, subtype determination, and age of onset of illness were confirmed by two board-certified staff psychiatrists on the basis of the Structured Clinical Interview for *DSM-III-R* (SCID; Spitzer et al., 1990). Intake interviews were conducted with any available caregivers to obtain the most complete history. Age of onset of schizophrenia was determined as

the reported age of onset of prodromal symptoms (or functional decline) (American Psychiatric Association, 1987). All participants were administered the Brief Psychiatric Rating Scale (BPRS; Overall and Gorham, 1962), the Scale for the Assessment of Positive Symptoms (SAPS; Andreasen and Olsen, 1982), the Scale for the Assessment of Negative Symptoms (SANS; Andreasen and Olsen, 1982), the Hamilton Rating Scale for Depression (HRSD; Hamilton, 1967), the AIMS (National Institute of Mental Health, 1975), and a comprehensive standardized assessment of neuropsychological functions as part of an intake evaluation. All neuropsychological assessments and clinical rating scales were administered to each patient after she/he had been physically, psychiatrically, and pharmacologically stable for  $\geq 4$  weeks. The BPRS, SAPS, SANS, HRSD, and

AIMS assessments were performed by members of the research team who were unaware of other clinical information and were trained to maintain high interrater reliability. The intraclass correlation coefficients for individual rating scales were  $\geq 0.77$ . Current neuroleptic dose was converted to milligrams of chlorpromazine equivalent (CPZE) (Jeste and Wyatt, 1982). On the basis of the neuropsychological assessment, a mean deficit score was computed, as described elsewhere (Heaton et al., 1994).

### 2.3. The Animal Fluency Test

Subjects were administered the Animal Fluency Test as part of the comprehensive neuropsychological evaluation. Subjects were asked to name as many animals as they could within 60 s. Verbatim responses were recorded by the examiner in the order they were generated. The semantic space analysis was performed on 16 target words (bear, camel, cat, cow, deer, dog, elephant, giraffe, goat, horse, lion, pig, rabbit, sheep, tiger, and zebra) that were among the 25 most frequent responses for the subjects and could be categorized into two possible dimensions (large-small, domestic-wild).

### 2.4. Data analyses

Multidimensional scaling (MDS) (see Young and Harris, 1993) is a mathematical tool used to analyze proximity data to indicate the degree of dissimilarity between two things. In the current project, MDS analysis was used to represent the similarities and dissimilarities between animal names. First, each subject's responses on the Animal Fluency Test were transformed into proximity data. That is, a  $16 \times 16$  half-matrix was obtained for each subject where the number in a cell represented the distance (in order of responses) between two animal names. For instance, the animal name 'dog' from this fluency output (dog, cat, lion, tiger, elephant, and giraffe) would receive the following proximity scores: dog-cat = 1; dog-lion = 2; dog-tiger = 3; dog-elephant = 4; and dog-giraffe = 5. Higher numbers represent greater distance (dissimilarity) and smaller numbers repre-

sent less distance (greater similarity) between animal names. The MDS model spatially displays each animal name in a multidimensional space so that greater distance between pairs of animal names represents greater dissimilarity among pairs of animals. That is, similar animals are closer together in the map than dissimilar ones. Two goodness-of-fit indices were used to evaluate the accuracy of the scaling solutions. The *stress level* index (Kruskal, 1964) represents error in the solution and ranges from 0.00 (low error) to 1.00 (high error); the  $R^2$  represents the variance accounted for by the scaling solution and ranges from 0.00 (low variance) to 1.00 (high variance).

Pathfinder (PF) analysis (Dearholt and Schvaneveldt, 1990), like MDS, can help reduce large amounts of proximity data into interpretable forms. Unlike MDS, PF analysis generates a network representation of the concepts instead of a continuous configuration. The strength of the association between two concepts is represented by their proximity. For instance, a pair of concepts with a long distance between them will have low proximity, whereas a pair of concepts with a short distance between them will have high proximity. Two concepts are directly connected in the network if, and only if, the distance of their direct link is shorter than all of their indirect links in the network.

Although we were unable to control the total number of responses given by each individual subject, the algorithm used in the analyses was constructed to account for the total number of responses given. For instance, to weigh the difference among subjects' total responses and the total response variance of animal pairs, the following algorithm was used to calculate the distance between each animal pair:

$$D_{ij} = N/(T^2_{ij}) \sum_{k=1}^{T_{ij}} d_{ijk}/n_k$$

where

$D_{ij}$  is the distance between animals  $i$  and  $j$  in the matrix;

$d_{ijk}$  is the distance between animals  $i$  and  $j$  of subject  $k$

$n_k$  is the total number of responses of subject  $k$ ;

$T_{ij}$  is the total number of actual responses for animals  $i$  and  $j$ ; and  $N$  is the total number of possible responses for animals  $i$  and  $j$ .

For example, the distances of *cat* and *dog* in the matrix with the following three subjects are:

subject 1 — *cat dog monkey giraffe*;

subject 2 — *cat tiger lion dog snake mouse goat*;

subject 3 — *cat mouse giraffe zebra*.

$$d_{ij1}/n_1 = 1/4 \quad d_{ij2}/n_2 = 3/7 \quad d_{ij3}/n_3 = N/A$$

$$N = 3 \quad T_{ij} = 2$$

$$D_{ij} = 3/2^2 (1/4 + 3/7) = 0.51$$

### 3. Results

The patients with schizophrenia generated significantly fewer ( $t = 5.06$ ,  $P < 0.001$ ) total correct responses (mean = 15.8, SD = 4.9) than did the NC subjects (mean = 20.5, SD = 3.4). When the patients were subdivided according to age of onset of illness, both the late-onset ( $t = 4.20$ ,  $P < 0.001$ ) and the early-onset ( $t = 4.26$ ,  $P < 0.001$ ) patients generated fewer correct responses than did the NC subjects, although the early- and late-onset subgroups did not perform differently from each other. Similarly, the paranoid and the non-paranoid subgroups did not differ significantly from each other, but both generated fewer correct responses than did the NC subjects (paranoid vs. NC:  $t = 3.22$ ,  $P < 0.002$ ; nonparanoid vs. NC:  $t = 4.67$ ,  $P < 0.001$ ). There were no significant differences among the groups on numbers of intrusions or perseverations. All groups of subjects generated more high-frequency (i.e., one hundred per million) animal names (according to the norms of Zeno et al. [1995]) than low-frequency (less than one per million) animal names. Given that the animal names chosen for analyses were those most frequently produced by the subjects in the current study, the problem of missing data was minimal and equivalent across groups. For instance, all subjects gave the response 'dog'; 98% of each of the schizophrenia and NC groups gave the word 'cat'; 83% of the NC and 81% of the patients gave

the response 'elephant', and so on. The least frequent animal name given that was used in the analyses was 'rabbit', which was generated by 40% of the NC subjects and 48% of the patients.

#### 3.1. MDS analyses

Eighty-four  $16 \times 16$  half-matrices, one from each subject, were analyzed by ALSCAL (SPSS, Norusis, 1993). According to Kruskal and Wish (1978), the accuracy of a cognitive map may decrease significantly if the number of stimuli is smaller than four times the number of dimensions. The present data were limited to no more than three dimensions. Preliminary solutions computed for two and three dimensions on the NC data accounted for 81% and 88% of the variance, respectively. The stress value (a measurement of errors in a solution) was 0.20 for the two-dimensional cognitive map and 0.13 for the three-dimensional map. The two-dimensional solution was chosen for further analyses for the following reasons: (1) the third dimension only accounted for 7% more variance and (2) the third dimension was uninterpretable. Given the relatively poor goodness-of-fit level, it was not surprising that the third dimension

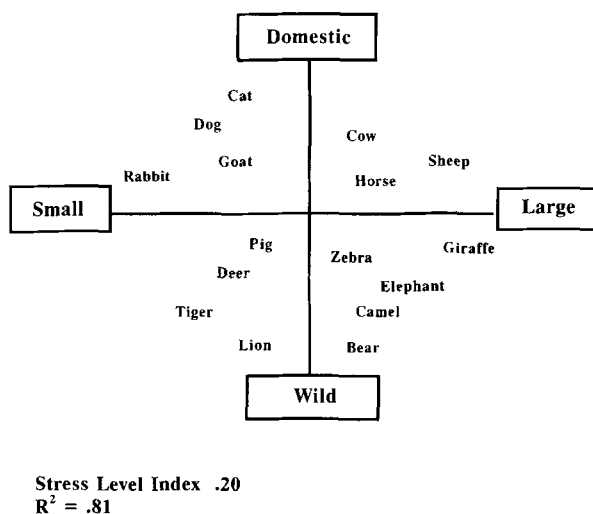
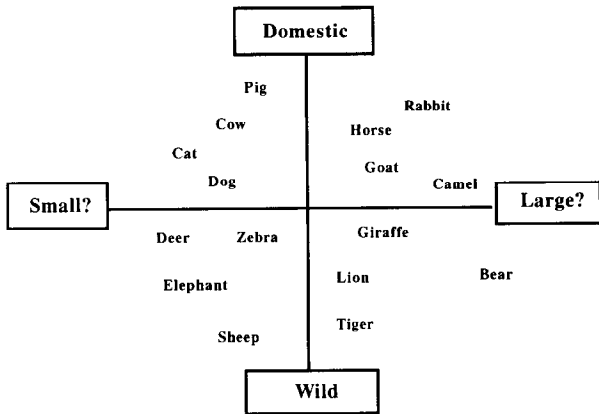


Fig. 1. Semantic network of normal control subjects obtained from multidimensional scaling analysis.



Stress Level Index .11  
 $R^2 = .87$

Fig. 2. Semantic network of patients with schizophrenia obtained from multidimensional scaling analysis.

could not be interpreted with any obvious known attribute. As Kruskal and Wish (1978) noted, '... when too many dimensions are used, the configuration adapts itself to the random error in the data, and this may actually make it more difficult to find the valid and interesting aspects' (p. 57). With interpretability as a primary criterion (Kruskal and Wish, 1978), the three-dimensional solution was therefore rejected.

Fig. 1 represents the cognitive map of the semantic network of the NC subjects. The first dimension appeared to be domesticity with domestic

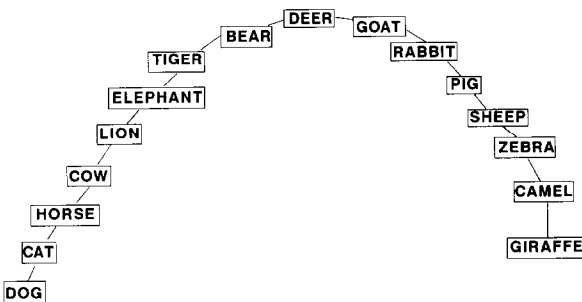


Fig. 3. Semantic network of normal comparison subjects generated by Pathfinder analysis.

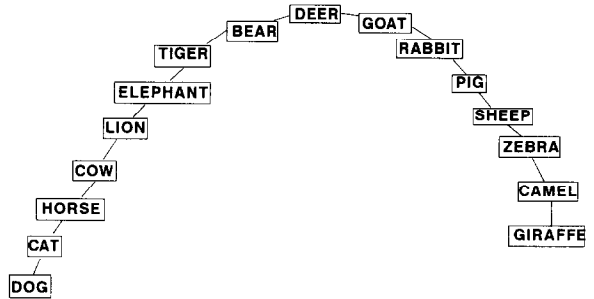


Fig. 4. Semantic network of patients with late-onset schizophrenia generated by Pathfinder analysis.

animals on one side and wild animals on the other side. The second dimension seemed to order the animals by size, with giraffe at one extreme and rabbit at the other end. With regard to semantic distance, animals with high conjunction frequency, such as *cat* and *dog*, *lion* and *tiger*, *horse* and *cow*, were closer together than animals that have less in common, such as *cat* and *elephant*, and *tiger* and *goat*. It appeared, then, that this measure of semantic distance was an adequate indicator of the relative strength of association between concepts.

Fig. 2 presents the MDS map of semantic distances obtained from the patients' animal fluency data. The solution accounted for 87% of the variance, and the stress value was 0.11. As shown

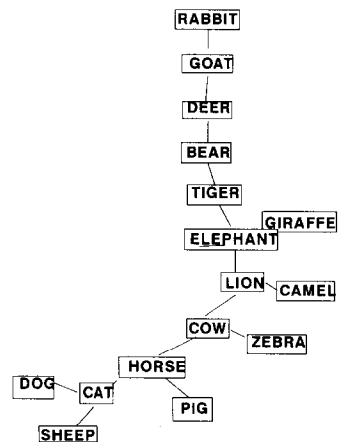


Fig. 5. Semantic network of patients with early-onset schizophrenia generated by Pathfinder analysis.

in Fig. 2, the first dimension separated wild from domestic animals. Interpretation of the second dimension, however, was less clear. When size was used as the second dimension, *elephant* was considered a small animal whereas *rabbit* was considered a large animal. Interpretation of individual concepts was also confusing. For instance, some animals with low conjunction frequency, such as *horse* and *goat*, or *elephant* and *deer*, were closer together than animals that have more in common, such as *horse* and *cow*, or *elephant* and *giraffe*.

### 3.2. Pathfinder analyses

To allow for a comparison of patient groups according to age of onset of illness and subtype of schizophrenia, group semantic networks were computed by averaging the data of all patients within a specific subgroup (late-onset vs. early-onset, paranoid vs. nonparanoid). This procedure resulted in a  $16 \times 16$  matrix for each of the subgroups within the schizophrenia group and the NC group, which was then analyzed by the PF procedure.

Results of the PF analysis for the NC group demonstrated a fairly simple semantic network with a minimum number of links between concepts (see Fig. 3). When the group of patients with

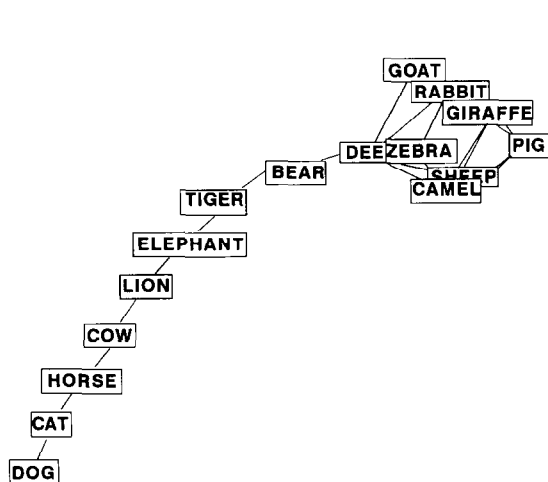


Fig. 6. Semantic network of patients with paranoid schizophrenia generated by Pathfinder analysis.

schizophrenia was subdivided according to age of onset of illness (see Figs. 4 and 5), the late-onset subgroup's network appeared identical to that of the NC subjects, whereas the early-onset subgroup's network was less organized and contained some atypical links (i.e., *cow* and *zebra*, *lion* and *cow*, *cat* and *sheep*).

When the patients were categorized by subtype, two different semantic networks emerged. The network of the paranoid subgroup appeared most similar to the NC network in that animals with high conjunction frequency (e.g., *cat* and *dog*, *horse* and *cow*) appeared next to one another and several links were nearly identical to those in the NC network (see Fig. 6). Only as the typicality of the animal names diminished did the network begin to vary from the NC group. In contrast, the network of the nonparanoid subgroup appeared highly complex and shared little with the NC network (see Fig. 7). Moreover, some very common animal names shared links with some less common animal names (i.e., *cow* had an equal likelihood of linking with *horse* as it had of linking with *zebra*).

The complexity of the PF results was examined by calculating the number of shared links in the semantic networks of each patient subgroup with that of the NC group. The NC network had 15 links that were identical to those of the late-onset

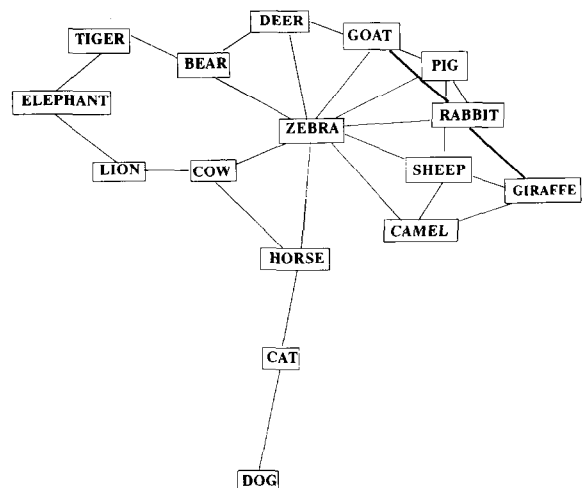


Fig. 7. Semantic network of patients with nonparanoid schizophrenia generated by Pathfinder analysis.

subgroup's network. The early-onset subgroup also had 15 links, but only 10 of these links were shared with the NC group's network. In contrast, the networks obtained by the paranoid and non-paranoid subgroups contained 25 and 26 links, respectively. (The number of links generated from group data varies depending on specific group composition.) Although the paranoid subgroup shared 15 links with the NC group, the non-paranoid subgroup had only 8 links in common with the NC network. A similarity index was calculated based on the method suggested by Goldsmith and Davenport (1990). This index was calculated by correlating the number of common links between a patient's group semantic network and the NC group's network, and the significance of the correlation was determined by a probability value. This similarity index ranges from 0 to 1, with 0 indicating two completely different networks and 1 indicating two identical networks. As expected, the semantic network of the late-onset patients was significantly more similar to the NC network (index = 1.00) than was the network generated from the early-onset patients' animal fluency data (index = 0.50) ( $P < 0.001$ ). The similarity index of the semantic network of the patients with paranoid schizophrenia yielded a mean similarity index of 0.58, whereas the nonparanoid patients' semantic network yielded a mean similarity index of only 0.25 ( $P < 0.001$ ).

### 3.3. *Post hoc analyses*

Given that the subgroups were not comparable in their gender distributions, MDS was conducted on age- and education-matched male and female NC groups to evaluate potential gender differences in animal fluency output. Results revealed that the maps were nearly identical, both achieving an RSQ > 94% and a stress level < 0.11.

Since age of illness onset and subtype of schizophrenia were associated in the current sample, we conducted additional subgroup analyses in an attempt to clarify our findings. Examination of the subgroups (early-onset paranoid,  $n = 16$ ; late-onset paranoid,  $n = 14$ ; early-onset nonparanoid,  $n = 20$ ; late-onset nonparanoid,  $n = 6$ ) revealed significant differences in age and education between the groups which precluded thorough com-

parisons of the subgroups. Age- and education-matched groups of early-onset patients divided by subtype allowed the greatest sample size for MDS comparison of two groups of 12 subjects each. Although this small sample size limits the generalizability of our findings, adequate solutions were achieved for both the paranoid (RSQ = 0.87, stress index = 0.13) and nonparanoid (RSQ = 0.81, stress index = 0.17) subgroups. The map generated by the paranoid subgroup showed clear domesticity and size dimensions whereas the non-paranoid map was less clear and had no size dimension. PF analysis of the paranoid early-onset subgroup revealed similarity with the NC of 0.47; 15 links were shared, although the paranoid subgroup had an additional 14 links. In contrast, PF analysis of the nonparanoid early-onset subgroup revealed a similarity index with the NC subgroup of 0.04; there were only two common links between the maps. Examination of age of onset, however, revealed that the paranoid group (mean age of onset = 28.0 years, SD = 7.7) had a somewhat later ( $P = 0.09$ , NS) age of onset than the nonparanoid group (mean age of onset = 24.0, SD = 5.6). In addition, we selected all paranoid subjects from the early- and late-onset subgroups and then selected pairs matched for age and education (EOS = 7, LOS = 7). The total number of animals generated during the 60-s Animal Fluency Test did not differ significantly between the two groups. The results of the MDS for the EOS versus LOS paranoid subgroups suggest that dimensions in the EOS map are less clear than those in the LOS map. Since the sample sizes are small, however, results may be nonrepresentative, and the study should be replicated in a larger number of patients.

## 4. Discussion

The results of the present study suggest that there is some abnormality in the organization of semantic knowledge in patients with schizophrenia. Fluency output was significantly different from that in age-matched normal subjects in several ways: (1) animal names with low conjunction frequency (e.g., *elephant* and *deer*) were organized in closer proximity to one another than

animal names with higher conjunction frequency (e.g., *horse* and *cow*); and (2) a category of organization frequently used by normal subjects (i.e., size) was not apparent in the schizophrenia group's network. These findings are consistent with previous schizophrenia research demonstrating impaired performance on neuropsychological tests considered sensitive to semantic memory. For instance, patients with schizophrenia often produce inappropriate words on verbal fluency tests (Allen et al., 1993), are deficient on tests of 'real world' knowledge (Tamlyn et al., 1992), and demonstrate atypical facilitation to loosely related words on reaction time priming tests (Manschreck et al., 1988; Spitzer, 1993).

Our findings suggest that models of semantic memory may be useful in characterizing some of the cardinal symptoms of schizophrenia (e.g., thought disorder) as well as illuminating underlying mechanisms for impaired neuropsychological performances on tasks of free recall, category fluency, and verbal priming. For instance, our data suggest that when the word *horse* is activated in the semantic network, normal subjects' activation spreads to the related concept *cow* whereas patients with schizophrenia have an equal probability of facilitating the activation of *cow* or *pig* (see Fig. 5). Extending this example for a patient with a nonparanoid subtype, activation may spread to the concepts *goat*, *zebra*, *sheep*, and *rabbit* when the concept *pig* is activated (see Figs. 6 and 7). According to this model of semantic memory, each component of a speech utterance is associated with activated units in the network. Given that concepts activated in the patients' networks are often weakly associated with the target concept, the spread of facilitation involves atypical (and sometimes bizarre) concepts or associations. Consequently, speech output may be disorganized and thought processes appear disordered.

Detailed analyses of the underlying semantic networks in the present study revealed that the performance of the patients with schizophrenia varied depending on age of disease onset. Patients with a later age of onset performed more similarly to NC subjects whereas the semantic network of early-onset patients was highly disorganized and significantly different from that of the NC group.

These findings are consistent with our previous research, which showed a significant relationship between age of onset of schizophrenia and episodic verbal learning and memory impairments (Paulsen et al., 1995).

There are several possible explanations for the findings in this study. Given that our patient groups were age-comparable, the poor performance of the early-onset patients may simply reflect a deterioration of cognitive function with disease progression; thus, it may be that the longer one remains psychotic, the more disorganized one's semantic network becomes. Longitudinal data would be needed to address this possibility. At least two other studies have noted selective language deterioration in chronic schizophrenia (Silverberg-Shalev et al., 1981; Thomas et al., 1990). Alternatively, it is possible that these differences are due to the longer previous opportunity for social interaction in late-onset patients. Finally, disorganization of semantic knowledge may reflect premorbid cerebral vulnerability which predisposes individuals to both disorganized thought organization and illness manifestation at an earlier age. The latter suggestion is consistent with neurodevelopmental theories of schizophrenia (Feinberg, 1982; Weinberger, 1987; Murray et al., 1988).

Findings from the present study show that the paranoid subtype of schizophrenia is characterized by less semantic disorganization than is the nonparanoid subtype. On the basis of PF analyses, the nonparanoid subgroup demonstrated the greatest semantic abnormality and generated cognitive maps that differed significantly from those of the NC subjects. This finding is consistent with previous neuropsychological research suggesting that cognitive ability is less impaired (Goldstein and Halperin, 1977; Bornstein et al., 1990; Heaton et al., 1994; Paulsen et al., 1994) and that clinical course and prognosis are generally reported to be better in the paranoid subtype of schizophrenia (McGlashan and Fenton, 1994).

It is important to note that subgroup differences among patients with schizophrenia were only evident when qualitative analysis of fluency output was used. With the traditional scoring techniques of category fluency (total number of correct ani-

mal names generated in 60 s), all patients performed significantly worse than the NC subjects and there were no differences between subgroups varying in age of onset or diagnostic subtype. A detailed analysis of the underlying semantic network, however, demonstrated that the organization of semantic knowledge was worse in patients with early-onset and nonparanoid subtypes of schizophrenia. These findings suggest that general fluency impairments (difficulties in initiation, retrieval, and search mechanisms) may be sensitive to a diagnosis of schizophrenia, *per se*, whereas specific deficits in the structure of semantic knowledge may be associated with distinctive characteristics of schizophrenia, such as an earlier age of onset and nonparanoid subtype. Further research is needed to understand the relationship between distortion of the semantic memory system, clinical features of schizophrenia, and structural/functional disturbance in brain systems.

There are some aspects to the present study which limit the conclusions that can be made. First, the validity of the qualitative analyses of animal fluency may be compromised by the quantitative differences among subject groups in total number of responses. To minimize the potential impact of missing data on the results, however, the animal names chosen for analyses were those most frequently produced by the subject sample as a whole. In addition, the missing data appeared to be equivalent across groups. Hence, it is unlikely that differences among groups were due to missing data. Another limitation was that age of onset of illness and subtype of schizophrenia were significantly associated in the current study. It may be difficult to clearly separate the contributions of subtype diagnosis and age of onset because there is a strong inherent relationship between late age of onset and paranoid subtype of schizophrenia. This finding has been consistently reported in other late-onset versus early-onset schizophrenia studies reported in the literature (Harris and Jeste, 1988). Although age of onset and subtype were confounded in our study, the *post hoc* analyses seemed to suggest that age of onset might be a somewhat better indicator of semantic distortion. For instance, when paranoid patients were divided by age of onset and data were subjected to MDS,

the early-onset paranoid subgroup's semantic map was less clear than that of the late-onset paranoid subgroup. In addition, when early-onset patients were divided by subtype and data were subjected to a PF analysis, the paranoid subgroup's results most closely mimicked those of the NC subjects, and they also had a somewhat a later age of onset than the nonparanoid early-onset subgroup. Although the current study was unable to separate the influence of age of onset and diagnostic subtype on semantic memory performances, it would be useful to replicate the paranoid versus nonparanoid comparison with subjects who all have either late- or early-onset schizophrenia. Similarly, age of onset of illness and subtype of schizophrenia were confounded by duration of illness such that the early-onset and nonparanoid subgroups had a significantly longer duration of illness than the late-onset and paranoid subgroups, respectively. In addition, the subgroups were not matched in gender distribution. Although we cannot rule out a potential contribution of gender to our findings, previous studies, as well as our own preliminary analysis, suggest that verbal fluency performance does not differ between men and women (Sarno et al., 1985; Zec et al., 1990). Finally, the MDS and PF analyses chosen for the present study allowed only categorical patient information (e.g., late onset vs. early onset, or paranoid vs. nonparanoid) to be used. Future studies designed to confirm the conclusions of the present study could involve continuous data to examine the relative contributions of age of onset and thought disorder to disorganization of the semantic memory system in schizophrenia. In addition, several alternative experimental strategies (e.g., semantic priming, typicality ranking, and sentence verification) and statistical analyses could be used in future research to confirm the conclusions made in the present study.

It is interesting, although somewhat speculative, to relate the results of the present study to certain other findings in schizophrenia. Investigators have reported smaller (than normal) thalamic volumes in chronic patients with relatively early onset of schizophrenia (e.g., Andreasen et al., 1994), while Corey-Bloom et al. (1995) found larger thalamic

volume in a sample of patients with late-onset schizophrenia. There is considerable literature on the possible role of the thalamus in language and related functions (Crosson, 1992). One wonders if the large thalamus in late-onset schizophrenia may be even indirectly related to the normal semantic network observed in the present investigation as well as the relatively unimpaired episodic memory associated with later onset of schizophrenia (Paulsen et al., 1995). Obviously, further work is needed to test the validity of such a speculation.

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