Category content and structure in schizophrenia: An evaluation using the instantiation principle.

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Abstract

Numerous studies have suggested anomalies in semantics in patients with schizophrenia. We addressed whether one such anomaly might reflect a difference in knowledge content or in the structure or organization of this information. Using a category member production task and a typicality rating task we assessed knowledge content, and found that patients' and controls' knowledge about categories of foods and animals was very similar. In terms of structure, our findings from a mathematical model of category judgment (the instantiation model; Heit & Barsalou, 1996) revealed a similar category structure in patients and controls. In conclusion, we suggest that the content and organization of categories is similar in patients with schizophrenia to that of healthy control participants.

The study of semantics deals with words as signs (symbols) and language that refer to entities in the world. The postulated storage and organization of these meanings is often referred to as semantic memory. There is a growing research interest in schizophrenia concerning what aspects of semantic memory are preserved and what are dysfunctional, and how these might relate to their cognitive deficit profile as well as to their symptoms. Specifically, we sought to examine the <u>content</u> and <u>structure</u> of this information (within the same experimental paradigm) in natural language categories, and evaluate how normal this is in patients with schizophrenia. A variety of studies have explored knowledge content and structure in schizophrenia, but have employed different paradigms to examine these components of semantic memory. For example, an examination of semantic memory content in patients with schizophrenia by Tamyln, McKenna, Mortimer, Lund, Hammond and Baddeley (1992) employed a simple semantic sentence verification task in order to index real world knowledge. The task was to state whether each of 50 spoken sentences (e.g., “Rats have teeth” and “Desks wear clothes”) are true or false, as quickly as possible. They found that patients’ verification times were significantly slower (than controls from normative data) and that patients made a surprising (given how easy the task is) number of errors. Another study predominantly focusing on structure of knowledge employed a comprehensive semantic test battery (designed by Hodges, Salmon and Butters, 1992), which systematically varies multiple input and output modalities to build a profile of the status of semantic knowledge that is independent of any one modality used to access or express it. Knowledge of living items and man-made items was probed through category fluency tasks, picture naming tasks, sorting picture cards into different categories, word-to-picture matching tasks and finally participants are required to generate defining features of items. MacKay, McKenna, Bentham, Mortimer, Holbery & Hodges (1996) reported that schizophrenic patients performed worse on almost all of the semantic subtests than did normal control participants, although in the word-to-picture matching subtest, the group differences were less pronounced. Interestingly, patients' performance was on average intermediate between normal individuals and patients with mild to moderate Alzheimer's disease.

Other data that may be broadly viewed as examining knowledge structure in schizophrenia are category fluency data in which one is to generate as many exemplars of a certain category (e.g., animal) in a specified time. Although the poor performance on this category fluency task has been used to argue that semantic memory is organized differently (i.e., sub-optimally for access) in patients with schizophrenia (e.g., Sumiyoshi, Matsui, Sumiyoshi, Yamashita, Sumiyoshi & Kurachi, 2001; but see Elvevåg & Storms, 2003 and Storms, Dirikx, Saerens, Verstraeten & De Deyn, 2003 for an evaluation of the statistical problems with this data-fitting approach to patient data), our own data suggest that the "clustered" output structure on a category verbal fluency task is similar to that of controls (Elvevåg, Fisher, Gurd & Goldberg, 2002), and moreover an indirect assessment of the amount of information on specific categories in the semantic store is found to be equivalent in patients and controls (i.e., lexicon size is intact; Elvevåg, Weinstock et al., 2001; see also Allen et al., 1993). These data have been interpreted within the framework provided by the "storage versus access" debate in semantics as reflecting a problem in the retrieval of words from the lexicon (i.e., semantic store) (e.g., Allen et al. 1993).

Following on from the idea of a problem in accessing knowledge versus a problem in knowledge structure are semantic priming studies, based upon the idea that semantic memory is organised as a network (Collins & Quillian, 1969). This process has been indexed using tasks in which target words are preceded by a prime (a cue), which if related to the target, speeds the recognition of the target. These tasks have been used to demonstrate deviations in the associational network, or aberrant associations between words, in patients with schizophrenia (e.g., Manschreck, Maher, Milavetz, Ames, Weisstein & Schneyer, 1988; Spitzer, Braun, Hermle & Maier,1993; Spitzer, Weisker, Winter, Maier, Hermle & Maher, 1994; Spitzer, 1997; Vinogradov, Ober & Shenaut, 1992; Ober, Vinogradov & Shenaut, 1995; Goldberg, Aloia, Gourovitch, Missar, Pickar & Weinberger, 1998; Goldberg, Dodge, Aloia, Egan & Weinberger, 2000), and have variously been interpreted as suggesting that there is a problem of concepts appropriately activating each other.

Our own research takes these previous studies as a starting point. Given the previous indications that there are some semantic deficits in patients with schizophrenia, we sought to pinpoint this deficit. In particular we explored to what extent such deficits are related to the content of information that is assessed or the structure and organization of this knowledge. The main goal of this study was to compare patients with schizophrenia to healthy control participants in terms of semantic knowledge about natural language categories (foods and animals), and assess whether any group differences are driven by differences in content or structure. First, to examine content of knowledge, we used two tasks, a category member production task and a typicality rating task. These tasks allowed us to assess whether patients and controls are alike in terms of naming category members (e.g., naming “dog” as an example of “mammal”) and judging their typicality to a superordinate (e.g., rating how typical a “dog” is to the superordinate “animal”). We predicted that if patients have different knowledge about natural language categories in terms of content, then exemplars generated in response to a specific category cue (e.g., “mammal”) would have a substantially different distribution than controls. Likewise, a difference in content of knowledge should lead to differences in typicality ratings for category members (e.g., “dog”). Second, to examine structure of knowledge, we applied the “instantiation model” (Heit & Barsalou, 1996) to data from the two groups. The instantiation model predicts a systematic relationship between two levels of categorical structure, in terms of statistical regularities between typicality ratings at the two taxonomic levels (e.g., the instantiation “dog” and the superordinate “animal”). The instantiation model has previously been validated for normal populations, for food and animal categories, and able to predict the statistical distributions (in terms of means and standard deviations) of typicality ratings for the categories (e.g., “mammal”), from the distributions of typicality ratings on the instantiations (e.g., “dog”) (see Heit & Barsalou (1996) for details, as well as the *Results* section below). Heit and Barsalou (1996) concluded that the good fit of the instantiation model to these data suggests that people were consistent between the two sets of judgments (see also De Wilde, Vanoverberghe, Storms & De Boeck, 2003). Applying the instantiation model to data from patients with schizophrenia should be informative about the consistency of patients’ category representation. A poor fit of the instantiation model for patients with schizophrenia would suggest that their knowledge is not as systematically structured or is structured in different ways. Therefore in the present study we compared the fit of instantiation model for patients to the fit for a control group, our goal being to compare the pattern of behavior in patients as compared to controls[1]. By no means is it our goal to propose the instantiation model as a diagnostic test or model of schizophrenia. Indeed it could well be the case that the instantiation model results in a good fit to data from patients with schizophrenia. Such an outcome would not be a “null result” because such a good fit of the instantiation model would require a statistically significant relation between dozens of judgments made at two taxonomic levels. Therefore, such an impressive outcome would present a very convincing case for some aspects of patients’ semantic category knowledge in terms of content and structure being well preserved (i.e., normal).

In sum, we hypothesized that if patients have different knowledge about natural categories in terms of content then the exemplars generated in response to a specific category cue would have a substantially different distribution than control participants, and should lead to differences in typicality ratings for category members. Furthermore, if controls and patients have similar knowledge about certain categories in terms of content, but patients display less consistently structured knowledge, or knowledge that is structured in a different way, the instantiation model would fit the data of patients worse than that of controls. Indeed, if the content of patients’ knowledge is different, but otherwise structured systematically in a similar fashion to controls, then the instantiation model could still give a good fit to the patients’ data. Furthermore, if the predictions based on the data of the control participants predict the performance of the patients well and vice versa, then that would provide evidence for very similar semantic structure across the groups.

Method

Baseline Tests. As a baseline assessment of intellectual function, all participants were administered the Wide Range Achievement Test-Reading (WRAT-R; Jastak & Wilkinson, 1984). The WRAT-R is widely used as a putative measure of premorbid intelligence (Goldberg et al., 1995; Kremen et al., 1996; Wiens, Bryan & Crossen, 1993). To estimate current intelligence, participants were administered a short form of the Weschler Adult Intelligence Scale-Revised (WAIS-R; Wechsler, 1981; see also Kaufman, 1990; Missar, Gold & Goldberg, 1994). The observed substantial drop in intelligence from estimated premorbid function is often reported in schizophrenia (e.g., Weickert et al., 2000). Participants were also administered a standard test of current non-verbal or fluid intelligence (g_f) - Cattell's Culture Fair Intelligence Test (Cattell, 1971; Institute for Personality and Ability Testing, 1973), Scale 2, Form A. The test involves timed spatial problem solving tasks.

Participants. There were 21 patients and 22 controls in the production task. These data were then collated separately for each group and used for the subsequent rating task which was administered to a separate sample of 20 patients and 21 controls in the rating task (for characteristics of patient and control samples, see Table 1)[2]. These same individuals (patients and controls) participated in Study 1 (food) and Study 2 (animals), which were administered on the same day. Patients were from the National Institute of Mental Health Neuropsychiatric Research Center at St. Elizabeth's Hospital, Washington DC, and inpatients and outpatients from the National Institute of Mental Health research ward in Bethesda, MD. All patients fulfilled DSM-IV criteria for schizophrenia or schizoaffective disorder as determined by the Structured Clinical Interview for DSM-IV (SCID), with three psychiatrists reaching a consensus diagnosis. Patients generally had multiple hospital admissions due to incomplete responses to conventional treatments. Normal healthy control volunteers were recruited through the National Institutes of Health volunteer panel. No participant, control or patient, with a history of traumatic brain injury, epilepsy, developmental disorder, diagnosable current substance or alcohol abuse or dependence, or other known neurological condition was included in this study. All participants had normal or normal corrected vision. All control participants and outpatients were paid for their participation and inpatients completed the study as part of their protocol for entering the hospital. This study was approved by the internal review board at the National Institute of Mental Health and informed consent was obtained from all participants prior to testing.

INSERT TABLE 1 HERE

Materials and Procedure. For the production groups, the category cues were nine subordinates of food, namely beverage, dairy product, dessert, fish, fruit, meat, poultry, seasoning and vegetable, and the seven subordinates of animal, namely amphibian, bird, fish, insect, mammal, micro-organism and reptile. These same seven subordinates of animal were modified by the adjectives small, and also dangerous. Participants were individually asked to name the first three instances that came to mind for each category cue. The cues were read to each participant one at a time in a pseudo-random order and the responses of the participants were recorded. Importantly, participants were not prevented from making mistakes such as producing crab as an instantiation of fish. Production controls produced a total of 178 unique instantiations to the nine food cues and 265 unique instantiations to the 21 animal cues, and production patients produced a total of 185 unique instances to the food cues and 269 unique instances to the animal cues.

For the control rating group, the stimuli to be rated were the unique instantiations produced by the control production group[3], and for the patient rating group, the stimuli to be rated were the unique instantiations produced by the patient production group. Additionally, the subordinate categories were also rated by both rating groups (e.g., 9 subordinates of food, and 21 subordinates of animal). Participants were to rate the food words on how typical a member they were of the category food, and how typical the animal words were of the category animal. They were given a clear illustration of the 1-9 scale that they were to use, with higher numbers indicating greater typicality. For example, participants were asked as to how typical milk is for the category food, and how typical beverage is for the category food. Note that participants never rated the instantiations on their typicality in the subordinate categories. For example, participants never evaluated the typicality of milk in beverage. Participants performed the rating task at their own pace.

Results

We describe first the results of the two tasks assessing content of knowledge, namely the production task and the typicality rating task. Then we present the application of the instantiation model, to assess the structure of knowledge for the patient group and the control group. Finally we present simulations to evaluate the sensitivity of the instantiation model to different types of "noise" in the semantic system.

Study 1: Food

Results and Discussion

Production task. We first examined the category members produced for the nine subcategories of food. The question of whether the category members produced by patients and by controls differ can be answered by looking at several different indices.

First, we looked at the number of distinct exemplars produced for each of the 9 subcategories of food, taking into account only the first instantiation of each participant. A reason for concentrating on the first instantiations only is that these can be considered the most prototypical, since production frequency and typicality correlate significantly (Storms, De Boeck, & Ruts, 2000). For beverages, dairy products, desserts, fish, fruits, meat, poultry, seasoning, and vegetables, the control participants generated 13, 5, 9, 13, 7, 11, 5, 13, and 12 distinct exemplars, respectively. The corresponding numbers of the patient group were very similar: 15, 7, 11, 10, 6, 11, 6, 12, and 12, respectively. A paired t-test did not show a significant difference, $t(8) = -.39$, $p = .71$. Across the nine subcategories, there was a significant correlation between the exemplars produced by the two groups, $r = .86$, $p < .01$. Thus, in terms of number of distinct exemplars produced for each category, the results were similar for patients and controls.

Second, we examined to what extent the actual words generated as first instantiations were similar across groups. For the nine subordinate categories, the percentage of instantiations in the patient group that were also generated in the control group varied between 52% and 90%. These percentages are fairly high, given that only the first generated instantiations in a relatively small group (N = 21) were compared.

Moreover, for seven of nine subordinates, the controls' most frequent instantiation was also the patients' most frequent instantiation. Occasionally, odd exemplars were generated (like, e.g., 'eggs' for poultry), but these peculiarities were rare in both the patient group and the control group. Overall, there was no evidence that the patients produced significantly less common or more unusual category members (or non-members), or responded with a substantially different probability distribution than the control participants.

Typicality rating task. A first important question relates to how similar the typicality ratings were within each group. It is conceivable that the participants of the control group are highly interindividually consistent (i.e., that they all rated the items in a very similar way), but that the patients differ considerably among each other in the way they rated typicality. Therefore, interindividual consistency within each of the two groups was evaluated with a standard psychometric reliablity estimation procedure: To obtain this estimate of the reliability of these mean ratings, the two groups were each split up at random into two half groups. Next, the mean ratings were calculated within each half group. Then, the inter-scorer reliability (i.e., interindividual consistency) of the mean ratings was estimated using the split-half correlation, corrected with the Spearman-Brown formula (Lord & Novick, 1968). The correlation between the means in the two half groups of control participants was .90, which results in an estimated reliability of .94. The corresponding correlation for the patients was .86, which results in an estimated reliability of .93. In other words, there was a high degree of agreement within the patient group as well as in the control group, as reflected in the means. The difference between the patients' correlation and the controls' correlation was not significant, z = 1.11. These, and the remaining correlations in this section on typicality ratings, were calculated over all instantiations that were rated both in the patient and in the control group. This finding thus argues against very idiosyncratic differences among the patients (and also among the control participants) in their typicality ratings.

Next, we conducted analyses comparing the consistency within each group, controls and patients, to the consistency between groups. The key question was whether the differences between patients and controls were greater than the difference within each group considered alone. To examine how closely the ratings of patients resembled those of control participants, correlations were calculated between half patient and half control participant groups over all exemplars that were rated by both groups. In this way, four different correlations could be calculated. The resulting values were .81, .87, .78, and .82, respectively. None of these values differed significantly from the correlations between the two half patient group, nor from the correlation between the two half groups of control participants. Hence, the between-group correlations were not lower than the within-group correlations.

We further investigated the homogeneity of the two groups by calculating, within every half group, the standard deviation of the typicality ratings for every instantiation. The reason why we investigated the within-item standard deviations of the ratings in details is because the fit of Heit and Barsalou's (1996) instantiation model, which will be discussed shortly, relies heavily on the within-item variance of the ratings. The correlation between these standard deviations (i.e., one for every instantiation) in the two half groups of control participants was .79 (which results in an estimated reliability of the standard deviations equal to .88). The corresponding correlation for the patients was only .61 (which results in an estimated reliability of .76). The difference between the patient correlation and the control correlation was significant, $\underline{z} = 2.74$, $\underline{p} < .01$. In other words, the degree of agreement within the control group, as reflected in the standard deviations, was higher than the agreement within the patient group.

In summary, the measures of reliability of typicality ratings addressed two issues. One issue is whether the two groups were equally consistent. The reliability analyses suggested that controls and patients were equally consistent in terms of mean typicality ratings, but there was more disagreement in the patient group when the standard deviations of typicality ratings were considered. The second issue is whether a mixed group, half control and half patient, would be less consistent than a pure group, either all control or all patient. If the mixed group is less consistent, it would suggest that there are indeed differences between controls and patients. However, for mean typicality ratings, we found that the mixed groups were about as consistent as the pure groups. For standard deviations of typicality ratings, we found that the mixed groups were not significantly less consistent than the pure patient groups, which themselves were somewhat inconsistent. Overall, the only evidence for a difference between patients and controls in typicality ratings was minor: The standard deviation measure was less reliable for patients.

<u>The instantiation model.</u> When participants are asked how typical “beverage” is of the category “food”, the instantiation model assumes that first an example of “beverage” (e.g., coca-cola) is generated, and then the evaluation of how typical “coca-

cola" is of the category "food" occurs. The manner in which the model implements this is to correlate the observed ratings of typicalities of "beverage" with the predicted typicalities of "beverage". These predicted typicalities are derived as follows: If 5 out of 20 participants in the original production task generated "coca-cola" in response to the cue "beverage", then "coca-cola" was used 25% of the time to predict how typical "beverage" is of the category "food". Next, a typicality rating for the instantiation was chosen randomly from the 21 typicality judgments that the participants in the rating task made for it. This was continued until all the typicality rating data entered into the simulation. Overall, a total of 420 participants (21 generation participants by 20 rating participants) were simulated for each subordinate in 20 cycles of 21 simulated participants each, thus ensuring the relative frequency of different instantiations is maintained in the simulated data.

The key results address the fit of the instantiation model for patients and controls. Because of consistency within the groups, the instantiation model was able to make good predictions of patients' mean typicality ratings for the nine subordinates, based on information from the instantiations produced by patients (r=.82) (see Figure 1). Likewise, the model was able to make good predictions of controls' mean typicality ratings for the nine subordinates, based on information from the instantiations produced by controls (r=.82)[4]. Also, just looking at the observed means for the nine subordinates, there was a high correlation (r=.87) between the means for patients and the means for controls, again suggesting that there was much overlap in content. Furthermore, since there was a large amount of consistency between patients' data and controls' data, it was possible to predict patients' subordinate judgments from controls' instantiations (r=.79) and controls' subordinate judgments from patients' instantiations (r=.72).

We next turn to information about standard deviations of the distributions of typicality ratings for the nine subordinate categories. In general, the correlations were lower for standard deviations than for means. Heit and Barsalou (1996) had a similar finding, with an overall fit of .64 for the instantiation model's prediction of standard deviations for foods, and attributed this lower correlation to a more restricted range for standard deviations and also that means are inherently more efficient (reliable) estimators than standard deviations. Here, the key results are a fit of .71 for patients and a fit of .81 for controls, both higher than Heit and Barsalou's own results. The fits for patients versus controls did not differ significantly. The other positive correlations reflect that there is some consistency between patients and controls, although not a perfect degree of consistency. For example, the model was better able to make predictions for patients' subordinates from patients' instantiations (r=.71) than from controls' instantiations (r=.33).

INSERT FIGURE 1 HERE

In sum, patients' and controls' knowledge about food categories seemed fairly similar. In terms of content, we did not observe significant differences in terms of category members produced or in average typicality ratings on these category members, although patients displayed somewhat more inconsistency in terms of the standard deviation measures. In terms of structure, the instantiation model, a mathematical model of category structure, was able to predict systematic relations between two levels of categorical structure, in terms of means and standard deviations. The instantiation model was successful in predicting both patient and control performance, and the two groups did not significantly differ in terms of how well the instantiation model fits their data. If patients' knowledge was less systematic than controls' knowledge, or if patients' knowledge was structured in a different way, then the instantiation model should not have fit the data as well.

In Study 2, we attempted to replicate this result using another semantic domain, animals rather than foods. Knowledge of animals and living things is perhaps a more usual domain of study for schizophrenia. In addition, the stimulus set for animals was much more extensive than the stimulus set for foods. For example, by including combined concepts such as small birds and dangerous reptiles, we were able to assess the fit of the instantiation model over 63 subordinates in Study 2, in comparison to 9 subordinates in Study 2.

Study 2: Animals

Results and Discussion

Production task. Following the procedure in Study 1, we examined the total number of distinct category members for the seven unmodified subcategories of animals (i.e., amphibians, birds, fish, insects, mammals, micro-organisms, and reptiles), for the same seven subcategories modified with the adjective dangerous (e.g., dangerous amphibians, dangerous birds), and modified with the adjective small (e.g., small amphibians, small birds). This comparison over the 21 subcategories resulted in a mean of 11.5 and 9.9 distinct instantiations for patients and controls respectively, based on the first instantiations only. This difference was not significant, $t(20) = 1.26$. For these twenty-one subordinate categories, the percentage of instantiations in the patient group that were also generated in the control group averaged 60%, which is high given that only the first generated instantiations in a relatively small group (N = 21) were compared. Also, for 10 of the 21 subordinates, the most frequent instantiation produced by the controls was also the most frequent instantiation produced by the patients. These results suggest that over a range of subcategories of animals, including combined concepts, patients and controls were similar in terms of the category member production task. These findings replicate that of Study 1 and provide evidence for its generality.

Typicality rating task. Mean ratings over participants were calculated for every instantiation, separately within each group, for all instantiations that were rated both in the patient and in the control group. As in Study 1, the inter-scorer reliability of the mean ratings was estimated. The correlation between the means in the two half groups of control participants was .91, resulting in an estimated reliability of .96 and the corresponding correlation for patients was .79, which resulted in an estimated reliability of .89. The difference between the patients' and the controls' correlation was significant, $z = 7.78$, $p < .01$, indicating a high degree of agreement within the control group, and a somewhat lower agreement within the patient group. Correlations were calculated between half patient and half control participant groups over all exemplars that were rated by both groups, and the resulting values were .88, .88, .87, and .87, respectively. None of these values differed significantly from the correlations between the two half patient group, nor from the correlation between the two half groups of control participants.

The homogeneity of the two groups was examined by calculating, within every half group, the standard deviation of the typicality ratings for every instantiation. The correlation between these standard deviations (i.e., one for every instantiation) in the two half groups of control participants was .64 (resulting in an estimated reliability equal to .78), and for the patients was only .35 (resulting in an estimated reliability of .52). The difference between the patients' and the controls' correlation was significant, $z = 6.43$, $p < .01$, indicating that the degree of agreement within the control group was larger than that within the patient group.

In summary, there was some difference between controls and patients in that as a group patients were somewhat less consistent. However, when mixed groups, half control and half patient were examined, these mixed groups were not significantly less consistent than the patients themselves. Hence, the difference between controls and patients was not greater than any differences within the group of patients.

The instantiation model.

We examined the correlations between observed and predicted means and standard deviations, respectively, for the two groups. These correlations are taken over 63 items, that is, for the 21 subordinates using typicality ratings in animals, dangerous animals, and small animals together. In terms of means the instantiation model was able to predict typicality ratings very well for both patients (r=.88) and controls (r=.90) (see Figure 2), as it was for standard deviations also (r=.70 for patients and r=.74 for controls).

In all cases, each correlation was significantly different than chance but the patient and control groups did not significantly differ from each other. In summary, the instantiation model appeared to give a very strong account of the structural relations between the subordinate categories and their instantiations, for both the patient and control groups.

INSERT FIGURE 2 HERE

Simulations

Results and Discussion

In light of our findings of a similar behavioral pattern in patients and controls, the question emerges as to how sensitive our approach is in detecting a possible impairment in the semantic domain. It seems very reasonable to assume that, if the patients show semantic deficits, the impairments of individual patients are not exactly identical. Thus, the resulting increased inconsistency in the data from the patient group could resemble increased randomness in the data.

To address the sensitivity of the instantiation model to randomness we present simulations that demonstrate that adding error to the data results in decreasing fit measures. For illustration purposes we simulated data for the 63 animal categories since large amounts of data are more informative and representative (than just a few categories), especially with regards to correlations. Naturally, there are many ways that error can be introduced into a “semantic system”. We describe two different procedures in detail below.

First, we introduced randomness into the instantiation process, the idea being that a person with a semantically disordered system might generate many incorrect instantiations for a given subordinate (e.g., if asked to generate a "mammal" names a dangerous fish such as a "piranha"). Two hundred data sets were run for four different percentages of random data (20%, 25%, 50%, and 75%). For instance, with 25% random data, a fourth of the instantiations were randomly shuffled. Thus, for these shuffled instantiations, the corresponding typicalities on which the calculations of the instantiation model were based were derived from incorrect animals (e.g., typicalities from *cat* could be used to estimate the typicality of *insects*). Table 2 shows the mean correlations, for averages and standard deviations, between the empirically obtained typicalities and the predicted typicalities based on the error-perturbed data. For comparison purposes, the predictive correlations for the real data reported earlier in this paper are also included in this table. Less that 1% of the simulation runs with 20% random instantiations resulted in a better predictive correlation than the real patient data. As can be seen in Table 2, the correlations systematically increase as the instantiation-type error decreases, and this is especially evident in the standard deviations.

INSERT TABLE 2 HERE

Second, we introduced randomness at the level of the typicality ratings, the idea being that one aspect of a particular semantic deficit might result in a person rating exemplars' typicality to a superordinate in a fairly random manner. In this second simulation procedure, a fixed percentage of the typicalities of every simulated data set were shuffled, distributed randomly over all instantiations and subordinates. This procedure thus ensures that the overall distribution of the typicality ratings was identical to the distribution of the empirically obtained data. As before, 200 datasets were run for four different percentages. The final columns of Table 2 show the mean correlations, for averages and standard deviations, between the empirically obtained typicalities and the predicted typicalities based on the error-perturbed data. Thus, although the predictive correlations for the averages and for the standard deviations start off a little higher, the decline as a function of the error percentage is more rapid than for the instantiation-type error.

In summary, the two simulation studies show that the instantiation model is sensitive to randomness in the data. Thus, our study clearly shows that the high predictive correlations for the patient data cannot be dismissed simply by doubting the sensitivity of the model and that these results should be interpreted instead as an indication of the similarity between the patients and the normal controls concerning the structure of their semantic knowledge.

General Discussion

In terms of semantic content of food and animal categories, overall we observed much similarity between patients and controls. In the category member production task, we did not find appreciable differences between patients and controls, either in terms of the overall distribution of responses or in terms of rare, idiosyncratic responses. In the typicality rating task, we found some evidence that the group of patients was less consistent than the group of controls. Given the numerous cognitive components involved in order to perform the rating task and the absence of significant group differences in the production task, we do not regard this as evidence of a group difference of the magnitude or type that could be indicative of an idiosyncratic (or consistent) disorder in category content in patients. Such an isolated finding (in context of all the other non-significant findings) makes for inherent difficulty in pinpointing a specific cognitive function of a task that is fairly complex. Indeed, data collection in patients with schizophrenia generally results in data with more variability, but how one chooses to interpret such data is of major concern in neuropsychological investigations of patients. Naturally, it could be interesting to further study these deviations specifically in order to pinpoint the cause of such variance in patients, but first it would be necessary to establish whether there is systematicity in these deviations (i.e., they are consistent). If these deviations are not stable over time (within patients), then it is very likely that the variance does not reflect systematic semantic differences, and is more likely indicative of "random" behavior triggered by environmental or task cues (see Elvevåg & Storms, 2003 and Storms et al., 2003 for further discussion). However, the key result we would emphasize is that the differences between the patient group and the control group were not greater than the differences within the patient group itself.

In terms of structure, there were two key findings. First, our results replicate the findings of Heit and Barsalou (1996) and of De Wilde et al. (2003) that the instantiation model accounts well for the data from healthy control participants. Second, the model is about equally suited for predicting the data from the patients with schizophrenia. The structural relations between superordinate categories and their instantiations, as assumed by the instantiation model, seem to apply to both controls and patients. Put another way, regardless of any differences in content of beliefs about foods and animals (and there was not much evidence of differences in content), the patients' beliefs seemed to be organized in a systematic way that paralleled the organization of the controls' beliefs. Although our data revealed little wrong with patients' concepts', it is of course possible that there could be a specific problem in combining concepts into more complex semantic expressions or in specific types of concepts (e.g., emotionally-laden concepts). Empirical examination of such a possibility would indeed be interesting.

Our current findings would seem to be at odds with previous findings (e.g., Tamlyn et al., 1992; MacKay et al., 1996). However, we note that unlike previous research, our own tests did not involve speeded judgments or in any other way measure fluency or response time. Likewise our own tests did not require participants to distinguish factual information from non-factual information. The production task asked participants to name a small number of category members, at their own pace, and the typicality rating task asked participants to assess the centrality of category members, based on their own beliefs. Of course, it is possible that the problem might not be within the semantic system itself, but in its "control" mechanisms. However, we would suggest that this is not a very strong candidate in light of some recent data that we have collected in patients with schizophrenia and healthy controls. In this study, we designed a paradigm in which participants were to determine rapidly whether one of two stimuli was larger or smaller in the real world than the other (Cohen, Elvevåg & Goldberg, submitted). Stimuli pairs were either words or their corresponding real-world entities (e.g., "ant" and "house"). We manipulated both real-world "distance" in terms of size (e.g., "ant" and "house", or "ant" and "key"), and "congruency" between real-world size and physical size on the monitor of the image pairs (e.g., small “ant” and large “house”, or large “ant” and small “house”), the latter being a task requiring a degree of cognitive control. Crucially, both the distance and congruency effects were qualitatively equivalent across the groups. This suggests that some aspects of semantic knowledge are represented equivalently in patients and controls, and that patients can use this information to override incongruent information in a manner similar to controls (i.e., this aspect of cognitive control is intact).

These findings are consistent with the current data in that the patients have similar representations of categories (see also Elvevåg, Weickert et al., 2002). In a similar vein, Kéri and colleagues have reported that prototype learning of dot-pattern category exemplars is intact in patients with schizophrenia (Kéri, Kelemen, Benedek & Janka, 2001) and patients are able to establish representations of complex categories (Kéri et al., 2000; but see Kéri’s other work for different conclusions, namely that abstraction is impaired in patients, (Kéri et al., 1999), although when there is a verbal category definition patients perform similarly to controls (Kéri et al., 1998)).

In a more general sense, we also have recent data which suggests that patients with schizophrenia organize information in memory in a qualitatively similar manner, again consistent with the results from the current study showing that the structure of categories is similar in patients and controls. In this recent study patients displayed a qualitatively similar distribution of memories retrieved across the lifespan in a free-recall (i.e., non cued) autobiographical memory study (Elvevåg, Kerbs, Malley, Seeley, Weinberger & Goldberg, 2003). Since we acquire representations over life, if there is a problem in the brain areas (i.e., left temporal parietal cortex) that are responsible for this representation process, then one might predict that patients would display a difference in terms of the content or structure of category information (given the neurodevelopmental nature of schizophrenia). Importantly, in the current study we did not find evidence of either a difference in content or structure of natural categories in schizophrenia. It is of course possible that the integrity of category structure is related to the severity of the deficit. Indeed, an examination of the consistency of face naming deficits in patients with schizophrenia across time concluded that the naming performance varied according to quantitative differences in deficit severity (Laws, McKenna & Kondel, 1998). Thus, it may be that with a more severe patient group our current findings may have been different, although this is probably unlikely given that our patients were fairly chronic. Naturally, it is possible that anti-psychotic medication may have interacted with our current findings, since all the patients in our current sample were medicated. Although we suggest that it is unlikely that our findings are simply artifacts of medication, the only way to resolve this issue is to examine it empirically (i.e., in unmedicated patients).

In light of our several studies that have found patients' performance to be indicative of various intact cognitive processes (within the semantic domain), the question emerges as to what could account for patients' "abnormal" behavior. Given the very nature of experimentally fractionating the various processes into their fundamental components, studies become necessarily and increasingly specific as to what subprocesses are intact and compromised. With reference to the clinical manifestation of the illness, such as the deviations in free-speech, it is noteworthy that here there are considerably less constraints than in most experimental language and semantic tasks (including those used here), and thus there is more scope for unusual associations and problems in the organization of the flow of speech. Indeed, the demanding nature of the dynamic cognitive processing required when assembling all the numerous components involved in free speech (e.g., comprehension, planning, organizing and composing coherent speech) is disproportionately more difficult (and affected). Thus, in patients with attentional and working memory problems, as well as some positive symptoms, there may be a multiplicative effect which may thus appear as a problem within the semantic domain, at least when evaluated through speech. Nonetheless, based on the current findings, it would seem improbable that the observations of patients' unusual content and structure in language reflects a disturbance in their actual knowledge contained in semantic concepts (and the words that are used to refer to these concepts). Fractionating the components of such language processing that in combination produce the "abnormal" behavior characteristic of patients with schizophrenia, especially those with positive symptoms, presents an exciting and useful challenge for future research.

References

Allen, H.A., Liddle, P.F. & Frith, C.D. (1993). Negative features, retrieval processes and verbal fluency in schizophrenia. *British Journal of Psychiatry, 163*, 769-775.

Cattell, R. B. (1971). *Abilities: Their Structure, Growth and Action*. Boston: Houghton-Mifflin.

Chen, E.Y.H., Wilkins, A.J. & McKenna, P.J. (1994). Semantic memory is both impaired and anomalous in schizophrenia. *Psychological Medicine, 24*, 193-202.

Cohen, J.R., Elvevåg, B. & Goldberg, T.E. (submitted). Ecological semantics and cognitive control in schizophrenia: Where the twain shall meet.

Collins, A.M. & Quillian, M.R. (1969). Retrieval time from semantic memory. *Journal of Verbal Learning and Verbal Behavior, 8*, 240-247.

De Wilde, E., Vanoverberghe, V., Storms, G. & De Boeck, P. (2003/ in press). The instantiation principle re-evaluated. *Memory*.

Elvevåg, B., Weinstock, D.M., Akil, M., Kleinman, J.E. & Goldberg, T.E. (2001). A comparison of verbal fluency tasks in schizophrenic patients and normal controls. *Schizophrenia Research, 51*, 119-126.

Elvevåg, B., Weickert, T., Wechsler, M., Coppola, R., Weinberger, D.R. & Goldberg, T.E. (2002). An investigation of the integrity of semantic boundaries in schizophrenia. *Schizophrenia Research, 53,* 187-198.

Elvevåg, B., Fisher, J.E., Gurd, J.M. & Goldberg, T.E. (2002). Semantic clustering in verbal fluency: schizophrenic patients versus control participants. *Psychological Medicine, 32,* 909-917.

Elvevåg, B., Kerbs, K.M., Malley, J.D., Seeley, E., Weinberger, D.R. & Goldberg, T.E. (2003). Autobiographical memory in schizophrenia: an examination of the distribution of memories. *Neuropsychology, 17*, 402-409.

Elvevåg, B. & Storms, G. (2003). Scaling and clustering in the study of semantic disruptions in patients with schizophrenia: a re-evaluation. *Schizophrenia Research, 63*, 237-246.

Goldberg, T.E., Torrey, E.F., Gold, J.M., Bigelow, L.B., Ragland, R.D., Taylor, E. & Weinberger, D.R. (1995). Genetic risk of neuropsychological impairment in schizophrenia: a study of monozygotic twins discordant and concordant for the disorder. *Schizophrenia Research*, *17*, 77-84.

Goldberg, T.E., Aloia, M.S., Gourovitch, M.L., Missar, D., Pickar, D. & Weinberger, D.R. (1998). Cognitive substrates of thought disorder. I: The semantic system. *American Journal of Psychiatry*, *155*, 1671-1676.

Goldberg, T.E., Dodge, M., Aloia, M., Egan, M.F. & Weinberger, D.R. (2000). Effects of neuroleptic medications on speech disorganization in schizophrenia: biasing associative networks towards meaning. *Psychological Medicine*, *30*, 1123-1130.

Heit, E. & Barsalou, L.W. (1996). The instantiation principle in natural categories. *Memory*, *4*, 413-451.

Hodges, J.R., Salmon, D.P. & Butters, N. (1992). Semantic memory impairment in Alzheimer's disease: failure of access or degraded knowledge? *Neuropsychologia*, *30*, 301-314.

Institute for Personality and Ability Testing (1973). *Measuring Intelligence with the Culture Fair Test*. Champaign, Ill.: The Institute for Personality and Ability Testing.

Jastak, S. & Wilkinson, G. (1984). *Wide Range Achievement Test-Revised*. Wilmington, DE: Jastak Assessment Systems.

Kaufman, A. (1990). *Assessing Adolescent and Adult Intelligence*. Boston: Allyn & Bacon.

Kéri, S., Kelemen, O., Benedek, G. & Janka, Z. (2001). Intact prototype learning in schizophrenia. *Schizophrenia Research*, *52*, 261-264.

Kéri, S., Kelemen, O., Szekeres, G., Bagóczky, N., Erdélyi, R., Antal, A., Benedek, G. & Janka, Z. (2000). Schizophrenics know more than they can tell: probabilistic classification learning in schizophrenia. *Psychological Medicine*, *30*, 149-155.

Kéri, S., Szekeres, G., Szendi, I., Antal, A., Kovacs, Z., Janka, Z. & Benedek, G. (1999). Category learning and perceptual categorization in schizophrenia. *Schizophrenia Bulletin*, *25*, 593-600.

Kéri, S., Szekeres, G., Kelemen, O., Antal, A., Szendi, I., Kovács, Z., Benedek, G. & Janka, Z. (1998). Abstraction is impaired at the perceptual level in schizophrenic patients. *Neurosci Lett*, *243*, 93-96.

Kremen, W.S., Seidman, L.J., Faraone, S.V., Pepple, J.R., Lyons, M.J. & Tsuang, M.T. (1996). The “3 Rs” and neuropsychological function in schizophrenia: an empirical test of the matching fallacy. *Neuropsychology*, *10*, 22-31.

Laws, K.R., McKenna, P.J. & Kondel, T.K. (1998). On the distinction between access and store disorders in schizophrenia: a question of severity? *Neuropsychologia*, *36*, 313-321.

Lord, F.M. & Novick, M.R. (1968). *Statistical theories of mental test scores*. Reading: Addison-Wesley.

MacKay, A.P., McKenna, P.J., Bentham, P., Mortimer, A.M., Holbery, A. & Hodges, J.R. (1996). Semantic memory is impaired in schizophrenia. *Biological Psychiatry*, *39*, 929-937.

Manschreck, T.C., Maher, B.A., Milavetz, J.J., Ames, D., Weisstein, C.C. & Schneyer, M.L. (1988). Semantic priming in thought disordered schizophrenic patients. *Schizophrenia Research, 1*, 61-66.

Missar, C.D., Gold, J.M. & Goldberg, T.E. (1994). WAIS-R short forms in chronic schizophrenia. *Schizophrenia Research*, *12*, 247-250.

Ober, B.A., Vinogradov, S. & Shenaut, G.K. (1995). Semantic priming of category relations in schizophrenia. *Neuropsychology, 9*, 220-228.

Spitzer, M., Weisker, I., Winter, M., Maier, S., Hermle, L. & Maher, B.A. (1994). Semantic and phonological priming in schizophrenia. *Journal of Abnormal Psychology*, *103,* 485-494.

Spitzer, M. (1997). A cognitive neuroscience view of schizophrenic thought disorder. *Schizophrenia Bulletin, 23*, 29-50.

Spitzer, M., Braun, U., Hermle, L. & Maier, S. (1993). Associative semantic network dysfunction in thought disordered schizophrenic patients: direct evidence from indirect semantic priming. *Biological Psychiatry, 34,* 864-877.

Storms, G., De Boeck, P. & Ruts, W. (2000). Prototype and exemplar-based information in natural language categories. *Journal of Memory and Language*, *42*, 51-73.

Storms, G., Dirikx, T., Saerens, J., Verstraeten, S. & De Deyn, P.P. (2003). On the use of scaling and clustering in the study of semantic deficits. *Neuropsychology*, *17*, 289-301.

Sumiyoshi, C., Matsui, M., Sumiyoshi, T., Yamashita, I., Sumiyoshi, S. & Kurachi, M. (2001). Semantic structure in schizophrenia as assessed by the category fluency test: effect of verbal intelligence and age of onset. *Psychiatry Research*, *105*, 187-199.

Tamyln, D., McKenna, P.J., Mortimer, A.M., Lund, C.E., Hammond, S. & Baddeley, A.D. (1992). Memory impairment in schizophrenia: its extent, affiliations and neuropsychological character. *Psychological Medicine*, *22*, 101-115.

Vinogradov, S., Ober, B.A. & Shenaut, G.K. (1992). Semantic priming of word pronunciation and lexical decision in schizophrenia. *Schizophrenia Research*, *8,* 171-181.

Wechsler, D. (1981). *Wechsler Adult Intelligence Scale – Revised.* San Antonio: Psychological Corporation.

Weickert, T.W., Goldberg, T.E., Gold, J.M., Bigelow, L.B., Egan, M.F. & Weinberger, D.R. (2000). Cognitive impairments in patients with schizophrenia displaying preserved and compromised intellect. *Archives in General Psychiatry*, *57*, 907-913.

Wiens, A., Bryan, J. & Crossen, J. (1993). Estimating WAIS-R FSIQ from the National Adult Reading Test-Revised in normal subjects. *The Clinical Neuropsychologist*, *7*, 70-84.

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Footnotes

Footnote 1: Naturally the model has limits. For example, the model does not specify how such knowledge will be used in speech.

Footnote 2: Two separate samples of participants took part in the production and rating tasks because of the time lag involved in collecting data from 21 patients on a ward which on average only had 10 patients at any point in time.

Footnote 3: Due to an error in the design of the rating sheets for control participants, the word ant was omitted. Therefore, we obtained typicality ratings of the word ant by testing a further 21 healthy control participants. We gave them three lists of 10 words that they were to rate the typicality of the items for the category animals, small animals and dangerous animals. The 10 words were selected from the entire production list and were words that spanned the continuum of typicality frequency (as rated by controls).

Footnote 4: For comparison, note that Heit and Barsalou (1996) found a correlation of .89 in a similar study with foods.

Table 1: Characteristics of patient and control samples in the production task (panel A) and in the rating task (panel B).

	Patients *n*=21 (17M, 4F)		Controls *n*=22 (11M, 11F)	
	M	SD	M	SD
Ages (years) *	37.00	10.44	30.14	6.91
WAIS-R IQ *	90.67	14.28	112.71	14.80
WRAT-R IQ	99.67	16.16	107.76	12.25
Cattell IQ *	82.78	19.15	113.90	18.73
Age at 1st hospitalization (years)	21.19	4.19	N/A	N/A
Years since 1st hospitalization	15.81	10.25	N/A	N/A
Neuroleptic medication	21		0	
- clozapine/olanzapine	9		-	
- risperidone	5		-	
- high potency drugs**	7		-	
- anticholinergics	7		-	
- adjunctives***	9		-	

[A]

	Patients *n*=20 (18M, 2F)		Controls *n*=21 (11M, 10F)	
	M	SD	M	SD
Ages (years)	37.35	8.27	36.00	7.73
WAIS-R IQ *	92.90	9.96	103.57	10.19
WRAT-R IQ	106.25	10.13	102.62	8.86
Cattell IQ *	94.47	18.17	106.80	15.67
Age at 1st hospitalization (years)	20.05	4.66	N/A	N/A
Years since 1st hospitalization	17.30	8.49	N/A	N/A
Neuroleptic medication	20		0	
- clozapine/olanzapine/ quentiapine	13		-	
- risperidone	6		-	
- high potency drugs**	4		-	
- anticholinergics	2		-	
- adjunctives***	13		-	

[B]

*p<.01 (independent samples t- test)
** = haloperidol, fluphenazine, loxapine
***=lithium, depakote, sertraline, lorazepam, venlafaxine, clonazepam, buspirone

We note that independent samples t-tests did not show any significant differences between patients in the production group to patients in the rating group in terms of age, WAIS-R, WRAT-R, Cattell IQ, age at first hospitalization, and number of years since first hospitalization (in all cases, $p>0.05$), although for controls, there were significant differences between controls in the production group to controls in the rating group in terms of age and WAIS-R (in both cases, $p<0.05$), although there were not any differences in terms of WRAT-R and Cattell IQ values (in both cases, $p>0.1$).

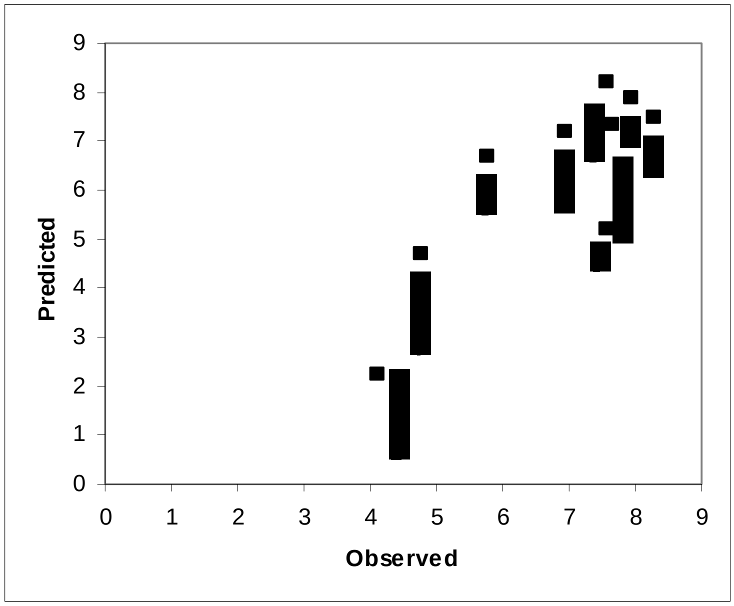
Table 2: Correlations from empirical data, random instantiations and random typicality ratings.

	Empirical Data		Random Instantiations (% random data)				Random Typicality Ratings (% random data)			
	Controls	Patients	20	25	50	75	20	25	50	75
M	.90	.88	.86	.86	.82	.61	.88	.88	.65	.34
SD	.74	.70	.64	.64	.52	.32	.72	.71	.25	.08

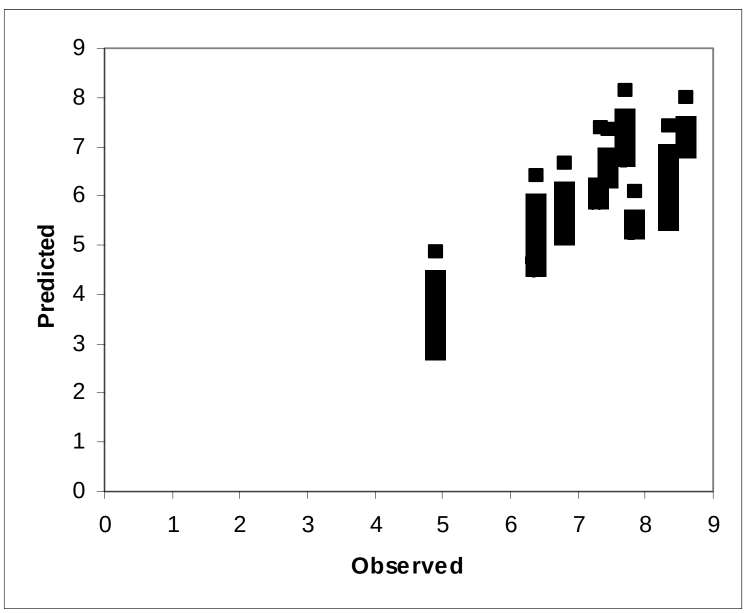
Figure Legends

Figure 1 Observed and predicted means of typicality ratings for *food*, Study 1 in controls (Panel A) and patients (Panel B).

Figure 2 Observed and predicted means of typicality ratings for all 63 *animals*, Study 2 in controls (Panel A) and patients (Panel B).


Predicted
Observed
0
1
2
3
4
5
6
7
8
9

[A]


Predicted
Observed
0
1
2
3
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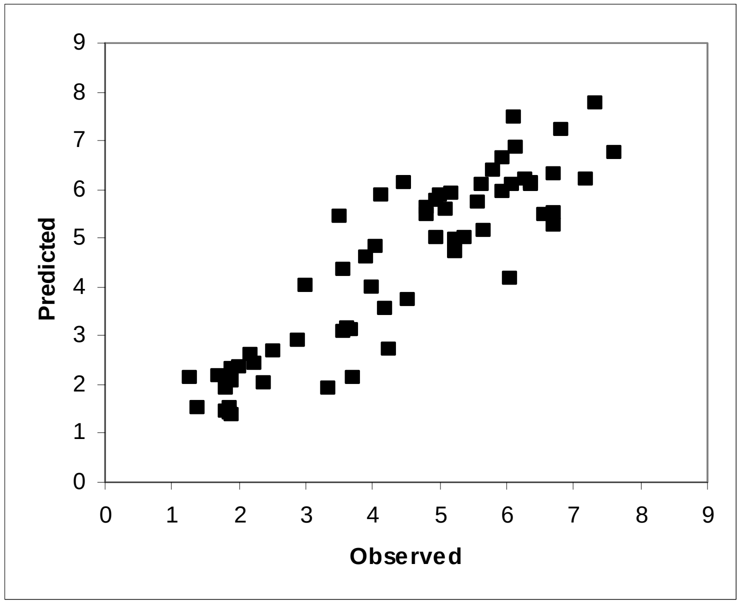
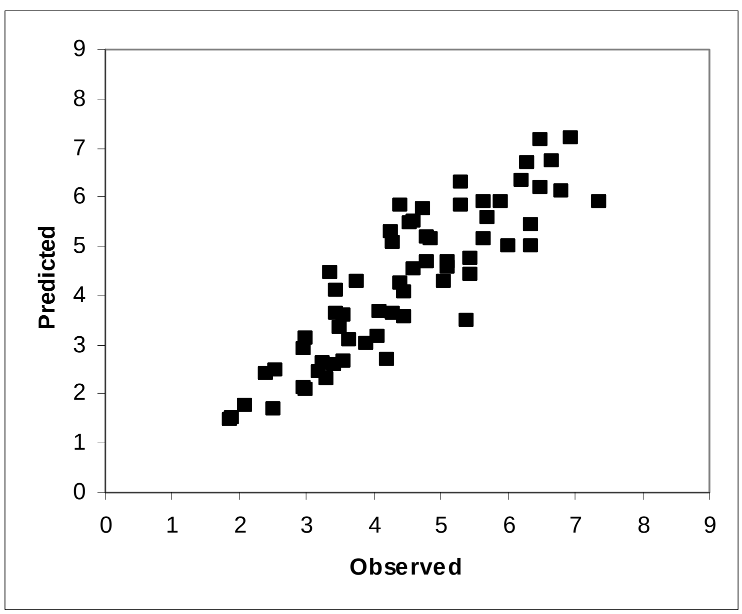
5
6
7
8
9

[B]

FIGURE 1


Predicted
Observed
0 1 2 3 4 5 6 7 8 9
0 1 2 3 4 5 6 7 8 9

[A]


Predicted
Observed
0 1 2 3 4 5 6 7 8 9
0 1 2 3 4 5 6 7 8 9

[B]

FIGURE 2