Category Learning and Perceptual Categorization in Schizophrenia

by Szabolcs Kéri, György Szekeres, István Szendi, Andrea Antal, Zoltán Kovács, Zoltán Janka, and György Benedek

Abstract

The aim of this study was to evaluate category learning in schizophrenia on tests of perceptual abstraction. Participants learned to categorize simple geometrical shapes. The categories were either well-defined (discrete categories, or DCs) or ill-defined (graded categories, or GCs). In DCs, the cues defining category membership can be verbalized in an all-or-none fashion, while in GCs they cannot be defined unambiguously. Three types of learning were used successively: serial presentation of category-exemplars, verbal description, and feedback. After the serial presentation, schizophrenia patients showed a deficit for GCs (p < 0.005) but not for DCs (p = 0.98). After the verbal definition of GCs, the difference between schizophrenia patients and controls diminished (p = 0.09). Finally, after the feedback learning of GCs, a significant difference was observed again (p < 0.0001), suggesting that schizophrenia patients were impaired in this learning paradigm. The GC-learning impairment after the serial presentation displayed a relationship with the score of the cognitive component assessed with the Positive and Negative Syndrome Scale (r = −0.66). In conclusion, the perceptual stage of abstraction is impaired in schizophrenia. This impairment can be partially compensated by instructions via top-down verbal processes.

Key words: Category learning, cognitive deficit, perceptual representation, schizophrenia.


The disorganization of semantic memory is an important aspect of the neuropsychology of schizophrenia (Spitzer et al. 1993; Chen et al. 1994; Clare et al. 1994; McKay et al. 1996; Spitzer 1997). Semantic memory is a factual representation of the world that involves both physical-perceptual and associative-conceptual features. Categorical organization is a central characteristic of semantic memory: similar facts are grouped together, while dissimilar ones are separated. This organization has two fundamental components: perceptual and conceptual (Caramazza 1996; Mandler 1996). For example, “bird” is a perceptual category, because sparrows, storks, eagles, and so forth all have structural-physical similarities. At the same time, “birds” have a common associative meaning, so they are also the members of the same conceptual category. In more general (superordinate) categories, such as “animal” or “man-made tool,” little perceptual commonness can be found among the members (Medin 1983; Mandler et al. 1991; Mandler 1996). Finally, the perceptual and the meaning-based information seems to converge into a common integrated semantic network (Vandenberghe et al. 1996). In schizophrenia, both perceptual and conceptual aspects of categorization have been shown to be impaired (Shallice et al. 1991; Chen et al. 1994). For instance, the reaction times of schizophrenia subjects were longer when they had to decide whether “aeroplane” belongs in the category “bird” or not (Chen et al. 1994). In this case, healthy controls decide easily by considering the large conceptual difference, whereas patients hesitate because of the perceptual similarities between “aeroplane” and “bird.” This hesitation may indicate a disturbance of the relationship between perceptual and conceptual categorization in schizophrenia. Shallice and colleagues (1991) also demonstrated impairments in both perceptual and conceptual aspects of categorization. For example, when a “plug” was briefly presented from an unusual view, schizophrenia patients categorized it as “candles in a church” (perceptual level) or a “switch” (conceptual level). The phenomenon of obscure and uncertain category boundaries is consistent with the theory of a hyperconnected and disorganized semantic network (Spitzer et al. 1993; David 1994; Paulsen et al.)

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However, in spite of extensive investigations of semantic memory, few data are available on simple perceptual category acquisition and organization in schizophrenia, although it is one of the fundamental principles of human cognition (Harnad 1987).

The first step in the present model of perceptual category learning, which is based on the original assumptions of Harnad (1987), is the presentation of a number of stimuli to enable the observer to extract the relevant features common in each exemplar. This generalized pattern is stored in the memory. After this learning phase, new stimuli are presented in a perceptual categorization task. The categorization of the new exemplars is determined by comparing the new stimuli with the stored representations (Carpenter and Grossberg 1993). Here we distinguish two kinds of perceptual categories, following Medin and Barsalou (1987). Discrete categories (DCs) are defined with features characteristic of the given category. The presence or absence of these features determines category membership in an all-or-none fashion. These well-defined categories are easy to verbalize (Homma and Vosburgh 1976; Medin and Barsalou 1987). In contrast, the representation of a graded category (GC) is an averaged central tendency, a summary representation of several individual exemplars (prototype). GCs are ill-defined because they are hard to verbalize and hard to define unambiguously. At higher levels of representation, categories can be labeled and described verbally. This symbolic representation allows quick cognitive (top-down) learning, but non-proportional information such as fine perceptual skills cannot be represented properly in this way: here the sensory-perceptual channels have an indispensable advantage (bottom-up learning) (Mandler 1996).

The aim of the present study was to examine category learning and perceptual categorization of DCs and GCs in schizophrenia, so as to gain more insight into the functioning of basic processes of abstraction in this disorder.

### Methods

#### Subjects

Twenty patients (6 women and 14 men) who met the DSM-IV (American Psychiatric Association 1994) criteria of schizophrenia participated in the study. The current symptoms were assessed with the Positive and Negative Syndrome Scale (PANSS; Kay et al. 1987). The social functioning was evaluated with the Global Assessment of Functioning scale of DSM-IV. Two of the patients were drug-free, and only 4 of the 20 were on anticholinergic medication. Demographic and clinical data are shown in Table 1.

The control group comprised 20 subjects (6 women and 14 men) without any history of neurological or psychiatric disorder. The control subjects were members of the university staff. The mean age was 36.25 years (standard deviation [SD] ±10.42), and the mean years of education was 11.10 (SD ± 2.86). All subjects had normal or corrected-to-normal visual acuity. The two groups were matched for age ($F(1,38) = 0.48$, $p = 0.49$) and for duration of education ($F(1,38) = 0.23$, $p = 0.63$). The educational levels of the controls and of the parents of the schizophrenia subjects were also comparable (mean 10.95 years, SD ± 2.19) ($F(1,38) = 0.03$, $p = 0.85$).

#### Stimuli

**Discrete categories.** The 30 instances of DCs consisted of five internal parts that were nonfigurative shapes. DC1 was defined with a coexisting circle and large spots, while in DC2 the cue features were a square and an irregular triangle consisting of small spots. The positions of category-relevant cues altered randomly in each stimulus.

### Table 1. Demographic and clinical data of the schizophrenia group ($n = 20$, 6 women/14 men)

<table>
<thead>
<tr>
<th></th>
<th>Mean</th>
<th>± SD</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, years</td>
<td>38.70</td>
<td>11.85</td>
<td>27–67</td>
</tr>
<tr>
<td>Education, years</td>
<td>11.55</td>
<td>3.02</td>
<td>8–18</td>
</tr>
<tr>
<td>Age at onset</td>
<td>30.05</td>
<td>10.45</td>
<td>17–59</td>
</tr>
<tr>
<td>Number of hospitalizations</td>
<td>4.00</td>
<td>2.59</td>
<td>1–10</td>
</tr>
<tr>
<td>GAF score</td>
<td>46.55</td>
<td>18.74</td>
<td>21–80</td>
</tr>
<tr>
<td>PANSS scores</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Global symptoms</td>
<td>48.10</td>
<td>12.07</td>
<td>27–67</td>
</tr>
<tr>
<td>Positive symptoms</td>
<td>19.10</td>
<td>9.30</td>
<td>7–47</td>
</tr>
<tr>
<td>Negative symptoms</td>
<td>21.80</td>
<td>8.15</td>
<td>9–40</td>
</tr>
<tr>
<td>Neuroleptic dose (chlorpromazine-equivalent), mg/day</td>
<td>285.10</td>
<td>183.79</td>
<td>0–900</td>
</tr>
<tr>
<td>Anticholinergic dose (procyclidine), mg/day</td>
<td>3.62</td>
<td>7.49</td>
<td>0–30</td>
</tr>
</tbody>
</table>

*Note.* —SD = standard deviation; GAF = Global Assessment of Functioning; PANSS = Positive and Negative Syndrome Scale.
Each DC member subtended 8.9 degrees in the horizontal and 6.8 degrees in the vertical direction, and each internal part subtended 2 degrees in the horizontal and 2 degrees in the vertical direction (figure 1).

**Graded categories.** The exemplars of GCs were computer-interpolated images of simple geometrical shapes: each point of the initial shape (a small circle with a square in the middle) passed toward its new position (a large circle with a circle in the middle) so as to depict a continuum between these extreme configurations (Brennan 1985). The continuum was divided into 30 parts, 15 for the first and 15 for the second category (GC1 and GC2). Each stimulus area subtended 6.8 degrees in the horizontal and 6.8 degrees in the vertical direction. The position of each point on the lines outlining the shapes was randomized (5 dot pitches in both horizontal and vertical directions). This randomization of the shape of GC exemplars was category-irrelevant noise. Note that we used simple geometrical shapes as category exemplars with little functional and associative content, minimizing conceptual levels of information processing (figure 1).

**Procedure**

**General design.** There were four consecutive phases of category learning in the same sequence in each subject. After each phase, the actual categorization performance was determined. The first phase was DC learning by sequential presentation of category exemplars; three different types of GC learning followed: sequential presentation of exemplars, verbal definition, and feedback.

**DC learning by successive presentation of exemplars.** The subjects first learned the two DCs by the sequential presentation of some category exemplars of DC1, and then of some DC2. In this phase, the task was to find the invariant, category-relevant key elements, and the subjects were asked to respond if they found these common features. The required presentations of DC1 and DC2 exemplars for the detection of key elements were counted and averaged for each subject individually.

The stimuli were presented on a Sampo monitor (0.28 mm dot pitch size) controlled by a Pentium 82430 FX/P54 CX personal computer. The exposure time was 700 ms. To guide the gaze of subjects, a black dot appeared on the screen. The subjects sat 100 cm from the computer screen.

In tests of the DC performance, previously unseen intermixed exemplars of DC1 and DC2 were presented, each for 28 ms. Participants were asked to categorize the new stimuli by pressing the previously learned category-associated keys on the computer keyboard. The number of presentations was 45 for each category. In this testing session, exemplars of DC1 containing a triangle or a square, and exemplars of DC2 with large spots or a circle were intermixed in the stimulus set as distracting elements.

The DC learning served as a basic test for measurement of the attentional abilities of schizophrenia patients.

**Figure 1. Exemplars of graded categories (circles) and discrete categories (squares)**
During the detection of perceptual-structural commonness and the execution of categorization tasks, the task evaluated the number of required presentations of exemplars in order to detect category-relevant cues, and also the categorization performance at a brief exposure time. Data from DC learning revealed that schizophrenia patients can execute these tasks successfully (see “Results”), which suggests that the learning and storing of category-relevant cues, the detection of cues, and the category decisions were not below the general abilities of patients. Thus, the same parameters were used in further tests with one exception: the exposure times in the testing phases were longer, in order to definitely exclude any attentional overloading effect.

**GC learning by successive presentation of exemplars.** Exemplars of GC1 and GC2 were presented, each for 700 ms, exactly as in the DC learning phase. The number of presentations was the same as the individual average value in the previous phase. Subjects were told that the previously seen forms belonged in two different groups of shapes. Category knowledge was tested by presenting 45 new exemplars for each category at an exposure time of 700 ms. Participants made category judgments as in the DC learning phase.

In both DC and GC learning phases, half the subjects began with the first category, and the other half with the second category. Performances of the groups in which learning began with the first categories (DC1/GC1) were not significantly different from the performances of the groups who began with the second categories (DC2/GC2). This was true for both the schizophrenia group and the control group (p > 0.6 in each case).

**GC learning by verbal definition.** Following the learning by serial presentation of GC exemplars, the complete verbal descriptions of GCs were given to the participants by the same author, with the same standardized sentences. The definition was repeated slowly once, as a nonperceptual modification of the former structural representation of categories gained in the previous phase. The effect of the verbal correction of category knowledge was measured by repeating the testing procedure used in the previous phases.

**GC learning by feedback.** In the feedback learning phase, subjects continued the categorization of GC members with the design applied in the previous testing phases, but incorrect responses were followed by a sound signal from the computer. The effect of feedback learning was assessed by repeating the testing phase without feedback.

**Data Analysis.** First, a one-way analysis of variance (ANOVA) was conducted to compare the number of required category exemplars for the detection of cue features in the control group and in the schizophrenia group. Second, a 2 (group: schizophrenia patients, controls) $\times$ 2 (category type: DC, GC) repeated measures ANOVA was performed on the categorization performances measured after the serial presentation of DCs and GCs. Third, an additional 2 (group) $\times$ 3 (type of learning: serial presentation, verbal definition, feedback) ANOVA was performed on the GC performances. For post hoc analysis, Scheffé's test was used.

**Results**

**DC and GC Learning by Successive Presentation of Exemplars.** The data were normally distributed. Schizophrenia patients required more stimulus presentations (mean 10.45, SD ± 4.65) to detect category-relevant elements of DCs than did the controls (mean 6.65, SD ± 2.92) ($F(1,38) = 9.57, p < 0.005$). The repeated measures ANOVA on the DC and GC performances after the serial presentation indicated main effects of group ($F(1,38) = 6.61, p < 0.02$) and category type ($F(1,38) = 116.23, p < 0.0001$). There was a significant interaction between group and category type ($F(1,38) = 9.97, p < 0.005$). Scheffé’s test revealed that the schizophrenia patients were significantly impaired in the GC task ($p < 0.005$) but not in the DC task ($p = 0.98$) (table 2).

**GC Learning by Verbal Definition and Feedback.** The two-way ANOVA revealed significant main effects of group ($F(1,38) = 10.05, p < 0.005$) and the type of learning ($F(2,76) = 113.15, p < 0.0001$). There was also a two-way interaction ($F(2,76) = 5.71, p < 0.005$). The post hoc analysis indicated that, after the verbal definition of GCs, the significant difference between controls and schizophrenia patients was not observable ($p = 0.09$). The verbal definition increased the performance significantly in both the schizophrenia and control groups ($p < 0.0001$) (figure 2; table 2). However, after the feedback learning of GCs, the performance of the schizophrenia subjects was again below that of the controls ($p < 0.0001$). In the schizophrenia group, the feedback learning did not change the categorization performance significantly ($p = 0.99$), whereas it did so in the control group ($p < 0.02$) (table 2).

**Correlation Between Test Performances and Clinical Data.** For comparison of the test performances and PANSS scores, Spearman's correlation coefficients were calculated. A significant negative relationship was found between the categorization performance after the serial presentation of GC exemplars and the scores of the cognitive component assessed with PANSS—conceptual disorganization, disorientation, difficulty of abstract thinking,
Table 2. Categorization performances of the control and schizophrenia subjects after serial presentation, verbal definition, and feedback learning

<table>
<thead>
<tr>
<th></th>
<th>Control subjects</th>
<th>Schizophrenia subjects</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean performance (%)</td>
<td>Range</td>
</tr>
<tr>
<td>Serial DC</td>
<td>80.20</td>
<td>69-96</td>
</tr>
<tr>
<td>Serial GC</td>
<td>66.50</td>
<td>50-85</td>
</tr>
<tr>
<td>Verbal GC</td>
<td>77.90</td>
<td>56-91</td>
</tr>
<tr>
<td>Feedback GC</td>
<td>84.65</td>
<td>56-96</td>
</tr>
</tbody>
</table>

Note.—SD = standard deviation; DC = discrete categories; GC = graded categories.

Figure 2. Mean categorization performances of the schizophrenia patients (n = 20) and the comparison group (n = 20) after serial presentation of graded category (GC) exemplars and after verbal definition

Discussion

The present study examined two aspects of category learning in schizophrenia. First, it has been suggested that the perceptual learning of DCs may be intact, while that of the GCs is impaired. However, the main finding of our study is that the verbal definition of GCs may compensate for impaired perceptual learning abilities in schizophrenia.

After the serial presentation of exemplars, the DC performance of schizophrenia patients appeared normal, while their GC performance was impaired. This suggests that schizophrenia patients can learn and store information about simple, well-defined (i.e., DC) visual categories, and are able to compare new information with these internal representations to make successful category judgments in a two-alternative, forced-choice task. This is not the case if the categories are ill-defined (i.e., GC). This finding demonstrates that the nature of the category structure affects category acquisition in schizophrenia. It is also possible that schizophrenia patients could not distinguish the category-relevant information from the category-irrelevant noise (Nuechterlein and Dawson 1984; Sarter 1994). Although category-irrelevant noise was also used in the case of DCs, its characteristic was quite different (see "DC learning by successive presentation of exemplars"). However, it must be emphasized that patients required more presentations of DC exemplars to find the cue. In other words, it was more difficult for them to recognize perceptual commonness, probably because of their limited attentional resources (Braff 1993).

The differential deficit between the DC and the GC performances must be interpreted with caution. First, the DC performance may have appeared intact because the task was easier than in the case of the GCs. However, the attentional demand was higher in the DC task than in the GC task. In the testing phase of category knowledge, the exposure time for the DC exemplars was 28 ms, which is close to the critical stimulus duration measured in former studies (e.g., Braff and Saccuzzo 1985; Saccuzzo et al. 1996) and in our own pilot experiments. This brief presentation induced 80 to 81 percent performances (see table 2), although subjects knew all of the category-relevant cues. Our pilot studies also revealed that the performance displayed only a slight improvement in response to practice in both the schizophrenia and control groups, suggesting that the attentional load of the task was high. Apart from this, future studies should control the question of stimulus complexity in psychometrically matched stimulus sets in order to replicate this differential deficit. In this respect, psychometric matching is quite difficult because of the different kinetics of DC and GC learning. The performance increases rapidly to the maximum for a DC if the key features are found, while in GCs the improvement in the performance is gradual (Homma and Vosburgh 1976).

The second problem is the different reliabilities of the DC and GC tests. It is suggested that schizophrenia...
patients are less impaired in tests with lower reliability (Chapman and Chapman 1978). In our case, the DC test was slightly more reliable (alpha coefficient, 0.62) than the GC test (alpha coefficient, 0.59). These psychometric data indicate that the differential deficit may not be due to external chance factors.

The most important result of our study is that, after the verbal definition, the difference between the schizophrenia subjects and the controls diminished. Human verbal and symbolic abilities are usually considered in relation to associative and meaning-based mental operations, although words can also describe structural and physical properties, with the exception of fine perceptual details. We investigated the effect of verbal description of visual appearance and found that schizophrenia patients could compensate for their impaired perceptual category acquisition in this way. Although several studies have provided evidence of verbal impairment in schizophrenia (e.g. see Andreasen 1979; Hoffman et al, 1986; Thomas and Fraser 1994), the present results indicate that patients can successfully use their linguistic aptitude when representing perceptual features of simple nonfigurative shapes.

Finally, using a feedback paradigm, participants learned small physical details of GCs, which are critical in discriminating similar exemplars near the category boundary. In this case, a significant increase in performance was found only in the control group, which shows that patients were not able to modify and refine their perceptual “hypothesis” concerning ill-defined category structures or to discriminate category exemplars with small differences. This finding is consistent with previous reports relating to impaired error-correcting behavior in schizophrenia (Malenka et al. 1982). In summary, the schizophrenia subjects had difficulties in the perceptual learning of simple categories if they are ill-defined (GCs), regardless of the type of learning (serial presentation and feedback).

However, the question is still open as to whether the GC impairment is a specific deficit or is the result of the general cognitive decline in schizophrenia. Miller and colleagues (1995) showed that if the difference between the controls and the schizophrenia subjects is greatest under conditions of medium difficulty (the accuracy of performance in a two-alternative test such as categorization is around 75% in this case), then the test result is a psychometric artifact because the true-score variance is maximal in this condition. Table 2 demonstrates that in our case the difference was minimal around this preferred accuracy level and increased for both higher and lower accuracy levels. The data showed a similar pattern when the same paradigm (serial presentation of exemplars) was used throughout the whole training procedure. Thus, it is unlikely that the GC impairment is an artifact. Further studies should confirm these findings.

The categorization impairment found in the GC task correlated with the scores of the cognitive component assessed with PANSS (Lindenmayer et al. 1995). Several studies have reported evidence of different levels of perceptual dysfunction in schizophrenia (Place and Gilmore 1980; Capozzoli and Marsh 1994; Lenzenweger and Korfine 1994; O'Donnell et al. 1996). However, most of the studies attempting to build bridges between neuropsychological and clinical phenomena usually emphasize the disorder of higher-order functions such as semantic memory, executive operations and other complex cognitive functions associated with the temporal and prefrontal cortex (Goldberg et al. 1987, 1990; Liddle 1987; Weinberger 1988; Liddle and Morris 1991; Morrison-Stewart et al. 1992; Shenton et al. 1992; McKay et al. 1996; Morice and Delahunty 1996; Andreasen et al. 1997). In the Wisconsin Card Sorting Test (WCST), which is the most popular test of prefrontal functions, the stimuli have three perceptual dimensions (color, number, shape) and only one of the dimensions is correct for the categorization. During the experiment, the relevant dimension is changed and subjects have to find the new rule (Heaton 1981). The WCST is a more complex test of perceptual categorization than ours; it requires a flexible application of category knowledge. The role of the prefrontal cortex in simple category learning cannot be excluded, although in an earlier study an amnestic patient who had impaired WCST scores successfully learned perceptual categories by serial presentation (Squire and Knowlton 1995). Recent studies suggest that certain types of perceptual category learning and other related memory paradigms, which are independent of the medio-temporal structures, are mediated by neocortico-striatal circuits (Squire and Knowlton 1996; Knowlton et al. 1996; Ashby et al. 1998). This hypothesis is fairly important for schizophrenia research, suggesting a non-frontal-nontemporal component of basic abstractional and classificational disabilities.

References


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