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Organization of semantic category exemplars in schizophrenia

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Abstract

Semantic memory was investigated in 27 individuals with schizophrenia and 30 healthy controls using an animal similarity judgment and organization test with reduced retrieval demands. Participants arranged 12 common animal names according to similarity on a computer screen and provided verbal descriptions of organizational strategies. Distance between each animal pair was compared to the number of shared semantic attributes between the pairs (e.g., size, diet, habitat). The three primary organizational strategies included *single* animals not related to other exemplars, *isolated clusters* of animals that shared a single strategic relationship (e.g., pets), and *overlapping clusters* that combined more than one strategic relationship (e.g., cats and mammals). A strong negative correlation was observed between distance ratings and number of shared semantic attributes, confirming that semantic features related to visual distances in both groups. Animal pairs that shared few semantic attributes were placed in closer proximity in the schizophrenia group, whereas the groups placed animal pairs sharing more features equidistantly. Analyses of clustering strategies revealed a double dissociation, with patients relying on isolated, non-overlapping clusters and controls producing more overlapping semantic clusters. Results suggest that performance differences on semantic tasks with limited retrieval demands in schizophrenia relate to difficulties utilizing higher-order categorization strategies.

Keywords: Semantic memory; Schizophrenia; Category organization

1. Introduction

Semantic memory is a person's general knowledge about basic meanings and facts and the processes by which we make use of that knowledge (Tulving, 1972). The study of semantic memory in schizophrenia is important because of possible relationships between core symptoms (i.e., delusions, formal thought disorder) and information processing systems

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that utilize semantic memory (see Spitzer, 1997). Explanations for semantic memory deficits in schizophrenia include degradation or disruption of semantic memory networks (Chen et al., 1994; Paulsen et al., 1996), deficient access to or retrieval from the semantic network (Giovannetti et al., 2003; Robert et al., 1998), or access and network deficits that vary according to severity or subtype (Laws et al., 1998; Minzenberg et al., 2002).

Comparison of word generation in response to semantic category versus phonemic cues (i.e., “fluency”) is one technique for exploring semantic memory in schizophrenia. These studies have consistently demonstrated reduced semantic versus phonemic fluency (Elvevåg et al., 2001; Kremen et al., 2003) and that semantic clustering on animal fluency tests is preserved in schizophrenia, although patients typically generate fewer total clustered words and more non-clustered responses (Moelter et al., 2001; Robert et al., 1998). These results suggest general slowing and inefficient semantic search, access, or retrieval strategies (Abwender et al., 2001; Elvevåg et al., 2002a). In a recent investigation, semantic fluency output was negatively related to the complexity of the semantic network, as measured by the degree of rated semantic similarity between animals (Vinogradov et al., 2002). Patients and controls rated most animal pairs similarly; however some animals rated as less similar by controls were rated as more similar by patients. Vinogradov and colleagues proposed that semantic networks in schizophrenia are characterized by increased complexity and diffusion of activation, thereby making retrieval from the network less efficient.

Retrieval demands during fluency tasks make distinguishing semantic from executive processes difficult. Evidence for semantic network impairment has been an elusive finding when retrieval demands are controlled. For instance, when patients and controls were presented with three category exemplars and asked to decide which two were most similar in meaning (i.e., a triadic comparison) more unusual pairings of exemplars were prominent in highly thought-disordered patients (Tallent et al., 2001). In a follow-up analysis, however, performance on triadic comparison was not consistent across testing sessions and showed considerable intra-individual variability, a finding that does not support a storage deficit (Elvevåg and Storms, 2003). In another study, people with schizophrenia endorsed more borderline category examples (e.g., tent as an example of furniture) as belonging to the category than controls (Chen et al., 1994), supporting the notion that semantic category boundaries are less distinct in schizophrenia. However, a recent attempt to replicate Chen et al.’s finding was unsuccessful (Elvevåg et al., 2002b).

The present investigation was designed to assess semantic organization when retrieval demands were reduced by asking participants to arrange animal names on a computer according to degree of similarity. Performance requires recognition of salient semantic features and use of higher order categorization processes. Although there are a number of theories of semantic knowledge organization (Caramazza and Shelton, 1998), most models agree that similar concepts share more semantic attributes than less well-connected concepts, creating stronger links between related concepts, reinforcing the probability that they will be classified as semantically similar. There is also evidence that category classification involves higher order (i.e., “top-down”) processes such as selective attention, inhibition, and working memory (Smith and Jonides, 1999) and that these processes are dynamic, changing with personal and situational goals (Barsalou, 1983; Ratneshwar et al., 2001).

We tested the ability of people with schizophrenia to organize animal exemplars in an unstructured, limited retrieval environment using a computerized version of the “Flags Board” Test of Ober and Shenaut (1999). In the original, participants arranged animal names mounted on dowels so that closer proximity reflected greater similarity and the examiner measured the distance between labels. We also quantified the degree of semantic feature sharing between our animal exemplars by incorporating a published scoring system (Giovannetti Carew et al., 1997; Moelter et al., 2001). Each animal was scored on six semantic attributes (size, geographic location, diet, zoological class, habitat, and zoological families or groupings) and the number of shared attributes between pairs was computed (see Appendix A). Reductions in the number of shared attributes between consecutive animal fluency responses has been associated with semantic memory deficits in Alzheimer’s disease and left temporal lobe epilepsy (Giovannetti Carew et al., 1997; Giovannetti et al., 2003).

We tested three hypotheses. First, we expected a negative relationship between visuospatial distances and shared semantic features. Supporting this hypothesis is necessary to ensure that obtained distance ratings are related to number of shared semantic features. Second, we predicted that animals sharing few semantic features would be placed in closer proximity in the schizophrenia group than the control group; we did not expect to observe a group difference in visuospatial distance when animals shared a high number of semantic attributes. This prediction is consistent with the finding of Vinogradov et al. (2002) of greater patient rated similarity between animals that were rated as less similar by controls. The third hypothesis compares self-reported clustering strategies in patients and controls. Each participant produces unique cluster groupings of varying complexity; some clusters may conform to simple groupings according to a single feature or prominent association while others may reflect a combination of clusters in an overlapping structure. We predicted that patients would show increased reliance on isolated clusters and less reliance on overlapping clusters, extending findings from a fluency study in which we observed preserved clustering of animals that shared many features in schizophrenia (Moelter et al., 2001).

2. Methods

2.1. Subjects

Participants were 27 patients with schizophrenia and 30 healthy controls from the Schizophrenia Center of the University of Pennsylvania. Patients were diagnosed using standard criteria (American Psychiatric Association, 1994) following medical, neurologic, and psychiatric evaluations, including the Structured Clinical Interview for DSM-IV, patient version (SCID I) (First et al., 1996). Healthy participants also underwent medical, neurologic, and psychiatric evaluation, including the Structured Clinical Interview for DSM-IV, non-patient edition (First et al., 1995). Control participants were excluded for history of Axis I psychiatric illness, Axis II diagnosis of schizotypal, schizoid, or paranoid personality disorder, or any medical condition, including substance abuse, that could compromise brain function.

Demographic, cognitive, and clinical characteristics are shown in Table 1. Patients and controls were matched for age, sex, race/ethnicity, and parental education, but patients had fewer years of education. Both groups showed average lexical experience on the National Adult Reading Test (NART) (Nelson, 1982), however, performance was lower in patients. Groups demonstrated similar levels of semantic knowledge on the Pyramids and Palm Trees test (Howard and Patterson, 1992). Patients were tested as clinically stable outpatients, and represent a chronic, but relatively well-functioning sample. Clinical symptoms were generally mild and all patients were receiving a stable dose of medication at the time of testing (11 typical, 18 atypical, 1 both). This clinical context allowed an opportunity to test semantic memory in patients who have responded well to treatment with few symptoms of current formal thought disorder.

2.2. Materials

A computerized version of the Ober and Shenaut (1999) Flags Board Test was developed using soft-

Table 1
Sample characteristics for normal control (NC) and schizophrenia (SC) groups

Variable	NC (n=30)		SC (n=27)	
	M	SD	*M*	SD
Sex (# of men)	17	–	17	–
Ethnicity (# of Caucasian)	22	–	14	–
Age	30.80	10.00	34.29	9.47
Education**	15.70	2.17	13.81	1.84
Mother education	13.70	3.09	14.12	3.07
Father education	13.67	3.64	15.29	3.46
NART*	107.3	7.63	101.6	9.70
PPTE	3.47	2.50	4.67	3.16
Duration of illness (years)	–	–	10.51	7.57
BPRS total score	–	–	32.92	8.13
SAPS total score	–	–	21.13	12.36
SAPS global rating	–	–	1.41	1.14
SANS total Score	–	–	23.38	21.05
SANS global rating	–	–	1.32	0.69

*$p<0.05$, **$p<0.005$.
NART=National Adult Reading Test IQ estimate.
PPTE=Pyramids and Palm Trees Test number of errors.
BPRS=Brief Psychiatric Rating Scale (Overall and Gorham, 1962).
SAPS=Scale for the Assessment of Positive Symptoms (Andreasen, 1984a).
SANS=Scale for the Assessment of Negative Symptoms (Andreasen, 1984b).

ware written in the Python language (Lutz, 1996; http://www.python.org). 12 animal names were presented in a random arrangement on a Macintosh Powerbook G3 laptop computer with 14.1″ TFT XGA active matrix screen set at 1024 × 768 screen resolution. The size of the field in which the animals were displayed was 600 × 450 pixels and all animals were presented in lowercase 11-point font. Selected animal names represented the 12 most common exemplars generated in our previous study of category fluency in schizophrenia (Moelter et al., 2001).

2.3. Procedure

Participants were asked to read each animal name to ensure that all words were correctly detected. Participants were instructed to arrange animals according to their similarity and no further direction was provided. When participants queried the examiner about arrangements, they were encouraged to “decide for yourself” or “do the best you can”. Words were organized by “clicking and dragging” to desired locations until the arrangement was satisfactory. There was no time limit and the test was administered once. At the conclusion, each participant was asked, “tell me how you organized the animals on the screen”? Responses were recorded verbatim while the animals remained on the screen. Participants were encouraged to consider each animal in the display. The computer recorded the *X–Y* coordinates for each name and the distances (number of pixels) between animal pairs. The completed animal arrangement was saved as a picture file for comparison with the written description of clustering strategies.

2.4. Cluster organization

A research assistant blind to diagnosis scored the organizational approach. Four types of strategies were recorded. *Single animals* were defined as animals that were mentioned as not paired with other animals or not included in the description (e.g., “monkey is not like the rest”). *Isolated clusters* were defined as 2 or more animals that did not contain any sub-clusters or overlap with other clusters (e.g., “horse and cow go together because they are both on the farm”). *Embedded clusters* were defined as animal clusters completely contained within a larger cluster, and *Overlapping clusters* included animals that completely or partially overlapped with other clusters. The response, “*lion and tiger go together because they are both big cats and elephant and rhino go together because they both have leathery skin and all four go together because they are in Africa*” contains two embedded clusters, *lion–tiger* and *elephant–rhino*, and one overlapping cluster (Africa) containing all four animals.

3. Results

3.1. Shared attributes/distances

For each participant, the 66 shared attribute similarity rankings (Appendix A) were correlated with spatial distance for that pair. Spearman–Brown rank order correlation coefficients for controls ranged from -0.10 to -0.72 ($n=30$) ($M=-0.48$, SD=0.16) and did not differ from the range of -0.04 to -0.75 for patients ($n=27$) ($M=-0.44$, SD=.17). The number of shared attributes was also examined relative to mean distances for all 66 animal pair combinations for each group (see Fig. 1). There was a strong linear fit between number of shared attributes and spatial distances for patients, $r=-0.71$, and controls, $r=-0.73$, $p<0.01$. Thus, a significant negative relationship between shared semantic attributes and visual distances was observed for both groups, regardless of whether data were examined at the group or individual level, confirming our first hypothesis.

To evaluate our second hypothesis, we conducted a 2 × 3 mixed factor multivariate analysis of variance with group as a between-subjects factor, level of shared attributes as the repeated factor, and distance between each animal pair as the dependent measure. The repeated measure was collapsed from seven levels to three, designated as low (0 to 1 shared), moderate (2 to 3 shared), or high (4 to 6 shared) shared attributes. The MANOVA revealed a main effect of level of shared attributes, F (2,54)=71.9, $p<0.01$, but no effect of group on visuospatial distance, F (1,55)=1.9, $p=0.17$, or an interaction between shared attribute level and group, F (2,54)=2.3, $p=0.11$. Results indicate that that both groups used similar amounts of spatial distance to organize output. As can be seen in Fig. 1, however, the slope of the regression line in the patient group was more shallow ($M=-26.56$, SD=15.05) than the line for controls ($M=-35.89$, SD=17.61), t (55)=-2.1, $p<0.05$, particularly when shared attributes were low.

Given the difference in slopes, we performed planned comparisons at each level of shared attributes. As predicted in hypothesis two, patients showed greater proximity rela-

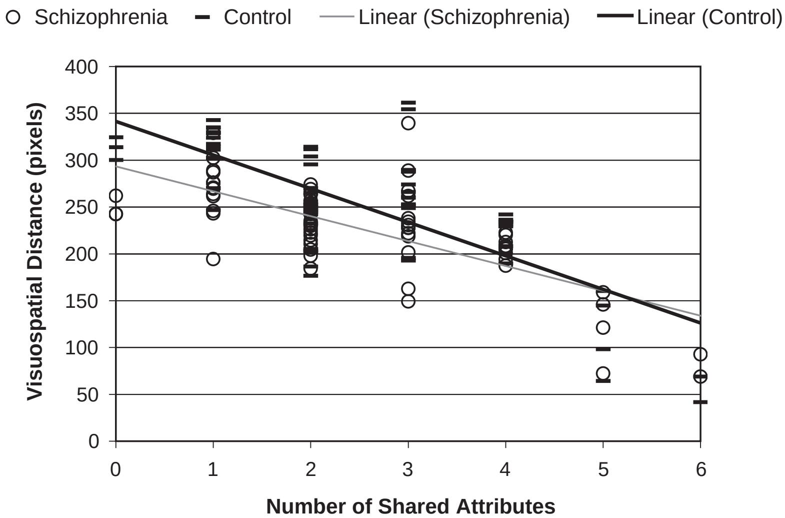

Fig. 1. A scatterplot depicts the nearly equal negative relationship between visual distances and shared attributes for control (black dashes and heavy regression line) and schizophrenia (open circles and light regression line) groups.

tive to controls when shared attributes were low, t (55)=2.0, $p=0.05$ (see Table 2). In contrast, participants arranged animals at similar distances when number of shared attributes was moderate, t (55)=1.0, $p>0.05$, or high, t (55)=0.3, $p>0.05$. Thus, although controls and patients generated similar overall correlation values and total distances between animal pairs, patients placed animals that shared fewer features in closer visual space than controls. This does not appear to be the result of patients drawing *all* associations in closer visual space than controls because there was no main effect of group on level of shared attributes nor were there group differences when two sets of animal pairs that shared all six features were considered individually, *elephant–rhino* t (55)=−1.34, $p>0.05$ and *lion–tiger*, t (55)=−1.20, $p>0.05$ (see Table 2). When a sub-sample of patients ($n=23$) matched to controls by NART-IQ score were considered, distances between animal

Table 2
Mean spatial distance at various levels of shared attributes

Variable	NC ($n=30$)		SC ($n=27$)	
	M	SD	*M*	SD
0 to 1 shared attributes*	314	101	266	74
2 to 3 shared attributes	256	96	234	61
4 to 6 shared attributes	175	96	168	54
All shared attributes	251	68	227	52
Elephant–rhino (6 shared)	69	57	93	77
Lion–tiger (6 shared)	42	18	69	124

All shared attributes = mean distance between all 66 animal pairs.
Elephant–rhino = mean distance between an animal pair that shares 6 out of 6 features.
Lion–tiger = mean distance between an animal pair that shares 6 out of 6 features.
* $p=0.05$.

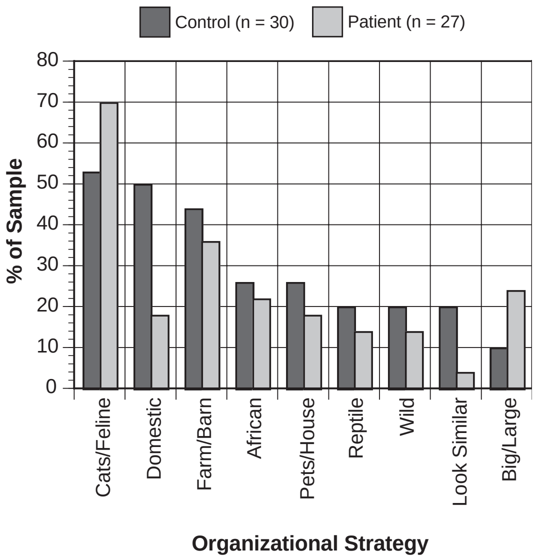

Fig. 2. Organizational strategies reported by at least 20% of the control or schizophrenia group. The bars represent the percentage of participants that reported each strategy. The groups differed in the use of domesticity and feline as organizing structures.

pairs sharing few attributes increased only slightly ($M = 267$) but significance was reduced to a trend level, $t\ (51) = 1.9$, $p = 0.07$.

3.2. Organizational strategies

There was no difference in the number of organizational strategies produced by control (Mean = 4.8 ± 2.1) and schizophrenia (Mean = 4.0 ± 1.7) participants, $t\ (55) = 1.5$, $p > 0.05$. Of the strategies reported by 20% or more of the patient or control groups, the only difference was in the use of domesticity or cats/feline as organizing principles (Fig. 2). Domesticity was reported by 50% of controls but only 18% of schizophrenia participants, whereas, 70% of schizophrenia and 53% of control participants patients identified cats or feline as a strategy. A 2 × 2 comparison of the reported frequency of these strategies in each group revealed a significant effect, $\chi^2\ (1) = 4.8$, $p < 0.05$.

The next analysis focused on the number of isolated, embedded, and overlapping clusters produced by each group. To account for a strong positive correlation between embedded and overlapping clusters, they were summed to create a single "overlapping" measure. Repeated measures MANOVA revealed a significant group by cluster type interaction, $F\ (2,54) = 4.75$, $p = 0.01$, a main effect of cluster type, $F\ (2,54) = 5.1$, $p < 0.01$, and no main effect of group, $F < 1$. As can be seen in Table 3, a double dissociation was apparent as patients generated more isolated clusters, $t\ (55) = -3.3$, $p < 0.005$, while controls produced more overlapping clusters, $t\ (55) = 2.1$, $p < 0.05$. No group differences were observed in number of single animals produced, $t\ (55) = 1.1$, $p > 0.05$. When analyses were repeated with a sub-sample of patients ($n = 23$) matched for NART-IQ, the mean number of isolated clusters ($M = 3.1$), and number of overlapping clusters ($M = 1.1$) were unchanged, and the interaction was preserved, $F\ (2,50) = 3.3$, $p = 0.05$. These results support our third hypothesis that patients use a less complex organizational structure that emphasizes highly related isolated clusters instead of overlapping clusters.

Table 3
Number of clusters of each type

Variable	NC ($n = 30$)		SC ($n = 27$)	
	M	SD	M	SD
Single animals	1.7	2.1	1.2	1.4
Isolated clusters**	1.9	1.6	3.3	1.7
Total overlapping clusters[a],*	2.2	2.7	1.0	1.7

*$p < 0.05$, **$p < 0.005$.
[a] Total overlapping clusters = sum of embedded and overlapping clusters.

4. Discussion

The present study provides several novel findings regarding semantic memory in schizophrenia. First, a new task was developed that paired a metric for semantic attribute sharing with a similarity-based distance rating, and revealed a significant negative correlation between these measures. We also showed that patients placed animals in closer proximity than controls when shared attributes were low, but equidistant when animals shared more features. This finding does not appear to be due to a general proximal perceptual bias in schizophrenia since animals that shared maximum features were equally distant in patients and controls. The most robust finding is a double dissociation between isolated and overlapping clusters. Patients produced more isolated clusters, while controls produced more overlapping clusters, supporting our third hypothesis that patients would use organizational approaches that focused more on isolated than on overlapping strategies. Although a general intellectual deficit may play a role, analyses with a subsample of patients matched to controls by NART-IQ indicated that results were largely unchanged. In the discussion below we evaluate potential explanations for these performance differences, including semantic network abnormality and executive dysfunction.

The notion of an extension of semantic network boundaries or increased spread of activation (Chen et al., 1994; Spitzer, 1997) has been reported in schizophrenia. However, an over-extension of category boundaries account does not appear to fit well with the organizational strategies reported during this study. An over-extension of category boundaries would suggest that patients but not controls would incorporate diverse animals into clusters, as demonstrated by the overlapping cluster variable. Moreover, patients might have been more likely to place unusual animal pairs within a cluster, thereby reducing the semantic-associative integrity of the cluster. We did not see this pattern of results. Patient clusters were generally well conceived and represented reasonable organizational strategies that varied from controls in only two domains, domesticity, which favored controls, and cats/feline, preferred by patients.

Using a different semantic network explanation, Vinogradov et al. (2002) suggested that elevated semantic network complexity results in diffuse spreading activation and difficulty retrieving exemplars during semantic fluency. Preservation of similarity-distance ratings of highly related but not less related animal pairs in the present investigation could be explained by a more diffuse spreading activation in schizophrenia. Presumably, highly associated exemplars can withstand such diffusion better than exemplars associated by fewer features. Diffusion of activation may also make it more difficult for patients to implement alternative categorization strategies that do not rely on especially salient characteristics. For example, when participants organized *cat, giraffe, lion, tiger* by similarity, controls placed *cat* at a considerable distance from the other three along a domestic–wild axis. Patients often used a feline-wild approach that placed *cat–lion–tiger* in close proximity based on salient feature sharing and *giraffe* was placed in proximity to this feline-wild cluster, perhaps due to shared features with other wild animals such as *elephant or rhino*. In this manner, semantic categorization strategies may explain why some patients rate animals that share few attributes (e.g., *cat–giraffe*) as more similar than controls.

We contend that the difference between patients and controls reflects the extent to which each group relied on perceptual and semantic-associative features to organize clusters versus a higher-order approach to categorization (Smith and Jonides, 1999; Barsalou, 1983; Markman, 2005). Barsalou's (1983) description of "ad hoc categories" suggests that diverse concepts such as *basketball* and *log* share few features but may be rated as similar if the situational goal or rule requires selecting exemplars that belong to the category "something that floats". Furthermore, Barsalou showed that implementing a situational context increases category variability. This is consistent with our finding that controls showed greater distance variability across levels of shared attributes (see Table 2). As Barsalou suggests, the ability to flexibly adapt a novel categorization strategy to achieve a goal is closely related to creativity and new category learning.

Difficulty implementing a novel category classification rule is characteristic of patients with Alzheimer's disease and may be more pronounced when a category or exemplar has less well-defined features (Grossman et al., 2001). In the present experiment, controls may have switched from a similarity-based attribute approach to a rule-based strategy when these strong semantic-associative features were not available, a switch that patients were less able to make. Clearly we cannot make a strong claim that our data establish a rule-based or situational context generation deficit in schizophrenia since the task was not specifically designed to distinguish these components. Nonetheless, we believe that this explanation most adequately accounts for the observed pattern of results and awaits confirmation and replication.

The patient participants in our study were chronically ill, but stable, with mild to moderate symptoms. The size of the patient sample and relative absence of current formal thought disorder (i.e., 3/27 patients) precluded analysis of specific clinical subtypes. A number of investigators have found that patients with symptoms associated with language disturbance (i.e., formal thought disorder) demonstrate the greatest level of semantic impairments (Goldberg et al., 1998; Spitzer, 1997). The extent to which these deficits are attributable to semantic or executive system dysfunction (Barrera et al., 2005; Kerns and Berenbaum, 2002) and persist following treatment, remain important areas of investigation (Goldstein et al., 2002). We acknowledge that additional insight may be gained by 1) selecting patients with a broad range of clinical and cognitive symptoms, 2) assessment of longitudinal stability of categorization approaches and 3) alternate study designs that vary category exemplars and type of categorization procedure. These results, from a relatively homogeneous sample of people diagnosed with mild to moderate schizophrenia, have provided a number of novel findings that will encourage additional studies that can expand these findings.

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Appendix A. 12 by 12 matrix showing animal stimuli and number of shared semantic features

	1 Bear	2 Cat	3 Cow	4 Dog	5 Eleph.	6 Giraf.	7 Horse	8 Lion	9 Monk.	10 Rhino	11 Snake	12 Tiger
1. Bear	–	2	3	2	2	2	3	2	1	2	1	2
2. Cat	–	–	2	5	1	1	2	3	2	1	3	3
3. Cow	–	–	–	2	3	3	5	2	2	3	1	2
4. Dog	–	–	–	–	1	1	2	2	2	1	3	2
5. Elephant	–	–	–	–	–	5	3	4	4	6	0	4
6. Giraffe	–	–	–	–	–	–	3	4	4	5	0	4
7. Horse	–	–	–	–	–	–	–	2	2	3	1	2
8. Lion	–	–	–	–	–	–	–	–	3	4	1	6
9. Monkey	–	–	–	–	–	–	–	–	–	4	1	3
10. Rhino	–	–	–	–	–	–	–	–	–	–	0	4
11. Snake	–	–	–	–	–	–	–	–	–	–	–	1
12. Tiger	–	–	–	–	–	–	–	–	–	–	–	–

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