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Structured Imagination: The Role of Category Structure in Exemplar Generation

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College students imagined animals that might live on a planet somewhere else in the galaxy. In the first experiment, they provided drawings and descriptions of their initial imagined animal, another member of the same species, and a member of a different species. The majority of imagined creatures were structured by properties that are typical of animals on earth: bilateral symmetry, sensory receptors, and appendages. Subjects also allowed shape, appendages and sense receptors to vary often across species but rarely within species. In Experiment 2, subjects' creations were influenced by correlated attributes; those told that the animal was feathered were more likely to produce creatures with wings and beaks, and those told it lived in water and had scales were more likely to produce creatures with fins and gills relative to subjects who were told the animal was furry or who were given no specific features. Experiments 3 and 4 revealed that many subjects approach the task by retrieving exemplars of known earth animals, but that instructions and task constraints can lead to greater use of broader knowledge frameworks. Experiment 5 revealed that the structuring found in college students' imagined animals also holds for extraterrestrials developed by science fiction writers. The results are consistent with the idea that similar structures and processes underlie creative and noncreative aspects of cognition, and are discussed in terms of the concept of *structured imagination*. That is, when subjects create a new member of a known category for an imaginary setting, their imagination is structured by a particular set of properties that are characteristic of that category.

Category structures and processes play a central role in many human activities. Consequently, they have been studied heavily over the past three decades, with particular attention being given to the topics of category learning, classification, and inductive inference. Although these are important cognitive activities, categories serve many other functions which have yet to be studied as thoroughly. One of these is in the use of

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imagination to go beyond currently existing ideas and products. For example, category knowledge is certainly accessed and used when people invent and design new products, when they modify existing designs, when they develop new characters, creatures and scenes for works of fiction, and when they simply imagine nonexistent but possible members of known categories. As an example of this last activity, a common human tendency is to imagine better products (e.g., an inexpensive newspaper ink that does not come off on one's hands) even though the individual imagining them might never intend to try to develop them.

Despite the pervasiveness and importance of imaginative activities, systematic research on these more creative aspects of category knowledge is lacking. The present work is a beginning attempt to understand the way in which individuals go beyond existing category information to generate something new. As such it is part of a more general focus on creative cognition and the emergence of new ideas (Finke, Ward, & Smith, 1992).

In the paradigm I have developed, individuals are asked generate a novel exemplar of some known category that would be appropriate to some imaginary setting. Although this exemplar generation paradigm could be used with many categories, in the present experiments, subjects were asked to imagine, draw, and describe the kinds of animals that might exist on other planets. Similar generation procedures have been used in previous studies in which subjects have been asked, for example, to design new coins (e.g., Rubin & Kontis, 1983; Rubin, Stoltzfus, & Wall, 1991), but these studies have not been concerned directly with imagination. In fact, subjects in these earlier studies were explicitly requested not to be creative or silly. In contrast, the present focus is on the creative use of imagination.

Because imagination has had many scientific and lay meanings, it is important to note that, in the present paper, it is viewed as the *deliberate* mental generation of some *novel* entity (see e.g., McKellar 1957; Murray, 1986). This focus on deliberateness means that simply experiencing a novel mental event that conflicts with present reality, such as an hallucination, is not imagination in the sense considered here because such events are involuntary. The focus on novelty means that just deliberately generating an image of some known but absent entity, such as a late relative, is not in itself imagination because the entity in question is not *novel*. However, deliberately bringing to mind a known entity *to serve as a basis for generating a novel entity* (e.g., using a retrieved individual as a starting point for a new character in a work of fiction) would constitute using one's imagination.

It is also important to distinguish between using one's imagination and completing an entity that would be judged to be imaginative. When one attempts to develop a novel entity, one can be said to be using one's imagination. Whether the resulting entity would be judged to be imaginative depends on many factors including how closely it resembles known existing entities.

In considering the more generative aspects of human cognition, an important theoretical issue arises. How can we best conceptualize the process by which people imagine and produce new entities? One view of imagination is that it is a highly individualistic, inherently unpredictable phenomenon governed by processes and structures unlike those involved in other forms of cognition. This way of characterizing imagination is consistent with what Weisberg (1986, 1988) has called a "romantic" view of creative phenomena in which creative ideas emerge from unique, unobservable processes, divine inspiration, or some other unpredictable source rather than from standard processes of retrieving information from predictable knowledge bases (see also Perkins, 1981). By such a view, imagination could not be studied effectively via normative experimental approaches, and research on noncreative cognition would not be helpful in generating predictions about imaginative functioning. For example, if we gave several individuals the task of developing an imaginary animal, the idiosyncratic nature of creative functioning would result in each individual relying on personalized information and developing something different, and there would be little basis for predicting properties their creations would have in common.

An alternative view is that imaginative thinking and other creative endeavors are structured by the same sorts of principles and processes that are involved in noncreative cognitive activities (see e.g., McKellar, 1957; Perkins, 1981; Weisberg, 1986; 1988). A more specific version of this view that will be examined in the present studies is that imagination is directed by the same structures and processes that are involved in the basic phenomena of noncreative categorization. Because people from similar backgrounds share roughly similar category knowledge bases, if such knowledge is accessed in predictable ways in tasks of imagination, one would expect many commonalities to emerge across different individuals' creations.

As a straightforward means of deciding between these alternative views of imagination, one can initially look for commonalities across different subjects' creations. However, it is important to have some principled means of predicting what sorts of commonalities are to be expected because with no constraints on what would count as a meaningful similarity, one could readily identify trivial ones. Surely, if one examined a set of drawings of imaginary animals long enough, one would be able to find many things they have in common (e.g., that most of them are drawn in pencil or ink rather than charcoal), but this would tell us little about the role of shared knowledge about animals in directing imagination.

Importantly, the view that imagination is directed by existing category knowledge suggests that one can use empirical and theoretical developments from traditional approaches to categorization to make predictions about the properties that should be found in imagined exemplars; novel products generated through imaginative thinking should possess properties that are reliably observed in basic categorization studies. The more those properties apply, the more reasonable it is to describe imagination as being a predictable phenomenon that operates according to the same types of processes that characterize noncreative forms of cognition.

FRAMEWORK FOR PRESENT STUDIES

Several models of categorization have been developed, including those in which category information is represented in terms of prototypes (Posner & Keele, 1968; Reed, 1972), features (Hayes-Roth & Hayes-Roth, 1977), exemplars (Medin & Schaffer, 1978; Nosofsky, 1986), and episodic traces (Hintzman, 1986). Despite their differences, the models share the common feature that they have been concerned primarily with how people make decisions regarding category membership. In deciding about the category membership of some unknown entity, the individual presumably evaluates that entity against the stored representation, be it in the form of a prototype, features, exemplars, or episodic traces. To the extent that a presented object is determined to be similar to the stored representation, it is judged to be a category member.

Because none of these models was developed to predict how individuals might use their imagination to create a novel category member, each type would have to be expanded to make predictions about imagination. One simple way to do so would be to suggest that the stored representation that is used for making category decisions is the same information used to generate a novel member of the category. When subjects are given the task of generating a novel animal, for example, the label "animal" might lead them to retrieve typical exemplars of their animal category. They would then use those activated representations as a starting point for the new creation. Because all of the models contain information that would at least translate into characteristic features of known category members, they all would predict that newly generated exemplars will possess those characteristic features. That is, the characteristic properties that are so influential in category decision making should also be influential in the development of novel instances. Presumably, a person using imagination would create a novel entity that was similar to the stored representation by projecting characteristic properties of that representation onto the entity.

Of primary interest in the first experiments in this series, then, was the

extent to which subjects' imagined animals possess properties that are characteristic of typical earth animals. The initial concern was not to determine which of the possible models is the best in accounting for performance in tasks of imagination. Rather, it was to determine whether or not imagination is structured in a way that any of these expanded models would predict it to be.

In the first experiment, findings from traditional attribute-listing studies were used to predict the characteristic attributes subjects would include in single novel exemplars as well as the variations they would allow within and across species. That experiment also made use of the concept of basic-level categories to determine the extent to which subjects' creations were influenced by basic-level distinctions. In the second experiment, the concern was with the presence of attribute correlations in subjects' creations. To anticipate, the studies revealed a great deal of structuring by known category properties. The next two experiments were designed to determine how subjects approached the task of imagining their animals (e.g., retrieving exemplars versus accessing general principles) and the extent to which they responded to particular demand characteristics. At issue was the question of why imagination is so heavily structured. The final experiment examined the extent to which these same types of structuring generalize to creatures from the science fiction literature.

EXPERIMENT 1

In this experiment, subjects imagined, drew, and described an animal living on a planet that was very different from earth. In addition, they generated a second member of the same species and a member of a different species.

Because attribute-listing studies provide a sampling of properties that are salient in subjects' existing category representations, they are useful for predicting how subjects' novel creations might be structured. Specifically, when subjects are asked to list the characteristic attributes of members of the category "animal," they tend to include certain observable attributes such as eyes (Tversky & Hemenway, 1984) and legs (Ashcraft, 1978). They also tend to include legs, wings, fins, and other specific appendages as well as eyes when listing the common properties of birds, insects, fish, and mammals (Ashcraft, 1978; Hampton, 1979; Rosch, Mervis, Gray, Johnson, & Boyes-Braem, 1976; Tversky & Hemenway, 1984). Furthermore, subjects often list more abstract attributes such as moving, eating and breathing, which are typically supported in earth animals by the observable, functional attributes of appendages, mouths, and noses. Thus, these data lead to the prediction that, if imagination is structured by the salient properties of known categories, then subjects' initial imagined animals will possess these types of observable characteristic features.[1]

In addition, the attributes people list for particular animals should not be thought of as isolated. Rather, they are structured into coherent wholes of particular shapes (Tversky & Hemenway, 1984) which are almost always symmetric. Because people's category representations of particular animals must include some information about relations among their attributes, the property of symmetry is likely to be either directly or indirectly included in the representations of most instances of known animals subjects would retrieve as a basis for their creations. Thus, even though subjects do not typically list bilateral symmetry as an attribute of animals, it is reasonable to predict that the attributes they include in their imagined animals will be configured into bilaterally symmetric wholes.

Because attribute-listing data reflect beliefs about attributes that are shared by members of the same category, they also lead to the prediction that the second member of the same species will tend to match the first creation in terms of appendages and sense organs. Similarly, because shape and parts are more critical than size in subjects' judgments of category membership (e.g., Landau, Smith, & Jones, 1988; Ward et al. 1989), it should be expected that, if subjects carry such principles over to imagined entities, they will allow shape and appendages to vary less often than size within species.

Members of different species may or may not embody a same-shape/same-parts constraint. If subjects tend to make their imagined species differentiation at the subordinate level (e.g., by creating two separate bird-like species), then overall shape and parts will vary little across species. However, if they make at least a basic-level distinction (e.g., one bird-like and one fish-like species), then shape and parts would vary across species (see e.g., Tversky & Hemenway, 1984).

[1] It could be argued that less observable properties, such as genetic structure and the capacity for reproduction, growth, extraction of information from the environment, movement, and so forth are more central to individual's concepts of animals than are the directly observable properties examined here. As a practical matter, however, determining whether or not subjects spontaneously include the observable properties in their creations is much more direct that determining whether or not they include nonobservable properties. The attribute of "capacity for growth" would be difficult to detect in a drawing, and it would be unlikely to be mentioned unless the instructions included a rather direct probe for that information. The problem of direct probes is that it is not clear whether subjects actually considered that their creation should contain the given attribute while they were in the process of developing it. Thus as a beginning attempt to assess the structuring of imagination, I have focused on observable features. Importantly, however, it may be that including observable properties (e.g., eyes) would occur because subjects have beliefs that such properties are correlated with and are the external manifestation of more essential underlying properties (e.g., the need to extract information) (see e.g., Medin & Ortony, 1989).

Method

Subjects. The subjects were 37 undergraduates enrolled in introductory psychology courses who participated as one means of satisfying a course requirement to gain direct experience with psychological research.

Procedure. Subjects were tested individually. They were given blank sheets of paper on which they were to draw pictures of imaginary animals. They were first asked to imagine going to another planet somewhere else in the galaxy that was very different from earth, to imagine finding an animal there, and to draw a front and side view of the animal. After completing their drawings, subjects were asked a series of questions intended to tap the subjects' ideas about nonvisible properties as well as to help to disambiguate visible aspects of the drawings that could have been unclear.

Subjects were next asked to draw another member of the *same species* as the first one and were asked what was the same and what was different about the two instances of the same species. Finally, subjects were asked to draw another animal from the same planet that was a member of a *different species* and to state what was the same and what was different about this new species in comparison to the first.

Coding. The drawings were coded in terms of (a) the properties of the first animal, (b) differences between the first animal and the second member of the same species, and (c) differences between the first animal and the member of a different species. The major coding categories within each of these broad domains are shown in Table 1. These categories are self-explanatory except for the listing of "other" under appendages and sense organs. The "other" categories involved a determination of whether or not there was anything atypical about the sensory systems or appendages. The depiction of the appendages was considered to be atypical if a drawing included an attribute that is not characteristic of most typical animals on earth (e.g., suction cups or wheels for feet), or an unusual use for a characteristic appendage (e.g., taking in nourishment through the legs). The depiction of the senses was considered to be atypical if a drawing included an unusual configuration of the senses (e.g., a mouth higher in the head than the eyes), an exaggerated or atypical sensory ability (e.g.,

TABLE 1

Major Coding Categories

Properties of first drawing:	Differences within species:	Differences across species:
Bilateral symmetry	Shape	Shape
Appendages	Appendages	Appendages
Legs	Sense organs	Sense organs
Arms	Gender	Gender
Wings	Size	Size
Tails	Color	Color
Other	Texture	Texture
Sense organs		
Eyes		
Ears		
Nose		
Mouth		
Other		
Size		

infrared vision detectors), a novel use for a standard sensory system (e.g., detecting odors by way of the skin), or some other feature that is not characteristic of most typical animals on earth (e.g., eyes at the end of long stalks).

Two trained individuals coded the drawings and responses of each subject. The coders relied primarily on the drawings in making their judgments, but subjects' responses to questions were used to clarify any ambiguities. As an example, thin tubular structures extending from the underside of the creature toward the bottom of the page (or ground) were coded as legs as long as the subject's verbal responses indicated that they were legs or those structures had enlarged areas at the ends that subjects labeled as feet. This approach reduced the likelihood of coding tentacles or some other novel structure as the more common property of legs. Occasionally, subjects gave functional information rather than an attribute name (e.g., "it has good eyesight"). These functional descriptions were also used to confirm the perceptual information available in the drawings. Intercoder reliability was computed for each of the rating categories using the formula (agreements − disagreements)/(agreements + disagreements). The reliabilities ranged from .84 to 1.00.

Initial coding data were used to develop three additional measures: unusual sense organs, unusual appendages, and the number of major differences from earth animals in general. The sense organs or appendages were classified as unusual if they had been categorized as atypical (see above) or if there was an unusual number of sense organs (e.g., three eyes) or appendages (e.g., nine legs), respectively. The possible number of major differences ranged from 0 to 5. A creature received a point for each of the following: asymmetry, lack of major appendages (legs, wings or arms), lack of major sense organs (eyes, ears, or nose), unusual appendages, and unusual sense organs. Note that a creature could receive a point for lack of major appendages (or sense organs) and also for unusual appendages (or sense organs). For example, the creature might have no legs, arms or wings but possess wheels that it uses to move around.

Results and Discussion

Properties of first animal. The vast majority of animals were bilaterally symmetric (89%), had at least one major sensory organ (eyes, ears, or nose) (92%), and at least one type of major appendage (legs, arms, or wings) (84%). Table 2 presents a breakdown of the numbers of subjects who included specific sense organs and appendages. As shown in that table, creatures with eyes were more common than those with ears or noses, and creatures with legs were more common than those with arms or wings. In addition, as shown in Table 2, those who included sense organs and appendages tended to depict creatures with typical numbers of those features. In many respects then, the properties of the subjects' initial creations were those that are highly typical of animals on earth.

TABLE 2

Number of Imagined Animals That Had Arms, Legs, Wings, Eyes, Ears, and Noses, and Typical Values of Each of Those Attributes

Type of attribute	Present in creature	Having typical value
Arms	11	9
Legs	29	24
Wings	4	4
Eyes	33	24
Ears	19	19
Nose	22	22

Note. Maximum possible number is 37. Creatures were counted as having a typical value of an attribute if they had two arms, wings, eyes and ears, one nose, and two or four legs.

Despite the overwhelming tendency to produce creatures that were symmetric and had typical appendages and sense organs, subjects did not always produce creatures that were identical to animals on earth. For example, a majority (57%) developed creatures whose senses were classified as unusual, and a substantial percentage (30%) developed creatures with unusual appendages. In addition, most individuals created animals with at least one major difference from earth animals (65%). On the other hand, creatures with more than two major differences from animals on earth were uncommon (11%). Thus, the overall tendency was to produce creatures that differ from earth animals in only a limited number of ways. Examples of creatures containing a range of differences from earth creatures are depicted in Fig. 1.

Differences within and across species. As shown in Table 3, only a minority of individuals drew a second member of the same species that differed from the first in overall shape, in the number or type of major appendages, or in the number or type of sensory receptors. Those few variations that were included tended to be distributed across different subjects; it is not the case that a small group of individuals tended to vary all three properties within species. The percentages of individuals who varied 0, 1, 2, or 3 of the properties were 59, 30, 11, and 0, respectively.

As can be seen in Table 3, in contrast to the limited variation within species, the majority drew a member of a new species that differed from the first creation in shape, appendages, or sense organs. Using a test of a difference between proportions from correlated samples, all three values are significantly higher across species than within species, $\chi^2(1) = 31.00$, $p < .01$ for shape, $\chi^2(1) = 18.61$, $p < .01$ for appendages, and $\chi^2(1) = 13.00$, $p < .01$ for sensory receptors.

In contrast to the greater variation across than within species noted above, subjects explicitly varied gender only within species (11%), and they were somewhat more likely to explicitly vary size within species than they were to vary it across species, although the difference was not significant $\chi^2(1) = 1.67$, $p > .20$. In a related way, in generating a second member of the same species they were significantly more likely to vary size than either shape, $\chi^2(1) = 12.80$, $p < .01$, or appendages, $\chi^2(1) = 10.89$, $p < .01$, and in generating a member of a different species, they were significantly less likely to vary size than either shape, $\chi^2(1) = 18.18$, $p < .01$, or appendages, $\chi^2(1) = 7.35$, $p < .01$ (see Table 3). Thus, the pattern of allowed variations differed within and across species. Subjects

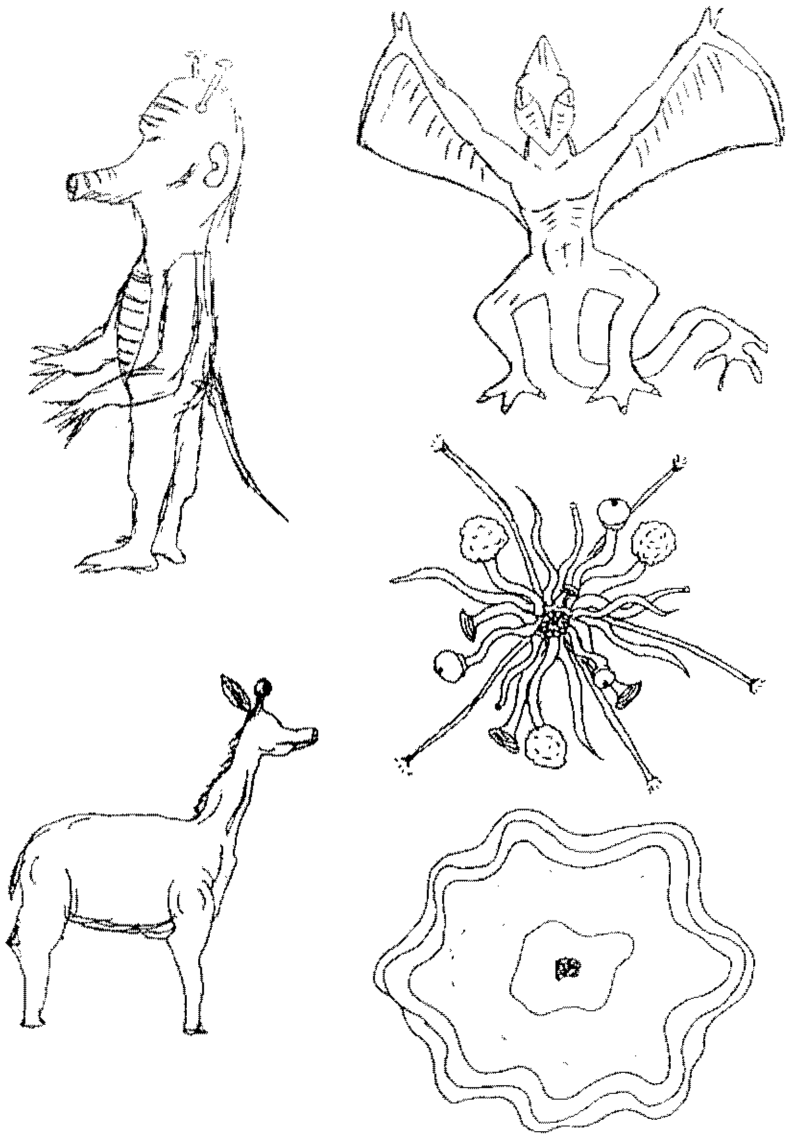

FIG. 1. Examples of creatures from Experiment 1 that contained a range of characteristic features of typical animals on earth and a range of major differences from earth animals.

were not simply using the heuristic that members of the same species ought to be more similar to each other than members of different species. Rather, they selectively emphasized some types of differences more than others for the different contrasts.

TABLE 3
Percentages of Subjects Who Varied the Shape, Sense Organs, Appendages, or Size of the Creatures within and between Species

Attribute	Varied within species	Varied across species
Shape	11	95
Sense organs	24	59
Appendages	16	76
Size	54	40

Taken together the results indicate that, when subjects generate new exemplars of the animal category for an imaginary setting, their creations are highly structured. The properties included in the first exemplars are ones that are often listed as being characteristic of common animals on earth (e.g., legs and eyes). In addition, the pattern of shape variations within and between species is consistent with data from attribute-listing studies (see e.g., Tversky & Hemenway, 1974), and with the idea that subjects treat the task of generating members of different imaginary species as being one of generating members of different basic-level categories. The fact that subjects varied size more often than shape or appendages within their imagined species also indicates that they extend to imaginary animals on other planets the idea that members of existing basic object categories ought to match in shape and parts but can differ in size (e.g., Ward et al, 1989). Thus, the type of knowledge that influences responding in traditional attribute-listing and classification tasks also manifests itself in the generation of new category members.

The greater importance of size and gender variations within species suggests that the projection of similarities and differences onto imagined animals may be guided by a broad relational structure in much the same way that noncreative categorization and similarity assessment are guided by an alignment of relational structures (see e.g., Markman & Gentner, 1993; Medin, Goldstone, & Gentner, 1993). In the present case, the relational structure is apparently a highly predictable one that would apply in imaginative and noncreative categorization tasks, and that helps to specify the most relevant attribute variations to consider for comparisons within and across species. For example, although a woman and a gander differ in sex, our broad understanding of the attribute differences that are most relevant to cross-species comparisons may provide a framework that decreases the relative salience of that difference and enhances the salience of other differences, such as appendages and means of movement. That same framework would increase the salience of a sex difference within species as in a comparison between a goose and a gander.

EXPERIMENT 2

The first experiment provides evidence that characteristic attributes of individual animals and characteristic differences within and between species influence the generation of novel exemplars. The next experiment examined the extent to which imagination is structured by another pervasive phenomenon that has been revealed in traditional studies of categorization: sensitivity to attribute correlations.

It is widely noted that the attributes of natural categories tend to cooccur (see, e.g., Mervis & Rosch, 1981; Rosch 1978; Rosch et al., 1976). A classic example of this phenomenon is that the properties of feathers, beaks, and wings are much more likely to occur together than are fur, beaks, and wings. Given the pervasiveness and importance of correlated attributes as a structuring principle in human categorization, attribute correlations are good candidates for possible structuring principles for imagination.

Experiment 2 was designed to examine the extent to which subjects' creations are influenced by knowledge of attribute correlations. Subjects were given no special information about the imaginary animals, or they were told that the animals had feathers, or fur, or that they lived in water and had scales. Based on the clusters of attributes people list as characteristic of birds and fish (e.g., Tversky & Hemenway, 1984; Hampton, 1979), it should be expected that subjects will tend to create feathered creatures that have wings, beaks and only two legs and scaled creatures that have fins, gills, and no legs. In addition, the overlap in feature listings for "animal" and various mammals suggests that subjects will tend to create similar creatures in the fur and neutral conditions (Ashcraft, 1978).

Method

Subjects. One-hundred and eighty individuals recruited from psychology classes participated in Experiment 2. None had participated in Experiment 1.

Procedure. Subjects were asked to imagine and draw an animal living on a planet very different from earth. Equal numbers of subjects participated in one of four conditions: control subjects received no special information about the imaginary animal, others were told either that the creature had feathers, that it was furry, or that it lived in water and had scales. After completing their drawings, subjects wrote descriptions of what they had taken into account in developing their creatures. Because pilot data revealed a tendency for many subjects to base their creations on specific instances of animals on earth, those descriptions were examined for references to specific species. This allowed a check on whether any differences between the creatures developed in the different conditions were related to the types of known exemplars subjects accessed. In addition, subjects' statements were examined for references to the creatures' environments as a way of assessing their tendency to reason from broader knowledge about adaptation to environments. All subjects' creations were examined by two coders, and, as measured by the same formula from Experiment 1, reliabilities ranged from .81 to 1.00.

Results and Discussion

Comparisons of appendages. As predicted, subjects in the feather condition were significantly more likely than those in the other conditions to draw creatures that had wings, $\chi^2(1, N = 180) = 79.69, p < .001$, whereas those in the scales condition were significantly more likely than the others to develop creatures with fins, $\chi^2(1, N = 180) = 77.02, p < .001$ and significantly less likely to develop creatures with legs, $\chi^2(1, N = 180) = 32.45, p < .001$. The magnitudes of these differences between the critical conditions and the other conditions are evident in Fig. 2, which also reveals the relatively minor differences across the other conditions on these variables.

Although subjects in the control, feather, and fur conditions were highly and equally likely to produce creatures with legs, those in the feather condition developed more animals with two legs (67%) than those

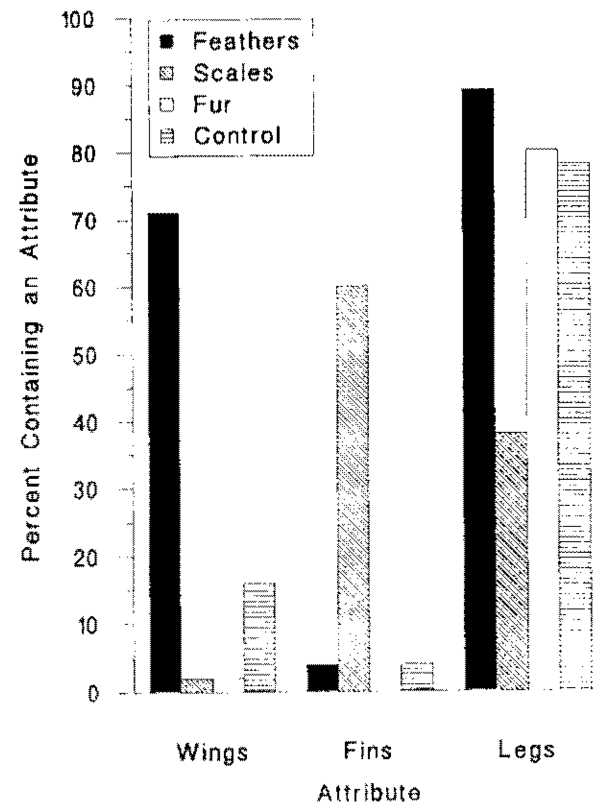

FIG. 2. Percentages of creatures from each condition of Experiment 2 that had wings, fins, and legs.

in either the control (38%) or fur (38%) conditions, $\chi^2(1, N = 90) = 7.53$, $p < .01$ in both cases. This last effect is predictable from the fact that attribute-listings specifically restrict birds, but not other animals, to two legs (Ashcraft, 1978; Hampton, 1979; Tversky & Hemenway, 1984). Regardless of differences across conditions in the *types* of appendages included, subjects in all conditions were equally likely to include one or more major appendage (arms, legs, wings, or fins). The percentages for the control, feather, fur, and scales conditions were 89, 96, 87, and 93, respectively.

Comparisons of sense organs and other properties. As expected, subjects in the feather condition were significantly more likely than those in the other conditions to develop creatures with beaks, $\chi^2(1, N = 180) = 73.18$, $p < .001$, and those in the scales condition were significantly more likely to develop creatures with gills, $\chi^2(1, N = 180) = 43.54$, $p < .001$. The magnitude of the effects, and the similarity in the extent of use of these attributes across the other conditions is evident in Fig. 3. Interestingly, there was also a significant difference across the conditions in the tendency of subjects to produce creatures with ears, $\chi^2(3, N = 180) = 16.20$, $p < .01$. As shown in Fig. 3, this effect is based on the fact that subjects in the feather and scales conditions were less likely than those in the control and fur conditions to draw creatures with ears. Although not directly predictable from attribute-listing data, the limited use of ears in the feather and scales conditions is sensible when considering the fact that birds and fish, the prototypic feathered and scaled creatures, do not have prominent ears; birds have an auricular region that is not perceptually salient, and fish lack even that. This last finding highlights the fact that new influential category properties (e.g., new attribute correlations) can be discovered in tasks of imagination, which can in turn generate predictions about what to expect in noncreative categorization tasks. As was true for major appendages, subjects in the control, feather, fur, and scales conditions were highly and equally likely to include at least one major sense organ (96, 98, 100, and 98%, respectively).

Examples of creations from the control, feather, fur, and scales conditions are shown in Figs. 4a–4d, respectively. Most of the major differences across the conditions are illustrated in these creations.

Subject reports. Table 4 shows the percentage of subjects in each condition whose open-ended statements included a mention of relying on mammals, birds, or fish in developing their creatures. The percentages include references to specific members of each class, or to the class itself,[2] and they include statements about using the whole entity (e.g., a

[2] The vast majority of these statements involved basic-level terms, such as dog and cat, rather than more general or more specific terms.

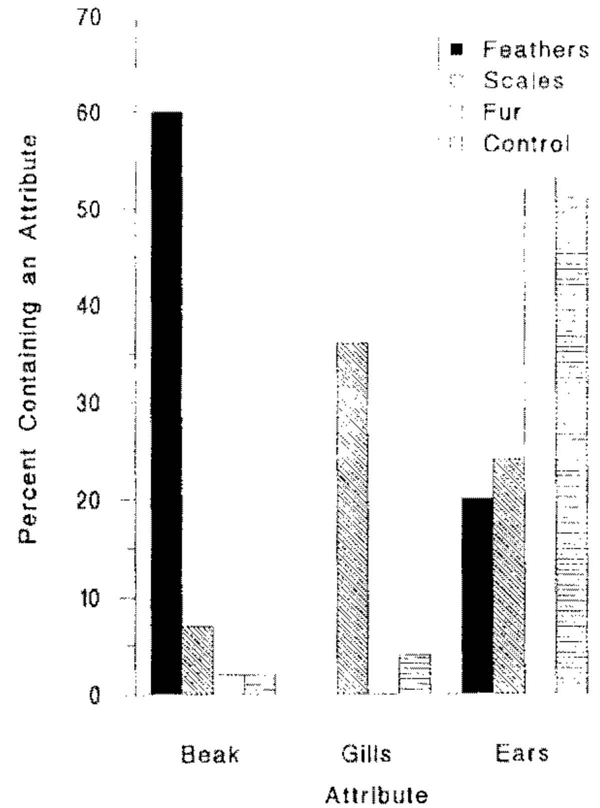

FIG. 3. Percentages of creatures from each condition of Experiment 2 that had beaks, gills, and ears.

dog) or only parts of it (e.g., the neck of a giraffe). As can be seen, there were systematic differences across the conditions, $\chi^2(3, N = 180) = 15.29$ for mammals, 86.10 for birds, and 73.08 for fish. The greater reported reliance on mammals, birds, and fish in the fur, feather, and scales conditions, respectively, is highly consistent with the properties of subjects' creations in those conditions, and suggests that the observed differences in subjects' creations are based, at least in part, on the types of earth animals they accessed in performing the task. Subjects appear to have a tendency to base their creations on typical earth animals, but which earth animals are considered most "typical" varies with the context, much as it does in less creative tasks (e.g., Barsalou, 1987).

The link between the animals subjects reported using and the details of their creations was even more direct as revealed by the fact that subjects in the feather condition who mentioned relying on birds were significantly more likely than the others in that condition to produce birdlike creatures

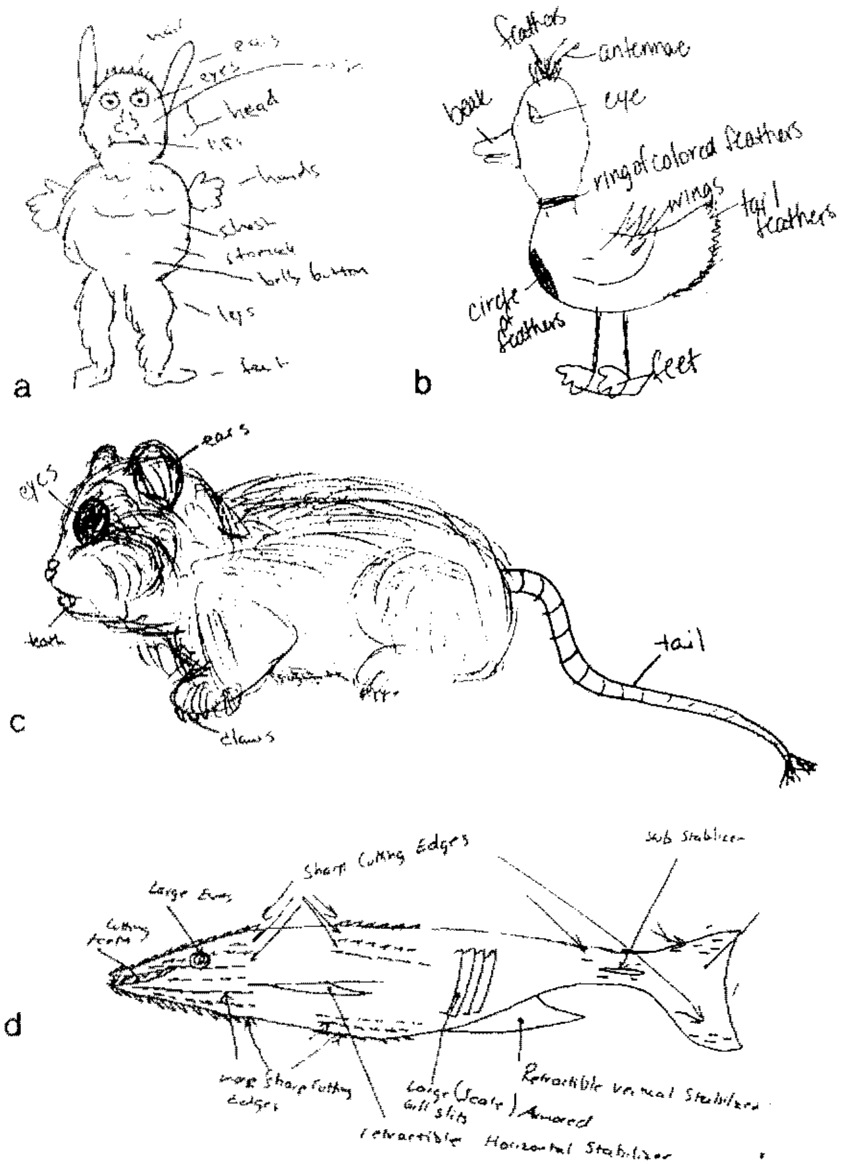

FIG. 4. Examples of imaginary animals developed by subjects in the control (a), feather (b), fur (c), and scales (d) conditions of Experiment 2.

TABLE 4
Percentages of Subjects in the Different Conditions of Experiment 2 Who Spontaneously Reported Using Mammals, Birds, or Fish, and the Percentage Who Reported Using any Type of Earth Species in Developing Their Imaginary Animals

	Condition			
Earth animal	Feathers	Scales	Fur	Control
Mammals	31	20	58	44
Birds	69	7	4	4
Fish	2	56	2	2
Any specific	84	82	62	58

(possessing at least five of the following: wings, beaks, two legs, claws or talons, bird-shaped bodies, and absence of arms), (58% versus 14%), $\chi^2(1, N = 45) = 7.48, p < .01$. Likewise, subjects in the scales condition who reported relying on fish were significantly more likely than the others to develop fishlike creatures (possessing at least four of the following: fins, gills, fish-shaped body, no legs, and no arms), (48% versus 15%), $\chi^2(1, N = 45) = 5.44, p < .05$. The creatures shown in Figs. 4b and 4d are birdlike and fishlike examples.

As shown in Table 4, a majority of subjects in all conditions reported at least some reliance on particular types of earth animals. Collapsing across conditions, those who did so were significantly less likely than the other subjects to produce creatures with unusual appendages (16% versus 29%), $\chi^2(1, N = 180) = 3.94, p < .05$, or unusual senses (26% versus 41%), $\chi^2(1, N = 180) = 4.23, p < .05$. In other words, subjects who report relying on particular earth species, appear to become fixated on the properties of those animals (i.e., normal appendages and senses) and their creations contain fewer innovations. These effects parallel others in which subjects' creations are found to conform to the properties of experimenter-presented examples (Jansson & Smith, 1991; Smith, Ward, & Schumacher, 1993), and they suggest that examples, whether self- or other-generated, can limit the extent of innovation in newly developed entities. Despite these differences in the nature of the appendages and senses, subjects who relied on specific earth animals were no more likely than the others to include major appendages (92% versus 88%), or major sense organs (98% in both cases). As was true of the contrasts across conditions, such attributes appear to be included regardless of subjects' approaches, although their specific manifestation can vary. Only a minority of subjects' statements across the conditions contained references to the creatures' environments (27%).

The results of this experiment indicate that the attribute correlations evident in subjects' listings of characteristic features of various animals also emerge when individuals imagine novel creatures. The effects seem to be due, at least in part, to shifts in the types of earth animals subjects retrieve in performing the task. Thus, the type of knowledge about attribute correlations that is apparent in attribute-listing, learning, classification and inference (see e.g., Mervis & Rosch, 1981; Rosch et al., 1976; Tversky & Hemenway, 1984; Wattenmaker, Dewey, Murphy, & Medin, 1986) is also manifested when categories are used to create something new.

EXPERIMENT 3

Another pervasive categorization phenomenon is that the attributes and correlations people attend to in noncreative tasks are heavily influenced by belief systems and naive theories (e.g., Chapman & Chapman, 1969; Murphy, 1988, Murphy & Wisniewski, 1989; Wattenmaker, Nakamura, & Medin, 1987; Wisniewski & Medin, 1991). Thus, it might be predicted that such knowledge will also impact on imaginative thought. On the other hand, it may be that broad knowledge structures can play a more limited role in imaginative activities. For example, once stored as part of a category representation, attributes could manifest themselves in new creations simply through retrieval of exemplars that contain those properties rather than through activation of the belief system that drove the original learning. For instance, feathered creatures may be drawn with wings (Experiment 2) because "feathered" leads people to retrieve exemplars of birds, which, only coincidentally happen to have wings, rather than because people access their general knowledge about why it makes sense for feathers and wings to be correlated. Subjects' reports of heavy reliance on specific animals are consistent with this possibility. Thus, the previous experiments do not provide compelling evidence that naive theories impact on imaginative uses of categories.

The present experiment sought to provide more direct evidence of the role of broader knowledge by giving subjects specific information about the planet prior to their creation of an imaginary animal. One planet was described as mostly molten rock with only a few islands of solid land, and the ability to travel from one island to the next to obtain food was described as an important adaptation. The other planet was described as having extremely violent winds swirling around it just above the surface, and avoiding the winds was described as important to survival. In addition, subjects were told either that the creature had feathers or that it had fur.

Although feathers and fur may be linked to specific instances of earth animals, the novelty of the environments means that subjects can not simply retrieve a specific exemplar that they already know to live in such an environment. If the specification of the environment is to have an

impact on their creations it will do so as a result of subjects accessing and reasoning from their more general knowledge about the kinds of organisms that could sensibly be believed to survive in particular types of environments.

An intuitively sensible adaptation to the survival demands of the molten planet that would reflect characteristic attributes of earth animals would be a creature with wings that could fly over the molten areas from one island to the next. In contrast, a sensible adaptation to the windy planet would be a flightless creature that spent most of its time close to the ground. Thus, if general knowledge about adaptation to environments is brought to bear on this task of imagination, winged and flying creatures should be more common in the molten than in the windy conditions. In addition, the environments may encourage subjects to access general knowledge to develop other specialized adaptations.

The present experiment also provided a test of the hypothesis that subjects' approaches to the task are under strategic control. After drawing their creature, subjects responded to a questionnaire regarding their approaches. The conditions should differentially favor particular approaches. Specifically, the demands of the molten planet and the presence of feathers both favor the use of birdlike exemplars. Thus, subjects in that condition should be highly likely to report basing their creations on specific exemplars; feathers may lead to the retrieval of birds (Experiment 2), and nothing about the molten environment would conflict with their survival. Because a reliance on specific animals appears to limit the modifications subjects impose on their creations, they also may be less likely than other subjects to include particular adaptations of the senses and appendages. In contrast, the demands of the molten planet conflict with most specific furry exemplars that would be retrieved (because they do not fly) and the demands of the windy planet conflict with most specific feathered exemplars (because they do fly). The demands of the windy planet do not necessarily conflict with the attributes of most furry exemplars, but there are also no unique examples of known furry creatures that would be as well adapted to the demands of that planet as birds would be to the demands of the molten planet. Thus in these last three conditions, reported reliance on specific exemplars may be reduced and modifications to meet the demands of the planets may be increased relative to the molten planet-feathered animal condition.

Method

Subjects. Eighty students enrolled in a psychology class participated. None had been in any of the previous studies.

Procedure. Subjects were asked to imagine and draw an animal that might live on a planet completely different from earth. They were divided into four equal-sized groups defined by crossing two levels of animal description with two levels of planet description. The animal was described as having either feathers or fur. The planet was described as being covered mostly with seas of molten rock with only a few small islands of solid land between them or as having extremely violent winds swirling around the entire planet from about two feet off of the surface all the way into the upper reaches of the atmosphere.

After completing their drawings, subjects described the special features of their animals that made them well-suited to living on the planet. Subjects also responded to questions about whether or not the animal walked or flew as a major means of transportation and the exact way in which the animal moved about. Finally, subjects responded to a questionnaire regarding their approaches to the task.

Coding. Drawings and descriptions were coded for many of the same properties as in previous experiments. In addition, descriptions were coded for the presence of particular adaptations such as flight, heat-resistant coverings, other protective devices, various specially adapted appendages and sense organs, shortness or closeness to the ground, heaviness, stockiness, and a streamlined shape. Two coders who examined all creations achieved reliabilities ranging from .80 to 1.00.

Results

Wings and flight. As shown in Table 5, the highest percentage of winged creatures occurred in the Molten–Feather condition and the lowest occurred in the Windy–Fur condition. The percentage of winged creatures in the Molten–Feather condition was significantly higher than in any of the other conditions, $\chi^2(1, N = 40) = 10.00$, 32.73, and 13.33 for the Molten–Fur, Windy–Fur, and Windy–Feather conditions, respectively. The percentage of winged creatures in the Windy–Fur condition was also significantly lower than in the Molten-Fur, $\chi^2(1, N = 40) = 10.99$, $p < .01$, and Windy–Feather, $\chi^2(1, N = 40) = 7.62$, $p < .05$ conditions, which did not differ significantly from each other, $\chi^2 < 1$.

As shown in Table 5, a similar pattern held for the percentage of creatures that were described as fliers. Subjects in the Molten–Feather condition were significantly more likely than those in the Windy–Fur and Windy–Feather conditions to develop flying creatures, $\chi^2(1, N = 40) = 25.60$, $p < .001$, and $\chi^2(1, N = 40) = 12.90$, $p < .001$, respectively. They were not, however, significantly more like to produce flying creatures than those in the Molten–Fur condition, $\chi^2(1, N = 40) = 2.5$, $p > .10$. Interestingly, subjects in the Molten–Fur condition were significantly more likely to produce flying creatures than those in the Windy–Feather condition, $\chi^2(1, N = 40) = 4.91$, $p < .05$. In other words, an environment that would encourage flight resulted in more flying creatures even though they were furry than an environment that would discourage flight even though the creatures had feathers.

TABLE 5
Percentages of Subjects in the Different Conditions of Experiment 3 Who Developed Creatures with the Attributes of Wings and Flight

	Condition			
Property	Molten fur	Molten feather	Windy fur	Windy feather
Wings	60	100	10	50
Flight	70	90	10	35

The tendency of subjects in the Windy–Feather condition to produce creatures whose normal means of movement is flight is actually even less than indicated in Table 5. The data in that table include any creatures that were described as capable of leaving the ground and travelling through the air. Six of the seven subjects who developed "flying" creatures in the Windy–Feather condition placed restrictions or qualifications on the creature's flight which are revealing with respect to their thinking about how the environment might impact on animals. For example, one subject suggested that the creature did not ordinarily fly, but that the feathers made it possible for it to glide down safely if it got caught up in the wind. Another developed the creature shown in Fig. 5 which can move through wind by way of a kind of windmill rotation.

Other adaptations. Subjects included features in their creations that were specifically designed to meet the environmental conditions of the different planets. For example, 22 of the 40 subjects in the Windy conditions developed creatures that had suction cups on their feet, or claws, or other appendages for gripping or digging into the ground. Only one individual in the Molten conditions developed a creature with such an appendage. In contrast, 11 of the 40 subjects in the Molten conditions developed creatures that had specially adapted heat-resistant feet that allowed them to stand on, or swim through, molten rock. None of the subjects in the Windy conditions developed creatures with this type of appendage.

Useful sensory adaptations included special devices to detect wind speed and direction (mentioned by 3 subjects in the Windy conditions but none in the Molten conditions), and sensors to detect or regulate heat or to extend vision into the infrared or ultraviolet regions of the spectrum (mentioned by 7 subjects in the Molten conditions and none in the Windy conditions). One subject, for example, described an extension of the visual sense that would allow the animal to detect colder prey against the hotter background of the molten planet. Subjects also developed various devices to protect the senses from wind and blowing sand/debris (17 subjects in the Windy conditions) or heat/glare/smoke (7 subjects in the Molten conditions).

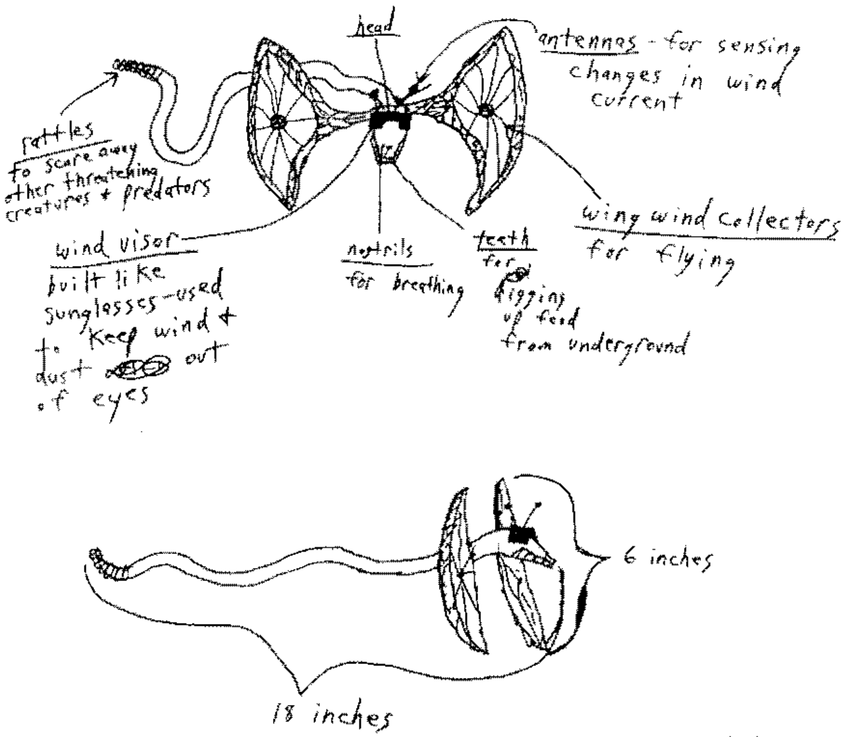

FIG. 5. Example of a flying creature from Experiment 3 having an atypical means of flight.

Other reasonable adaptations commonly mentioned by subjects in the Windy conditions included shortness or closeness to the ground (to stay below the winds) (50%), extreme heaviness (50%), stockiness (15%), aerodynamic or streamlined shape (15%), and four or more legs (to provide a stable base) (60%). These same attributes were included by only 5, 7, 0, 2, and 25%, respectively, of subjects in the Molten conditions.

Interestingly, although these differences across conditions reveal the impact of broad knowledge about the adaptation of organisms to environments, there were also some indications that specific types of exemplars may have interacted with that knowledge to determine the exact types of adaptations subjects considered. For example, all of the subjects in the Windy conditions who produced stocky creatures had been told that the creature was furry. In contrast, 5 of the 6 subjects in the Windy conditions who produced streamlined creatures had been told that the creature was feathered. Likewise, 16 of the 24 creatures that had four or more legs were created by subjects who had been told the creature was furry. The

findings are consistent with the idea that the attributes of fur and feathers led people to retrieve specific or general information about mammals and birds, respectively, and that the properties of those types of animals influenced the nature of the subjects' creations. That is, because mammals would tend to be less streamlined and have more legs than birds, retrieval of one or the other would be expected to constrain adaptations in the way described above.

Impact of conditions on subjects' approaches. As expected, subjects in the Molten–Feather condition were more likely than those in the other conditions to report basing their creations on specific exemplars of earth animals (65% versus 37%) and less likely to report approaches dominated by a consideration of the environment and/or general properties of animals (10% versus 55%), $\chi^2(1, N = 70) = 10.27$, $p < .05$. Consistent with these reports, significantly more of the flying creatures were birdlike in the Molten–Feather condition (13 of 18) than in the Molten–Fur condition (4 of 14), $\chi^2(1, N = 32) = 6.02$, $p < .05$, a finding that parallels the concomitant reliance on exemplars of birds and development of birdlike creatures in the feather condition of Experiment 2. Figure 6 shows ex-

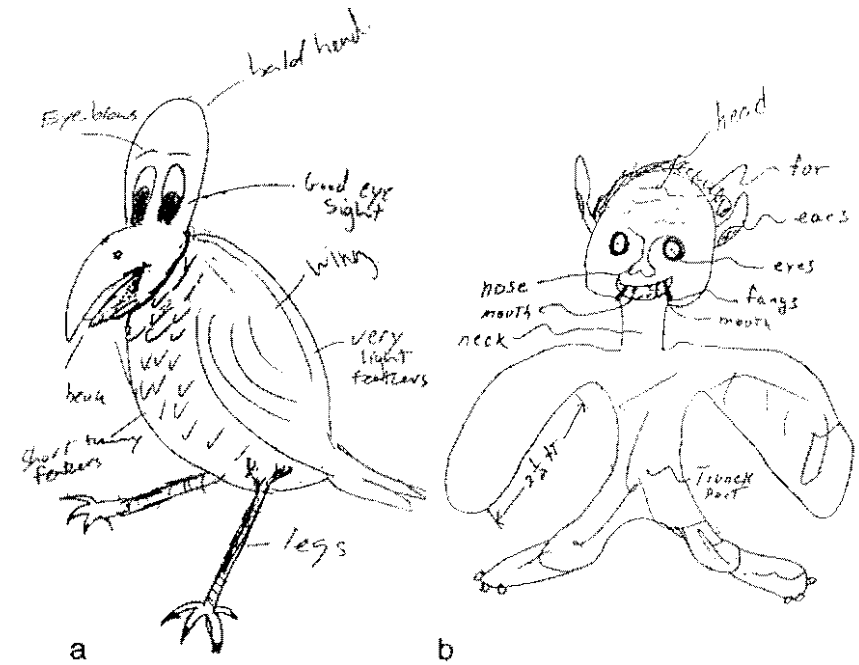

FIG. 6. Examples of birdlike (a) and non-birdlike (b) animals from the Molten–Feather and Molten–Fur conditions, respectively, of Experiment 3.

amples of birdlike and non-birdlike flying creatures from the Molten conditions. In addition, consistent with their greater reported reliance on specific instances of earth animals and the results of Experiment 2, subjects in the Molten–Feather condition were less likely than subjects in the other conditions to produce creatures with novel adaptations to the appendages (30% versus 57%), $\chi^2(1, N = 80) = 4.27, p < .05$, or senses (15% versus 43%), $\chi^2(1, N = 80) = 5.21, p < .05$. Having specific models in mind appears to limit innovation.

Discussion

The most important finding of this study is that specification of a novel environment influenced subjects' creations in predictable ways. When given an environment in which flight would be highly adaptive, most subjects created flying creatures; when given an environment that would be hostile to flying creatures, most subjects developed creatures that did not fly. In addition, subjects included modifications that were sensible given the environmental demands of the different planets. Because the planetary conditions were novel, subjects could not have simply retrieved exemplars that they knew lived in those environments. Rather, they must have used more general knowledge about the kinds of animals and attributes that would be adapted to particular kinds of environments. In addition, the results indicate that broad knowledge can be at least as powerful as specific exemplars in influencing subjects' creations; even though the presence feathers would be likely to lead to the retrieval of exemplars of birds, there were more flying creatures in the Molten–Fur than in the Windy–Feather condition.

The results also indicate that the process by which individuals imagine new entities is flexible and can include retrieval of specific instances as well as synthesis of new exemplars based on general knowledge and environmental considerations. For example, self-reports and the birdlike nature of their creations indicate that subjects in the Molten-Feather condition directly retrieved and used birdlike exemplars. In contrast, self-reports and the fact that their flying creatures were not very birdlike indicate that subjects in the Molten–Fur condition developed creatures by synthesizing the kinds of novel organisms that would be best adapted to the environmental conditions; only wings and flight are critical, not other birdlike properties.

EXPERIMENT 4

The previous experiments demonstrate that, when individuals are asked to imagine novel entities, their creations are structured in ways that are predictable from prior empirical and theoretical work on the more traditional, nongenerative functions of categorization. An important question that remains is *why* subjects' creations are so highly structured. The present experiment addressed two aspects of this question, with the most important one being whether or not the structuring is due to the perceived demand characteristics of the situation. Do subjects only include typical features of earth animals because they believe, for example, that they are supposed to draw creatures that would be believable or understandable to another individual (e.g., the experimenter)? Because subjects in the previous studies were given no special instructions to be either imaginative or imitative, it is possible that they adopted a conservative strategy as a default.

To address this question about expectations, subjects in the present study were given different instructional sets. Some were told that they should try to create animals that were realistic and believable, whereas others were told to use their wildest imagination without concern for creating a believable creature. If subjects develop creatures with earthlike characteristics only because they perceive a demand to create something believable, then subjects in the wild imagination condition should be less likely to include those characteristic features.

A second component of the "why" question concerns the knowledge domain subjects use to structure their creations. The assumption in the previous studies was that they were using knowledge about animals on earth and extending it to creatures elsewhere in the universe. However, an alternative hypothesis is that subjects based their creations more directly on knowledge about extraterrestrials as gleaned from science fiction books, movies or other sources. Although references to science fiction sources were not common in subjects' open-ended statements (Experiment 2), it is possible that they used this type of information but failed to state it spontaneously. In the present experiment, subjects in all conditions responded to direct questions about the basis of their creations. In addition, the present experiment included a condition in which subjects were to imagine an animal that lives on a previously undiscovered island on earth. Because they were to create a novel earth creature, subjects in this condition should be highly likely to access knowledge about other earth animals in generating exemplars. To the extent that subjects assume the properties of earth creatures are relevant for life on other planets as well as for life on earth, the reported approaches and included properties should be similar to those in the other conditions.

Method

Subjects. The subjects were 94 college students enrolled in an introductory psychology course.

Procedure. Subjects in three of the four conditions were asked to imagine an animal on a planet completely different from earth. Of those individuals, the 22 subjects in the *Control* condition were given no special instructions about how to create that animal. The 22 subjects in the *Wild Imagination* condition were told that they should use their wildest imagination and not to be concerned with creating an animal that would make sense or be believable to anyone else. The 22 subjects in the *Believable* condition were instructed to try to create an animal that would be believable to other people and that could actually exist. The remaining 28 subjects participated in an *Earth* condition in which they were told to imagine an animal living on an as-yet-undiscovered island on earth. As was true for the subjects in the Control condition, these individuals were given no special information about how to develop their animals.

After subjects completed their creations, their drawings were collected and they filled out a questionnaire regarding their approach to the task. The alternatives listed on the questionnaire included basing the creation on specific known earth animals, specific known science fiction creatures, general attributes of animals on earth, general attributes of science fiction creatures, considerations about the environment on the planet or island, starting to draw and seeing what took shape, and other approaches that were to be described by the subject. Subjects were allowed to choose more than one alternative.

Two trained coders examined all subjects' creations. Reliabilities ranged from .77 to 1.00.

Results

Manipulation of expectations. Subjects in the Control, Wild Imagination and Believable conditions were highly and equally likely to create animals that had major appendages, senses, and symmetry (all $\chi^2 < 1$). Thus, the inclusion of those properties is not dependent on expectations that believable creatures are required. The data for appendages and symmetry are shown in Fig. 7; data for sense organs are not included because all subjects included senses regardless of condition.[3]

Importantly however, the manipulation of expectations was not entirely without effect. Subjects in the Wild Imagination condition were significantly more likely than those in the Believable condition to produce creatures that had something unusual about their sensory systems (see Fig. 7), $\chi^2(1, N = 44) = 7.37$, $p < .01$. Thus, although the presence of major senses appears to be essential regardless of instructional set, the exact manifestation of those senses can vary. As can be seen in Figure 7, subjects in the Control condition produced an intermediate percentage of creatures that had something unusual about their sensory systems, which did not differ significantly from either the Wild Imagination condition, $\chi^2(1, N = 44) = 2.31$, $p > .05$, or the Believable condition, $\chi^2(1, N = 44) = 1.57$, $p > .10$.

Reliance on particular knowledge sources. Because subjects in the Control condition were given no special instructions about how to perform the task, data from that condition provide the purest measure of subjects' spontaneous approaches. The most common response to the postcreation questionnaire was that the imagined creature was based on specific known earth animals (13 of 22 individuals or 59%), with 3 of those individuals also mentioning a reliance on general properties of earth animals. None reported an exclusive reliance on things that are true in general about earth animals. Only three individuals reported a reliance on specific fictional space creatures or general properties of fictional space creatures. Subjects in the Wild Imagination and Believable conditions also reported more reliance on earth species (48%) than science fiction sources (20%), and more reliance on specific instances of either type (41%) than on general properties of either type (18%). In addition, across conditions, only 23% of the subjects reported considering the creatures' environments. Thus, subjects rely more on earth animals than on science

[3] The creatures were also examined for some of the more exotic variations that occasionally are found in science fiction, such as combinations of plant and animal life, silicon-based creatures, and creatures that are not bounded solids. One creature in the Wild Imagination condition was the embodiment of the emotion "fear," and another was a tree-like organism. There was also a plant/animal combination in the Earth condition.

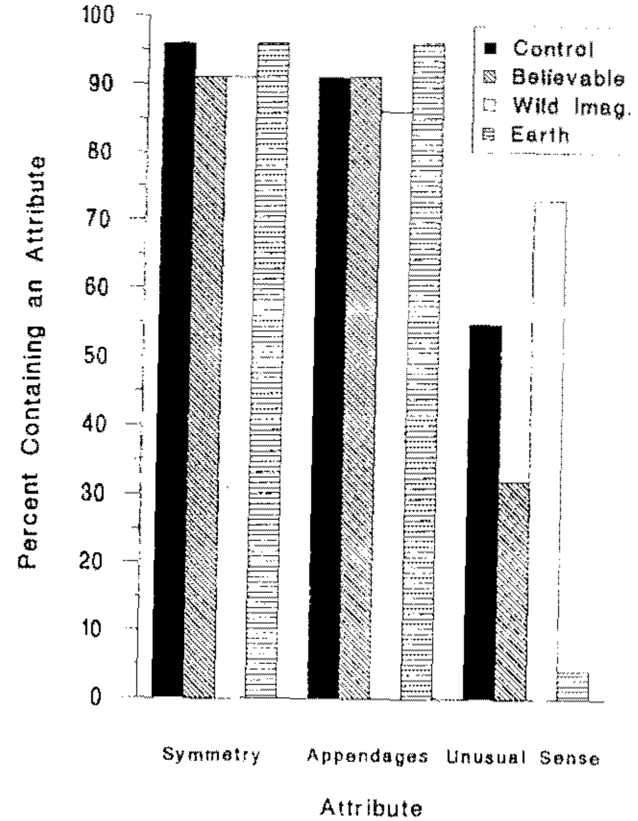

FIG. 7. Percentage of creations from each condition of Experiment 4 that possessed appendages, symmetry, and unusual senses.

fiction creatures, and they are less likely to be consciously aware of accessing broader knowledge structures than specific exemplars as they approach the task of imagining some new animal. As in the previous experiments, subjects who reported using specific instances of earth animals were as likely as the other subjects to produce creatures with appendages, sense organs and bilateral symmetry, $\chi^2 < 1$ in all cases, and significantly less likely than others to produce creatures with an unusual sensory apparatus (24% versus 67%), $\chi^2(1, N = 66) = 10.56, p < .01$. In other words, although they were no more likely to include certain central properties, their creatures were more similar to animals on earth in the exact manifestation of those properties.

Because subjects in the Earth condition also were given no special instructions about how to create their animals, a comparison of data from that condition with data from the Control condition provides another perspective on the extent to which approaches and properties deemed relevant for earth creatures are extended to creatures from other planets. Subjects in the Earth condition did not differ significantly from those in the Control condition in their reported tendency to rely on specific earth exemplars (71% versus 59%), $\chi^2(1, N = 50) = .83, p > .10$, general properties of earth animals (14% in both cases), specific known space creatures (21% versus 9%), $\chi^2(1, N = 50) = 1.39, p > .10$, or general properties of space creatures (4% versus 9%), $\chi^2 < 1$. In addition, they did not differ from those in the Control condition in the tendency to produce creatures with appendages, sense organs and symmetry (see Fig. 7), $\chi^2 < 1$ in all cases. Thus, these properties are deemed to be as relevant for animals on other planets as they are for novel animals on earth. Subjects in the Earth condition were, however, less likely than those in the Control condition to produce creatures with unusual sense organs (4% versus 54%), $\chi^2(1, N = 50) = 16.64, p < .001$.

Discussion

The results indicate that the structuring of imaginary creatures is not entirely dependent on the expectation that believable creatures are required. Subjects produced symmetric creatures with appendages and sense organs even when they were encouraged to use their wildest imagination. These types of properties appear to be central to people's ideas of what animals should be like regardless of where in the universe they are found.

Subjects more often report relying on specific instances of earth animals to develop their creatures than on general knowledge about animals, environmental considerations, or information about fictional space creatures. Thus, they appear to extend ideas about what is relevant for particular earth creatures to animals in other places in the universe. The

heavy reliance on specific instances is consistent with subjects' open-ended statements in Experiment 2, but conflicts with the greater reported reliance on more general knowledge in all but the Molten–Feather condition of Experiment 3. Apparently, when environmental constraints are not specified (this experiment and Experiment 2), or are easily met by the most likely retrieved exemplars (Molten–Feather condition of Experiment 3), subjects are less likely to consult (or become aware of consulting) broader knowledge in generating or modifying their creations than when environmental constraints conflict with the most likely retrieved exemplars (other conditions of Experiment 3).

Not surprisingly, the animals produced by subjects in the Earth condition were also highly similar to typical animals on earth. The structuring of these creations in terms of known properties of earth animals is highly consistent with other observations that subjects use their existing knowledge about the attributes of animals on earth to structure their decisions about novel earth creatures (see e.g., Nisbett, Krantz, Jepson, & Kunda, 1983). The results also converge with similar observations of how subjects design new artifacts (e.g., coins) and develop new words (e.g., labels for pain relievers) when the explicit domain to which those entities are relevant is earth and when subjects are encouraged not to be creative or silly (Rubin & Kontis, 1983; Rubin et al., 1991). What the present studies add to these previous findings is that subjects extend at least the central structuring principles even to extraterrestrials and even when they are asked to be wildly imaginative.

EXPERIMENT 5

Two related concerns in interpreting the present findings are that the college students tested may not be very imaginative and that the very brief experimental situation does not provide enough opportunity or incentive for individuals to develop truly imaginative creatures. Do the highly imaginative professionals who write science fiction for a living and operate under less constraining conditions also tend to create aliens that are symmetric and have appendages and sense organs? A challenge in answering this question is to identify some reasonably broad sample of readily codable pictures of such creatures. As an approximation to this ideal, the present study coded all 50 creatures depicted in *Barlowe's Guide to Extraterrestrials* (Barlowe & Summers, 1979). Barlowe and Summers selected their creatures from the existing science fiction literature to be "challenging to the imagination" (p. 11) and also biologically possible, two properties that may represent a compromise between the pressures of the Wild Imagination and Believable conditions of Experiment 4.

Method

Two coders examined all 50 creatures in Barlowe's Guide for the presence of symmetry, major appendages (arms, legs, or wings), and major sense organs (eyes, ears, or nose). Coders relied on the main pictures, information available in the "sketchbook" and written descriptions. Reliabilities were .80 for symmetry and .96 for appendages and senses.

Results and Discussion

Eighty percent of the creatures were symmetric, 74% had appendages, and 74% had sense organs. Because this sample of creatures is not likely to be completely representative of all science fiction creatures, statistical comparisons with the animals developed by college students would not be meaningful. What is clear, however, is that, although the percentages are somewhat lower than those for the college samples, the great majority of these science fiction creatures did possess the central properties of symmetry, appendages and sense organs. Adherence to these structuring principles is not limited to college students participating in brief experiments. In addition, the details of classic myths and fairy tales also appear to be influenced by existing conceptual structures (e.g., Kelly & Keil, 1985). Thus, even the novel creations of highly imaginative individuals appear to be constrained by certain basic properties that are characteristic of known categories.

GENERAL DISCUSSION

When people imagine novel animals, the properties of their creations are readily predictable from research on noncreative aspects of categorization. They generate creatures that are highly structured in terms of characteristic properties of common earth species, including single attributes, relations within and between species, and attribute correlations, and their creations are sometimes influenced by broader knowledge structures or naive theories. Further, much of this structuring occurs even when subjects are asked to use their wildest imagination, regardless of their reported approaches to the task, and when the "subjects" are creative writers. These results, which indicate important commonalities across creative and noncreative aspects of categorization, are consistent with other general arguments for the similarity of creative and noncreative forms of cognition (Finke et al., 1992; Perkins, 1981; Weber & Dixon, 1989; Weisberg, 1988).

This tendency to imagine extraterrestrials that reflect the characteristic properties of animals on earth also generalizes beyond college students and creative science fiction writers. For example, Frank Drake, a noted astronomer involved in the search for extraterrestrial intelligence, has suggested that intelligent aliens might easily be mistaken for humans at 100 yards at twilight (Drake & Sobel, 1992). In addition, reported encounters with extraterrestrials, which may or may not be the products of imagination, almost always involve humanoid aliens (Malmstrom & Coffman, 1979).

The constraining impact of existing category properties on imaginative or productive thought is also not limited to the speculative development of imaginary animals; designs for new practical products and inventions sometimes contain properties of existing categories that are unnecessary and possibly even harmful in the new object. Lorenz (1974), for example, notes that early designs for train cars included the property of running boards which were a common feature of horse-drawn carriages, but were clearly a danger to conductors. Only later did designs include a central aisle through which a conductor could walk more safely. More recently, 80-column computer displays are direct descendants of the punch-card era, even though this limitation is no longer relevant, nor even necessarily optimal.

In addition, although they may reflect aspects of imagination not directly considered here, cognitive phenomena as diverse as hypnogogic states, dreaming, delusion, and children's imaginative play may also be structured by principles similar to those involved in normal waking, noncreative cognition (see e.g., Foulkes, 1978; Harris & Kavanaugh, 1993; McKellar, 1957). Imaginative and noncreative thought may be more similar than they are different, and an exploration of their commonalities and differences could advance our broader understanding of human cognition.

Structured Imagination and the Centrality of Attributes

The tendency for newly generated entities to consistently maintain particular properties of existing categories can be referred to as *structured imagination*. Imagination is structured or directed by knowledge of the category or categories most related to the individual's goals. As such, the study of imagination can enhance our understanding of category structures and processes, and the study of those structures and processes can contribute to our understanding of imagination. The present studies reflect these complementary goals.

As an example, the present procedures can help to identify what may be termed *central* aspects of category representations. The attributes most subjects retain across varying tasks are presumably most central or essential to the category representation. Across the present studies, subjects did not vary in the basic tendency to include appendages and sense organs, but they did vary in the exact number and type of appendages and sense organs they included. Thus, appendages and sense organs may be central to the category "animal" even though the specific manifestation of those properties can vary. The findings help to confirm observations from traditional attribute-listing studies that these attributes are salient in people's animal category representations. They also suggest new central attributes, such as bilateral symmetry, which could, in turn be investigated in tasks of noncreative categorization. Again, these observable attributes may take on an important role in category representations because of their link to broader, abstract understandings of what animals are like (e.g., they move and extract information from their environments; see Footnote 1 again).

This focus on identifying features that are more or less central is related to and extends Barsalou's (1982) distinction between context independent properties of concepts which are always activated by the word for the category in question, and context dependent properties that are typically activated only by particular contexts. In Barsalou's work, attributes themselves were identified as either context independent or context dependent. In the present case, the distinction is slightly different; some attributes appear to be context independent (e.g., appendages), but the exact manifestation of those attributes is context dependent (e.g., number or type of appendages).

More generally, much recent discussion has focussed on the usefulness of similarity as a construct in explaining categorization phenomena (e.g., Medin et al., 1993; Murphy & Medin, 1985). A key issue is that the factors that lead to the selection of attributes to be considered in similarity comparisons may be at least as important as the process of assessing the extent to which objects match and mismatch on those attributes. By helping to identify stable and variable attributes, as well as the exact links between task situations and the nature of included attributes, tasks of imagination can provide important information about those factors.

Structuring by Specific and General Information

In the Introduction I noted that categorization models have focused on the nature of the information that would be used to *identify* instances of a category, but not on how people might use category information to *generate* new instances of the category. As a simplifying assumption, I suggested that the models could use whatever information was supposed to underlie identification as a basis for generating a new member. To extend this point, if a model only included one type of information in the category representation (e.g., exemplars), the model presumably would be constrained to rely on only that information to generate a new member. With this added assumption, the central properties that appear in subjects' creations could occur because most known exemplars have those properties, the category prototype has them, they have a high frequency of representation in a feature list or they fit with naive theories about the minimum requirements for viable life forms.

Rather than favoring one of these specific category models over the others, the present results argue that several types of information may be used. For example, subjects reported relying on several types of category information, including specific instances, attributes that are true in general of members of the category "animal," and beliefs about what kinds of animals are suited to particular types of environments. Basing creations closely on specific instances of earth animals dominated spontaneous approaches (Experiments 2 and 4), but was reduced when task constraints forced individuals to consult broader knowledge frameworks (e.g., the Molten–Fur condition of Experiment 3). These findings suggest that individuals' approaches to tasks of imagination are under strategic control and that there is not a single, inevitable sequence involved in imagining new entities.

Although these self-reports by college students do not necessarily reflect the actual underlying structural representations of their categories, they are nevertheless consistent with other observations that professionals who design new entities in applied settings also rely both on specific category instances and more general knowledge (Goel & Pirolli, 1989; Jansson, Condoor, & Brock, 1993). In addition, there are consistent relations between subjects' reports and the properties of generated creatures which support their validity and indicate that there are *functional* consequences of adopting those particular approaches. For example, when subjects report relying on specific instances, their creations have fewer novel sensory variations than those of subjects who report relying on general properties and environmental considerations. The fact that such relations exist and that they are so consistent with the constraining effects of experimenter-presented specific examples (e.g., Smith et al., 1993) means that subjects' experiences of using particular types of information do identify psychological phenomena that are real enough to exert a predictable impact on observable behavior. Thus, the diversity of reported approaches may be a valid indicator of the diversity of category information in at least a functional, if not a structural sense.

Importantly, details of different subjects' creatures also point to the use of different types of information. For example, subjects in the Molten–Feather and Molten–Fur conditions of Experiment 3 were highly likely to generate flying creatures, but they apparently arrived at those flying creatures by different paths. That is, the flying creatures in the Molten–Feather condition were very "birdlike" animals indicative of subjects retrieving and using exemplars of birds quite directly, whereas the flying creatures in the Molten–Fur condition were distinctly non-birdlike, indicative of subjects constructing or synthesizing creatures from stored features (e.g., wings) that their knowledge indicated would meet the demands of the planet.

What the present results suggest, then, is that category information, at least as available to introspection and as applied in tasks of imagination includes exemplars and abstracted properties that are organized and related to one another by broader knowledge structures. Approaches focused strictly on exemplars to the exclusion of naive theories and vice versa will be inadequate to explain the use of category information in imagination.

Any model that only included exemplars, for example, would need to explain why, with the exception of having wings, the creatures in the Molten–Fur condition were so non-birdlike. One could suggest that the competing cues of the planetary conditions and fur led subjects to retrieve and combine birdlike and non-birdlike exemplars with the consequence that only some birdlike features were retained in their creations. However, unless subjects accessed broader knowledge about how organisms can meet the demands of particular environments it is unclear why they would consistently retain the birdlike feature "wings" and consistently drop the birdlike feature "beak," or why the demands of the molten planet would lead to the retrieval of birdlike instances to begin with. Similarly, a model that minimized the role of specific instances would have difficulty explaining why the creatures in the Molten–Feather condition were so much more birdlike and why their similarity to birds was so consistent with subjects' reports that they had relied on specific instances.

Correlated Attributes

Another way to characterize the creatures in the Molten–Feather and Molten–Fur conditions is that the former preserved the correlations among flight, wings, and several other birdlike properties, whereas the latter preserved only the correlation between flight and wings. Why might subjects in the former condition, who also reported a greater reliance on specific exemplars, produce creatures that preserve more attribute correlations? One possible explanation is that some attribute correlations are explicitly stored only in specific exemplars, whereas others are also stored in broader knowledge structures that contain explanations for certain correlations. Alternately, correlated attributes may be more tightly bound together in specific instances than in broader knowledge structures such that many irrelevant attributes would be retrieved as integral parts of whole exemplars, whereas only those attributes critical to the task at hand would be retrieved when broader knowledge structures are accessed. It appears that some types of correlations are acquired simply because they occur frequently across category members (Billman, 1992; Medin, Altom, Edelson, & Freko, 1982; Younger & Cohen, 1986), whereas others are acquired primarily or solely because they fit with existing knowledge structures (e.g., Chapman & Chapman, 1969; Murphy & Wisniewski, 1989). Perhaps the former are preserved primarily as part of the representations of specific category instances (e.g., all encountered and stored instances of birds have beaks and claws or talons), whereas the latter are preserved in larger knowledge structures and are central to explanations about the workings of the world (e.g., wings are useful for supporting a body in flight).

Beyond the theoretical questions about exactly where and how correlated attributes are represented, the present findings raise a practical concern. If the attributes that participate in correlations are not readily independently accessible in specific exemplars, then designs for new entities that are developed largely on the basis of retrieving specific existing exemplars would have a strong potential for including irrelevant and perhaps harmful attributes simply because those attributes happen to be associated with other useful attributes of the retrieved exemplar. Broader knowledge frameworks may be needed to sensibly screen out unwanted attributes, a point that is pursued more fully below.

The Path of Least Resistance and the Tyranny of the Particular

The present pattern of results can be considered within the framework of a tentative model. In imagining a new entity, individuals initially determine that a particular knowledge domain is relevant to the task and then access information from that domain to construct the novel entity. In the present studies, for example, most subjects implicitly or explicitly chose the domain of "animals on earth" as relevant to the task of imagining animals on other planets. In simple tasks, such as the present one, existing knowledge might be used to construct the novel entity in working memory, much as it would be used in constructing noncreative concepts (Barsalou, 1987). More complex tasks, as might arise in engineering design, may require longer term representations and external storage.

Although the process by which one accesses information about the relevant domain and constructs a novel representation would be under strategic control, a relatively easy approach would be to retrieve a specific exemplar from that domain and pattern the new creation after that entity. Given no constraints on the environment in which the creature must survive, many individuals spontaneously followed this path of least resistance and retrieved specific instances of earth animals. Just as in using this type of retrieval for noncreative purposes, such instances are likely to be "typical" category members, with typicality being contextually determined (see e.g., Barsalou, 1987). For example, birds may be less typical of the category "animal" than are mammals except when the context includes the cue of "feathers" (Experiment 2). Because most or all exemplars will have certain central or context independent attributes, those attributes will be present in new creations despite such shifts in typicality, thereby limiting innovation.

Continuing with a relatively unmodified specific instance is most likely to occur when the novel entity must satisfy few, if any, constraints or when properties of the retrieved instance already satisfy any specified constraints. In contrast, if constraints in the task are not satisfied by the retrieved instance or those constraints militate against attributes of that instance, it may be either rejected or modified extensively, or a new entity may be synthesized from more general knowledge to satisfy the specified constraints.

One consequence of being forced to rely on more general knowledge to modify old or synthesize new exemplars is that individuals who do so include more innovations in their creations than those who rely more directly on specific exemplars. Thus, experiencing difficulty in developing a satisfactory product from a known exemplar can increase the possibility of creative outcomes. This idea is consistent with suggestions that constraints can enhance creative functioning (e.g., Finke et al., 1992) and with other views regarding the facilitative effects of failure experiences (e.g., Holland, Holyoak, Nisbett, & Thagard, 1986, Murray, 1986; Schank, 1988). Schank (1988), for example, has described the fact that script-based thinking occurs because scripts provide an easy means of interpreting a given situation. This is similar to the "path of least resistance" idea noted above. Most importantly, when following a script results in failure, as might occur in a novel situation, the failure experience creates the possibility of examining and modifying the script and hence taking a more creative approach.

Creative innovation may be more likely when subjects consult broader knowledge frameworks than when they rely more exclusively on specific instances for two reasons. First, a person who relies on a specific instance may become fixated on its properties. For example, a person who retrieved and used a dog would presumably have a greater chance of producing a creature with two eyes located symmetrically in the head than a person who considered the more abstract idea that a creature must have some means of extracting information from the environment. Second, innovations must be appropriate or useful to be considered creative. Although one might randomly vary attributes of retrieved exemplars, without the guidance provided by access to broader knowledge structures, there is little chance of those novel variations being appropriate for a given task.

Heavy reliance on specific instances to the exclusion of broader knowledge may be more characteristic of relative novices adopting a casual approach to imagination than of experts adopting a more serious approach. For example, creative writers and artists stress the importance of considering the environment of an alien's home planet as a technique for imagining new life forms (e.g., Gillies, Mayhar, & Parkinson, 1991). However, Barlowe also noted that many writers "take the easy way out when creating an extraterrestrial" (e.g., putting a cat's head on a human body) without considering its evolution, environment, and so forth (Barlowe & Summers, 1979, p 12). Similarly, although design professionals must consult broad knowledge frameworks in developing designs for new products, protocol analysis reveals that they also pattern new objects after highly specific examples of known entities (e.g., patterning a self-serve post office after a specific version of an automated bank teller, see, Goel & Pirolli, 1989; 1992). In addition, models of how engineers design new products include a role for specific instances and general knowledge.

The model described here is similar to Jansson's *parameter analysis* model of engineering design (e.g. Jansson, 1990; Jansson et al., 1993) which assumes that the development of new designs occurs in two spaces: a configuration space and a concept space. The configuration space contains representations or concrete realizations of specific physical objects (much like specific instances), whereas the concept space represents more abstract knowledge such as theories, beliefs, and principles (broader knowledge). In Jansson's model, designers often first choose a specific category prototype (e.g., a worm gear) to initially represent a problem solution in configuration space; theories and belief systems associated with that prototype then provide the basis for reasoning about the given design problem in concept space. If a given specific configuration is found to be unsuitable, the designer must return to the concept space where the basic principles can be reconsidered. Once change occurs in the concept space, that change can, in turn, be manifested in a newly synthesized configuration. In other words, innovation occurs primarily when individuals consult broader knowledge. Even with this new configuration, however, designers can remain fixated on certain limiting properties of their initially retrieved prototype which can result in workable, though not optimal solutions. To minimize such fixation it may be better, initially, to represent problems in terms of abstract principles that must be satisfied rather than in terms of specific instances of solutions to prior problems.

Conclusions

The present studies are intended as a preliminary example of using the exemplar generation approach to examine how existing category knowledge is manifested in generating novel category exemplars. Other similar approaches have been used to examine the availability of surface features in stored representations of words (Rubin, et al., 1991), the emergence of prototypes (Busemeyer & Myung, 1988) and the development of the ability to represent nonexistent members of very specific categories (e.g., people) (Karmiloff-Smith, 1990). Despite these initial efforts many questions remain about how existing knowledge influences imagination, and how such effects might be overcome to make imagination less constrained.

As a way of characterizing the present results it is useful to ask the question of whether or not they could have turned out differently. The answer is Yes. Subjects could have decided to pattern their creations after any of an infinite variety of visual forms, including recently encountered clouds, rocks, sand dunes, plates of spaghetti, or other entities. Each individual could have selected a different source of inspiration, or even attempted to avoid any particular influences. Even if they relied on knowledge about earth animals, they need not have tended so commonly to be influenced by the most typical properties or instances, and even if they all retrieved instances of typical earth animals, they could have imposed such idiosyncratic and drastic modifications that their creations would be unrecognizable by any properties of earth animals. Some rare exceptions in the science fiction literature, such as creatures with no obvious senses or appendages, or even any fixed shape or clear external boundaries attest to the fact that it is possible to imagine wildly different sorts of animals. However, college student subjects did not, and science fiction writers usually do not do so. Thus, the argument here is not that people can never access some other knowledge base or avoid the impact of the characteristic attributes of a given knowledge base. Rather, it is that this most often does not occur; the normative tendency in using imagination is to base creations on the central features of a predictable, highly related knowledge base.

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