Chapter 6

THE AMBIGUITY OF MENTAL IMAGES: INSIGHTS REGARDING THE STRUCTURE OF SHAPE MEMORY AND ITS FUNCTION IN CREATIVITY

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Mental images *must* differ from pictures in some respects. Neither percepts nor mental images are pictures of physical objects. A critical question is how to characterize the ways in which mental images differ from pictures, and how to use those characteristics to learn about the mental structures underlying mental imagery and shape memory. Furthermore, to the extent that we find that the mental structures underlying shape memory have different characteristics from the mental structures underlying linguistic or propositional memory, we can begin to explore the extent to which these different mental structures can play different roles in creativity.

Three lines of experimentation have indicated some of the ways in which pictures and images differ:

First, Reed (1974; Reed & Johnsen, 1975) demonstrated that the embedded figures task could not be performed very well in mental imagery; imagery did not seem capable of supporting the repartitioning processes necessary for finding embedded figures. It should be noted, however, that those embedded figures that were least likely to be found in an image were the same as those that were least likely to be found in a picture. In other words, Reed's experiments did not indicate a complete dissociation between imagery and perception.

Second, Hinton (1979a) demonstrated that the memory image of a three-dimensional cube failed to specify its three-dimensional structure precisely. Hinton's subjects reported that they could imagine a diagonal line connecting the lower left front corner of a cube to its upper right back corner. They also reported that they could imagine rotating the cube so that the imagined diagonal line became vertical. Nevertheless, most of Hinton's subjects were unable to report either the correct number or the correct location of the corners that would lie between the cube's top and bottom corners following this rotation.

Third, Chambers and Reisberg (1985) demonstrated that observers who saw only one interpretation of Jastrow's (1900) duck/rabbit when viewing a picture were unable to reverse their mental image from duck to rabbit (or vice versa[1]); this finding was replicated in other experiments using the Necker cube and the Schroeder staircase. Chambers and Reisberg demonstrated that their results were not attributable to image degeneration by showing that all of their subjects could find the alternative interpretation in drawings generated from their own images. Based on their evidence, Chambers and Reisberg (1985; see also Reisberg & Chambers, 1991; Reisberg & Logie, this volume) claimed that mental images differ from pictures in that *mental images cannot be reconstrued; that is, they cannot be separated from their interpretations.*

The first two lines of research described above indicate that not all of the part relationships that can be found in a picture or an object are preserved in a mental image. All three lines of research described above clearly demonstrate that pictures and mental images are not isomorphic. These previous experiments do not, however, demand the broad and general conclusion proposed by Chambers & Reisberg (1985), that mental images are inextricably bound to their interpretations. Moreover, other experiments conducted by Finke, Pinker, and Farah (1989) have showed that certain types of mental images *can* be reinterpreted. For example, observers in the Finke et al. experiments combined imagined letters according to a set of instructions and were able to discover that a particular combination of a "J" and a "D" formed an umbrella.

How are we to reconcile the findings of Finke et al. (1989) with those of Chambers and Reisberg (1985)? Finke et al. proposed two untested solutions: (1) that the complexity of classical reversible

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[1] Henceforth, I will use the term "duck-to-rabbit reversals" to indicate rabbit-to-duck reversals as well.

figures might preclude their reversal in mental imagery, and (2) that the reversal of classical reversible figures might require processes that are available in perception but not in mental imagery. I argue that neither of these conjectures captures the critical determinants of imagery reversal. Rather, I propose that the route to understanding reversals in mental imagery lies in appreciating both the diversity of types of reversal and the mechanisms and processes of shape recognition.

Types of Reversal

Perception theorists studying reversible figures have long known that reversals are not unidimensional (e.g., Price, 1969). In fact, perceptual reinterpretations come in at least three types, as illustrated in Figure 1.

First, there are reversals that entail a *reference-frame realignment*. By "reference-frame realignment," I mean the reassignment of the top-bottom and/or front-back directions in a figure. Hence, when I use the term "reference frame" I mean the specification of the shape's top and bottom and/or of its front and back. I will not use the term to denote an axis of symmetry or an axis of elongation, as some have done (cf. Marr, 1982). Reversals of the Necker cube and Mach book figures shown in Figures 1a and 1b are examples of reference-frame realignments.

Second, there are reversals that entail a *reconstrual* of the parts of the figure, but no (or little) reference-frame realignment. For example, in a reversal of Fisher's (1976) snail/elephant figure (Figure 1c), the snail's shell becomes the elephant's head and ears, and the body and head of the snail become the trunk of the elephant. Both the front and back and the top and bottom of the snail and the elephant are the same; hence, a reversal between the snail and elephant interpretations does not entail a reference-frame realignment. Reversal of Hill's (1915) wife/mother-in-law figure (Figure 1d) mostly entails part reconstrual, although some slight change in reference frame might occur as well. Henceforth, I will refer to reversals that entail no or little reference-frame realignment as "reconstruals." Note that reversal of the duck/rabbit figure, shown in Figure 2a, entails both reconstrual and reference-frame
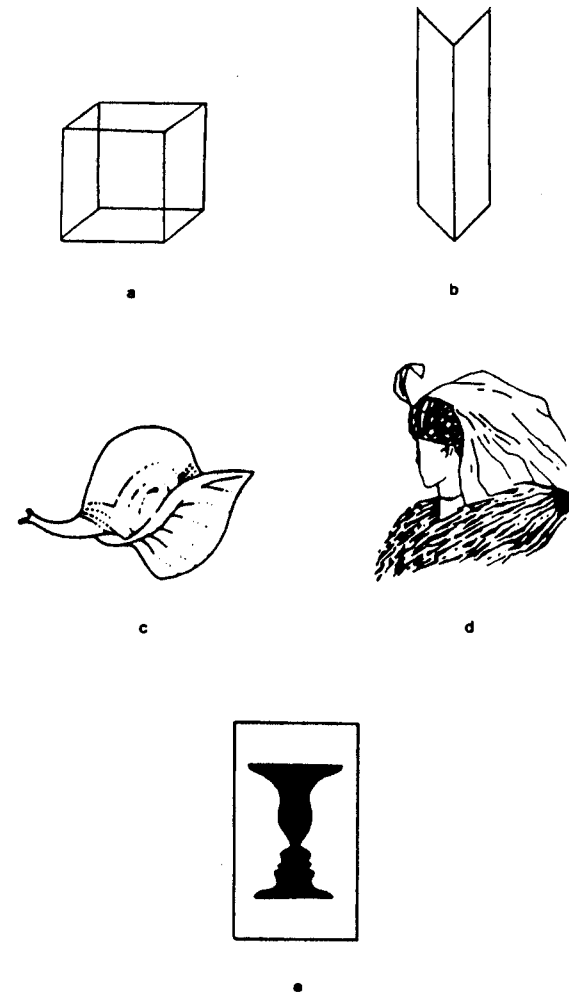

Figure 1

Types of reversal. Reversals of *a* and *b* require reference-frame respecification. Reversals of *c* and *d* require part reconstrual only. Reversal of *c* requires figure-ground alternation. (From "Mental images can be ambiguous: Reconstruals and reference-frame reversals," by M. A. Peterson, J. F. Kihlstrom, P. M. Rose, & M. L. Glisky, *Memory & Cognition, 20*, 109.)

realignment: the bill of the duck becomes the ears of the rabbit, and the front of the head of the duck becomes the back of the head of the rabbit.

Third, there are reversals that entail a redetermination of *figure and ground relationships* and hence, a repartitioning of the shape's contour. In figure-ground reversals, the part structure of the figure changes from one minute to the next, as Hoffman and Richards (1985) demonstrated so elegantly. The Rubin (1915) vase/ faces stimulus, shown in Figure 1e, is an example of this type of reversal. When the white region is figure, the faces are seen, and the parts of a face can be identified along the white side of the border between the black and white regions of the stimulus. The vase is not seen when the white region is figure; the black region becomes an undifferentiated background against which the faces are viewed. On the other hand, when the black region is figure, the vase is seen, and the parts of a vase can be identified along the black side of the border between the black and white regions of the stimulus. The faces cannot be seen when the black region is figure; the white region becomes an undifferentiated background against which the vase is viewed. Note that the parts of the vase and the faces are seen in different regions of the stimulus, both as defined by color (side of border) and as defined by contour segment: The noses begin and end at contour minima of curvature defined from the white side of the border whereas the bowl of the vase, although roughly coextensive, begins and ends at contour minima of curvature defined from the black side of the border. Henceforth, I will call these reversals "figure-ground reversals"; in figure-ground reversals, both figure-ground structure and part structure changes (Hoffman & Richards, 1985).

For the remainder of this chapter, I will concentrate on reconstruals and reference-frame realignments only and not on figure-ground reversals. Research in my laboratory indicates that only certain types of borders support true figure-ground reversals (e.g., Peterson & Gibson, forthcoming; Peterson, Harvey, & Weidenbacher, 1991). On the basis of these experiments, I do not expect that true figure-ground reversals can occur in mental imagery, although some have been reported (see Reisberg & Chambers, 1991; Reisberg & Logie, this volume). In what follows, I will describe a series of experiments in which we examined

whether mental images of classical ambiguous or reversible figures were categorically incapable of reversal, as implied by Chambers and Reisberg's (1985) claim, or whether some types of reversal, say reconstruals, are not more likely to occur in mental imagery than other types, say reference-frame realignments.

Shape Recognition Theory and Its Implications for Mental Imagery Reversal

Reconstruals

Our expectation that reconstruals might occur in mental imagery was grounded in current theories of basic level shape recognition. In these theories, the shape representation medium is characterized as composed of a finite vocabulary of representational components. Were these components visible, they would correspond roughly to generalized cylinders (i.e., cross sections swept out in depth along axes orthogonal to the plane of the cross section) (e.g., Biederman, 1987; Binford, 1971, 1981; Marr & Nishihara, 1978). A componential analysis of a shape may operate at a number of different hierarchical levels (Marr, 1982). For example, at one level of analysis, a human arm and hand can be described by a single cylinder. At a more subordinate level of analysis, it can be described by three end-connected cylinders, one for the upper arm, one for the forearm, and one for the hand. At a yet lower subordinate level of analysis, the hand itself can be described by six cylinders (Marr, 1982; Marr & Nishihara, 1978). The components employed for basic level shape recognition may be those that can be fit between the minima of curvature identified along an object's contour (Hoffman & Richards, 1985; Marr, 1977).

I will focus on Biederman's (1987) Recognition-by-Components (RBC) theory of shape recognition as a framework for this discussion because Biederman has taken the most explicit stand on the issues we find relevant to reversal of mental images. According to RBC, the vocabulary of representational components is quite small — 24 to 36 components, with a subset of these components used to represent any particular shape. If the 30,000 or so shapes we can potentially recognize are represented by this

small set of components, then each component must itself be capable of supporting thousands of interpretations (Biederman, 1987). According to Biederman, in any given shape, a single component is disambiguated both by the particular combination of other components to which it is connected and by their spatial inter-relations. Of course, features and details may contribute to further disambiguation.

It seemed reasonable to assume that mental images might be assembled from the same components as those used in shape representations. If that is the case, then it follows that reconstruals of individual components might be quite likely, given that each component can support so many interpretations. Some proportion of these component reversals might find support in the particular arrangement of other components in the whole mental image and might, as a consequence, induce a reversal of the whole mental image. Hence, considering the question of image reversals within the context of shape recognition theory generates the prediction that reversals entailing reconstrual only should occur commonly in mental imagery.

Reference-Frame Realignments

Inspection of the shape recognition literature affords a prediction regarding the likelihood of reference-frame realignments in mental imagery that likewise is quite different from that espoused by Chambers and Reisberg (1985; Reisberg & Chambers, 1991; Reisberg & Logie, this volume). A substantial body of shape recognition evidence shows that observers' latency to name disoriented shapes increases linearly as the disparity between the shapes' typical orientation and the presented orientation increases (e.g., Jolicoeur, 1985, 1988; Tarr & Pinker, 1989). Most investigators take the linear shape of the function relating disorientation to naming latency to indicate that a process similar to mental rotation precedes the recognition of disoriented shapes.

Let me suggest another interpretation of the naming latency data: In the recognition process, descriptions of disoriented shapes may first be matched to shape representations whose canonical reference frame matches the viewer-centered or environment-centered reference frame. If a good match cannot be found in this

set of representations, the shape description may be matched against sets of representations specified in other reference frames. The sets of representations searched first are those with reference frames similar to those of the input shape. The greater the disparity between the presented orientation and the shape's typical orientation, the larger the number of sets of representations searched prior to recognition. Recognition occurs when the description of the presented shape is matched to the appropriate structural representation, specified in the canonical reference frame.

A finding that the latency for reference-frame reversals is longer than the latency for reconstruals would be consistent both with my interpretation of the naming latency data and with the mental rotation interpretation. Neither of these interpretations provides any foundation for predicting that reference-frame realignments would be impossible in mental imagery, however. Nevertheless, Chambers and Reisberg (1985; Reisberg & Chambers, 1991) have repeatedly demonstrated a failure to obtain reference-frame realignments in imagery. Of course, it is possible that certain aspects of Chambers and Reisberg's experiments *limited* the number of reversals they obtained. In particular, the demonstration figures used by Chambers and Reisberg to familiarize their subjects with the notion of reversibility (e.g., the Necker cube, the Mach book, and the Rubin figure-ground stimulus) all reverse in different ways than the duck/rabbit figure which served as their test figure (see Figure 1). Consequently, using them as demonstration figures may have induced incorrect strategies, thereby making duck/rabbit reversals *less* likely than if no strategies had been suggested or if a correct strategy had been suggested.

Overview

In what follows, I will describe two experiments examining imagery reversal that were drawn from a series of experiments conducted with John Kihlstrom, Patricia Rose, and Martha Glisky (Peterson, Kihlstrom, Rose, & Glisky, 1992). The experiments show (1) that reference-frame realignments can occur in mental imagery, but (2) that other types of reversal — reconstruals in

particular — are more common in mental imagery than reference-frame realignments, and (3) that the demonstration figures used are critical to whether or not reference-frame realignments are obtained. We obtained these effects using two classic ambiguous figures: the Jastrow duck/rabbit figure, shown in Figure 2a, and Fisher's snail/elephant figure, shown in Figure 1c. In addition, I will describe two experiments that examine the structural versus semantic nature of the imagery reversal reports. Finally, I will discuss the implications of these findings for the structure of shape recognition systems and for the role of visual imagery in creativity.

Experiment 1

Subjects in this experiment ($N = 116$) were shown a full version of the duck/rabbit figure for 5 seconds and were asked to form a good memory image of it so that they would be able to draw it later. Following image formation, they were shown either (1) the goose/hawk figure (Figure 2c), (2) the chef/dog figure (Figure 2b), (3) the Rubin vase/faces figure (Figure 1e), or (4) no demonstration figure. These demonstration figures were designed to provide the subjects with different types of implicit hints about reversal strategies.

The goose/hawk figure was adapted from Tinbergen (1948). Similar processes are involved in reversal of the goose/hawk figure and the duck/rabbit figure, as can be seen in Figure 2: Both require reversing front/back directions in the reference frame as well as reconstruing certain components. Accordingly, we predicted that if the demonstration figures serve to induce reversal strategies, subjects viewing the goose/hawk figure should be more likely to reverse the duck/rabbit figure than subjects viewing the other demonstration figures.

The chef/dog figure was one of the demonstration figures used by Chambers and Reisberg (1985). Reversal of the chef/dog figure entails a reference frame reversal as well as a part reconstrual in that the top of the chef's hat becomes the hindquarters of the dog, as shown in Figure 2b. Because reversal of the chef/dog figure entails a reference-frame realignment as well as part reconstruals, its presence as a demonstration figure might induce some subjects
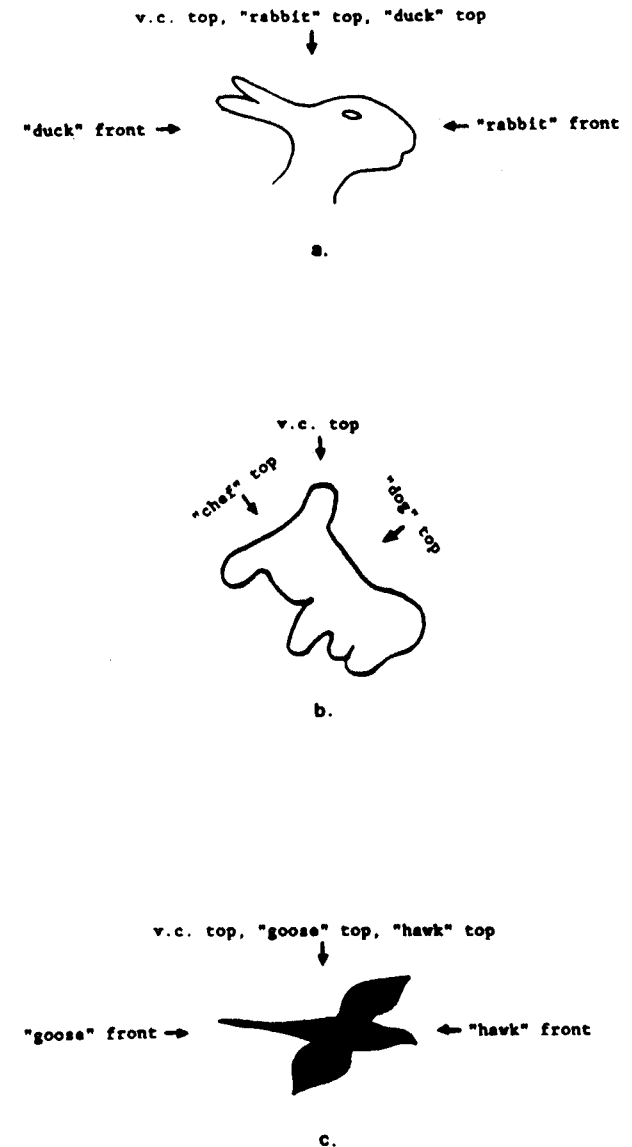

Figure 2
The duck/rabbit figure *a*, the chef/dog figure *b*, and the goose/hawk figure *c* with reference frame annotations.

to use the correct strategy in reversing their image of the duck/ rabbit.

Remember, however, that Chambers and Reisberg had used the chef/dog figure as a demonstration figure and had obtained no reversals of the duck/rabbit image whatsoever. Indeed, notice that reversal of the chef/dog figure entails a different type of reference-frame realignment than reversal of the duck/rabbit figure does. For example, the object-centered top is not the same as the environment-centered (or viewer-centered) top for either the chef or the dog interpretation, whereas the object-centered top of both interpretations of the duck/rabbit figure corresponds to the environment-centered (viewer-centered) top of the stimulus. Notice also that reversal from the chef interpretation into the dog interpretation for the chef/dog figure requires a 90° respecification of the object-centered top, whereas reversal from the duck interpretation into the rabbit interpretation for the duck/rabbit figure requires a 180° respecification of the object-centered front. Thus, the reversal strategies suggested by the chef/dog figure may not be completely appropriate for the duck/rabbit figure. Consequently, subjects viewing the chef/dog figure might be less likely than subjects viewing the goose/hawk figure to reverse the duck/rabbit figure.

The Rubin vase/faces figure-ground stimulus was also among the demonstration figures used by Chambers and Reisberg (1985), whose subjects failed to report any reversals of their mental image of the duck/rabbit figure. As noted earlier, reversals of figure-ground stimuli may follow different principles than those involved in reversals of the duck/rabbit figure. Thus, any strategies induced by figure-ground stimuli would be inappropriate for reversing the duck/rabbit figure. Therefore, we predicted that subjects in the figure-ground demonstration figure condition would be unlikely to reverse their image of the duck/rabbit figure.

In the condition in which no demonstration figure was shown, subjects counted backwards from 500 for durations that were matched to the durations subjects in the other conditions viewed the demonstration figures.

Immediately following their exposure to the demonstration figures, subjects were told that the picture they had viewed originally (i.e., the Jastrow duck/rabbit figure) was (also) an

ambiguous figure and they were asked to try to find an alternative interpretation in their mental image. Subjects who did not report a duck-to-rabbit reversal were then asked to attend first to the left side of their mental image and then to the right side in an attempt to find an alternative interpretation. (These strategies were suggested to subjects by Chambers and Reisberg, 1985, as well.) Subjects who were still unable to report a duck-to-rabbit reversal were given the two explicit reference-frame hints used by Hyman (this volume; Hyman & Neisser, 1991). The first explicit hint contained no reference to animals; we simply asked the subjects to "Consider the front of the thing you were seeing as the back of something else." We refer to this hint as the "abstract" reference-frame hint. Subjects who failed to report a duck-to-rabbit reversal following the abstract reference-frame hint were given a second hint, containing category information as well as reference-frame information. They were asked to "Consider the front of the head of the animal you just reported as the back of the head of some other animal." We refer to this hint as the "conceptual" reference-frame hint. Hyman and Neisser had found that the conceptual reference-frame hint was more effective than the abstract reference-frame hint in prompting a reversal.

At the end of the experimental session, we clarified any uncertainties about the interpretations subjects had named earlier by asking them to point out the parts of the interpretations they had named, as well as the front/back and top/bottom object-centered directions.

Our subjects offered many interpretations of their mental images other than, or in addition to, ducks and rabbits. Of course, some interpretations were more valid than others. We considered an interpretation to be valid if it met a two-part criterion: (1) The interpretation had to be of the entire mental image, not just a single part. This meant that interpretations like "nose" and "fingers" were not considered valid. (2) The interpretation had to name a particular shape depicted by the mental image, and not merely describe the image in general terms. This meant that interpretations like "shape" and "animal" were not considered valid. The valid interpretations were *structural reconstruals* of the mental image in that their componential structure matched that of the original figure. Examples of the valid interpretations are listed in

Table 1, along with a specification of whether their reference frame was considered to be the same as that of the duck or the rabbit interpretation of the duck/rabbit figure. The componential structure of the duck/rabbit figure and of these valid interpretations is shown in Figure 3. It is clear that, at a basic

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TABLE 1

The proportions of subjects reporting each of the "valid" interpretations of the duck/rabbit mental image classified according to whether their reference frame is the same as that of the duck or the rabbit interpretation.

Interpretations	Reference Frame	Proportion
Rabbit	R	.94
Duck	D	.34
Hand making a peace sign (or shadow figure)	D	.14
Fish	R	.11
Pair of scissors	D	.10
Deer/antelope	R	.09
Dog/puppy	R	.08
Profile of person with hair streaming behind head (or wearing a feather headdress)	R	.06

Note: The reference frame for the various interpretations is marked with a *D* if we considered the front to be the same as the front of the duck, and an *R* if we considered the front to be the same as the front of the rabbit. Interpretations within the same reference frame that followed one another were scored as reconstruals. Interpretations within different reference frames that followed one another were scored as reference-frame realignments.

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level, the components of all of the valid interpretations are similar.

Duck-rabbit Reversals. Reversals between the duck and rabbit interpretations of the mental image of the duck/rabbit figure are shown in the top part of Table 2. The data in the table are grouped according to reversals obtained before the explicit
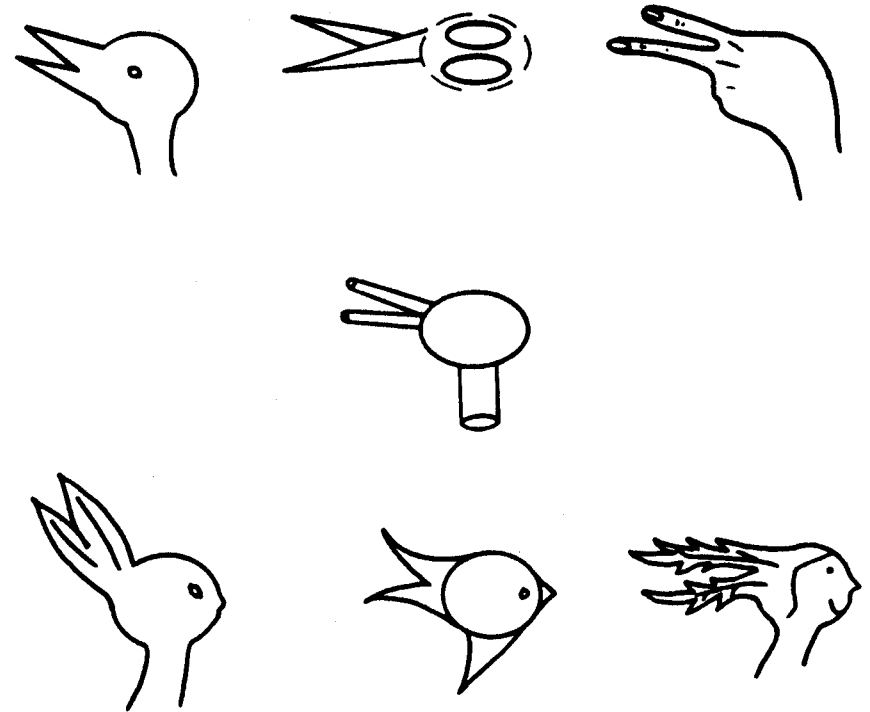

Figure 3

The central figure is the basic componential structure of the Jastrow duck/rabbit figure and of a number of alternative interpretations. The interpretations shown above the basic structure are those specified in the same reference frame as the duck interpretation; they are from left to right, a duck, a pair of scissors, and a hand making a peace sign. The interpretations shown below the basic structure are those specified in the same reference frame as the rabbit interpretation; they are, from left to right, a rabbit, a fish, and a person with hair (or headdress) streaming behind.

reference-frame hints and reversals obtained after the explicit reference-frame hints. Note that some subjects in each group reported duck-to-rabbit reversals (i.e., reference-frame realignments) before the explicit reference-frame hint. Except in the figure-ground condition, the proportion of subjects reporting duck-to-rabbit reversals prior to the reference-frame hint was significantly greater than expected on the basis of Chambers and Reisberg's experiments ($3.07 \leq z \leq 12.69$, $p < .001$).[2] In addition, the proportion of subjects reporting duck-rabbit reversals prior to the reference-frame hint was greater in the goose/hawk condition than in the other conditions, $zs \geq 2.27$, $ps < .02$, as predicted.

Subjects in all conditions were more likely to report a duck-to-rabbit reversal after the reference-frame hints than before the reference-frame hints, but the increase in reversals was statistically significant only in the figure-ground condition. We did not find, as Hyman and Neisser had, that the conceptual reference-frame hint prompted more duck-to-rabbit reversals than the abstract reference-frame hint, $z < 1$. Accordingly, the responses to the two types of reference-frame hint are not reported separately here (for details, see Peterson et al., 1992). Despite the increase in duck-to-rabbit reversals following the reference-frame hints, the total proportion of duck-to-rabbit reversals remained larger among subjects who had viewed the goose/hawk demonstration figure than among subjects in any of the other three conditions ($z \geq 1.94$, $ps < .03$).

All Reference Frame Realignments. The middle part of Table 2 shows reference-frame reversals of any sort, including both duck-to-rabbit and other reference-frame realignments (i.e.,

[2] The tests of significance of these proportions were found in Bruning and Kintz (1977). When comparing our proportions against expected values, we could not use an expected value of 0, which is the correct value based on Chambers and Reisberg's (1985) experiments. Accordingly, we calculated an expected value of .02, using the following reasoning. Chambers and Reisberg tested a total of 55 subjects, not one of whom reported a reversal in imagery. If we suppose that the next subject might have reported a reversal, then we arrive at .02 as a conservative theoretical estimate of the predicted probability of reversal. Because our predictions regarding the presence of reversals in imagery were clearly unidirectional, we employed one-tailed tests for these comparisons. All other tests were two-tailed.

reversals between any two interpretations listed in Table 1 that are specified in different reference frames). When the proportions of all reference frame reversals in imagery were examined, reversal probabilities before the reference-frame hints were greater in the chef/dog condition than they were when only duck-to-rabbit reversals were counted (.27 vs. .10), $z = 3.22$, $p < .002$). There were similar trends

TABLE 2

Duck-to-rabbit reversals, all reference-frame realignments, and all reversals reported by subjects in Experiment 1.

Questions	Goose/Hawk	Chef/Dog	Figure-Ground	None
Duck-to-Rabbit Reversals				
Before RF hints	.35	.10	.06	.10
After RF hints	.52	.23	.27	.24
All Reference-Frame Realignments				
Before RF hints	.38	.27	.24	.21
After RF hints	.66	.65	.52	.48
All Reversals				
Before RF hints	.69	.69	.65	.69
After RF hints	.93	.83	.86	.89

Note: Reversals are cumulative. All reference-frame realignments include duck-to-rabbit reversals as well as other reference-frame reversals. All reversals include all reference-frame realignments as well as reconstruals. RF = reference frame.

in the figure-ground condition (.24 vs. .06) and in the no demonstration figure condition (.21 vs. .10), although these did not reach statistical significance. When all reference-frame realignments were considered, the differences among the conditions disappeared: A minimum of 21% of subjects in all conditions reported reference-frame reversals of their image of the duck/rabbit figure before the

explicit reference-frame hints were given (range 21% to 38%). Once again, the likelihood of reporting a reference-frame realignment increased following the reference-frame hints.

All Reversals. The bottom part of Table 2 shows all reversals (including reconstruals as well as reference-frame realignments). When reconstruals are counted, the likelihood of reversal prior to the explicit reference-frame hints is significantly greater in all conditions than it is when only reference-frame realignments are counted, $2.36 \leq z \leq 3.67$, $ps < .02$. Between 65% and 69% of all subjects reported a reconstrual of their mental image of the duck/rabbit figure before the reference-frame hints were given. In all conditions, the likelihood of reversal increased still further following the reference-frame hints.

The results of Experiment 1 support the hypothesis that the type of demonstration figures used is critical to whether or not duck-to-rabbit reversals are obtained in mental imagery: Reversals between duck and rabbit interpretations were most likely when reversal of the demonstration figure (the goose/hawk figure) entailed the same types of reversal as did reversal of the experimental figure. Experiment 1 also suggests that the type of demonstration figures used may be less critical to whether or not reconstruals or other reference-frame reversals are obtained: These types of reversals were equally likely in all demonstration figure conditions.

In addition, Experiment 1 demonstrates clearly that reference-frame reversals are possible in mental imagery: At least 20% of the subjects in all demonstration figure conditions (including the no demonstration figure condition) reported reference-frame reversals before the explicit hints were given (see the third row of Table 2). Finally, Experiment 1 shows that reconstruals are common in imagery: At least 65% of the subjects in all demonstration figure conditions (including the no demonstration figure condition) reported reconstruals before the explicit hints were given (see the fifth row of Table 2). Moreover, the occurrence of reconstruals was unaffected by the demonstration figures, as expected.

Why did we obtain reversals of mental images when Chambers and Reisberg did not? One possibility consistent with our results is that the reversal strategies suggested by the set of demonstration figures used by Chambers and Reisberg (1985) (i.e., the Necker cube,

the Mach book, and the Rubin figure-ground stimulus) were sufficiently misleading so as to preclude duck-to-rabbit reversals, even though the more appropriate chef/dog figure was presented later. Second, Chambers and Reisberg discounted responses other than "duck" and "rabbit," assuming that these other responses were not reports of true mental image reversals, but rather were simply responses to the demand character of the experiment, implicit in the experimenter's repeated questioning. Given that we obtained some duck-to-rabbit reversals, the second explanation is not sufficient to explain why we obtained reversals of mental images whereas Chambers and Reisberg did not. Moreover, I will show below (Experiments 3 and 4) that the valid interpretations of Experiment 1 are unlikely to be generated via non-structural routes. A third possibility is that Chambers and Reisberg's subjects were not sufficiently motivated to report reversals of their image, perhaps because they were recruited for the experiment while they were visiting the library for other reasons (our subjects received either course credit or monetary payment). Chambers and Reisberg not only recruited their subjects in the library, they conducted their experiments there as well (ours were conducted in a conventional laboratory environment). Perhaps implicit demands present in a library setting and not in a controlled laboratory setting conspired to lower the likelihood that Chambers and Reisberg's subjects would report reversals (e.g., subjects' desire to get back to what they were doing before being interrupted).

Experiment 2

The valid interpretations of the duck-rabbit figure which we scored as reconstruals or as other reference-frame realignments in Experiment 1, while structurally consistent with the Jastrow duck/rabbit figure, were clearly not the designated interpretations for that figure. Although some observers do report these interpretations when viewing pictures, the proportions are quite small (see Experiment 3, below). We are left with the question of whether reversals of mental images necessarily differ in nature from reversals of pictures.

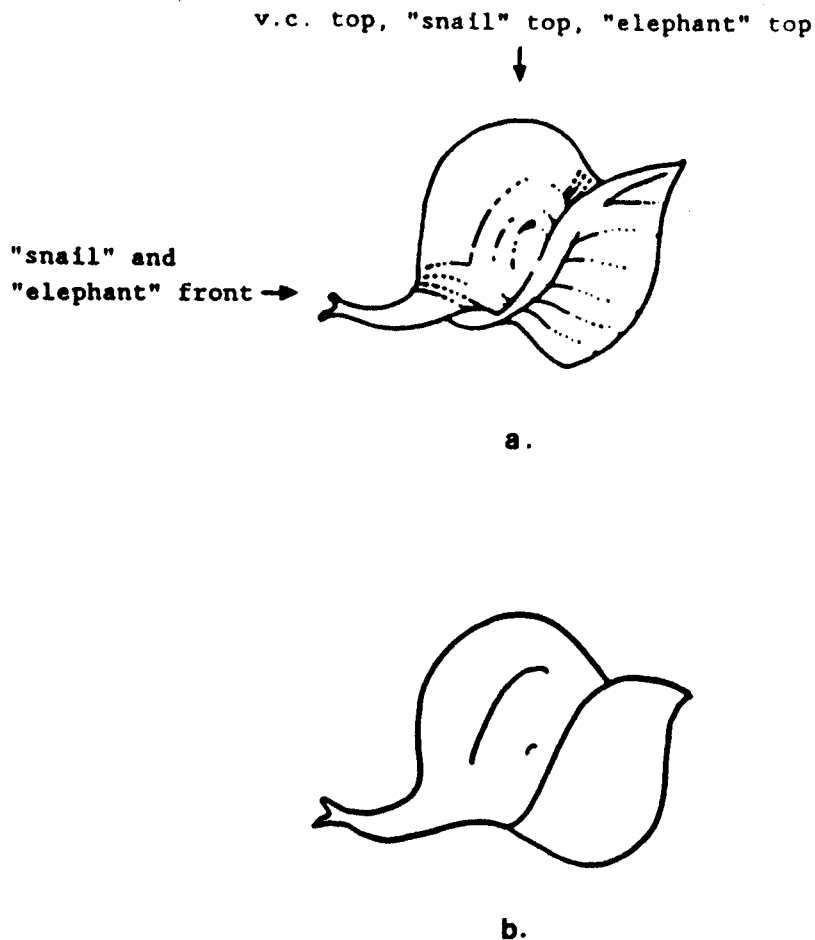To examine this question, we conducted another experiment,

v.c. top, "snail" top, "elephant" top

"snail" and
"elephant" front →

a.

b.

Figure 4

(a) Fisher's snail/elephant figure with reference frame annotations. (b) The simplified snail/elephant figure. (From "Mental images can be ambiguous: Reconstruals and reference-frame reversals," by M. A. Peterson, J. F. Kihlstrom, P. M. Rose, & M. L. Glisky, *Memory & Cognition, 20,* 118.)

using a figure whose two dominant interpretations require reconstrual only, without any reference-frame realignment: Fisher's snail/elephant, shown in Figure 4a with reference frame annotations. If imagery reconstruals, which we found to be pervasive in Experiment 1, are similar to perceptual reconstruals, then reversal between the two designated interpretations of the snail/elephant figure should occur commonly in imagery. Such a finding would indicate that imagery reversals do not necessarily differ in kind fromperceptual reversals.

We began by constructing a simpler version of the snail/elephant figure (Figure 4b), which we thought might be easier to hold in imagery than the original version. We tested whether our simplified version still supported snail-to-elephant reversals by asking perceiving subjects to list as many objects resembled by the picture as they could. This procedure also served as a means of identifying other valid reconstruals for the image *a priori*: Interpretations offered by more than 10% of these perceiving subjects were designated as valid interpretations for the image. As shown in the top part of Table 3, perceiving subjects reported both of the designated interpretations of our simplified snail/elephant figure, and a number of other valid interpretations as well (e.g., bird, seashell, leaf, flower, helmet/hat). Alternations between any two of these valid interpretations constituted a reversal (with one exception: seashell did not count as a different response from snail and vice versa).

In the imagery section of this experiment, 12 subjects viewed the snail/elephant figure under conditions similar to those employed in the no demonstration figure condition of Experiment 1. As shown in the bottom part of Table 3, we found that 83% of our imagining subjects reported reversals between two valid interpretations of our snail/elephant figure. Of these reversals, 60% were snail-to-elephant reversals. Thus, Experiment 2 demonstrates that reversals between the two dominant perceptual alternatives also dominate in imagery when those reversals entail reconstrual only, without reference-frame realignment. Thus, reversals of images do not necessarily differ in kind from reversals of pictures.

Implications of Experiments 1 and 2

Taken together, the results of the first two experiments

TABLE 3

Proportions of perceiving subjects reporting the valid interpretations of the simplified version of the snail/elephant figure and the proportions of imagining subjects reversing between two valid interpretations in Experiment 2.

Interpretations	Proportion of Subjects
Perceiving Subjects	
Elephant	73%
Snail*	69
Bird	31
Seashell*	20
Leaf	20
Flower	16
Helmet/Hat	13
Imagining Subjects	
Snail/Elephant	.33
Elephant/Snail	.17
Snail/Leaf	.17
Snail/Bird	.08
Elephant/Flower	.08
Total Reversals in Imagery	.83

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*Alternations between these two interpretations were not counted as reversals. Note: An additional 39 interpretations were offered by less than 10% of the viewers looking at the snail/elephant figure.

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demonstrate that reconstruals occur commonly in imagery, regardless of whether the most common type of perceptual reversal is a reconstrual (Figure 4b) or a reference-frame realignment (Figure 2a). Furthermore, the results of Experiment 1 indicate that reference-frame realignments are clearly possible in mental imagery even

without the administration of explicit or implicit hints, even though they are less common than reconstruals.

Perception Versus Imagery

What remains to be explained is why reconstruals of the duck/rabbit figure dominate in mental imagery, whereas reference-frame reversals dominate in perception. (We confirmed this latter assumption by showing the duck/rabbit figure to perceiving subjects, and found that 93% of them reported duck-to-rabbit reversals.) In our view, reversals in both imagery and perception illuminate the structure and operation of shape memory. We argue that in both initial recognition processes and reversal processes, there exists a stage in which a structural description of a shape is not connected to an interpretation; the connection may not yet have been made in recognition, whereas it may have been severed in reversal. At this stage, we propose that all representations specified in the same reference frame as that initially assigned to the input shape are searched exhaustively. If a good match is found, recognition (or reversal) occurs. For any number of reasons (perhaps including fatigue of the best-fitting representation in reversal situations), a good match may not be found in this original search set. In the absence of a good match in the original set of representations, the search through memory representations is widened gradually to include representations specified in different reference frames. Thus, representations in memory are accessed in functional subsets according to their reference-frame specifications.

A process such as this one could underlie the naming latencies found by Jolicoeur (1985, 1988) and others in shape recognition experiments. It can also account for our imagery results, and for the discrepancy sometimes obtained between the types of reversals found in mental imagery and in perception, as follows. Suppose that the individual components as arranged in the duck/rabbit figure support a number of interpretations within the original reference-frame set. All but one of these interpretations within the original reference-frame set may be subverted by the surface details available on a picture that is continually in view. Consequently, these subverted reconstruals will not be seen when the picture is present. When

reversal opportunities occur for pictures that remain in view, the failure to find an alternative match in the original reference-frame set will precipitate a search through sets of representations specified in different reference frames, until finally a good match is found in a set of representations with a reversed front/back reference frame, producing a duck-to-rabbit reversal.

What's different about imagery reversals? Two things perhaps: First, it may be the case, as Kosslyn (1980) has argued, that fewer surface details are present in the image than in the picture. Hochberg (1968, 1981) makes a similar claim about the relationship between percepts and objects. (Or it may be the case that subjects can choose to ignore details in an image more easily than in a picture.) If indeed, fewer details are present in the image than in the picture, potential reconstruals within the original reference-frame set might not be precluded in mental imagery. Consequently, reconstruals would be more common in imagery than in perception.

A second distinction between imagery and perception is required to account for our finding that reference-frame reversals are less common in imagery than in perception. This characteristic might be a consequence of the fact that it takes longer to complete a match between a structural description and a representation specified in a reference frame different from that of the input shape (e.g., Gibson, in progress; Jolicoeur, 1985, 1988; Peterson, et al., 1991). Within the time frame required to complete this match, certain processes endemic to mental imagery may interfere with reference-frame reversals. For example, suppose that mental images must be regenerated periodically, as Kosslyn (1980; Reiser, Kosslyn, Farah, & Fliegel, 1983) has proposed. Suppose further that image regeneration is conducted within the original reference frame in which a mental image was specified. If the periods of image regeneration fall within the time required to conduct the search that culminates in a reference-frame reversal, then the image regeneration process might interfere with the search process, by re-setting it, for example. Hinton's (1979a & b; Hinton & Parsons, 1981) proposal that mental images are generated within a viewer-centered reference frame is consistent with this interpretation. Reconstruals would not be affected by this re-setting procedure because, by definition, they are described in the same reference frame as the original interpretation. (Of course, the finding that at

least 21% of the subjects in Experiment 1 reported reference-frame reversals before the reference-frame hint suggests that the search process is not totally constrained by an image refreshing process.) In addition, Experiment 1 suggests that observers given implicit or explicit hints can intervene in this matching process, thereby causing a reference-frame reversal to occur.

Experiment 3

The prediction that reconstruals might be more likely to occur when fewer surface details are present need not be limited to mental imagery conditions; it should extend to perception conditions as well. Accordingly, a test of this prediction was conducted in Experiment 3 with perceiving subjects. Subjects viewed different versions of the Jastrow duck/rabbit and listed all the objects the picture could depict. One group ($N = 43$) viewed an intact version of the Jastrow duck/rabbit figure. Other groups of subjects ($N = 46$/group) viewed schematic versions of the Jastrow figure that were missing certain details, either the eye and/or the rabbit's nose.

The results of this third experiment are shown in Table 4. Note first that perceiving observers reported many of the interpretations that had been reported by imagining subjects in Experiment 1 (see Table 1). Some of the interpretations were more likely to be reported by observers viewing schematic versions of the duck/rabbit figure than by observers viewing the intact duck/rabbit figure. For example, 24% of the observers viewing a schematic figure reported that the figure resembled a fish, whereas only 2% of the observers viewing the intact Jastrow duck/rabbit figure reported that it resembled a fish. In addition, some interpretations offered for the schematic duck/rabbit figure and for the mental image in Experiment 1 were not offered by observers viewing the intact figure (e.g., deer; profile of a person with hair streaming behind; hand-held hair dryer[3]). These interpretations were offered by our imagining subjects, as shown in Table 1.

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[3] The "hand-held hair dryer" interpretation was not offered by any of the imagining subjects in Experiment 1. This interpretation was offered by imagining subjects in other experiments reported in Peterson, et al. (1992), however.

Thus, the results of Experiment 3 are consistent with the claim that the non duck-to-rabbit reversals reported by imagining subjects were structural reversals. The same interpretations were offered by perceiving observers. In addition, there is some suggestion in the results of Experiment 3 that details present on the picture may preclude fitting certain interpretations to the picture, interpretations that can be fit when schematic versions of the picture are viewed.

TABLE 4

Interpretations offered by observers looking at the intact Jastrow figure and schematic versions.

Interpretations	Intact Jastrow Figure (%)	Schematic Jastrow Figure (%)
Duck	93	92
Rabbit	100	90
Fish	2	24
Hand making shadow figure or peace sign	9	8
Profile of person with hair streaming behind	0	4
Deer/antelope	0	2
Pair of scissors	2	1
Dog/puppy	2	0
Hand-held hair dryer*	0	3

*This interpretation was not offered in Experiment 1 of this paper, but it was offered in other experiments using similar methodologies (see Peterson, et al., 1992).

Experiment 4

We have argued that the reconstruals reported by our subjects were *structural reconstruals*, in that they depend on the componential structure of the image (see Peterson, et al., 1992). But we have not shown that structural reconstruals differ from semantic associates that might be produced to mental images of ducks and rabbits, or to the corresponding concept. Empirical evidence regarding a distinction between structural and semantic reconstruals is relevant to our claim that imagery reversals and perceptual reversals do not necessarily differ in kind. Experiment 4 was designed to identify the semantic associates of the words "duck" and "rabbit" and of mental images generated in response to these words. Subjects were asked to list all the objects that came to mind when they saw either the word "rabbit" ($N = 12$) or the word "duck" ($N = 12$) printed on a page, or when they created a mental image of either a rabbit ($N = 12$) or a duck ($N = 12$) in response to the printed words. They were given one minute to generate these associations. Different subjects participated in each of these conditions. None of the subjects in this experiment was shown the Jastrow duck/rabbit figure; hence, their mental images of ducks or rabbits were not expected to resemble the rather idiosyncratic Jastrow figure.

We had two goals in examining the associations generated by subjects under these conditions. First, we were interested in seeing whether or not any of the interpretations we had considered to be valid reversals out of a duck (or rabbit) interpretation in Experiment 1 were offered as semantic associates of ducks (or rabbits) under the conditions of Experiment 4. If so, that would undermine our assessment that those reversals of mental images of the idiosyncratic Jastrow duck/rabbit figure were structural reversals rather than semantic reversals. Second, we were interested in seeing whether the associates generated to a mental image of an object were the same as those generated to the corresponding word. If not, that would suggest that the mental structures indexed by the activation of the mental image were different from those indexed by the activation of the lexical item. If associations generated to a mental image of an object can be shown to differ from associations generated to the name of that object, then Experiment 4 may serve to indicate one way in which the use of visual imagery can lead thought in creative directions.

Subjects generated an average of eight associations per condition. Table 5 shows the average proportion of associations that

were duplicated across any two of the conditions. Notice first the overlap between items generated in response to ducks and rabbits. Across both word and image conditions, approximately 15% of the items generated in response to one of these stimuli was also generated in response to the other. Thus, very small proportions of associates were generated for both ducks and rabbits. The duplicated responses included items like "hunter," "grass," "food," "baby," "white," and "animal." None of these responses would have been

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TABLE 5

Proportions of associations duplicated across conditions.

Conditions	Duck		Rabbit	
	Word	Image	Word	Image
Duck				
Word	1.00	.40	.14	.14
Image		1.00	.16	.14
Rabbit				
Word			1.00	.34
Image				1.00

---

scored as a valid reversal in Experiment 1. Indeed, the only one of these items that was ever reported as an interpretation of an image in Experiment 1 was "animal," and in Experiment 1, "animal" was not accepted as a valid interpretation. Thus, it appears that subjects in Experiment 1 were not simply generating semantic associates to their initial interpretation in response to the experimenter's continued prompts for alternative interpretations. The results of Experiment 4 show that taking a semantic route from duck does not lead one to a rabbit (or vice versa), nor to a pair of scissors, nor to a hand making a peace sign (see Table 1 and Figure 3). The failure to

obtain these items under the conditions of Experiment 4 is consistent with the interpretation that the reconstruals obtained in Experiment 1 were *structural reconstruals*; that is, they were matches between representations in shape memory and the structural descriptions of the imagined shape.

Two subjects in the word-duck condition and one in the image-rabbit condition reported "dog" as an associate. Although "dog" was one of the valid interpretations in Experiment 1, none of the imagery subjects who initially saw the duck/rabbit figure as a duck

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TABLE 6

Proportions of associations in various categories that were offered in the word and image conditions of Experiment 4.

Category	Image (N = 191)	Word (N = 187)
Actions	.03	.04
Adjectives	.12	.06
Alternative name	.00	.03
Color	.05	.06
Exemplars	.02	.05
Perceptual parts/attributes	.15	.16
Scene Components	.28	.20
Semantic Associates	.24	.26
Sound	.01	.02
Superordinate	.04	.05
Miscellaneous	.05	.08

---

reinterpreted it as a dog. Thus, the fact that it was reported as a semantic associate to the word "duck" in Experiment 4 is of no consequence for the results of Experiment 1. However, quite a few subjects in Experiment 1 reported "dog" as a reconstrual of mental images they had initially interpreted as rabbits. All but one of these

subjects also offered other reversals of their mental images, so the pattern of results obtained in Experiment 1 would remain essentially unchanged were we to exclude "dog" from the list of structural reconstruals.[4]

The second pattern to notice in the data shown in Table 5 is that less than half of the associates reported to an object and the corresponding name were the same. Indeed, 65–67% of the associates reported to the imagined objects were unique to the mental image condition (i.e., these items were not produced when the corresponding word served as the seed for the association responses). This finding suggests that the majority of the mental structures indexed by the activation of a mental image were different from those indexed by the activation of the corresponding lexical item.

The associates offered to the mental images and to the names of the objects were classified into the categories shown in Table 6. Even though the item overlap in the word and mental image conditions was low, it is clear that for the most part, the different items generated to mental images and to lexical items belong to similar categories, at least for the following categories: actions (e.g., "running," "swimming"); colors (e.g., "white," "green"); exemplars (e.g., "jackrabbit", "Donald"); perceptual features (e.g., "ears," "bill"); semantic associates (e.g., "car," "chocolate," and "Easter" for rabbit; and "cartoon," "dinner," and "orange" for duck); sounds (e.g., "quacking"); and, superordinate terms (e.g., "animal," "bird"). The degree of overlap is somewhat lower for adjectives (e.g., "fast," "silly"), and for a category of responses labelled "scene components." Scene components were defined as concrete objects that might be found along with the critical item in a typical scene. Examples of objects scored as "scene components" are "lake," "tree," and "park." The data suggest that a larger proportion of adjectives and of scene components are indexed when mental images rather than words served as the association cues. These data are merely suggestive because the number of items sampled was so small, but they suggest an intriguing direction for future research. It is of note that previous investigators whose work has been taken as relevant to imaginal associative processing did not use an association paradigm like that used in Experiment 4. Instead, previous investigators either used a scanning paradigm to test the spatial structure of mental images of a production paradigm to study the structure of mental scripts (for a summary, see Clark & Paivio, 1987).

Implications for Creativity

An idea is called creative when it represents a novel solution to a problem, regardless of whether the problem itself is ordinary or extraordinary. The results of the experiments reported here suggest that employing visual images in problem solving situations might produce solutions quite different from those produced by simply thinking about the problem, using propositional memory structures (Intons-Peterson, this volume; Shepard, 1978). In particular, it is now clear that images can be reconstrued, and that the reconstruals entail a structural reinterpretation of the form of the mental image. They are not simply semantic associations indexed via a conceptual route; the structural reconstruals of mental images of the idiosyncratic Jastrow duck/rabbit figure were different from the semantic associates generated to the words *duck* and *rabbit* and to mental images of ducks and rabbits generated from long-term shape memory.

The ability to reconstrue the structure of a mental image may provide an avenue for creative solutions. One possibility is that structural reconstruals may be the source of problem solutions which might otherwise appear to be "remote analogies" (for discussion, see Weisberg, 1988). Consider, for example, Kekulé's description of how he discovered the ring structure of benzene:

> My mind's eye, sharpened by repeated visions of
> similar art, distinguished now greater structures
> of manifold form: long rows, sometimes more
> closely fitted together, all twining and turning *in*
> *snake-like motion* [italics mine]. But look! What
> was that? One of the snakes had seized hold of
> its own tail, and the whole form whirled
> mockingly before my eyes. (Rothenberg, 1979,
> p. 396)

In propositional terms, snakes may be considered only remotely analogous to atoms, but Kekulé's description clearly states that the structure of the mental image was momentarily "snake-like." Thus, the structure of the mental image may have been reconstrued as a snake, which in turn, facilitated Kekulé's discovery. This is a clear example of how structure-dependent reinterpretations can propel

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Implications of Experiments 3 and 4

The results of Experiments 3 and 4 support the notion that the interpretations of the duck/rabbit image that we scored as valid interpretations in Experiment 1 were indeed structural reversals: In Experiment 3, perceiving subjects reported seeing many of those interpretations. Moreover, the fact that some of these interpretations were more likely to be offered by perceiving subjects viewing schematic stimuli in Experiment 3 is consistent with the proposal that one difference between perception and imagery may be the presence versus absence of details. Furthermore, the finding that the list of associations generated in Experiment 4 was largely different from the list of valid interpretations for the duck/rabbit figure provides additional evidence of the structural nature of the reversals and reconstruals in Experiments 1 and 2. Subjects in Experiment 4 were not asked to list other items resembled by their mental images, but rather, to list other things they thought of while they observed their mental image.

Experiment 4 yielded an additional interesting finding: A majority of the associations generated when mental images of objects served as seeds for the association process were different from those generated when the name of the object served as the seed. Beyond their obvious implications for theories of mental imagery and shape recognition, the results of the four experiments discussed here have implications for theories of creativity.

thought in new and creative directions.

Furthermore, the finding that the associations generated in response to mental image cues were largely different from those generated in response to the names of the same objects suggests another route through which mental images can serve as the source of ideas that are extraordinary, when ordinary is defined on the basis of associations generated to the lexical items. Note that the subjects in the experiments reported here did not possess exceptional powers of imagery, unlike those Shepard (1978) has discussed. Therefore, these experiments suggest that novel solutions can be produced by ordinary people who attend to their mental images in the course of trying to solve a problem. I do not mean to imply that a creative approach to problem solving necessarily involves the use of mental images. My claim is only that adding mental imagery to one's repertoire of problem solving strategies might increase the likelihood of finding creative solutions.

This proposal is consistent with the view that one's potential for creativity increases with one's knowledge relevant to the problem domain (Weisberg, 1988). It has been shown that it is not sufficient for the problem solver simply to possess the relevant knowledge, however; it's relevance to the problem at hand must be apparent as well (for discussion see Weisberg, 1988). Similarly, Experiment 4 implies that knowledge associatively encoded with a structural representation may not be available when the corresponding lexical representation is activated; instead the structural representation must itself be activated via mental imagery in order for the knowledge associatively encoded with it to be reported in an association task. Therefore, it seems plausible that mobilizing mental imagery along with propositional knowledge may suffice to increase the size of the knowledge base operative in a given problem solving situation; this in turn may lead to superior solutions. Increasing the number of individuals working on a problem improves the chances of reaching a superior solution (Maier, 1950). Increasing the number of mental structures employed may operate in a similar fashion.

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