I began this mental imagery research in response to a set of experiments that I found unbelievable. Chambers and Reisberg (1985) found that people could not discover the alternative interpretation of an ambiguous figure by using mental imagery. In my original response to that work (Hyman & Neisser, 1991), I was interested in outlining some conditions that would facilitate reversals of ambiguous figures using images. I attempted to frame discovery using mental images as a question of the experimental methods employed, rather than as indicative of the underlying relationship between imagery and vision. In subsequent investigation, I have tried to discern how manipulation of visual information using imagery is similar to other memory tasks, such as the reconstruction of a story. Phrasing the issue of imagery-based discovery in the language of reconstructive memory rather than the language of perception and perception/imagery equivalences provides an alternative view of the problem.

Chambers and Reisberg (1985) asked people to view a figure, such as the duck/rabbit figure, and to form a mental image of the drawing. The subjects then attempted to discover the alternative interpretation from their mental image of the figure. Not one could do so by examining their mental images, but almost every one could when viewing their own drawing of the figure made after searching their images. This demonstrated that the failure to reinterpret the figure was not due to a lack of information. Chambers and Reisberg claimed that images could not be reconstructed because mental imagery does not involve construal in the
first place -- people know what they are visualizing. The only way to discover anything is to imagine a different image. Since the subjects in the Chambers and Reisberg experiments did not know what the other interpretation was, they could not change their mental image.

Because I would have expected this to be a reasonably simple task, I was surprised by these results. Apparently, I was not the only person. Chambers and Reisberg (1985) themselves noted that a priori they expected people to be able to do this task. Furthermore, they continued to conduct research in this area and found that under some conditions people could find novel interpretations of mental images (Reisberg & Chambers, 1986; 1991). In the midst of a series of meaningless shapes that subjects were to imagine, subjects were shown an outline of the map of Texas rotated 90° counter-clockwise. They did not recognize this form as Texas. When they were asked to rotate their mental image 90° clockwise they still did not recognize the figure. When, however, they were told to make the left side the top of the figure and that it was an outline of a familiar geographical form, about half of the subjects discovered Texas. Reisberg and Chambers suggested this was an example of subjects changing their understanding of an image and therefore changing the image itself, by reassigning the top of the form. With the new image, subjects were reminded of something known and this allowed many people to discover the form of Texas. In this fashion, changing mental images could lead to discoveries through remindings but not through the process of interpretation that is used in vision.

Finke, Pinker, and Farah (1989) were also challenged by the original Chambers and Reisberg results. They conducted a series of experiments in which subjects imagined, rotated, combined, and edited simple figures using mental imagery. Their subjects were able to discover new interpretations from their images. Finke and his colleagues argued that images do contain visual information that allows interpretation and reinterpretation. They resolved the differences between their results and those of Reisberg and Chambers by suggesting that classical ambiguous figures are unique: To reinterpret an ambiguous figure one must be able to perceive the whole figure at once. Images, however, are composed of dynamically fading and regenerating pieces, and the process of regeneration requires the resources of working memory. Because the whole ambiguous figure must be maintained for reconstruction to occur, and because imagery tends to fade and regenerate over time, reinterpreting ambiguous figures is difficult, to say the least. According to Finke et al.,
the difficulty of maintaining a whole figure for reinterpretation is beyond the limits of working memory.

Finke et al.’s argument is interesting because it suggests that the differences between imagery and perception found in discovery studies may be explained by similarities between imagery and another cognitive process—memory. Most models of imagery discuss the reliance of visual images upon memory processes. For example, Kosslyn, Pinker, Smith, and Shwartz (1979) stated that images are created from stored information and maintained in a visual buffer (or working memory). Deterioration of stored information in long term memory causes an image to be less clear and detailed than the original percept. In addition, visual working memory holds a limited amount of information and must constantly be refreshed. Thus some constraints on the imagery system are dictated by memory limitations.

Additional limitations on the imagery system, and hence limitations on the ability to make discoveries using imagery, may be due to the process of creating an image with a reconstructive memory system. Bartlett (1932) is known for his early studies concerning reconstructive remembering of verbal material. He asked subjects to recall a short story and then looked at the errors people made, including both omissions and intrusions. He interpreted the pattern of errors as evidence for the influence of general knowledge structures on the recreation of a story. Bartlett referred to these general knowledge structures as schemata. Since Bartlett, there has been a great amount of research conducted on the reconstruction of verbal material (e.g., Bransford & Franks, 1971; Hyman & Rubin, 1990; Jenkins, 1974; Kintsch & van Dijk, 1978; Mandler & Johnson, 1977), and, relatedly, on autobiographical memories (e.g., Barclay, 1986; Neisser, 1982). According to Bartlett’s reconstructive view of memory, the recall of a story is guided by story details that are available from memory at the time of recall, story gist, knowledge of events like those described in the story, similar personal experiences, cultural understanding of narrative forms, and general world knowledge. Reconstructive story recall adds information to fill gaps in the story and in memory, and may also change details to fit with general knowledge structures.

Although Bartlett is known primarily for his studies of story memory, he also investigated memory for pictures. In having people describe line drawings of faces, he found evidence of schema-based reconstruction based on an analysis of both omission and intrusion errors. This finding is particularly interesting because of the claim that mental images are
similar to pictures (e.g., Kosslyn, 1981). Thus, there is reason to expect that the creation and maintenance of a mental image may involve reconstructive memory.

Reconstruction of a visual memory as a mental image, like reconstruction of a story, would be based on visual details available at the time of recall, general visual form, knowledge of objects like the one being imagined, knowledge of the visual world, and cultural understanding of pictorial representation. The reconstructive creation and maintenance of an image should focus on the gist. In the case of images, as opposed to stories, the gist may be the general form. The reconstruction should also overwrite inconsistent details and fill in gaps in the remaining information. These additions will conform to the general form and to knowledge of the category of objects or events being imagined. The maintenance of the image will continue to emphasize the general form at the expense of details. Thus one can imagine a house without knowing the number of windows or the color of the trim.

The reconstructive view of image construction suggests some constraints on discovery using mental images. Namely, discovering something about the gist or consistent details should be fairly straightforward, discovering something about less important details or something that contradicts the gist should be more difficult.

This reconstructive view of imagery led me to two types of experiments. The first line of experiments (Experiments 1 and 2) investigated whether classical ambiguous figures can be reinterpreted using mental imagery (see Hyman & Neisser, 1991, for more detail). Others have also addressed this point (see Chambers, Kaufmann & Helstrup, Peterson, and Reisberg & Logie, all this volume). Our experiments were modeled on the success of the Reisberg and Chambers (1986, 1991) Texas experiment but used the duck/rabbit and chef/dog figures. We reasoned that subjects' images may have been limited by the gist of the figure they were imagining, until they were provided with instruction that allowed subjects to fill in details of the figure. The results of these experiments suggest that a view of image creation as a reconstructive memory task may be productive. The other line of experiments is based on ongoing research that more directly investigates the relation between reconstructive memory and mental imagery. I report one experiment (Experiment 3), conducted with Jeremiah Faries, that explored how the gist and details of visual information are remembered. This second area of research outlines some limitations that the
reconstructive nature of remembering places on imagery-guided discovery.

**Experiment 1**

**Method**

If subjects who imagine one interpretation of the duck/rabbit or chef/dog figure are bounded, or limited, by the gist of the figure, their image may not include enough detail that is consistent with the alternate construal to be reinterpreted. If, however, subjects are encouraged to fill in detail, they may then be able to discover the other interpretation. Experiment 1 was conducted to see if explicit instructions concerning the nature of the alternate construal make a difference in the reversibility of an imagined figure. The explicit instructions are assumed to cause the instantiation of additional information, thereby increasing the likelihood of discovering an alternative interpretation. There were two conditions, minimal and full information. Little or no reconstructions were expected in the minimal information condition because this condition was similar to Chambers and Reisberg's (1985), and their subjects were not able to reconstrue their images. If reconstructions are dependent on detail, then our full information instructions—those that encourage instantiations of detail—should produce reconstructions.

**Subjects**

Forty Emory University undergraduates were tested individually. They were assigned to one of two conditions that varied in the amount of instructions provided to help them reverse their images.

**Procedures**

Subjects were first familiarized with ambiguous figures. They were shown the Necker Cube, the Schroeder staircase, and the vase/faces figures. Subjects had to indicate that they were able to see both interpretations. If subjects experienced difficulty seeing both interpretations they were provided with clues. Subjects were then told that the next part of the experiment would concern visual memory. They were told that they would be shown a line drawing for five seconds, that
they should form a mental picture of the line drawing, and that they would later be asked to draw the figure from memory. Subjects were then shown either the duck/rabbit or the chef/dog figure.¹ Both figures were used for all subjects and order was counterbalanced. Orientation of the chef/dog was also counterbalanced. Subjects were instructed to hold the image in their mind and then were asked if they had noticed, during presentation of the figure, that the figure had two interpretations like the figures they had seen earlier. Data from subjects who said yes were discarded.² Subjects were then told that the figure did indeed have two interpretations and were asked to find the other interpretation. The information provided to subjects varied according to condition.

**Minimal Information (n=20):** This condition was modeled on the procedure of Chambers and Reisberg (1985). For the duck/rabbit figure, subjects were advised that it might help to shift their focus across the image. For the chef/dog, subjects were advised to rotate the image 90° clockwise or counterclockwise as appropriate with respect to whether the figure had been shown in the dog or chef orientation originally.

**Full Information (n=20):** These subjects were given both orientation and categorical information about the alternative interpretation, modeled on information that was given to the subjects in the Reisberg and Chambers (1986, 1991) Texas experiment. For the duck/rabbit figure, subjects were told to consider the back of the head they already "saw" to be the front of the head of a different animal. For the chef/dog figure, they were told to rotate their image so that what they "saw" as the

¹I do not include illustrations of the duck/rabbit figure because the figure is included in other chapters within this chapter.

²About one quarter of the subjects were discarded because of previous familiarity with the duck/rabbit figure. This minor problem arose because the duck/rabbit figure was included in the text used in the introductory psychology class. However, the experiment was conducted before the figure was encountered in the course, and we were able to collect data from the students who had not looked ahead in the book.
front would be the bottom of either the head of a man
or an animal, as appropriate since the original
presentation was counterbalanced to be in either the
dog or chef orientation.

Subjects succeeded by either naming the alternative interpretation
or by providing a reasonable description. In keeping with the approach of
Chambers and Reisberg (1985), other interpretations were accepted—such
as *whale for dog*, if the subject described the back end as appearing like a
tail. All subjects were asked to draw the figure and those who had not
reversed their mental image were asked to find the other interpretation in
their drawing. The other ambiguous figure was then presented and the
procedure repeated.

**Results**

Very few of the subjects in the minimal information condition
reversed their images, while approximately half of those in the full
information condition discovered the alternative interpretation (see Table
1). It is important to note that even in the minimal information condition
a few subjects (one of 20 for the chef/dog and two of 20 for the duck/rabbit)
were able to reverse their mental images. Although the numbers of
successful discoveries in the minimal information condition are low, they
contrast with the complete failure to reconstrue images shown by
Chambers and Reisberg's (1985) subjects.

**Experiment 2**

The second experiment was a replication and expansion of the first
experiment. The full information condition in Experiment 1 provided
subjects with guidance concerning both orientation and category
membership of the alternative interpretation. The number of conditions
was expanded in Experiment 2 to investigate both orientation and category
information separately as well as in combination. It was expected that
providing only one piece of information would lead to a number of
reversals intermediate to the minimal and full information conditions.
Because several subjects in Experiment 1 were dropped due to familiarity
with the duck/rabbit figure, only the chef/dog figure was used in this
experiment.

<table>
<thead>
<tr>
<th>Table 1</th>
<th>The number of subjects who reversed the figures using mental imagery</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Experiment 1</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Figure</strong></td>
<td><strong>Chef/Dog</strong></td>
</tr>
<tr>
<td>Reversed Image?</td>
<td>Yes</td>
</tr>
<tr>
<td>Condition:</td>
<td></td>
</tr>
<tr>
<td>Minimal</td>
<td>1</td>
</tr>
<tr>
<td>Full</td>
<td>8</td>
</tr>
<tr>
<td>$X^2 = 5.16, p&lt;.02$</td>
<td>$X^2 = 7.29, p&lt;.01$</td>
</tr>
</tbody>
</table>

| **Experiment 2** | |
| **Figure** | **Chef/Dog** |
| Reversed Image? | Yes | No |
| Condition: | | | | |
| Minimal | 2 | 20 (5) |
| Orientation | 3 | 19 (7) |
| Category | 2 | 20 (10) |
| Full | 8 | 14 (3) |
| $X^2 = 7.96, p<.05$ |

*Note:* Parenthetical numbers indicate how many subjects later reversed the figure using their own drawings.

**Method**

**Subjects**

The subjects were 88 Emory University undergraduates randomly assigned to one of four conditions and tested individually.
Procedures

The procedure from Experiment 1 was generally followed here. The subjects were first shown the Necker Cube, the Schroeder staircase, the vase/face, and the duck/rabbit to familiarize them with ambiguous figures. Subjects were then told that the next part of the experiment would concern memory. They were shown the chef/dog figure for five seconds and asked to form and hold a mental picture of it. The subjects were asked to continue holding the image in their mind and then they were asked if they had noticed that the drawing had two interpretations. The data from any who said yes were discarded. The subjects were told that the figure did contain two interpretations and were asked to find the second interpretation. There were four instruction conditions.

**Minimal Information** (n=22): As in Experiment 1, subjects were given little guidance. They were advised to rotate their image 90° clockwise or counterclockwise as appropriate for presentation orientation. For example, if the original orientation showed the dog, subjects were asked to rotate their image 90° clockwise so that the profile of the chef would be upright.

**Orientation Information** (n=22): These subjects were asked to rotate their image so that the "front" they "saw" would be the "bottom."

**Category Information** (n=22): The 11 subjects who had originally seen the figure in the dog orientation were told that the alternative interpretation was a man's head and were asked to describe it more completely. The other subjects were told that the alternative interpretation was an animal and were asked to name or describe the animal.

**Full Information** (n=22): These subjects were given both orientation and categorical information about the alternative interpretation as in Experiment 1.
A correct response was one in which a subject either correctly named the alternative interpretation or provided a detailed description of an interpretation. Some subjects noted, for example, that the man was "wearing a funny kind of hat," or that the animal "looked like a fetal pig with its legs sticking down." Subjects then drew the figure and, if they had failed to reverse their image, attempted to reverse their drawing.

Results

As in Experiment 1, very few of the subjects in the minimal information condition were able to reverse their images, while nearly half of those in the full information condition were able to do so (see Table 1). Contrary to expectations, few subjects in the two intermediate conditions were able to discover an alternative interpretation. It appears that people will most readily discover the alternative interpretation of the chef/dog figure using imagery if they are provided with knowledge concerning how to orient the figure and what type of figure it will resemble.

Discussion of Experiments 1 and 2

Based on the results of these first two experiments, we can dismiss the claim that classical ambiguous figures cannot be reversed using mental imagery. Under some conditions our subjects did reverse ambiguous figures using imagery. Even under conditions very similar to the original Chambers and Reisberg (1985) experiments we found that five to ten percent of the reversed their image—an important finding in light of the complete lack of reversals in their work.

One interesting observation was that the phenomenological aspect of discovering the alternative interpretation is similar when using vision and imagery—subjects experienced an "ah ha" type of reaction in both of the training trials, which relied on vision, and the test trials, which relied on imagery. Although records were not kept, many subjects made some expression such as "oh" or "now I see," just before noting the alternative interpretation. These types of exclamations were similar to the comments subjects made when viewing the familiarization figures and are perhaps similar to more dramatic expression accompanying discoveries, such as Archimedes shouting "Eureka" in his bathtub.

Finding conditions in which subjects can regularly discover the
alternative interpretation removes the need for Finke et al.'s (1989) theoretical explanation of the qualitative difference between attempting to reverse images of classical ambiguous figures and reinterpreting other types of figures. More likely, the differences between Finke et al. (1989) and Chambers and Reisberg (1985) can be explained methodologically. It is not the difference between types of figures, but rather the difference between types of instructions. Finke et al. gave detailed instructions to their subjects whereas Chambers and Reisberg gave limited instructions. When we provided detailed instructions and used the same figures as Chambers and Reisberg, we found results more in line with the work of Finke and his colleagues.

Claiming that the differences in findings are due to methodological differences does not mean there are not interesting theoretical issues in this domain. Reisberg and Logie (this volume), for example, argue about the similarities and differences between imagery and perception and make claims about the content of percepts and images based on this research domain. Peterson (this volume) also discusses the links between images and pictures and attempts to characterize the differences between the two in terms of the reversibility of figures, both imagined and seen. Both claim that such research will inform us about the types of discoveries people can make using mental images and the conditions under which such discoveries should be possible.

While not disagreeing with this perspective, I would like to use these data to consider the links between imagery and a cognitive process other than perception: namely, reconstructive memory. The creation and maintenance of a visual image probably relies on the same memory processes that are involved in the recall and reconstruction of a story or an autobiographical experience. Reconstruction of a story builds on information from the story that remains available in memory, both the gist and the details. Reconstruction also relies on other information, including knowledge of events similar to the events being recalled, knowledge of the people involved, cultural biases in the manner in which stories are told, and other general information. Thus the story or event that is reported is a new construction that emphasizes the gist and includes consistent details that are available. The construction fills in gaps in the original story and gaps in memory, and may ignore or replace inconsistent information.

I argue that mental images are created and maintained using similar reconstructive memory processes. Thus, in a fashion similar to the reconstruction of a story, a great variety of knowledge would go into the
creation of a mental image: knowledge of the object being imagined, of details from the particular object, of other items that look like it, of other objects categorically similar to it, and of how society typically displays visual information. The image should emphasize the gist of the object or event to be imagined. The gist is most likely the general form of the object/event. In addition, the reconstruction of an image, like that of a story, will fill gaps in details and either overwrite or ignore less important or inconsistent details. The result of the reconstructive process is that in the image, the general form, or gist, should be fairly clear and the details more vague.

Discovering something about the gist, and to a lesser extent consistent details, should be relatively easy because the image emphasizes the gist. Discovering information about other details should be more difficult because they may not be consistent with the gist of the image. Discovering something that contradicts the gist will be most difficult because it will require reworking the image. In the first two experiments, the gist of the duck was not enough to discover the rabbit. Drawing the figure helped because it forced the instantiation of details left vague in the image. Instructions helped because they constrained the possible ways of looking at the remaining visual information while suggesting alternative ways of organizing the details. The lack of facilitation when subjects were provided with either orientation or category information alone suggests that for people to successfully discover the other interpretation, they need to know how to restructure the available details and how to apply general knowledge structures to the image.

**Experiment 3**

Although the reconstructive language used in the discussion above may not differ theoretically from other descriptions, such as those looking at perception/imagery correspondence, it may suggest new ways of looking at the problem of discovery using mental images. With Jeremiah Faries of Northwestern University, I have been engaged in some new research that addresses the relation between reconstructive memory and imagery more directly than did the first two experiments. In the current experiment, we explored subjects’ ability to keep details in mind when they concentrated on the whole, a problem similar to the one with the ambiguous figures, where subjects held an image of the overall figure (gist) while trying to use
the details of the imaged figure to discover an alternative interpretation. In our experiment we asked subjects to construct a coherent whole (i.e., gist) from pieces (i.e., details) and then looked at their ability to recall both the completed figure (gist) and the constituent pieces (details).

We chose recall as a measure, rather than frequency of reversibility or discovery, to probe the influence of reconstructive remembering on the contents of mental images. Nonetheless, we address both imagery and discovery because the pieces are presented so that the subjects need to use imagery to discover, through combination, the overall shape, or gist, of the figure.

The final forms of the figures used were geometric shapes, such as squares, triangles, and rhombuses. The pieces presented were varied to explore the effects of complexity on the ability to discover the figure and on recall for the whole, or gist, and the pieces, or details. There were three types of pieces: canonical (e.g., square); simple (not easily labeled, but containing simple, straight inner edges); and complex (not easily labeled and containing irregular inner edges). We also varied whether the pieces were present or absent during drawing to investigate the effects of remembering on the recall of visual information.

Method

Subjects

Twenty-seven Northwestern University undergraduates participated in this experiment. The research was conducted in groups of four to seven subjects.

Materials

Thirty-six puzzles with three pieces each were created. All puzzles could be combined to create the well-known geometric shapes of square, rectangle, isosceles triangle, right angle triangle, square rhombus, or rhombus. The pieces themselves were of three different types: canonical, at least two of the three pieces were themselves well-known geometric shapes (square, rectangle, etc.); simple, all pieces had only a few, very straight internal edges, but could not be easily labeled; or complex, the three pieces were created with complicated internal edges. Figure 1 shows examples of the types of pieces and the completed figures for each set.
Figure 1 also shows another aspect of the puzzle pieces—the number of pieces that were presented in the same orientation with respect to one another was varied from all three in the same orientation to all three in different orientations.

Procedure

Subjects were presented with a series of three-piece puzzles. Each set of three pieces was shown for five seconds. Subjects were asked to memorize the pieces and discover the completed pattern. The subjects were then asked to draw the completed figure, with the internal lines representing the distinct pieces. On half the trials this task was a memory task (i.e., the pieces were removed from the subjects' view after the initial five seconds) and on half it was not (i.e., the pieces were left in the visual field while the subjects completed their drawings). For each drawing subjects were asked whether or not they had discovered the completed figure during the viewing period.

Design

Two within-subject manipulations are of interest with respect to reconstruction of visual information. The first is the type of pieces: canonical, simple, or complex. The second is whether the drawing of the completed figure was a memory task or not; on half of the trials the pieces were withdrawn after five seconds; for the other half the pieces remained in view during the drawing phase. The orientation of the pieces with respect to one another was also systematically varied, but this is of less interest to the issue of reconstructive memory for visual figures.

Results

This was primarily a study of memory for visual information. Discovery using imagery was involved for if subjects discovered the correct figure, they generally did so while the pieces were visually present by imaginantly manipulating the pieces. We were concerned with two aspects of the subjects' drawings: whether the completed figure was correct and whether the individual pieces were correct. Thus, each subject was given two scores in each of the $2 \times 3$ (memory condition x piece type) conditions. One score was the number of
Figure 1
Sample puzzle pieces and completed patterns: a) canonical pieces; b) simple pieces; c) complex pieces.
drawings with correct figures while the other was the number with correct pieces. Because the subjects were presented with six sets of pieces in each treatment condition, the scores ranged from zero to six.

For the number of drawings with correct figures, a $2 \times 3$ analysis of variance indicated a main effect of memory condition, $F(1,26)=18.89$, $p<.01$, a main effect of piece type, $F(2,52)=10.27$, $p<.01$, and no interaction. It was easier for subjects to draw the whole figure correctly when the pieces remained in the visual field than when they were forced to rely on their memory. In addition, as the pieces became more complex it was easier to form the whole figure correctly. Table 2a shows the mean number of correct whole figures in each condition.

For the number of drawings with correct pieces, a $2 \times 3$ analysis of variance indicated a main effect of memory condition, $F(1,26)=230.13$, $p<.01$, a main effect of piece type, $F(2,52)=75.11$, $p<.01$, and a significant interaction, $F(2,52)=5.11$, $p<.01$. When subjects were forced to rely on memory they drew fewer of the pieces correctly than when the pieces remained in vision (see Table 2b). Subjects drew canonical pieces more accurately than simple pieces and simple pieces more accurately than complex pieces. The interaction is explained by the mean score in the memory, complex pieces condition, which was nearly zero.

Table 3 presents a combination of the two scores. For each condition, it shows the mean number of drawings with both the figure and pieces correct, the figure correct and the pieces incorrect, the figure incorrect and the pieces correct, and both the figure and pieces incorrect. As the pieces became more complex it became easier to discover the whole figure but more difficult to recall the pieces.

Two additional observations about the drawings are, first, that subjects generally drew the figure before the internal lines that described the individual pieces. It is possible to draw each piece individually so that they fit together to form the whole figure, but we saw very few examples of this approach. Second, errors made when drawing internal lines from memory indicated that the details maybe known in only a vague way. When drawing internal lines for complex pieces, for example, many subjects drew squiggly lines inside the figure in approximately the shape of the pieces.
TABLE 2
Number of drawings of correct figures and of correct pieces, Experiment 3

(a) The number of drawings with correct figures

<table>
<thead>
<tr>
<th>Piece Type</th>
<th>Memory condition</th>
<th>Canonical</th>
<th>Simple</th>
<th>Complex</th>
</tr>
</thead>
<tbody>
<tr>
<td>Visual</td>
<td></td>
<td>3.22</td>
<td>3.85</td>
<td>4.22</td>
</tr>
<tr>
<td>Memory</td>
<td></td>
<td>2.66</td>
<td>3.18</td>
<td>3.52</td>
</tr>
</tbody>
</table>

(b) The number of drawings with correct pieces

<table>
<thead>
<tr>
<th>Piece Type</th>
<th>Memory Condition</th>
<th>Canonical</th>
<th>Simple</th>
<th>Complex</th>
</tr>
</thead>
<tbody>
<tr>
<td>Visual</td>
<td></td>
<td>4.74</td>
<td>4.33</td>
<td>3.07</td>
</tr>
<tr>
<td>Memory</td>
<td></td>
<td>3.02</td>
<td>1.70</td>
<td>0.04</td>
</tr>
</tbody>
</table>

Note: Scores can range from 0 to 6.

Discussion

The results of Experiment 3 are informative about the general process of discovery with visual information. Although discovery of the completed figure occurred while the pieces were visually present, subjects relied on imagery to rotate, move, and combine the pieces. In addition, more complex pieces were combined into the correct whole figure more readily. This is because complex pieces constrained the manner of their combination: the jagged edges had to be internal and the number of internal corners facilitated finding similar edges. In addition, canonical pieces may have been more difficult to combine than the simple pieces because they were known pieces that resisted reinterpretation. Discovery when information is not visually present is probably similar. The more the information constrains thinking toward a solution the more likely that solution will be discovered, just as complex pieces containing similar edges
TABLE 3

Drawings scored for correctness of figure and pieces by condition

<table>
<thead>
<tr>
<th>Condition</th>
<th>Combined Drawing Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Figure Correct</td>
</tr>
<tr>
<td></td>
<td>Pieces Correct</td>
</tr>
<tr>
<td>Canonical</td>
<td></td>
</tr>
<tr>
<td>Visual</td>
<td>3.00</td>
</tr>
<tr>
<td>Memory</td>
<td>1.59</td>
</tr>
<tr>
<td>Simple</td>
<td></td>
</tr>
<tr>
<td>Visual</td>
<td>3.07</td>
</tr>
<tr>
<td>Memory</td>
<td>1.37</td>
</tr>
<tr>
<td>Complex</td>
<td></td>
</tr>
<tr>
<td>Visual</td>
<td>2.37</td>
</tr>
<tr>
<td>Memory</td>
<td>0.00</td>
</tr>
</tbody>
</table>

Note: Scores can range from 0 to 6.

constrain the possible figures that the pieces could form. Also, the more that information restrains thinking to the current state, the less likely any solution will be discovered, as when canonical pieces are seen as complete, independent figures. This view is relevant to Roskos-Ewoldsen’s (this volume) work concerning the properties of pieces that make them "good" for combining into wholes.

With respect to memory for visual information, the results of this experiment suggests that reconstructive memory approaches such as Bartlett’s (1932), may usefully be applied. Subjects were able to recall and draw the whole figure across all piece types—conditions, although they performed better with complex pieces. Subjects were not, however, able to recall the pieces in all conditions. As pieces became more complex, subjects were less able to draw them from memory. Subjects recalled pieces accurately when the piece was coherent or canonical. They performed less well when the pieces had no internal coherence but remained relatively simple. They almost never recalled pieces correctly when they were complex.
in spite of the fact that they could correctly draw the whole figure better than in the other conditions, and could draw such pieces when the pieces were visually present. In essence, subjects were able to recall the gist—in this case the whole figure and the general shape of the pieces and were able to reconstruct details when the pieces made sense. When the pieces were complex, the errors showed that subjects were reconstructing based on the general shape.

Conclusion

The first two experiments reported in this chapter demonstrated that mental images of classical ambiguous figures can be reversed, especially when subjects are given appropriate instructions. Thus the difference between Chambers and Reisberg’s (1985) finding that classical ambiguous figures could not be reversed and Finke et al.’s (1989) finding that discoveries could be made with simple figures need not be explained as qualitative differences in the figures (Finke et al., 1989). Instead, the explanation is most likely due to the differences in instructions provided in the two experiments. Chambers and Reisberg provided minimal instructions whereas Finke et al. provided explicit instructions. When explicit instructions concerning how to manipulate an ambiguous figure were provided, subjects were able to discover an alternative interpretation.

Further, it is likely that imaging relies on the visual system for its processing much as perceiving does. Therefore, a variety of discoveries about visual aspects of information should be possible with mental images. Looking at an image, however, is not the same as looking at a picture. Thus, not all tasks that can be accomplished when looking at a visual display will be completed with the same ease when one relies on mental images. A primary distinction between perception and imagery is the source of the information for the visual system: in perception that source is the world, while in imagery it is memory. This difference is important because relying on memory introduces schema-based distortions—both omissions and intrusions because recalling information from memory is often a reconstructive process. The types of errors will limit the ability to make discoveries with imagery.

Experiment 3 investigated whether creating and maintaining
an image is a reconstructive memory task in the same way that Bartlett (1932) viewed story recall as reconstructive. Memory for gist, which is considered to be the general form of the figure, was excellent in all conditions. Recall of details unrelated to the gist, in this case the specifics of the internal lines based on the original pieces, was affected by the complexity of the task with more complex pieces remembered less well than canonical or simple pieces. The errors made by subjects suggests a reconstructive memory process at work, and it seems reasonable to argue that an image is a product of reconstructive memory.

This view of image creation differs from that of Kosslyn and his colleagues (Kosslyn, 1980; Kosslyn et al., 1979). In their view, image creation involves calling up a single store representation of the to-be-imagined object and a straightforward filling in of the visual buffer based on that information. Applying Bartlett's (1932) approach to images, the creation of an image is a construction based on the general form of the figure (which is similar to the gist of a story), the remaining details of the figure, knowledge of similar objects (i.e., a visual schema), knowledge of the category of the object, and other general knowledge such as cultural norms for pictorial representations. The remembered general form should be emphasized in the image and will be a compromise between the information about the figure and general knowledge structures. Consistent details, such as the external lines and corners in Experiment 3, will be imaged well, to the extent of the system to maintain details in an image. Irrelevant details, such as the internal lines in Experimental 3, will be less explicit or ignored. Gaps in the original information or forgotten information will most likely be overwritten by a combination of the gist and general knowledge structures. Inconsistent details such as the bumps on the back of the rabbit's head in Experiment 1 (see also Chambers, this volume) may be the most difficult to maintain and may therefore be replaced by the gist and general knowledge structures. When someone draws a picture based on an image, the gist should again be emphasized. Consistent details should occur more frequently and accurately in the drawing because the constraints of the imagery system in maintaining details are not present to limit performance. Irrelevant and inconsistent details may not appear in drawings at all because they are not supported by the general frame of the reconstruction.
Discovery using images will depend on the relationship of the task to reconstructive memory. If the task emphasizes or is congruent with the gist or general form of the figure then it should be performed easily. If the task is based on consistent details then it should also be performed well as long as the limits of working memory are not exceeded. If the task is inconsistent with the gist, or is based on irrelevant or inconsistent details, it will be much more difficult to perform. This seems to be the case in attempting to discover the alternative interpretation of ambiguous figures using mental images. Such tasks may require additional instructions about how to regroup details, which unspecified details to instantiate, and which general schemas to reference.

Individual differences may also play a role in the more difficult tasks in our case, those with complex pieces. People with high mental imagery ability may be better able to manipulate their images or better able to visualize more extraneous details than people with low imagery ability (see Kaufmann & Helstrup, this volume). Thus, they may make more discoveries with images and engage in image-based thought more frequently. People more familiar with the domain in question may also be able to make more discoveries. Their more complete schemas should guide explicit image construction more easily than those people of less familiar with the domain who would possess less complete schemata.

This last issue of individual differences and expertise probably deserves special mention with respect to scientific discoveries made with mental images. Experts in any field have, by definition, excellent knowledge of the domain. This knowledge may enable them to form more complete images less effortfully, to manipulate the images easily, and to have a better understanding of the constraints on manipulations. Thus creative insights may occur during thinking, playing, or dreaming since their schemas may allow images that are more complete.

Another, related form of discovery involves the application of schemata from one domain to a second domain. In this case, a scientist may visualize a problem in the form of pictorial representation or image that has previously been used for a different purpose. One famous example of this phenomenon is of a chemist visualizing a benzine ring as a snake biting its tail.
In conclusion, I have attempted to frame my imagery research in terms of similarities between imagery and memory rather than between imagery and perception. This change in focus suggests different styles of experiment, of which Experiment 3 is a first step, and should provide a valuable addition to theories of mental imagery. This view is not suggested as an alternative theoretical approach, but rather as a means of expressing some limits on the creation of images that in turn will limit the amount and type of discoveries people can make.

References


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