When Can Visual Images Be Re-Interpreted? Non-Chronometric Tests of Pictorialism.

Peter Slezak
Center for Cognitive Science
University of New South Wales
P.O. Box 1, Kensington 2033 NSW., Australia
peters@spinifex.cs.unsw.oz.au

Abstract

The question of re-interpreting images can be seen as a new focus for the imagery debate since the possibility would appear to be a direct prediction of the pictorial account. Finke, Pinker and Farah (1989) have claimed that their results "refute" the earlier negative evidence of Chambers and Reisberg (1985), while Peterson, Kihlstrom, Rose & Glisky (1992) have used the ambiguous stimuli of Chambers and Reisberg to show that under certain conditions, these images may be re-interpreted after all. By employing newly devised tasks, our own experiments have provided further conflicting evidence concerning the conditions under which images can and cannot be reinterpreted. We consider their bearing on the fundamental 'format' issue which neither Finke et al (1989) nor Peterson et al. (1992) address directly.

New Focus for Imagery Debate

Kosslyn, Finke and other 'pictorialists' take internal representations to be importantly like external ones regarding their 'privileged' spatial properties of depicting and resembling their referents. Thus, Finke (1990) suggests that "perceptual interpretive processes are applied to mental images in much the same way that they are applied to actual physical objects. In this sense, imagined objects can be "interpreted" much like physical objects" (1990, p. 18). Elsewhere he suggests that "The image discoveries which then 'emerge' resemble the way perceptual discoveries can follow the active exploration and manipulation of physical objects" (1990, p. 171).

The impasse in the imagery debate has led some (Anderson 1978) to conclude that the issue between pictorialism and the 'tacit knowledge' alternative is undecidable in principle on the basis of behavioral evidence. On the contrary, however, the experiments reported here show that divergent predictions from the contending theories may be readily formulated and tested with an appropriate experimental paradigm.

At least part of the reason for the persistence of the imagery debate has been the fact that the dispute has centered upon alternative explanations of the *same* body of reaction-time data concerning tasks such as mental rotation and scanning. Since the rival theories make identical predictions for chronometric evidence, adducing new evidence of time-dependent measures, as has repeatedly been done, cannot strengthen the case for a pictorial, spatial medium against the tacit knowledge theory. Thus, experiments are needed on which the contending accounts deliver *different* predictions.

The issue of reinterpreting visual patterns in mental imagery has recently emerged in this way as a new focus for the controversy since the question of whether, and under what conditions, novel information may be discovered from images provides a new means for testing the properties of the conjectured pictorial medium and the claimed parallel between imagery and perception..

Our own evidence concerns perceptual organization tasks which provide unequivocal criteria of the successful rotation, inspection and re-interpretation of images using "recognition processes" and "shape classification" procedures. However, despite the demonstrated ease of our tasks under *perceptual conditions*, naive subjects have generally been unable to succeed in some of the tasks under imagery conditions as would be predicted on the pictorial theory. Just as in the classical "crucial experiment" of Michelson and Morley concerning the speed of light, one might conclude from our null results that the pictorial medium, like the luminiferous ether, does not exist. However, as is familiar from the history of science, the situation is somewhat more complicated, as our own further experiments and those of others have shown.

There can be strictly no such thing as a "crucial experiment", since a falsified prediction can always be blamed on the auxiliary hypotheses on which any theory must depend. Thus, with the shift to non-chronometric investigations of image reinterpretation, the situation in the "imagery debate" has become less a matter of deciding between predictively equivalent theories than a matter of comparing their respective virtues according to the usual criteria of explanatory comprehensiveness, simplicity etc. in relation to the full set of available evidence. Above all, rather than being posed on either side of the debate in a partisan manner as "refuting" the competing theory, the inconsistent data on image reconstrual provide an opportunity for considering the significance of experimental conditions. A step in this direction has been taken by Peterson, Kihlstrom, Rose and Glisky (1992), who have used the ambiguous duck/rabbit figure to show that, under certain conditions, images may be reinterpreted after all, despite the null results of Chambers and Reisberg (1985).

"Equivalence"

Although the recent investigations of image reconstrual have a direct bearing on the deadlocked issue between pictorial and 'tacit knowledge' theories, it is noteworthy that the question is not addressed directly in these studies which focus more narrowly on the issue of reinterpretation itself. However, the possibility of reinterpreting an image follows as a direct implication of the pictorial theory which posits an "equivalence" between imagery and perception, and so the data on image reconstrual has deeper theoretical significance for the vexed question of the nature of mental representations. On the pictorial view, a mental image is conceived to be a "surrogate percept, allowing people to detect some pattern or property in a remembered scene that they did not encode explicitly when they saw the scene initially" (Pinker and Finke 1980, p. 246). Kosslyn (1987, p. 149) explains that one purpose of imagery involves "recognition processes" to discover information which is not stored explicitly in memory and an image "can then be reprocessed as if it were perceptual input (e.g., the shape could be recategorized)" (1987, p.155).

By contrast, the 'tacit knowledge' account would predict that the re-interpretation of images is difficult because it assumes that the mental representations are very abstract output of 'higher' cognitive processes and the encodings of conceptualizations or beliefs and, in this sense, already intrinsically meaningful and not requiring interpretation, - nor susceptible of easy *re*-interpretation (Pylyshyn 1978).

Conflicting Evidence

Consistent with Pylyshyn's explicit predictions, Chambers and Reisberg (1985) found that subjects were uniformly unable to reverse their mental images of the familiar ambiguous figures such as the duck/rabbit and Necker cube. Chambers and Reisberg see their results as supporting the "philosophical" arguments for taking imagery to be conceptual, symbolic representations. However, despite these negative results and earlier skeptical claims, Pinker and Finke (1980) report subjects' ability to "see" novel properties which "can be 'read off' the display" and which should emerge from images after mental rotation. Finke and Slayton (1988) have extended this work, providing further evidence "that people are capable of making unexpected discoveries in imagery" and that novel patterns can "emerge" from within imaged patterns. In the same vein, Finke, Pinker and Farah (1989) have shown that subjects can inspect and reinterpret their images by "applying shape classification procedures to the information in imagery" (1989, p. 51). Most recently, Peterson, Kihlstrom, Rose & Glisky (1992) have shown that, notwithstanding the negative results of Chambers and Reisberg (1985) with ambiguous figures, under suitable conditions subjects can reconstrue these very shapes in imagery.

It is in the light of this clash of experimental results and theoretical claims that our own experiments are to be understood. The findings of Peterson et al. (1992) are restricted to the case of ambiguous shapes, whereas our study seeks to investigate image reconstruals of entirely different kinds - notably, 'mental rotations' among others. Furthermore, our experiments avoid the specific objections by Finke et al. to Chambers and Reisberg.

Peterson et al. (1992) cite certain differences between the experiments of Chambers and Reisberg (1985) and Finke et al. (1989) as relevant to their discrepant outcomes. For example, the role of demonstration figures and hints to subjects might affect the strategies employed and thereby the relative ease of reconstruals. Also cited by Peterson et al. are the differential effects of the fidelity demanded in retention instructions to subjects. Yet another difference is the quality of the stimulus figures regarding their familiarity. However, Peterson et al. do not mention certain crucial methodological differences between the two studies which are likely to be even more important in accounting for the discrepant outcomes. Of particular interest is the fact that in our own experiments we have eliminated the uncertainties which had been introduced as a result of these differences between the basic experimental paradigms of Finke et al. and Chambers and Reisberg. Peterson et al. evidently overlook a crucial difference when they observe that, unlike Chambers & Reisberg, Finke et al. gave their subjects no instructions to remember the picture exactly as it was presented. But this is because, in a significant departure from earlier procedures, Finke et al. did not present subjects with visual stimuli at all. In order to avoid perceptual confounding, Finke et al. resorted to generating images by means of *verbal descriptions* of certain patterns. However, this serves to obscure the precise relevance of their results to the question in dispute. In our own study, by reverting uniformly to visual stimuli and avoiding perceptual confounding in other ways, we are able to make inferences concerning the likely causes of the discrepant results. That is, by keeping experimental paradigm constant, we can reasonably infer that the variability in image reconstrual can be attributed to particular features of the stimuli in question. Of considerable significance is the fact that, among our own stimuli, those which subjects were more readily able to re-interpret have a close resemblance to those of Finke et al. (1989).

Although Peterson et al. (1992) show that reinterpretation of imagined figures is possible, these successful reconstruals do not necessarily count against a 'tacit knowledge' account, since there is no reason to believe that the "reversal strategies" encouraged by the demonstration figures and other experimental conditions are the same as those employed in perception itself. On the contrary, the

very need for special conditions which encourage successful strategies suggests precisely the *difference* between imagery and the spontaneous reversals in perception. The issue turns on the precise character of the "reversal strategies" about which presumably nothing is known, though they seem more akin to problem solving heuristics and inferences than perception. In particular, "reference frame" orientation is more likely to be part of the abstract, higher cognitive representations or tacit knowledge of objects and their properties (see Bryant & Tversky, 1992 and Hinton & Parsons, 1981).

Experiment 1a: Mental Rotation.

As reported in detail (Slezak, 1991), when tested on a non-chronometric, perceptual organization task providing unequivocal criteria of successful rotation and recategorization, subjects have been generally unable to perform imagery tasks which have been taken as well established.

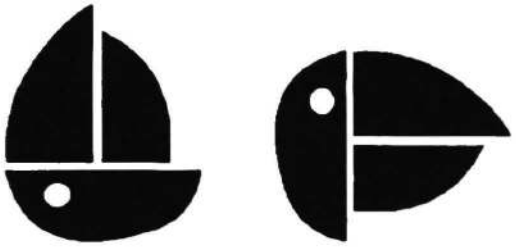

Figure 1.

The stimulus materials have been designed to have two distinct interpretations which are highly orientation specific. Thus, the figures are recognizable as a certain object in one orientation, but are interpretable as an entirely different object when rotated by 90 degrees. These stimuli are variants of the stimuli used by Rock (1973), and are considerably improved in their recognizability. In this respect, the shapes have the important feature that the alternative interpretations are readily obtained by rotation under *perceptual* conditions.

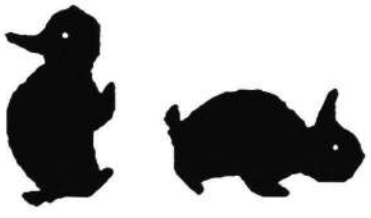

Figure 2

It is important that the task of reinterpretation can be readily accomplished in this way during perception because this makes the conditions for reconstrual under imagery conditions as favorable as possible. Thus, for example, when subjects are shown figure 2 in one orientation, it is immediately recognized as the duckling; then upon rotating the figure by 90 degrees, subjects immediately notice (with frequent expressions of surprise and delight) the alternative interpretation, the rabbit.

The direct expectation of the pictorial medium theory is that the same effect should be obtainable under imagery conditions. That is, if subjects are shown the figures in only one orientation, it would be expected that they could *rotate their image* and *discover* the alternative construal by inspection *from their rotated image*. Of course, the tacit knowledge alternative account takes images to be abstract, intrinsically interpreted conceptualizations and would predict that such reinterpretation would be difficult or impossible for subjects to perform in this way on their rotated images.

At first glance, the experimental results appear somewhat equivocal on the question of reinterpretation since subjects were generally able to reconstrue in imagination about *one third* (35%) of the figures they were presented. Even on these data it is clear that reinterpretation of the rotated image was difficult to perform, even if not always impossible. However, these results across multiple presentations take on a greater significance when the *order of presentation* is taken into account: It is most significant that no subject was able to reconstrue the *first* stimulus presented, which is, of course, the only one for which they did not know in advance that there might be an alternative interpretation. This striking relevance of stimulus order supports our conjecture concerning the effect of loss of naivete regarding the task. Moreover, stimuli were presented in order of decreasing suitability as confirmed by later experiments, and this supports our explanation for the slight improvement in subjects' success rate. In order to clarify this issue, we control for these confounding factors in the follow up experiments reported here, but even without making such allowances the mean success rate overall was still only 35 per cent and surprisingly low given the expectations of the pictorial theory. Typical of the predicted difficulty was the reaction of subjects when pressed to interpret their rotated image of the duckling: just as one would expect on a tacit knowledge account according to which the image is intrinsically bound to its interpretation, many subjects would volunteer that it is a "duckling on its back"!

Expt. 1b. Practice & Perception

The ordering effect in the foregoing data in which subjects showed a slight improvement from their initial failure could be due to practice in the task rather than to perceptual confounding as we had suggested. We controlled for this possibility by giving each subject prior practice with image rotation using Cooper's (1975) random polygon experiment.

At the same time, in order to preserve subjects' naivete on all the stimulus figures, we altered the previous instructions so that the imagery task would not be known until *all* the figures had been viewed

and memorized in their initial orientation. Once all stimuli had been memorized in this way subjects were prompted by the brief flash of a figure on the screen, and asked if they were able to recall the shape clearly. Only then were subjects asked to rotate the shape 90 degrees clockwise and asked whether they were able to find an alternative interpretation.

Results: Significantly, prior practice with rotation of images on the Cooper (1975) random polygons had no effect on subjects' performance and this possibility could, therefore, be eliminated as a possible explanation for the ordering effect in the preceding data. Indeed, despite practice in rotating images, there was a dramatic drop in the success rate as a consequence of the new strategy to avoid perceptual confounding. Our data show only 8 successful reconstruals in 100 trials, and these were almost entirely confined to two of the figures whose shapes were said by subjects in debriefing to be a "give-away" due to certain telling clues which led them to speculate about possible alternatives in a way which was clearly not a "perceptual" apprehension, but rather a kind of inferential, searching process.

Experiment 1c. Image quality.

It could be argued that under the new conditions for avoiding perceptual reconstrual, the high failure rate was now due to poor, inaccurate or otherwise degraded images. In order to clarify the possible role of this factor, we altered the conditions in such a way as to maximize the accuracy of encoded shapes in memory.

Subjects were tested on the imagery rotation task now only after being permitted a very long (3 minute) visual presentation of one of the stimuli (following the usual distractors). During this extended viewing time, subjects were encouraged to remember details of the single figure as accurately as possible. When the stimulus was removed, subjects were asked to draw it from memory in order to have some evidence of the accuracy of the image. Subjects were then asked to rotate and reinterpret it in imagination. In addition, D.F. Marks (1973) VVIQ (Vividness of Visual Imagery Questionnaire) was administered for further evidence of image accuracy.

Results and Conclusion.: Despite high scores on the VVIQ averaging 2.5, there were still only 2 successful reconstruals in 23 trials. Above all, the accuracy of the drawings now provided firm grounds for supposing that degraded image quality is not a likely reason for the failure of image reconstrual.

The significance of our negative results derives from the fact that the mental rotation and reinterpretation are not only explicitly predicted by pictorial theorists, but involve precisely the mental transformations which have been classically taken as well established. Of additional importance is the fact that our task is readily performed under perceptual conditions, thereby entitling us to expect it in imagery as well according to the pictorial account. Further favouring reconstrual is the fact that our figures are considerably simpler than the representations of blocks stacked in three dimensions employed by Shepard and Metzler (1971) for which the mental rotation has been claimed, and our own shapes are geometrically no more complex than those of Cooper (1975) for which complexity was specifically found *not* to be a factor in the claimed ease of rotation.

Even if the Finke et al. (1989) study is not problematic in the ways I have suggested (Slezak 1991), their "refutation" is specific to the ambiguous stimuli and, therefore, irrelevant to our entirely different imagery tasks. A pattern of such failures on diverse perceptual phenomena would leave only *ad hoc* ways of avoiding their significance for the pictorial theory of imagery. Therefore, as a follow-up, we have devised additional experiments which attempt to reconstruct yet other perceptual phenomena in imagery.

Expt 2. Figure-Ground Reversal

The shapes illustrated in the left half of figures 3 are such as to encourage perceptual organization into several black objects which may, however, be reversed to become the ground and thereby reveal the letters "EI". Since the reversal in this form is somewhat difficult to achieve in perception itself, the effect can be readily elicited by asking subjects to bring the horizontal lines together to touch the shapes as in the right hand figures, clearly revealing the letters.

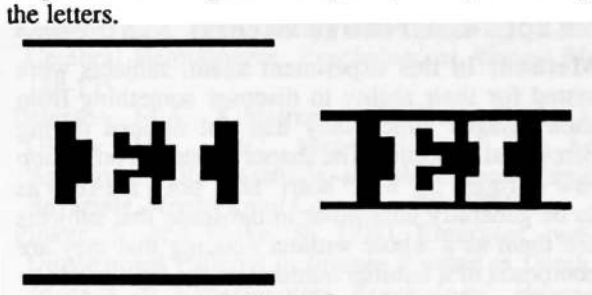

Figure 3

Despite the ease of the imagery task, not a single subject in twenty trials was able to reconstrue their image to reveal the alternative construal as letters. This was despite the fact that subjects' subsequent drawings of their memorized image were highly accurate.

Expt. 3. Kanizsa Illusory Contours

Stimuli of the sort illustrated in figures 4 were designed to produce the familiar illusory contours, but were, of course, not presented to subjects in this form, since the effect would then be created in perception. In order to test the parallel with imagery, circumstances must be contrived which generate the figure only in imagination and, accordingly, the entire figure was not presented at once.

Figure 4

Instead, the black shapes were designed to have good gestalt properties and are such as to discourage any inferences about other shapes of which they might be a part. These shapes were presented one at a time for 30 seconds at their respective positions and then removed from view. Having seen them only one at a time, subjects were instructed to imagine them all together and were then asked whether they were able to detect any other emergent shape, figure or object in their reconstructed image.

Despite research on "creative mental synthesis" which suggests that people can use imagery to mentally assemble the separately presented parts of a pattern (Finke 1990, p.21), only one subject out of thirty trials reported seeing a geometrical shape, correctly identifying the emergent white figure. Again, this overwhelming difficulty with the task was despite the fact that subjects' drawings were highly accurate and they were generally able to notice the emergent shape from their own drawing with frequent expressions of surprise.

Expt. 4. Creative Mental Synthesis

Method: In this experiment again, subjects were tested for their ability to discover something from their images which they had not noticed during perceptual exposure. The shapes illustrated on the *top row* in figure 5 ("M", "heart" and "pot") are such as to be generally unfamiliar in the sense that subjects see them as a whole without noticing that they are composed of a familiar numeral on the right joined to its mirror image on the left. As in each of the foregoing experiments, an essential feature of these stimuli is the fact that the imagery task is one which can be readily accomplished *in perception*. In this case, although people invariably fail to recognize the symmetrical shapes, when partially covered to reveal only the right-hand half, as in the bottom row, this remainder is instantly recognized as the familiar numeral.

Figure 5

The symmetrical shapes were shown to subjects with the instruction to memorize them as accurately as possible in order to answer certain questions afterwards. To avoid the possibility of perceptual confounding, the task was explained to subjects only after all three shapes had been memorized. This explanation was by means of a demonstration showing a different shape (a square) together with its right half alone. Subjects were then asked to recall each of the stimuli and, in the fashion of the demonstration, to imagine their right halves standing alone. When subjects confirmed that they were visualizing the right half of the figure by itself, they were asked whether it looked like any familiar shape or object.

Results: With these stimuli, the results were strikingly different from those of the previous experiments. In 54 trials, a significant proportion (65 per cent) of subjects were easily able to report the numerals "1", "2" and "3" as a discovery made from their image. In each case they confirmed that they had not noticed the familiar shape when shown the figures and had only realized its meaning from "inspecting" their image.

The ease of reconstrual in these cases is in marked contrast with the earlier experiments, despite the essentially similar logic of the imaginal task. The overall success rate of 65 percent should be qualified by noting an order effect in which there was a consistent improvement from only 50 percent success rate on the first stimulus to 66 percent on the second and 77 percent on the third. From subjects' reports it appeared that if they once discovered a numeral from their image, this provided a strategy which helped to make the subsequent discovery by directing their search in a specific way. Though no less genuine discoveries from imagery, this improvement gives further insight into the scope and limitations of operations with images and supports the insight of Peterson et al (1992) regarding the value of appropriate strategies. The facilitation effect evident here is not a matter of perceptual confounding, but nonetheless suggests that later tests should nevertheless be considered separately from the first naive attempt at discovery in imagery. In the case of this first, naive test, the 50 percent success rate in imagery is still evidence of some significant difficulty of re-interpretation, despite the instantaneous result in perception.

Though qualified in the ways just noted, it remains that our results in this experiment broadly support those reported by Finke et al. (1989). The significant level of image reconstrual needs to be accounted for by the tacit knowledge theory which would predict difficulty in the task. Symmetrically, however, the roughly equal failure rate needs to be explained by the pictorial theory which would predict less difficulty in the imagery task if performed "perceptually".

This situation reinforces the point that there is an acute need for both accounts to develop theoretically motivated explanations for their respective *anomalies* rather than merely adducing supporting evidence. This requirement has evidently not been acknowledged on either side of the controversy between 'tacit knowledge' and pictorial accounts even though, as often in science, the mark of a successful explanatory theory is how well it can accommodate the full range of available empirical evidence.

Our results can be seen as casting further light on the *precise conditions* under which visual imagery transformations are possible and it is perhaps significant that the stimulus figures in this fourth experiment bear a similarity to those of Finke et al. (1989) - namely, line drawings of geometrical shapes which are somehow relevant to their easier reconstrual. On the other hand, our own figures have a more obvious interpretation than those of Finke et al., even if they are highly stylized, and this is not fully consistent with our own supposition that it is the intrinsic meaningfulness of images which makes reconstrual difficult or impossible.

Conclusion.

Notwithstanding the claim by Finke et al. (1989) to have "refuted" Chambers and Reisberg (1985), we have shown that image reconstrual is generally difficult or impossible to perform under certain conditions in which one would have expected it according to the pictorial theory. These negative results, are precisely as one would expect on the tacit knowledge account according to which imagery is highly abstract and cognitive, and does not involve any internal, surrogate, 'objects' to be apprehended by the visual system.

On the other hand, our own positive evidence of image reconstrual, like that of Finke et al. (1989) and Peterson et al. (1992) must be accommodated into our preferred theory, as *prima facie* counter-examples. Peterson et al. showed the importance of appropriate strategies for enhancing the likelihood of image reconstrual and the improved positive results with our own last experiment can be plausibly explained in the same way, as noted.

Finally, it must be acknowledged that, although we have placed emphasis on the semantic interpretability of shapes as a factor in explaining their memory encoding and subsequent difficulty of reconstrual, this kind of factor is not invoked with equal plausibility in the case of all our own results. This factor suggests itself most obviously in the case of our orientation-dependent shapes and even the figure-ground reversals of Experiment 2 can be seen as involving the interpretation of objects. The subjective contours are less obviously cases of this sort, but even here one might suggest that the black shapes presented singly cohere as good gestalt objects which then resist the reinterpretation in imagery to being seen as partially occluded background.

Recent investigations have neglected the the fundamental question of the 'format' of mental representations. Since image reconstrual is clearly not an all-or-none phenomenon, these studies can illuminate this issue by revealing constraints on imagery processes which the contending theories must explain.

References

Anderson, J.R. 1978. Arguments Concerning Representations for Mental Imagery. *Psychological Review* 85:249-277.

Bryant, D.J. and Tversky, B. 1992. Assessing Spatial Frameworks with Object and Direction Probes. *Bulletin of the Psychonomic Society*, 30 (1):29-32.

Chambers, D. and Reisberg, D. 1985. Can Mental Images Be Ambiguous? *Journal of Experimental Psychology: Human Perception and Performance* 11:317-28.

Cooper, L.A. 1975. Mental Rotation of Random Two-Dimensional Shapes. *Cognitive Psychology* 7:20-43.

Finke, R.A. 1990. *Creative Imagery*. NJ: Erlbaum.

Finke, R.A., Pinker, S. and Farah, M.J. 1989. Reinterpreting Visual Patterns in Mental Imagery. *Cognitive Science* 13:51-78.

Finke, R.A., & Slayton, K. 1988. Explorations of Creative Visual Synthesis in Mental Imagery. *Memory and Cognition*. 16:252-257.

Hinton, G.E. and Parsons, L.M. 1981. Frames of Reference and Mental Imagery. In J. Long & A. Baddeley, eds., *Attention and Performance IX*. Hillsdale: Erlbaum.

Kosslyn, S.M. 1987. Seeing and Imagining in the Cerebral Hemispheres. *Psychological Review* 94: 148-175

Peterson, M.A., Kihlstrom, J.F., Rose, P.M., & Glisky, M.L. 1992. Mental Images Can be Ambiguous: Reconstruals and Reference Frame Reversals. *Memory and Cognition*, 20:107-123.

Pinker, S. and Finke, R. 1980. Emergent two-Dimensional Patterns in Images Rotated in Depth, *Journal of Experimental Psychology: Human Perception and Performance* 6(2):244-264.

Pylyshyn, Z. 1978. Imagery and artificial intelligence. In *Minnesota Studies in the Philosophy of Science*, C. Wade Savage ed. Vol. IX. Minnesota: University of Minnesota Press.

Reisberg, D. and Chambers, D. 1991. Neither Pictures Nor Propositions: What Can We Learn from a Mental Image? *Canadian Journal of Psychology*, 45 (3): 336-352.

Rock, I. 1973. *Orientation and Form*. New York: Academic Press.

Shepard, R.N., and Metzler, J. 1971. Mental rotation of three-dimensional objects. *Science* 171:701-703.

Slezak, P. 1991. Can Images Be Rotated and Inspected? *Proceedings of 13th Annual Conference of the Cognitive Science Society*, 55-60. N.J.: Erlbaum.