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Can Images Be Rotated and Inspected? A Test of the Pictorial Medium Theory.

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Abstract

Since the “equivalence” of imagery and perception has been one of the central tenets of the pictorial theory, the negative results of Chambers and Reisberg (1985) on an image reinterpretation task may be seen as posing a fundamental challenge for the pictorial account. Finke, Pinker and Farah’s (1989) claimed refutation of these negative results may be questioned on a number of methodological grounds. In addition to examining these issues, we report results of an experiment which tests what is seemingly another direct prediction of pictorial theories. Our investigation employs newly devised imagery tasks whose success *depends* on being able to “rotate”, “inspect” and reinterpret images. Our negative results add further weight to a tacit knowledge account of images as intrinsically interpreted, abstract symbols.

New Focus for Imagery Debate

After twenty years of the recent controversy, the ‘imagery debate’ is widely regarded as having become stalled, with no new ideas on how to break the impasse by bringing some decisive evidence to bear. It is in this regard that the possibility of reinterpreting visual patterns in mental imagery has recently emerged as new focus for the long-standing controversy. The question of whether, and under what conditions, novel information may be discovered from images may shed new light on the debate, since it provides a new means for testing the claimed parallel between imagery and perception and the properties of the conjectured pictorial medium.

“Equivalence” of Imagery and Perception

Specifically, the possibility of reinterpreting an image follows as a direct implication of the pictorial theory which posits an “equivalence” between imagery and perception. 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). It is in this sense that the uninterpreted images in a spatial medium are themselves “functionally equivalent to physical objects or events” (Finke, 1980 p. 113), and cause the same mechanisms to be activated as in actual visual perception itself (ibid, p. 130). Kosslyn (1987, p.

149) explains, one purpose of imagery involves “recognition processes” to discover information which is not stored explicitly in memory and thus we “look” at our images in a way which is analogous to the way we look at external objects in order to inspect them.

Divergent Predictions

By assimilating imagery so closely with vision, indeed by claiming their “equivalence”, pictorialism is committed to predicting closely similar “perceptual” phenomena in imagery to those found in perception itself. It is this deep commitment to the perceptual character of imagery which is the source of its vulnerability to such asymmetries as those of Chambers and Reisberg (1985) and our own results.

Thus, Kosslyn suggests that “image interpretation is at the heart of the role of imagery in cognition (if one cannot inspect imaged patterns, they are useless)” (1988, p. 249). In line with the remarks we have seen by Pinker and Finke, Kosslyn too suggests, “The recognition mechanisms [of vision] can be used in imagery as a way of accessing stored information” (1988, p. 264) and his model entails that “images depict visual information, and that this information is interpreted by some of the same sorts of classificatory procedures used in classifying sensory input during vision” (1980, p. 32). Kosslyn explains further that “the purposes of imagery, in large part, parallel those of vision” and “one may ‘recognize’ parts and properties of imaged objects that had not been previously considered” through the “use of recognition processes” (1987, p. 149). Thus, the significance of reinterpreting images as a crucial test of the pictorial theory is evident in Kosslyn’s explicit predictions:

The image is formed by forcing a change of state in the visual buffer in the attended region, *which can then be reprocessed as if it were perceptual input (e.g., the shape could be recategorized)*, thereby accomplishing the purposes of imagery that parallel those of perception. (1987, p. 155; emphasis added)

By contrast with these direct implications of the quasi-perceptual, pictorial-medium theory, the ‘tacit knowledge’ account would predict that the re-interpretation of images is difficult because it construes

the mental representations as highly abstract entities which are the output of 'higher' cognitive processes; these are encodings of conceptualizations or beliefs and, in this sense, already meaningful and not requiring interpretation, - nor susceptible of easy *re*-interpretation (Pylyshyn 1973, 1978).

New Paradigm: Non-Chronometric Tests

At least part of the reason for the persistence of the imagery debate has been the fact that the dispute has involved alternative explanations of the *same* chronometric evidence. Accordingly, experiments are needed on which the contending accounts deliver *different* predictions. In particular, more directly illuminating would be data concerning a task whose success is directly dependent upon the operation of the postulated process. Julesz's (1971) random-dot stereograms served in this way as an unambiguous and unfakeable test for stereopsis. Divergent predictions of the contending theories on an 'all-or-none' task is a significant feature of the experiment which we report here. Our own evidence concerns a perceptual organisation task which provides unequivocal criteria of the successful rotation, inspection and re-interpretation of images using "recognition processes" and "shape classification" procedures. Despite the demonstrated ease of our task under *perceptual conditions*, naive subjects have been uniformly unable to succeed in the task under imagery conditions as would be predicted on the pictorial theory.

Chambers & Reisberg Negative Results

This question of reinterpreting visual images had been brought into sharp relief with the work of Chambers and Reisberg (1985) who 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 more conceptual and cognitive, in the sense that they are intrinsically interpreted symbols which do not need, and do not easily permit, further interpretation. Since the close parallel, indeed "equivalence" of imagery with the mechanisms of perception has been one of the central tenets of the pictorialist theory (Podgorny and Shepard 1978, Finke 1980, Farah 1988), the results of Chambers and Reisberg are surprising and may be seen as posing a fundamental challenge for the pictorial theory.

Of course, the negative results of Chambers and Reisberg provide experimental support for the specific claims made over a decade ago by Pylyshyn (1973, 1978) in his critiques of pictorial theories. Despite these earlier skeptical claims, however, in the intervening period there has been experimental evidence of just such abilities of people to detect novel properties in imagined scenes. Pinker and Finke (1980) report subjects' ability to "see"

novel properties which "can be 'read off' the display" and 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.

Response by Finke, Pinker and Farah.

Most recently, Finke, Pinker and Farah (1989) have sought to reinforce these claims with new experiments which also purport to show that subjects can inspect and reinterpret their images by "applying shape classification procedures to the information in imagery" (1989, p. 51). This latter work is of particular interest because it has been specifically designed to counter the skeptical conclusions warranted by the negative results of Chambers and Reisberg and sets the scene for our own investigation. Thus, it is in the light of this clash of experimental results and theoretical claims that our own experiment is to be understood: Our new experiment avoids the specific objections to Chambers and Reisberg results while also addressing potential problems of their own procedures. In this way, by falsifying central entailments of the pictorial medium theory in a different manner, our results can be seen as illuminating the precise conditions under which such seemingly contradictory results can be obtained.

Methodology of Falsification

Discounting "philosophical" considerations, Finke et al. claim to "refute" Chambers and Reisberg by showing them to have been mistaken on the "strictly empirical" claim that mental images are not subject to reconstrual. Construing the question at stake in this way as a "strictly empirical" one, Finke et al. assert "our experiments show that the answer to it is that such reinterpretation is possible" (1989, p. 74). But this notion of refutation uncharitably construes the Chambers and Reisberg case in its most implausible and most uninteresting form. The logic of their claim is not merely that images cannot be interpreted in some unqualified and completely general sense, and consequently refuted by finding a contrary case. The Chambers and Reisberg investigation derives its significance from showing the inability of image reconstrual precisely *under conditions in which we would have expected it according to the quasi-perceptual account*. By demonstrating the possibility of reinterpretation under entirely different conditions, Finke et al. have merely avoided the issue. It is not the "strictly empirical question" of whether or not images can be reconstrued *simpliciter*. To be sure, *this* is an empirical question in an unproblematic sense, but it is not the question raised by the investigation of Chambers and Reisberg. Undeniably, "*given suitable conditions*", as Finke et al. say, people *are* able to reconstrue their images. But clearly, it only begs the deeper questions raised by

Chambers and Reisberg, - questions which are, moreover, inescapably the "philosophical", that is, *theoretical*, ones Finke et al., have wished to dismiss (See Slezak 1990). The apparent conflict among the data requires careful analysis which will clarify the precise conditions of discrepant results.

Interpretation and Nothing But

In their attempt to deflect the consequences of the negative findings of Chambers and Reisberg, Finke et al. claim that they "refute one kind of explanation for this difficulty: [namely] that visual images *do not contain information about the geometry of a shape necessary for reinterpreting it...*" (1989, p. 51; emphasis added). That is, Finke et al. devote much of their effort to refuting what they refer to as "the strong position that images are nothing but interpretations" and consistently attribute to Chambers and Reisberg the conclusion that "images *do not contain uninterpreted information*" (1989, p. 54). They take Chambers and Reisberg to claim "that images lack 'uninterpreted' information pertaining to the geometry of an object" (ibid, p. 54). This is misleading because Chambers and Reisberg do not need to go so far as to deny the presence of any purely geometric information in images. They only assert the intrinsic association of such information with a semantic interpretation and that this information is abstractly encoded, inherently interpreted and, therefore, not readily dissociated from the old interpretation and re-associated with a new one by visual mechanisms. That is, the claim of Chambers and Reisberg is only that images are "created as symbols of something and hence *need no interpretive process*" (1985, p. 317).

Interpretation as Semantic Content

It is essential to notice that the notion of interpretation at issue for Chambers and Reisberg is explicitly 'semantic' in the sense of taking the symbol (the image) to have a referent or meaning. Though they dismiss such "philosophical" considerations as irrelevant, this point is crucial in appreciating both the failure of the critique by Finke et al. and also the manner in which their own experimental design is problematic. The relevant notion of interpretation certainly does not preclude the encoding of geometric information as Finke et al. have claimed, and is a semantic one, being referential or 'intentional' in Brentano's sense that every mental phenomenon has "reference to a content" or "direction toward an object" (1985, p. 318). The interpretation of an image in this conception consists in the fact that images are *about* some object or scene

Consistent with having neglected this "philosophical" point in their critique, Finke et al. also design their experiment in a way which minimises the crucial relevance of the intentionality of symbols. The departure of the experiments of Finke et al. in this regard from the

paradigm, serves to weaken their relevance for those of Chambers and Reisberg. Finke et al. want to show that "people *can* assign novel interpretations to ambiguous images" (1989, p. 51) but the "stimulus" figures or patterns employed were all of a *purely* geometric character including letters and numbers. That is, there is, at best, only a very attenuated sense in which one can speak of 'interpretation' and 're-interpretation' in regard to these patterns at all, and certainly there is nothing which corresponds to the full-bodied meanings or semantic content of the ambiguous duck/rabbit, for example. This crucial difference in the stimuli used by Finke et al., is such as to weaken the force of their claimed refutation of the Chambers and Reisberg results. It is significant, therefore, that in our own experiment, when the stimuli have a semantic interpretation in the fullest sense, once again the subjects were unable to accomplish the reconstruals which are easy and instantaneous in perception.

Finke et al. anticipate a possible objection that their stimuli had no initial construal of their stimuli to be switched away from. They answer by claiming that all of their "stimuli" had at least two interpretations, notwithstanding "The fact that one of the two interpretations was invariably characterised by a complex articulated description rather than by a single word" (1989, p.69). However, the issue is not the complexity or otherwise of *descriptions* but rather the nature of a *perceptual gestalt*. In particular, it is not the one-word *labels* which might attach to the ambiguous figures such as 'duck' or 'rabbit' which is their salient property, but rather the fact that the figure permits a *visual* identification and interpretation *as* something in the first place - that is, other than the geometrical figure itself. It is the claimed "equivalence" with the interpretive mechanisms of visual perception which is at stake here, and it is precisely this possibility of semantic interpretation which is absent from the geometrical figures in Finke et al.'s experiment.

"Suitable Conditions"

Finke et al. claim that their experimental results "show that the kind of object a mental image corresponds to need not be assigned during an act of perception" (1989, p. 67) in a way which might prevent its easy re-interpretation, as would be expected on Pylyshyn's view. However, it must be noticed that, in a further significant departure from the experimental paradigm of Chambers and Reisberg, the "stimuli" and "patterns" used in their experiments were not visually presented perceptual objects at all. Finke et al. use *verbal descriptions* of certain patterns. As is well known, seeing the film and reading the book are radically different in their consequences for memory encoding and in the constraints placed on imagination. As a matter of experimental procedure, Finke et al. rightly require that any *new* interpretation of a pattern should not have been the result

of “having encoded that interpretation while the stimulus was *actually visible*” (1989, p.55; emphasis added), but they manage to avoid this problem of perceptual confounding by avoiding relevant perceptual encoding altogether. In the absence of explicit theoretical justification, this further departure from the experimental conditions which have been central to the dispute obscures the relevance of their results. A particular virtue of our own experiment is its reverting to visual stimuli, while avoiding the confounding by perceptual reconstrual in other ways.

Episodic and Semantic Images

The relevant distinctions here correspond closely with Tulving’s (1972) distinction between ‘episodic’ and ‘semantic’ memory. Tulving’s ‘episodic’ memory stores information about dated episodes or events such as specific perceptual experiences coded in terms of perceptible properties or attributes of the events and their autobiographical reference. Of particular relevance in connection with the debates over re-interpretation of visual images is the supposed difference between episodic and semantic memory regarding the retrieval of information. Tulving writes:

The episodic memory system does not include the capabilities of inferential reasoning or generalization. Inferential reasoning, generalization, application of rules and formulas, and use of algorithms, on the other hand, represent important methods of utilization of information stored in semantic memory. By relying on his semantic memory, it is literally quite possible for a person to know something he did not learn. (1972, p. 390)

The Experiment

Predictions of the Pictorial Theory

The experiment¹ is concerned to test the ‘quasi-perceptual’ claims of the pictorial theory according to which “the purposes of imagery, in large part, parallel those of vision” in “the use of recognition processes” through which Kosslyn claims “one may ‘recognize’ parts and properties of imaged objects that had not been previously considered” (1987, p. 149) The abilities being tested are exactly those which are claimed to have been demonstrated by Pinker and Finke (1980) who reported subjects’ ability to “see” novel properties which could emerge from images only after they had been mentally rotated where new properties of images “can be ‘read off’ the display” (1980, p. 262). The ability to “re-parse” an image by using perceptual shape classification procedures has been claimed by Finke et al. (1989), just as Finke

¹Independently, Reisberg and Chambers (1990) have conducted methodologically similar experiments, but they are not concerned with the “format” question as such, and, in fact, appear to endorse Kosslyn’s pictorial medium view as “fully persuasive”.

and Slayton (1988) claim to have shown “that people are capable of making unexpected discoveries in imagery”.

Non-Chronometric Test

The new 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.

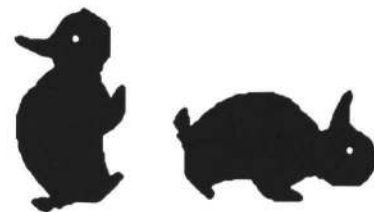


Figure 1.

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 favourable as possible. Thus, for example, when subjects are shown figure 1 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.



Figure 2.

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.

Method

Subjects. The subjects were 15 students and staff at the University of New South Wales who participated on a voluntary basis.

Materials and Viewing Arrangement. The stimulus figures were presented in the form of black and white computer displays to subjects who were seated at a normal viewing distance of approximately 40 cm from a high-resolution Apple Macintosh screen. The display was under the control of the experimenter.

Procedure. Without marking any distinction among the stimulus figures, subjects were first shown several distractors in the form of silhouettes of easily recognizable animals such as an elephant, ostrich and marlin, none of which were orientation-dependent shapes having any alternative interpretation. This was to set subjects' expectations for the subsequent stimuli which were, in fact, orientation-dependent figures. For each presented figure, subjects were asked if they could recognize it and to name it. Subjects were then shown an orientation-dependent figure and were asked to remember it in order to answer a question afterwards. After 10 seconds the stimulus figure was then removed from view and the subject was asked to imagine rotating it by 90 degrees in a clockwise direction. When the subject confirmed that the figure was being imagined in this rotated position, he/she was asked if it could be interpreted as anything else from this viewpoint. This procedure was repeated with each of the orientation-dependent shapes in turn.

As Finke et al. rightly emphasize, an important methodological problem arises from the danger that subjects might encode both interpretations during the original perceptual exposure since in this case they would not be relying on imagery processes to discover the alternative interpretation. In particular, it is evident that the problem may arise when subjects are set the imaginal rotation task more than once, since after the first one they are no longer naive concerning the possibility of a second construal of the figure. On any subsequent test, they may unavoidably seek a second interpretation during the initial perceptual exposure. This possibility can be minimised by restricting exposure time as Chambers and Reisberg have done to a duration which is long enough to establish the image and yet not long enough to seek alternative interpretations. However, this is a risky procedure since subjects who are aware of a possible reconstrual are frequently able to notice both interpretations almost immediately and simultaneously.

Results. 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 confirms the anticipated effects due to loss of naivete concerning the task. Subsequent stimuli were, nevertheless, worth testing and it is significant that even in these cases the difficulty of reconstrual is apparent.

The interpretation of these preliminary results will be clarified in subsequent testing which can eliminate possible confounding due to two factors. The ordering effect in which subjects showed an improvement from initial failure could be due to practice in the task rather than perceptual confounding. This will be controlled in follow-up experiments by giving subjects prior practice with image rotation using Cooper's (1975) random polygons. The uniform observed difficulty with the first naive exposure to an orientation-dependent shape will then be less likely due to the inherent difficulty of the task itself. Present data showing slight improvement following the first stimulus could also have been due to the fact that the shapes were not presented in random order. Given the considerable difficulty in devising suitable figures, they are not equally good in their orientation specificity. Stimuli were presented in order of decreasing suitability and this could account for the slightly improved success rate across subjects. In repeating the experiment, the shapes can be independently rated for their recognizability and orientation-specificity, and the order of presentation can be randomized.

Even if we disregard ordering and other effects such as practice which might have made the task easier, the mean success rate overall was still only 35 per cent. Typical of the predicted difficulty of reconstrual was the reaction of subjects when pressed to reinterpret their rotated image of the duckling: just as we would expect on a tacit knowledge account according to which the image is intrinsically bound to its interpretation, many subjects would volunteer the response that it is a "duckling on its back"!

Discussion and Conclusion. We have noted that the significance of our negative results derives from the fact that, unlike chronometric data, our own experiment permits a *direct* inference about the rotation and inspection of imagery. Of additional importance is the fact that the 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 of images is the fact that our figures are considerably simpler than the representations of blocks stacked in three dimensions employed by Shepard (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.

Rock, Wheeler and Tudor (1989) have recently obtained negative results which also challenge the claims of mental rotation and scanning in a pictorial medium. Although supporting his results and conclusions, our experiment has the advantage of utilizing *recognizable* shapes whose identification is the unambiguous criterion of success in the imagery task. As Rock et al. have acknowledged, their amorphous-shaped wire stimuli are unusual and not representative of objects typically encountered. Although this factor is discounted by Rock et al., the issue does not arise as a potential objection with our stimuli.

As distinct from reaction-time data, when tested on a task which actually *requires* these abilities for success we have found subjects to perform very poorly or not at all. Although these results are contrary to the explicit predictions and direct implications of the pictorial theory, they are precisely as would be expected on a tacit knowledge account. It must be admitted that the tacit knowledge theory is little more than a sketch or hint of the *kind* of theory required rather than a worked out alternative to the quasi-perceptual account. Nevertheless, filling out this sketch will draw on theories of higher cognitive processes in long term memory which have independent theoretical justification.

Contrary to some views (Anderson 1978), we have shown that there *are* significant empirical differences between these two theories of imagery, and their markedly divergent predictions may be readily tested. As a follow-up, we have devised experiments which reconstruct other perceptual phenomena in imagery. Preliminary investigations suggest that *figure-ground separation* is exceedingly difficult or impossible to perform in imagery, although once again the parallel would be expected on the pictorial account. Likewise, the *Kanizsa illusory contours* appear not to be imposed under imagery conditions. We are also repeating an earlier image inspection experiment of Binet's using an array of letters which has not received discussion in the recent debate, but which has the same negative implications regarding the claimed ability to "inspect" images. 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.

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