Pylyshyn and Yuille have results which they claim show that, at least for fairly complex images, the whole figure is not rotated at once. At best it is rotated piece by piece. On the other hand, recent work by Robertson & Palmer {51} lends strong suppport to Shepard's view that rotation is holistic. But we do not really have the space here to go into the details of such recent disputes. Our concern for the moment is to trace just how, and in what particular contexts, imagery regained its status as an important, though far from uncontroversial, concept of psychological science. The most **prima facie** straightforward interpretation of these experiments, and the one accepted by the original and most prolific experimenters, is in imagery terms. And images which can be rotated, shifted and folded look to be about as real as mental objects can get. Through the early 1970s the burden of proof was inexorably being shifted onto the shoulders of those who would deny the reality of imagery, and the empirical (though not the theoretical) contexts in which the arguments would take place were almost entirely being set by the iconophiles.

§I.C.4. Image Scanning.

At the beginning of the previous section we drew a parallel between some considerations which seem to have lead many scientists to believe in the reality of mental images and considerations which might reasonably justify

them in believing in the real existence of electrons. I think the parallels are there, but there are also important disanalogies between the two cases. In §I.A.1 we gave a rough and ready definition of "existence" as the occupation of a section of space-time. Despite the complications introduced by the Uncertainty Principle, electrons do seem to be reasonable candidates for existence in this straightforward sort of sense. It is not at all clear that mental 'objects' like images are even candidates for this sort of existence. If psychologists do say that they "exist" or "are real", as many seem to want to, then a broader, more sophisticated construal of "existence" or "reality" must be being invoked. There is nothing wrong with this - at least since Plato argued for the reality, indeed the pre-eminent reality, of eternal forms philosophers have been aware that "existence" and "reality" have proper uses beyond the sphere of the crassly material - but it does perhaps mean that electrons can be said to exist in a more down-to-earth sense than can ever be the case for mental images.

In other respects, however, images may seem to have a greater claim on reality than do electrons. One obvious point is that imagery is experienced directly, without the need for inference or instruments, whereas electrons are certainly not. But this is not the only respect in which the image may seem the more real. Electrons, after all, at least in the current state of knowledge, seem not to possess any discernible internal structure. In this they

differ sharply from our paradigmatic examples of real existents, the macroscopic material objects of ordinary experience - trees, tables, tigers, etc.. On the other hand, if we take mental images seriously as objects then we seem bound to admit that they do have structure in just the same way that these ordinary material objects do. Indeed, images would seem to have a structure exactly reflecting the perceptual structure of the object or scene which they represent. Where a tiger has four legs we would expect an image of a tiger to contain four sub-parts each corresponding to one of these legs. Another part would correspond to the head, which itself would have sub-parts corresponding to the eyes, ears, mouth, etc., and so on {1*}. Unfortunately, however, the common acknowledgement of these 'facts' about imagery seems to arise from pure introspection, and psychologists, as we saw in chapter I.B, have long since come to regard introspection as at best a highly unreliable source of information about the contents and workings of the mind. Although it surely has considerable heuristic value, on the whole the caution with which contemporary psychologists treat introspection seems to me to be well justified. What is needed is some objective way of demonstrating the structured nature of images, or at least some way of disciplining and keeping an external check on introspective processes.

As far as experiments on the mnemonic properties of imagery go it seems fair to say that little or nothing is revealed about the internal structure of the images

involved. For the most part this work gives us no more justification for ascribing structure to images than we have for ascribing it to electrons. The 'mental rotation' work of Shepard, Cooper and their colleagues, on the other hand, does implicitly reveal images as structured objects. It would be meaningless, after all, to speak of the enantiomorph, the mirror reflection, of something entirely formless. However, the psychologist whose work has dealt most directly with the structural aspects of imagery has been Stephen Kosslyn, who over the last dozen or so years has become one of the most prolific and controversial of all imagery researchers.

Despite Shepard's claims about the ecological and evolutionary value of the ability to rotate images {2} the notion of mental rotation does, surely, continue to seem rather esoteric, a product of the psychology lab rather than everyday life. If a layman thinks about what he can do with his mental images his first thought is not, surely, of how he can set them spinning. He is much more likely to be aware of how he can scan over them and pick out various details and features. This more ordinary type of image manipulation directly reveals the structured nature of imagery, and it is with this, scanning and picking out features, that Kosslyn's research has been mainly concerned. The stylistic difference between his approach and Shepard's is perhaps reflected in the way their respective imagery research programmes began. Shepard, as we have seen, conceived of his first mental rotation

experiment during a hypnopompic reverie. Kosslyn's interest in imagery seems to have been piqued by the innocently introspective remarks of a couple of experimental subjects. His interest in imagery, he relates:

> began quite inadvertently, during an experiment on the organization of "semantic memory," when I noticed that two people in a row had judged as false the statement "A flea can bite." I made it a habit to talk to the subjects after each session and to review with them any peculiar responses. When asked about this strange mistake (I was convinced that everyone, even people who had never owned a dog or cat, knew fleas could bite!), one subject said something like "I looked for a mouth, but couldn't find one." The other subject said "I looked, but couldn't see any teeth." Looked? See? What is this, I wondered, this talk about visual imagery? Imagery did not seem to fit in at all with the semantic net models I had been thinking about, and it was not clear how factors that should affect the organization of such a net would affect using imagery. Thus, I asked all my subjects whether they had tended to use mental imagery in deciding whether the statements presented to them were true or false, and I graphed the results separately for people who claimed to use imagery and for those who did not. Amazingly, the patterns were wildly different. For those who professed not to use imagery, decision times decreased with decreasing association strength between a noun and a property, as I had expected (if association strength reflects "distance" between two representations in some kind of net). But for those who used imagery, times were not affected by association strength at all!
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> {3}.

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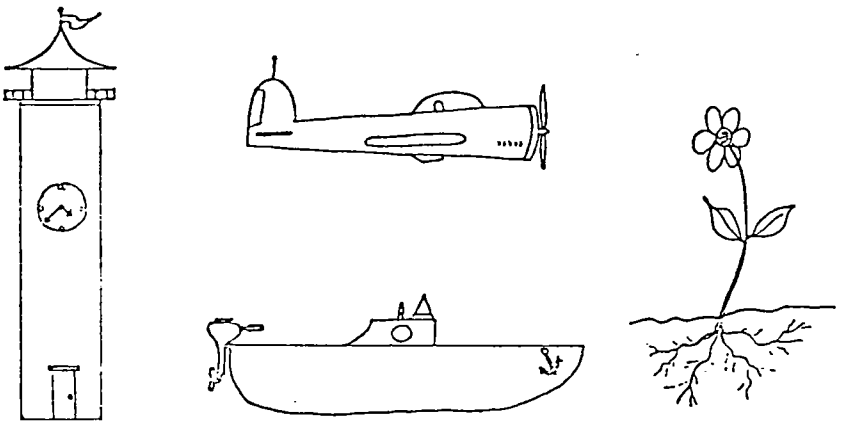
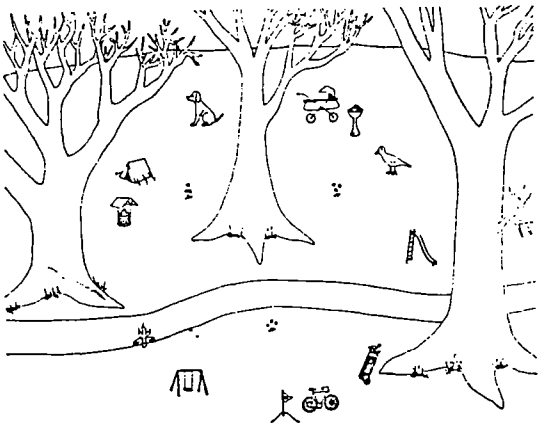
These fortuitous observations led Kosslyn towards two different types of experiment, both of which involved having subjects pick out certain details of an imagined object or scene. Kosslyn, perhaps more than any other contemporary imagery researcher, takes seriously the



Examples of the line drawings used as stimuli by Kosslyn (1973).

Figure I.C.4_1
(Reproduced from Kosslyn [1980].)



A typical set of loci given to subjects in the second and third experiments reported by Lea (1975).

Figure I.C.4_2
(Reproduced from Kosslyn [1980].)

conventional analogy between seeing a mental image and looking at a real picture or photograph {4}. When we look at a reasonably large picture (or a scene) we do not generally take in the whole thing at a single glance, but rather we concentrate our attention on one particular small area or feature for a while, and then move to concentrate on another, and so on {5*}. Kosslyn reasoned that if considering an image is analogous to looking at a picture then similar mental 'fixations' should occur, and furthermore the time needed to shift the centre of attention from one detail of an image to another should increase with increasing relative distances between these details in the image. Such considerations led him to his studies on image 'scanning'.

In the first of these experiments Kosslyn {6} presented his subjects with simple line drawings such as those in figure I.C.4_1. Each of the drawings used had an elongated shape, either horizontally or vertically, and had an obvious and easily nameable feature at either end and in the middle. All of Kosslyn's subjects were shown the pictures and asked to memorize them, along with an appropriate name which was provided for each of them by the experimenter (e.g. tower, airplane, boat, flower, etc. for those in fig. I.C.4_1 - ten different drawings were used in all). However, half of the subjects were told to remember the pictures by forming mental images of them, and half were told to "describe the pictures silently to themselves" {7*}. After learning the pictures in the prescribed way all

the subjects were given a reaction time task. In this they all heard each of the names of the pictures in succession, followed, five seconds after each name, by the name of a feature, which they had to signal as being present or absent in that picture as quickly as they accurately could {8*}. However, different instructions were given as to how to carry out the task. One half of the group who had been told to form images (i.e. a quarter of all the subjects) were simply told to form an image of the whole drawing upon hearing each name, and to respond by pressing the appropriate button as soon as they 'saw' that the subsequently named (probe) feature was present or absent in their image. The other half of the imagery group were told to focus their attention on the feature at a specified end of an image of each drawing (i.e. top, bottom, left or right) when they heard its name. They were then to "look for" the probe feature and respond like the first group. The subjects who had memorized the pictures verbally were similarly divided between those who were to bring the description of the whole picture to mind upon hearing its name, and those who were instructed to describe a specified end of the drawing to themselves.

Unsurprisingly for those subjects who were told to imagine or mentally describe the whole of each drawing the reaction times did not systematically vary according to the position of the probe (describers did take longer than imagers, however). The most interesting results, from Kosslyn's point of view, were those for the subjects who

had had to focus on one end of their images. For these subjects the reaction times increased in a linear manner from instances where the probe feature was right at the already focused end, through instances where the probe was in the middle, and reaching a maximum when the probe feature was at the far end of the picture. Kosslyn interprets this as reflecting a smooth "scanning" of the focus of attention along the image until the probe feature is found. It should be noted that those subjects instructed to **describe** one end of the object to themselves before hearing the probe also showed a similar increase in response time with increasing distance from the 'focused' end. However, the times were longer overall than for the image group, they increased more sharply with distance, and the increase was not linear. Furthermore, the direction of 'scanning' was was very significant for this 'verbal' group, being much slower when they had to move from right to left (i.e. against the normal direction of reading). No such directional effect appeared for the imagers. Kosslyn thus concluded that his experiment had differentiated adequately between imaginal and verbal strategies, and that he had revealed the structured, the "intrinsically spatial" nature of visual images {9}.

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This is not really the place to deal with alternative possible explanations of the 'mental scanning' effect; that is an issue for part II. However, we may note that Kosslyn is not unreasonable in taking it as providing support for his own "quasi-pictorial" theory of imagery

{10}, and it certainly seems to raise **prima facie** difficulties for the 'descriptional' theories of imagery {11} which Kosslyn sees as the main rivals to his own position {12}. Perhaps in implicit recognition of this, the considerable debate which his work on 'mental scanning' has provoked has centred not so much around possible alternative mechanisms for the effect but much more around whether the effect is real at all, and not just some kind of experimental artifact. It turns out that there are some serious objections which can be raised along these lines. The first of these was pointed out by Lea, who noted that Kosslyn's experiment had confounded the parameter of distance across the image with "the number of loci (features) in the image between the focus and the probe" {13*}. The point is that in Kosslyn's experiment a subject who was given a probe feature at the opposite end of his image from that which he had been told to mentally 'fixate' would have to pass over the intervening middle feature on his way, and it might have been the effect of having to deal with this, rather than a simple effect of distance, which produced the pattern of Kosslyn's results. Lea describes a couple of experiments of his own which seem to confirm this suspicion. The first of these is a version of the classical 'method of loci', very much like that earlier investigated by Ross & Lawrence {14}. Students remembered an ordered list of objects by visualizing them as placed in a series of positions encountered along an imaginary walk around the university campus buildings. The second experiment involved memorising a sequence of small pictures

of objects which were laid out in a circular array against the background of a picture of a countryside scene (see figure I.C.4_2). In both cases Lea found that times to report which imagined object was to be found a given number of places away from a certain starting point depended on the number of intervening objects to be gone over, but not at all on the distances between them. He concluded that Kosslyn's interpretation, in terms of scanning a spatial array, was thereby refuted {15}.

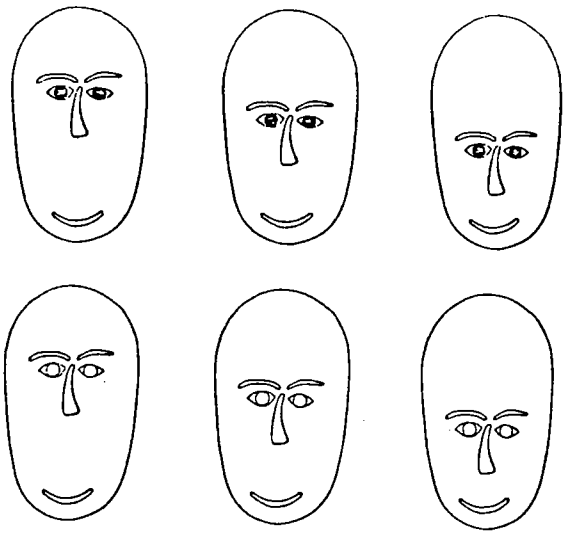
Lea's results and interpretation are not at all incompatible with taking imagery seriously. After all, he did instruct his subjects to use images in the tasks he gave, and the 'method of loci', which is what he sees himself as investigating, dates back to the earliest known beginnings of thinking about imagery, and has coloured much subsequent thinking on the matter {16}. His interpretation is not, I think, even incompatible with the notions that image representations are "analog" {17} or "quasi-pictorial" {18}. However, as Kosslyn acknowledges {19}, Lea's explanation of the 'mental scanning' experiments fits nicely with theories which would reduce mental imagery to an epiphenomenon of the unconscious cognitive processing of 'propositional' 'list structures' {20} which are supposed to encode all the information in our brains within a single homogeneous format. Kosslyn's own interpretation (i.e. that the effects on reaction time are a function of distance **per se**) is far less easily reconciled with such theories {21}, and since Kosslyn has appointed himself chief defender of

the integrity and pictorial nature {22} of image representations he has good reason to want to see his original view vindicated. To this end, he and his colleagues devised a series of experiments which avoided the confounding of distance with the number of features scanned over {23}.

In the first of these experiments the subjects were presented with a series of horizontal lines 8 inches long, along which three letters of the alphabet were placed at varying intervals. Some of the letters were capitals and some were lower case. After briefly studying each of these arrays the subjects were told to cover it up and to form a mental image of it. They were then told to "mentally stare" at either the left or right hand end of the imagined line. Next they were given the name of one or other of the letters along that line, and their task was to "scan to the named letter and classify it according to its case" {24}. They responded by pressing one button to indicate a lower case letter and another to indicate upper case. The experiment was set up so that in different trials the subjects might have to scan over one or two other letters, or perhaps none at all, to find the target one. Since the letters were ranged unevenly along the line the distances to be scanned could be varied independently of the number of intervening letters scanned over. This allowed any slowing of response due to items scanned over to be distinguished from any caused by distance in itself. The findings were that both the number of items scanned over

and the distance scanned seemed to be slowing the response times quite independently of one another {25*}. The fact that the number of features scanned over affects the time taken to scan is in itself no threat to Kosslyn's basic position - which is that spatial information is contained in imagery in a functionally analogue or 'pictorial' form. So long as distance alone has an independent effect, as it seems to in this experiment, then considerable support is leant to such a view.

Of course, experiments like these can only deal with relative distances. Although the lines and distances in the stimulus figures are of definite and measurable length the same is not true of the 'distances' in an image. We cannot measure them. It is not clear that it is even meaningful to ask what is the relationship between real and the equivalent imaged lengths {26*}. Nevertheless, we do seem to be able to imagine things at different subjective sizes, or perhaps it is at different subjective distances, and Kosslyn has proposed that the 'mind's eye' has a determinate "visual angle", analogous to that of the real eyes, which an image of something may fill to a greater or lesser degree. He has even attempted to measure this internal "visual angle" {27}. Perhaps a less dubious enterprise is to study the size variations of mental images in the context of mental scanning experiments. To this end, Kosslyn, Ball & Reiser {28} devised an experiment which used the six schematic faces shown in figure I.C.4_3. These differ in that the eyes can be either light or dark and



The schematic faces that subjects imaged at one of three sizes.

Figure I.C.4_3
(Reproduced from Kosslyn [1980].)

The fictional map that subjects later imaged and scanned across.

Figure I.C.4_4
(Reproduced from Kosslyn [1980].)