from the one which they had initially seen. The subjects were then allowed to draw the figure on the basis of their image, and were all quite easily able to see the alternative interpretation in their own drawings {15*}. This seems to make particularly clear how pictures can easily reparsed whereas images cannot.

Hinton's demonstration can perhaps be explained in terms of a very vague, and quite redundant, pictorial image associated with a description unsuited to the given task. It seems to me, however, that the Chambers & Reisberg results cannot be well explained even on this basis. After all, the subjects were able to draw a **reversible** figure from their own images (both they and others could see both aspects). If the image were too vague (and some of the subjects tested as vivid imagers) and the drawing were made wholly or primarily on the basis of a single aspect description surely there is no reason to expect the drawings to turn out thus reversible. Rather it is as if the way-of-looking-at-it is inherent in the image itself.

§II.B.6 Imagery and Spatial Knowledge in the Blind.

Kosslyn's account of the image concerns itself specifically and exclusively with the **visual** image. He can hardly be blamed for this - hardly any cognitive psychologists have much to say about imaginings involving the other sense modes {1*} - but it does give one pause to wonder whether explanations of the quasi-pictorial type are really appropriate to non-visual images. In fact, on first reflection the problem does not seem to be too serious. Just like quasi-pictorial visual images, imaginary sounds, smells and tastes can easily be envisaged as arising when information from memory is fed into the informational flow which is supposed to run from the sense organs to the centre of consciousness. The problem is even more straightforward here, it would seem, than it is for visual imagery. No spatial structure has to be represented, so the equivalents to the 'visual buffer', the internal 'screen', can be dispensed with. Imaginary touch and kinesthesis would perhaps be a little more difficult to deal with in such terms, but the problems do not really look insoluble. What does seem clear, however, is that an approach like Kosslyn's implies a strict separation of the different modes of imagery. There is no room on the 'visual buffer' for representing sounds, smells, tastes etc. {2*}, and, likewise, there would be no room in the auditory, olfactory and gustatory 'channels' for the sort of spatial information which, as Kosslyn has been so anxious to prove {3}, seems to be carried in the visual image. Furthermore, any spatial information deriving from 'feel' would presumably require a separate 'buffer' or 'buffers' of its own to 'display' imagined experiences. This separation of the sensory channels is, of course, quite traditional, dating back to Locke at least {4*}.

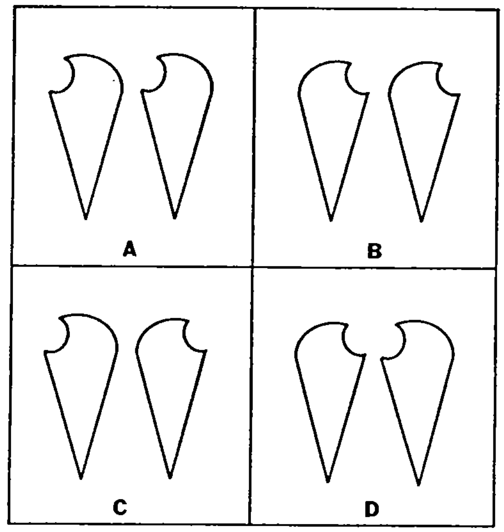
Now there is one small segment of the population who presumably do not have visual imagery. These are the congenital or early blind {5*}. Since the time of Locke and Molyneux their potential abilities have been regarded as a test case for views about the independence of the senses and the nature of spatial understanding {6}. The early blind might or might not have the neural structures which Kosslyn would require to support his 'visual buffer' {7*}, but they would certainly have nothing meaningful to put into such a 'buffer'; no stored visual memories to be recalled or recombined. It thus comes as something of a surprise to find that nearly all of the effects which have led cognitive psychologists to take imagery seriously have been reproduced using congenitally blind subjects.

Let us first consider the mnemonic properties of imagery. Paivio speculated {8}, quite reasonably, that words which are inclined to arouse primarily **visual** imagery in the sighted would have an effectively low imagery value for the early blind. On the other hand, words which would seem likely to evoke **auditory** imagery (e.g. "singer, laughter, prayer, echo, etc. {9}) should have a high imagery value even, or especially, for the blind. Thus the blind should remember them better. Working with Okovita, Paivio was indeed able to show that the early blind remembered words with a high auditory imagery value better than others (an effect which did not seem to occur in the sighted) {10}. However, words which Paivio took to have a high **visual** image evoking capacity **also** seemed to be remembered by the blind better than more 'abstract' words. A similar finding comes from Craig {11}, who again found that the early blind remembered highly visually imagable words better than abstract ones (although the effect was not so large as it was in the sighted). Zimler & Keenan {12} even found that the early blind, like the sighted, remembered highly visually imagable word pairs better than pairs like "bang-growl, honk-sneeze, click-whisper" and "pop-clang" {13}, which one would expect to arouse auditory imagery.

These results are puzzling, but to add to the puzzle it seems that **instructions** to use imagery seem to improve the verbal memory performances of the congenitally blind as much, or more, as they do for the sighted memorizing the same material. Jonides, Kahn & Rozin {14} were the first to report this, and they conclude:

> We are quite sure that the imagery effect is **not** essentially visual. Frankly, we are quite puzzled as to what it is. {15}.

Further confirmation of these results have come from Zimler & Keenan {16} and Kerr {17}. In both these experiments congenitally blind subjects were given three types of image to form, each involving two objects. Some of the images were of the two objects in physical association, with both clearly 'visible'; other images were to consist of one object hidden inside or behind another; and yet others were to contain the objects in separated locations. After having formed all their images the subjects were tested by being told the name of the first object of each pair, to which



1. The exhaustive set of stimulus pairs: same pair (A), same pair (B), different pair (C), and different pair (D).

Figure II.B.6_1
(Reproduced from Marmor & Zaback [1976].)

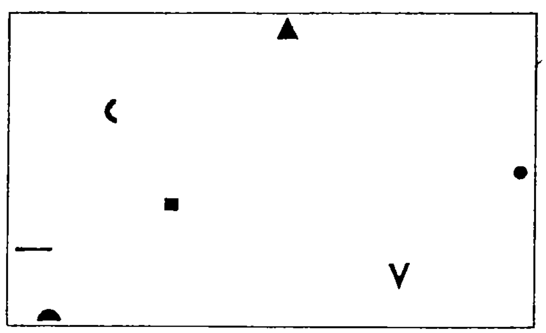


Figure II.B.6_2
(Reproduced from Kerr [1983].)

they were supposed to reply with the name of the second one. The patterns of results were, in each case, just the same as the respective authors had found when performing a similar experiment on sighted subjects {18*}.

Perhaps it seems hard to believe that the congenitally blind can properly understand instructions to use imagery, let alone form images anything like those of the sighted. However, that may perhaps be because it is so hard to shake the vestiges of naïve pictorialism from our heads {19*}. In fact, it is not only the mnemonic effects associated with imagery which have been reproduced in the blind. Mental manipulations such as rotation and 'scanning' have been demonstrated too. The first such demonstration is due to Marmor & Zaback [1976], who devised a version of the Shepard & Metzler {20} rotation experiment in which the stimulus figures could be presented haptically, by touch. They presented their subjects with a pair of two-dimensional asymmetrical plastic shapes (see figure I.B.6_1) laid on a horizontal board so that the subjects could touch and explore them both simultaneously by feel. As in the experiments by Shepard's group, the experimental task was to indicate as quickly and as accurately as possible whether the two shapes presented on each trial were the same or were mirror images of one another. The left hand shape was always presented upright (i.e. with the point at the bottom), whereas the right hand shape might be presented upright or turned 30°, 60°, 120°, or 150° in a clockwise direction. The timer was started automatically as soon as the subject touched the plastic shapes, and they made their response by pressing a foot pedal (one foot for 'same' and another for 'mirror image'). The experiment was carried out on three groups of subjects: early blind; late blind (blinded at around 15 years of age); and blindfolded sighted subjects. With a few explicable anomalies {21*}, a linear response time with increasing angle was found - just as Shepard & Metzler {22} had found with visually presented shapes. What is more, on subsequent questioning:

> Sixty-three percent of the early blind, 94% of the late blind, and 69% of the sighted reported using mental rotation. There was little difference in the pattern of results between those who reported using mental rotation and those who did not. {23*}

There were differences between the experimental groups, however. The sighted were distinctly faster than the early blind, with the late blind being intermediate in their 'speed of rotation'.

In his monograph on imagery Kosslyn {24} attempts to deny the relevance of these results to his imagery model. As we noted in §I.C.3, and as Kosslyn himself points out {25}, it is not altogether obvious that 'rotation' experiments of the type which Shepard & Metzler pioneered must necessarily involve imagery at all. After all, both figures to be compared are perceptually present throughout the experiment, and subjects performing the task can, and seemingly do {26}, constantly transfer their visual attention back and forth between them. Thus Kosslyn, in considering the results of Marmor & Zaback, remarks:

> I am not sure that they bear on the issue

> of what is being mentally rotated in the experiments discussed in the previous parts of this chapter [principally the work of Cooper, as discussed in §I.C.3 above]. Unlike the previous experiments, this one does not depend on manipulating some internal representation per se. That is, one presumably can perform this task by touching the figures in the corresponding places. {27}.

It is not altogether clear to me how Kosslyn thinks subjects can determine what are the relevant "corresponding places" without manipulating some sort of internal representation. But what is of most significance for us here is that Kosslyn clearly realizes that it is very important for him to reject the notion of mental rotation by the blind, since it will raise serious difficulties for his model. It is so important, indeed, that he is prepared to sacrifice the Shepard & Metzler results, which are generally taken as providing some of the most striking evidence available for the reality of imaginal representations. Kosslyn himself is not above citing them as such elsewhere {28}.

We argued in §I.C.3 that although the relevance of the Shepard & Metzler studies to imagery can reasonably be questioned if they are taken in isolation, an imagery interpretation becomes much more plausible when they are taken in conjunction with the work of Cooper and her collaborators {29}. Cooper's experiments do **not** involve simultaneous presentation of both the figures to be rotated and compared, and so presumably **must** involve comparison of a percept with an internally generated representation. In fact Kosslyn himself has made such an argument in defence of an imagery interpretation of the Shepard & Metzler results {30}! Carpenter & Eisenberg {31} have now provided a study which adapts the procedure used by Cooper & Shepard {32} so that it is appropriate for the blind. The Cooper & Shepard experiment, it will be recalled, involved having subjects differentiate between normal alphanumeric characters and their mirror reflections when the characters were presented rotated out of the canonical, upright, position. It was hypothesized that this task would be done by rotating a mental image until the orientation of the character presented was matched by that of the image of the normal character as retrieved from memory {33*}, whereupon a direct comparison could be made. The results, which showed increasing response times with increasing rotation of the presented figure away from the upright position, seemed to support this hypothesis.

Carpenter & Eisenberg were able to do a version of this experiment with congenitally blind subjects because they had access to a group of such subjects who were experienced at reading tactually, not only through braille but also through the use of an "Optacon", "an electronic device that translates print into a tactile stimulus" {34}. They were thus familiar, through touch, with letters of the alphabet in their standard orientations. The experimenters made cut-outs of the letters **P** and **F**, and of their mirror images, and backed them with 'Velcro' material so that they could be firmly positioned on a board (also covered with 'Velcro') in various orientations. As usual, the subjects' task was to report whether the letters presented were the normal letter or its reflection, and the letters were presented rotated by varying amounts from the vertical. The only important difference from the Cooper & Shepard {35} experiment was that the subjects, who included both the group of early blind subjects already mentioned as well as some sighted but blindfolded subjects, could perceive the test letters only through touch. The pattern of results, however, were very similar to those obtained when Cooper & Shepard used visual presentation {36*}. What is more, in this case the blindfolded sighted subjects and the blind ones seemed to 'rotate' the letters at about the same speed. Also, as in other experiments on 'mental rotation', the subjects, blind and sighted, generally did claim to have done the task by rotating a mental representation. Carpenter & Eisenberg conclude that:

> These results indicate that visual abilities are not a necessary prerequisite for mental rotation. Blind individuals had no difficulty in performing the mental rotation task. Hence, mental rotation is an operation that requires a representation with spatial components rather than specifically visual components. The question still remains as to whether sighted sighted subjects do use representations that include visual attributes. {37}.

Anyway, when we take these results (which, to the best of my knowledge, Kosslyn had never attempted to controvert) together with those of Marmor & Zaback {38} we can hardly avoid agreeing that if the sighted can rotate mental images then so can the congenitally blind.

Kosslyn's own experimental work has not, of course, been concerned primarily with either mental rotation or with imagery and memory. His discoveries, and the centrepieces of his research programme, have been the 'mental scanning' and the image size effects which we discussed in §s I.C.4 and 5. Both of these effects have now been reproduced in congenitally blind subjects by Kerr {39}. To demonstrate mental scanning Kerr {40} devised an analogue of the 'island' experiment of Kosslyn, Ball & Reiser {41}. Instead of drawing a map of an imaginary island Kerr simply stuck seven cardboard shapes onto a rectangular board (as depicted in figure II.B.6_2), and assigned an appropriate name to each of them (circle, crescent, square, triangle, etc.). The board was presented to the blind subjects who were given every opportunity to examine it and learn its layout by touch. They were also supplied with the names of each of the shapes. When they were thoroughly familiar with the board it was taken from them and the experiment commenced. Pairs of the shapes were named, and the subjects were under instruction to

> scan mentally across the board from the location of the first figure to that of the second. They were instructed further that in order to scan from one figure to the other, they should imagine a raised dot moving at a constant speed, as fast as possible, from the center of one figure to the center of the other. As soon as that dot reached the center of the second figure, they were to push one button. {42}.

Just as Kosslyn, Ball & Reiser had found in their version of this experiment {43}, Kerr found that the times between the experimenter's naming of the second figure and the subjects' pressing of the response button increased linearly with the distance between the two named figures.

As a control, she also took the trouble to repeat Kosslyn's original experiment, but using her board instead of the island map. That is, she had sighted subjects learn the layout of the board visually, and then gave them the same scanning task. In this case the speed of 'scanning' was faster than with the blind, but the linear trend was again apparent. If such an experiment provides evidence for imagery with spatial structure in the sighted, as Kosslyn claims it does, there would now seem to be equivalent evidence relating to the non-visual mental representations which can seemingly be generated by the congenitally blind.

It is rather unfortunate, it seems to me, that Kerr chose this particular version of the 'mental scanning' experiments to reproduce in the blind. We have argued {44} that all Kosslyn's scanning experiments are vulnerable to being explained away as the product of "experimental demand characteristics"; but for none of them is such a dismissal so attractive as for those which call for the imagining of a "moving speck". Kerr may have shown no more here than that the blind are susceptible to experimental demand too. However, we also argued {45} that Kosslyn's work on the effects of imagined size is not so easily dismissed, and Kerr has reproduced that in her congenitally blind subjects also. The experiment she replicates this time is the one in which Kosslyn {46} had his subjects imagine some medium sized 'target' animal next to an elephant or a fly as a context, forcing them to imagine the 'targets' as small or large respectively. He then asked the subjects to look for and report 'seeing' some feature of the target animal in their image, and found that they took consistently longer to find features on an animal imagined small (next to the elephant) than on one imagined large (next to the fly). Blind subjects could not be expected to be perceptually familiar with elephants or, indeed, with some of the other animals used by Kosslyn. Kerr thus substituted suitable household objects for the 'target' animals, and used "car" and "paperclip" as the 'context' objects. Otherwise, however, the experiment {47} followed Kosslyn's closely. Once again Kosslyn's results were reproduced. Kerr found that sighted subjects were somewhat faster overall than congenitally blind ones, but both groups found the probe features on an object imagined next to a paperclip significantly more quickly than on an object imagined next to a car.

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Marmor & Zaback {48}, Carpenter & Eisenberg {49} and Kerr {50} all conclude that their work demonstrates that it is **spatial** rather than simply **visual** mental representation which is important in 'imagery' tasks. This, of course, raises serious problems for a theory like Kosslyn's, in which the spatial aspect of the image **arises out** of its visual aspect, being a consequence of the functionally spatial way in which visual information is displayed on the inner 'screen' of the "visual buffer". Now in fact, until fairly recently, the view that the ability to think spatially was crucially dependent on the ability to think visually was a psychological orthodoxy. In the

1930s von Senden had argued persuasively, and with considerable clinical detail, that the congenitally blind have little or no spatial understanding {51}, and the view that normal spatial ability is dependent on vision, or at least on visual imagery, seems to have been still very much current in the 1960s and early 1970s {52*}. However, more recently a number of studies have indicated that even the congenitally blind are quite capable of spatial thinking, although it is notable that even they very often find it convenient to use visual language to describe spatial awareness acquired through the other senses {53*}. Perhaps the visual bias of our ordinary spatial language has been a factor in misleading us.

Casey {54} carried out a study on 20 students (from 16 to 21 years old) at a school for the blind. Ten of these were congenitally and totally blind, whilst the other ten were partially sighted. Casey supplied his subjects with wooden blocks, each one similar in shape to one of the buildings on the school campus, and labelled in braille with the name of that building. He also supplied them with a number of strips of cloth which could represent paths. The subjects were each asked to construct a 'map' of the blind-school campus by laying out these materials appropriately. Unsurprisingly, the maps produced by the partially sighted students (although they were blindfolded whilst constructing their maps) were on the whole considerably more accurate than those produced by the congenitally totally blind. However, some of the latter,