

38. Cooper & Shepard, 1973 experiment I (described above).

39. 1976.

40. Cooper, 1975.

41. Cooper, 1975.

42. Typical rotation speeds for the 'three-dimensional' objects used in the Shepard & Metzler [1971; Metzler & Shepard, 1974] experiments were a great deal slower than those found with the two - dimensional objects used in Cooper's work. (However, dimensionality may not be the crucial factor in this - see Shepard & Cooper [1982 pp.178-9].)

43. For recent reviews see Corballis [1982, 1986]. These papers also point out that, albeit in a very different form and context, 'mental rotation' research antedates Shepard's entry into the field.

44. Shepard, 1981, 1984a,b.

45. Kosslyn, 1973; Kosslyn, Ball & Reiser, 1978; Kosslyn & Shwartz, 1978; Finke & Pinker, 1982.

46. 1975; Larsen & Bundersen, 1978.

47. See Shepard & Cooper, 1982 pt.II.

48. 1972.

49. E.g. Pylyshyn, 1979; Dennett, 1978a pp.167-9.

50. Yuille, 1983; Yuille & Steiger, 1982.

51. 1983.

Notes to §I.C.4.

1. C.f. Shepard [1975; Shepard & Chipman, 1970] on the "second order isomorphism" between the image representation and its object. I think the point as I have expressed it here should be fairly uncontroversial. However, some iconophobic thinkers have expressed quite the opposite intuition in the cases of more numerous and less well defined features, such as the tiger's stripes. These contentions will be considered in §II.B.4.

2. E.g. Shepard, 1981, 1984a,b.

3. Kosslyn, 1980 p.vii.

4. See chap. II.B below.

5. To a large extent this pattern of successive shifts of attention can be directly observed, because it is reflected in our eye movements [see e.g. Noton & Stark, 1971a,b; Gaarder, 1975]. However, it seems that a certain amount of visual attention shifting can take place independently of eye movements [Kaufman & Richards, 1969].

6. 1973.

7. Kosslyn, 1973 p.91. It is notable that at this time, as in the earlier work of Paivio [e.g. 1971], Kosslyn is contrasting images with verbal representations. By 1974, however [e.g. Kosslyn, 1974 p.78], he has moved to stressing the contrast between imagery and the so called "propositional" representations which Pylyshyn [1973] and Anderson & Bower [1973] had recently proposed would account for apparently verbal and apparently imaginal memories alike.

8. As in all the reaction time experiments described in this section, the responses were given by pressing a button under the right hand to affirm one alternative, and one under the left hand to affirm the other. As is standard, in order to balance out effects of handedness half the subjects used the right hand to signal 'true' responses, and half used the left.

9. Kosslyn, 1973 p.94.

10. See chapter II.B below.

11. See chapter II.C below.

12. See Kosslyn & Pomerantz, 1977 pp.72-4.

13. Lea, 1975 p.97. It is probably not insignificant that Lea wrote from Carnegie-Mellon University, the original home of the theory which would reduce mental images to "propositional" descriptions [see §§ II.C.1 and II.C.2 below], whereas Kosslyn gained his 1974 doctorate from Stanford, the home of Roger Shepard and Gordon Bower. (Although we should note that Kosslyn claims to have had little awareness of Shepard's mental rotation work when he conceived his first experiments on image scanning [Kosslyn, 1980 p.vii], and that Bower has played a somewhat ambiguous, though certainly important, rôle in the imagery story.)

14. 1968.

15. Lea, 1975.

16. See Yates, 1966.

17. Shepard, 1978b.

18. Kosslyn, 1978a.

19. Kosslyn, Ball & Reiser, 1978 p.47.
20. See e.g. Pylyshyn, 1973, 1981 - and chap. II.C below.
21. See Kosslyn & Pomerantz, 1977 pp.72-4.
22. See chap. II.B below.
23. Kosslyn, Ball & Reiser, 1978.
24. Kosslyn, Ball & Reiser, 1978.
25. The rates of increase were not entirely linear this time, however [Kosslyn, Ball & Reiser, 1978 p.50].
26. However, see Morgan, 1979.
27. Kosslyn, 1978b.
28. 1978 experiment 4.
29. Kosslyn, Ball & Reiser, 1978 p.57.
30. Kosslyn, Ball & Reiser, 1978 p.57. The final condition is called "overflow" because Kosslyn conceives of the image becoming so large that its edges overflow the bounds of the 'internal screen' on which it is displayed. The implicit metaphor here seems to be cinematography or some related technique. Kosslyn also likes to talk of "zooming in" on images when they are made subjectively larger.
31. Kosslyn, Ball & Reiser, 1978 pp.57-8.
32. These are experiments 2 and 3 of Kosslyn, Ball & Reiser, 1978.
33. Kosslyn, Ball & Reiser, 1978 p.51.
34. Kosslyn, Ball & Reiser, 1978 p.54.
35. See Kosslyn [1976a,b] (which we discuss in the next section) for corroboration of such an interpretation.
36. There is a problem here in that, in the light of the "faces" experiment described above, one might expect the group instructed to "overflow" their image of the map to take longer than the "black speck" group, for the latter's images would be subjectively larger. In fact there was little difference between the two groups. Kosslyn, Ball & Reiser [1978 p.56] speculate that imagining the speck might have slowed the first group down and thus obliterated the difference. However, it seems unlikely that the size of any such effect should so very nearly equal that caused by the 'enlarged' image, and in general this coincidence must lend credibility to the 'demand characteristics'

interpretation of mental scanning experiments, which we shall discuss shortly.

37. 1975.

38. Kosslyn, Ball & Reiser, 1978 pp.53,59-60. On my own reading of Lea's paper the relevant point is not made entirely clear.

39. Or in others he has used. See e.g. Kosslyn [1975, 1976a,b].

40. Kosslyn, 1973 p.92.

41. See Kosslyn, 1973 p.92; Kosslyn, Ball & Reiser, 1978 pp.49,52,54,57.

42. See Kosslyn, Ball & Reiser, 1978 experiment 3.

43. Lea, 1975 experiment 1.

44. Kosslyn, 1973 p.92.

45. Orne, 1962.

46. See Intons-Peterson, 1983; Neisser, 1970, 1972a; DiVesta, Ingersoll & Sunshine, 1971 - and §I.B.2 above.

47. I can corroborate this from my own experience. In an attempted replication of some of Kosslyn's other results [Kosslyn, 1976a], which I carried out at U.C. Davis in collaboration with Mr. Gordon Smith, I questioned more than 40 subjects in this way. Only one came anywhere guessing what were the main variables of interest, and his guess at the likely results were not in accord with my own expectations.

48. Richman, Mitchell & Resnick, 1979a; Mitchell & Richman, 1980.

49. Richman, Mitchell & Resnick, 1979b.

50. 1979b, 1981.

51. 1978.

52. 1979a.

53. Richman, Mitchell & Resnick, 1979a p.18; Richman, Mitchell & Resnick, 1979b.

54. 1949 chap.8.

55. The similarities of Pylyshyn's position and Wittgenstein's is no accident, of course, but a consequence of their common view that knowledge is by definition propositional. Pylyshyn [1973 p.6] appeals to the authority

of N.R. Hanson on this point:

Knowledge of the world is not a montage of sticks, stones, colour patches and noises, but a system of propositions.

[Hanson, 1958 p.26].

and Hanson is of course echoing the Wittgenstein of the *Tractatus*:

The world is all that is the case. The world is the totality of facts, not of things. [Wittgenstein, 1961 §1 & 1.1].

Where Hanson has epistemologised upon Wittgenstein's ontology, Pylyshyn has psychologised Hanson. But the common thread remains.

56. C.f. Taylor, 1981.

57. Kosslyn, Ball & Reiser, 1978 p.49.

58. The work of Pinker [1980; Pinker & Kosslyn, 1978] on mental scanning in the third dimension relies extensively on the 'moving speck' and similar techniques. For this reason I have grave doubts about its relevance to genuine psychological issues.

59. One is tempted to say that the notion of mental scanning is part of the 'folk psychology', or at least that it follows pretty directly from a 'folk' theory of imagery as 'pictures in the head. However, when Denis & Carfantan [1985] administered a questionnaire to 148 French students (first year psychology students who had not yet been taught anything about imagery) they found that only 9.5% thought a distance/time correlation was likely to be found in image scanning (58.8% thought it unlikely). This seems somewhat at odds with the results of Richman et al. I shall not venture to speculate whether this difference reflects a cultural difference between France and the U.S.A., or whether it is yet another example of the power of experimenter effects or task demands.

60. 1971; Metzler & Shepard, 1974.

61. I.e. Kosslyn, 1973.

62. Kosslyn & Shwartz, 1977 - see §II.B.1 below.

63. Kosslyn, Ball & Reiser, 1978 p.60; Kosslyn, 1978b, 1980 pp.53-4. This would account for the fact that in the map scanning experiments of Kosslyn, Ball & Reiser [1978] there was no variation of response time with distance when the whole map was imaged, with all features simultaneously in view (and there was no requirement to imagine the moving speck) but they did covary when the subjects were required to imagine the given features in close-up. It is as if the map is 'scrolling' across the 'mental screen'. However, unfortunately for the parsimony and empirical content (in Popper's sense: i.e. how much is forbidden [Popper, 1959 p.113]) of Kosslyn's theory, he later proposed that both forms of scanning, attention

shifts and mental "translations", can take place. Worse still, he has argued that "blink transformations", instantaneous movements of the image across the 'mental screen', also need to be postulated [Kosslyn, 1981 pp.53-4].

64. Shepard, 1981, 1984b.

65. See Shepard & Cooper, 1982.

66. Finke & Pinker, 1982, 1983.

67. A tachistoscope is a device used by psychologists to make precisely timeable, and sometimes very brief, visual presentations.

68. Finke & Pinker, 1982 p.144.

69. 1980 - see Finke & Pinker, 1982 p.144n.

70. Finke & Pinker, 1982 p.144n.

71. §I.C.1.

72. Pylyshyn [1981] has put this point, although in a different context.

73. Finke & Pinker, 1983 experiment 4; Pinker, Choate & Finke, 1984.

74. Except that dot positions very near the arrow head raised special difficulties and consequently produced longer response times than did more distant dots. The particular reasons for this are explained by Finke & Pinker [1983], and need not detain us.

75. 1971.

76. I have in mind such things as the 'black speck' method used by Kosslyn, Ball & Reiser [1978 experiment 4], and also by Pinker in his studies of the third dimension in imagery [Pinker & Kosslyn, 1978; Pinker, 1980]. Also the attempt to measure the "visual angle of the mind's eye" [Kosslyn, 1978b]. I do not say that this work is worthless, but it is certainly open to considerable methodological criticism, even if the basic phenomenon of image scanning is accepted.

77. See chap.II.B below.

78. It is also probably not irrelevant that Shepard was already a well established and highly regarded figure long before he came to study rotating images. Kosslyn, by contrast, published his first paper on scanning [1973] before he had gained his doctorate [Kosslyn, 1974].

79. Kosslyn, Pinker, Smith & Shwartz, 1979a p.544.

80. 1983.

81. Reed, Hock & Lockhead, 1983.

Notes to I.C.5.

1. E.g. 1975, 1978b.

2. Kosslyn, 1975 p.342.

3. Kosslyn, 1980 pp.vii-ix, and see the opening pages of §I.C.4 above.

4. E.g. Kosslyn, 1975 p.342; 1980 p.1; 1983 p.2; 1985.

5. See Kosslyn, 1980 chap.7 for a review of the situation to that date.

6. Pylyshyn, 1984 pp.231-245, and p.244.

7. The principal results to be outlined below first appeared in the form of Kosslyn's doctoral thesis [1974] but have since been published [Kosslyn, 1975, 1976a,b].

8. Kosslyn, 1980 p.vii; 1975 p.342.

9. See e.g. Kosslyn & Shwartz, 1977; Kosslyn, 1980 p.6; 1983 p.206.

10. This is experiment 1 of Kosslyn [1975].

11. Kosslyn, 1975 p.346.

12. This is Kosslyn [1975] experiment 2.

13. Kosslyn, 1975 experiment 3.

14. This is Kosslyn [1975] experiment 4.

15. Kosslyn, 1975 experiment 5.

16. Kosslyn, 1975 p.359.

17. Five others were also apparently able to guess the purpose of this, but they claimed only to have reached this realization after their participation was over. It was thus considered acceptable to use the data from them [Kosslyn, 1975 pp.361-2].

18. Kosslyn, 1980 p.vii - quoted in §I.C.4 above.

19. See Kosslyn, 1980 p.vii. The work done with Nelson has never been published.