group the landmark and the hidden object must be more directly linked in memory for the landmark to designate location. In the terminology traditional in regard to symbols, they must not be too 'distanced' from each other—with distance here meaning perhaps either feet and inches, or more likely, intervening spatial relations (i.e. object to box, box to couch). Thus, changes in landmark usage and knowledge during the second year of life seem to parallel changes seen in domains more traditionally thought of as symbolic.

The chapter on landmark development that probably opens with the onset of self-produced locomotion, does not close for a long while. In fact, there is probably continual development across the lifespan as individuals learn to deal with landmarks even more 'distanced' from their referents (in maps or on a compass) or more complex in the spatial relations they convey. Clearly systems of landmarks also become important components of spatial cognition, so that the role of the single landmark that was such a milestone for the infant, takes on the aura of 'mere' topological spatial notion—a primitive in the Piagetian scheme of things spatial. But to the infant it was a milestone—and therefore, I would argue, a landmark worthy of note.

Landmarks and the coordination and integration of spatial information

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About 10 years ago Pick, Yonas & Rieser (1979) suggested that a single landmark might be a minimal frame of reference. Since that time, Rieser (personal communication) has argued that while logically it might be possible to consider a single landmark a frame of reference, practically speaking a frame of reference implies multiple landmarks organized or perhaps perceived as a system.

The question of exactly what constitutes landmark information seems most approachable through the consideration of how landmarks are used. If we ask 'What is a landmark?', we find that the term sometimes applies to the prototypical case of a stationary object marking a fixed position in a space, but that there are also applications of the term to moving objects such as the sun, and to fixed objects (e.g. a high-water mark) whose purpose is to indicate the position of something that moves such as the incoming tide. The resulting impasse is reminiscent of the one that Goodman (1978) describes in connection with the question 'What is art?', and there seem also to be parallel advantages to adopting Goodman's solution, which was to change the question. In our case the question becomes 'When is a landmark?'.

Huttenlocher & Newcombe (1984), Huttenlocher & Presson (1979) and Pick (1976) suggest that three distinct but undifferentiated landmarks are necessary and sufficient to localize any target point in a two-dimensional plane (except when the target is coincident with or visible from a landmark; in such a case, one landmark might suffice). If the landmark structures are non-symmetrically differentiated, one structure may provide the three cues necessary to locate the target unambiguously. Depending on its form and appearance, therefore, a single object or structure in an environment can constitute one, two, three or more landmark cues. The frame might be a fixed allocentric frame, in which locations are known relative to stable, recognizable objects or places, or it might be what is ordinarily called an abstract allocentric frame, consisting of Cartesian axes or polar coordinates not tied to any stable place (Huttenlocher & Presson, 1979).

However, properties of egocentric frames (front–back; left–right), and information about environments stored in memory, may be used to reduce the number of necessary environmental cues to two or one, or even to zero in unusual cases (Huttenlocher & Presson, 1979). Although three pieces of locational information would still be required at a minimum, they can be supplied mentally or by reference to the body. Presumably, right–left knowledge is tied to one's hands or to particular imaginary spaces. In addition, under normal conditions of movement we maintain some memory of the directions in which we have moved, and this allows us to orient without the full contingent of three environmental features. In cases of well-developed environmental knowledge, one could orient along an indirect pathway towards some goal even when blindfolded (given knowledge of one's starting location). Thus, crucial reference-frame information can be supplied by environmental features, parts of one's body or features stored in memory.

The coordination of reference systems may be of particular developmental interest. Pick *et al.* (1979) discussed the coordination of landmarks (as minimal frames of reference), including the case when the use of a landmark is contingent on one's position in relation to another landmark, as might happen in following the direction: 'Go straight until you come to a petrol station, then turn left.' This might be considered to imply using the petrol station as one landmark, then doing something with respect to the left hand as a second landmark. In this case, the two landmarks are drawn from different domains, i.e. geographic space and egocentric space. Goldsmith (1979) studied the following contingent coordination problem: children aged from 3 to 7 years were led into a square room that was uniform, except that two adjacent walls were coloured red and the other two yellow. In front of each wall was a small container and the children watched the experimenter put an object in one of the containers. Then they closed their eyes and turned around so as to become disorientated. The children then had to find the hidden object. Solving this problem would require them to somehow or other keep in mind both the colour of the wall in front of which the object was hidden and the relation of that wall to their own body. They would have to remember something like: 'It is in the container in front of a red wall, the red wall that is to the left of the other red wall.'

Contingent use of landmarks was more difficult than non-contingent use and both improved with age. Contingent problems appeared relatively harder for the younger than the older children. Although the interaction (between age and contingency) did not reach significance when measured in terms of the number of correct solutions, it did so when indexed by the amount of time it took the children to make their choice. The older children took significantly longer than younger children to respond in the contingent situation, but not in the non-contingent situation, which suggests that they were sensitive to the more complex information-processing demands of the former situation.

A very different kind of spatial task that greatly increases the complexity of the required coordination of landmarks occurs when two spaces need to be integrated. Such situations entail the use of the landmarks of one space as a reference system for the landmarks of the other space. We recently tried to model this sort of integration, by familiarizing adults with two simple routes, separately, and then informing them that the two routes are connected at a particular point and in a particular way. This is all done under conditions that do not permit them to see an overview either of the routes or of their connection. Their task, after hearing about the connection between the two spaces, is to estimate the distance and direction of several within-space and across-space linear paths that they have never travelled directly.

How might the knowledge and use of landmarks enter into this kind of integration of spaces? If two separately learned routes are to be integrated with one another, at least one of them must be capable of being captured within an allocentric frame of reference. The problem of placing a route within an allocentric frame is essentially the problem of establishing relative positions in a two-dimensional plane. Because local geographic space can safely be considered Euclidean (Shepard & Hurwitz, 1984), we reasoned that knowledge of three non-collinear points would be sufficient to identify relative locations within a plane. Accordingly, the routes that we asked people to integrate were each based on a set of three non-collinear positions. Each of the routes consisted of two sides of a triangle, the angle between the sides being less than ($< ABC$) or greater than ($< XYZ$) 90 degrees.

The three positions on each route (A, B, C : X, Y, Z) may be considered landmarks, around which or in terms of which two frames of reference can be defined. Solving the integration problem then becomes a question of superimposing one frame of reference on, or integrating it with, the other. The superimposition must be correct both as to orientation and as to absolute position. We are interested in how well people will be able to achieve this, when they are given three new pieces of information after learning the two routes separately: (i) that position B, on one route, is in fact the same as position Y on the other; (ii) that the two path segments A–B (on one route) and Y–Z (on the other) are collinear; and (iii) that the segments A–B and Y–Z do not overlap. Figure 1 shows the two routes integrated with one another.

We provided the adults with information about directions and distances in each of the two spaces by means of actual paths, connecting points to and from which they walk repeatedly (A, B and C in one space; X, Y and Z in the other). This seems to imply that the only way to integrate the spaces is through the mental manipulation of two allocentric frames of reference. However, as we have argued, this allocentric information may not be the only type of landmark information playing a part. If, as in our task, the person is in a particular orientation to one of the spaces (say the one containing points A, B and C) when the integration problem is posed, a solution may

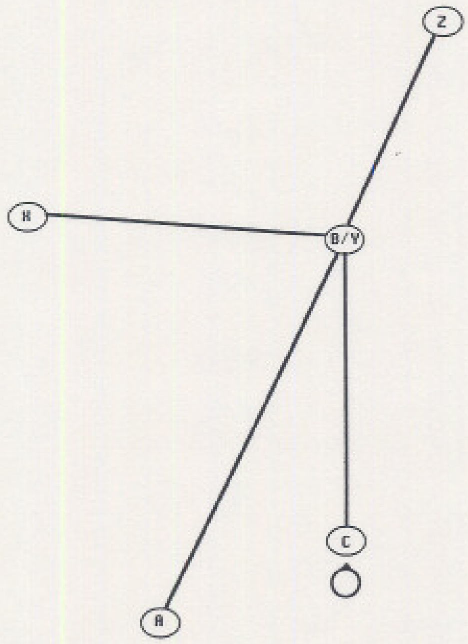

Figure 1. The integrated arrangement of the paths *ABC* and *XYZ* that subjects learned separately. The subject was asked to imagine being positioned at *C*, as shown, at the time of integration.

be achieved by considering the positions in that space in relation to the body, while at the same time coordinating those positions allocentrically with a representation of the other space (the one containing *X*, *Y* and *Z*).

Landmarks serve as 'pegs' for the alignment of reference frames. Just as three spatial cues or features are necessary to establish a single frame unambiguously, as many as three might be required to align and integrate two frames (in our route study, the coincidence of landmarks *B* and *Y*; the collinearity of the three landmarks *A*, *B*/*Y*, and *Z*; and the non-overlap of segments *A*–*B* and *Y*–*Z*). The integration task thus requires at least some use of landmark information that is independent of bodily orientation at the time. This information is necessary to specify the directions and distances of positions in one space with respect to positions in the other. In this respect the integration problem differs from the contingent problems discussed earlier, in which there is no requirement to coordinate two spaces allocentrically.