The main problem with this position is its completely speculative nature. It is open to empirical evaluation, however. For instance, if this approach is correct, it would seem that young children's use of landmarks should be markedly influenced by the scale of the context in which landmark and object are located, and the separations between other pairs of objects or landmarks in the environment.

Early perceptual estimation and ordering

The Piagetian definition of what is meant by metric knowledge is not always clear, and may have been blurred in recent discussions. Piaget *et al.* (1948/1981) character-ize the first stage in the construction of Euclidean space as involving acquisition of a qualitative understanding of conservation of distance, length, area and volume, and the use of transitive reasoning when using one object to compare the size of two others. This certainly leaves open the possibility that, even before the acquisition of such abilities, children are able to estimate distance or area, at least roughly, and order such quantities, especially if only two quantities are involved (i.e. to which of two landmarks is a specified object closer?). In this sense, it may not be inconsistent with a Piagetian position to admit that children understand the idea of extent, and can order perceptually estimated extents, at least in pairwise comparisons. Of course, these claims also would require direct empirical assessment.

Points of reference in spatial cognition: Stalking the elusive landmark*

Clark C. Presson and Daniel R. Montello

Department of Psychology, Arizona State University, Tempe, AZ 85287-1104, USA

There are two major foci in studies of spatial development, and the construct of a landmark has been important to each. One is spatial orientation and the processes of finding the way, updating and route following. The other is the representation of spatial knowledge. Accounts of spatial development (in terms of orientation and of representation) have placed heavy weight on the construct of landmarks (e.g. Hart & Moore, 1973; Siegel & White, 1975), and many empirical studies use the term.

Lynch (1960) defined a landmark as any element that can 'potentially serve as a point-of-reference', recognizing that point-of-reference could refer to multiple things. The minimal sense of the term landmark is of elements or features in space that might serve as points-of-reference. In this sense, a landmark is any distinct object or feature that is noticed and remembered. This minimal definition has been stated or implied by Appleyard (1969), Carr & Schissler (1969), Siegel & White (1975), Hazen,

Lockman & Pick (1978) among others. However, if all remembered elements are landmarks, then the term means little. The substantive part of Lynch's definition is 'point-of-reference'. To locate an element in space requires some specification of the relation of that element to other known elements in space, including oneself. Cognitive space is relational.

The term is often used to describe a spatial cue associated with a location, target object, or behavioural contingency. This sense of landmark has wide currency in the empirical literature, although it is not clear whether the relation between the cue and the element is based on spatial relations or is simply an associative one. These two alternatives are often difficult to separate (Presson & Somerville, 1985). Typical studies examine the role of discriminating features to help subjects locate a target (spatial location cues) by adding an element to a space to provide additional information. This is useful as far as spatial reference is concerned but it does not necessarily mean that such elements become enduring landmarks. In some contexts the 'landmark' cue serves to differentiate otherwise equivalent objects or locations (e.g. Acredolo & Evans, 1980). Whenever a location is related to another element, the element used as standard is a cue in this sense.

Even in cases where the spatial nature of the association between two elements is obvious, it is often not clear which element is the target and which the cue. In any environment some elements are more likely to serve as cues in particular cases due to salience and position in the environment. However the nature of the task largely determines the 'landmark' or target status of particular elements. Results may reflect as much about the task structure as they do about the underlying processes of spatial representation.

The term landmark is also used to refer to spatial reference points (as distinguished from the more general 'point-of-reference'), features that are 'relatively better known and ... define the location of other points' (Sadalla, Burroughs & Staplin, 1980). This sense of landmark provides the strongest definition of the term and it suggests landmarks are cognitively distinct from other elements in spatial memory and central to the nature and organization of spatial representation. The relation of reference to non-reference points is assumed to be asymmetric although the notion that there are a few elements to which many others are spatially related does not require this to be so. Non-reference points are more likely to be defined in terms of their relation to reference points than vice versa, and the judged distance from a reference point to a non-reference point may not be equal to the same distance judged in the reverse direction (Sadalla *et al.*, 1980). The presence of landmarks in this strongest sense would imply that the structure and organization of spatial memory is fundamentally influenced by the existence of landmarks. There is some support with children for the notion that landmarks organize spatial information (Presson, 1987a), but no sign of any change in this effect during the grade school years.

The notion of landmarks as spatial reference points was developed (Sadalla *et al.*, 1980) from the concept of 'cognitive reference points' (Rosch, 1975). The idea leaves open the question whether this sense of landmark is uniquely spatial, or whether it reflects a more general property of cognition. One possibility is that cognitive reference points are also prototypic features in semantic memory (Rosch, 1975), whereas spatial landmarks are not prototypical in the same way. This sense of

landmark implies that context is important. A campus library may serve as a reference point for other campus buildings, but not for the larger city in which the campus is located.

The issues that we have raised apply to route landmarks as well. Characterizations of landmarks in routes have applied the minimal definition (e.g. all distinctive features that are remembered) based on their potential to serve as a cue within the route (Siegel & White, 1975). Detailed distinctions between route decision landmarks (cues to turnings at decision points) and route maintenance landmarks (cues intermediate to the turns that indicate that the person is still on the correct route) are examples of the functions described above. The cue provided by the 'landmarks' may or may not have a uniquely spatial quality. The serial nature of route execution may lead to temporal associations, for example. Also, the identification of what are the critical landmarks within a route is not easily achieved. I might remember features associated with the route that in fact are not central to my route knowledge. Of course, many features do provide an important, even vital, role in defining routes and headings and turns within routes. These features mark important spatial decision points within the route. Critical spatial features may not be specific objects or elements but may consist of larger configurations.

Two additional uses of the term, symbolic landmark and distant landmark, do not require networks of spatial relations to be specified. Symbolic landmarks are singular features that symbolize or come to stand for a locale or region (e.g. the Eiffel Tower in Paris). In this case the feature provides a strong identification for its surrounding area but may or may not aid orientation or provide a representation of other spatial relations. When I look out the hotel room window and see the Eiffel Tower I may know that I am in Paris, but knowing the Eiffel Tower's location may not help me find my way back to the hotel after going to breakfast, unless it also serves as a distant landmark in the sense described below. Whether navigation in the vicinity of symbolic landmarks is different from that in regions without such singular landmarks is not known. It may be that schemes for local navigation are a function of the local topography more than the presence of symbolic landmarks.

This example also illustrates an additional use of the term 'landmark' to describe a visible, distant point of reference with respect to which I can directionally orient. For example, a mountain peak can provide a clear anchor for a direction, say north, from most locations within a region. Thus, a traveller could use that distant landmark to provide a constant heading, even if the traveller did not know specifically how that landmark was related spatially to other locations.

A final sense of the term landmark arises in the context of navigating in a space when one is not certain where one is. In this case the landmark provides a point of correspondence between spatial experience and known spatial representations (either physical charts or memorial representations). In that case, the potential of a feature to be a landmark is contingent on its presence (and perhaps its salience) in the physical or cognitive representation. This sense of landmark as point of correspondence is important to the processes by which children decode and use information in maps and other spatial symbols (Presson, 1982, 1987*b*).

Several tasks remain. One is to indicate more precisely in our work with spatial development to what we refer when using the term 'landmark'. We must identify

what the clear questions about spatial development are and in that context determine the appropriate definition(s) of 'landmarks'. In assessing these potential definitions of the term, it is also important to consider in what sense the specific uses are uniquely spatial, or whether they reflect more general properties of cognitive organization and processing. A third task is to identify the potential models for developmental change in the use and functioning of landmarks.

Toward an ecological conception of landmarks: A developmental perspective

Jeffrey J. Lockman

Department of Psychology, 2007 Percival Stern Hall, Tulane University, New Orleans, LA 70118, USA

Although much of the research on spatial development has been in labs, using toy objects as landmarks, developmental psychologists have recognized the importance of conducting cognitive mapping research in children's everyday environments and have moved their investigations to children's homes, schools and neighbourhoods (Acredolo, 1979; Anooshian & Kromer, 1986; Siegel & Schadler, 1977). However, the concern with ecological validity has been almost entirely one-sided, focusing on the environment and not the organism residing in the environment. An alternative approach, based on the Gibsons' ecological approach to perception (E. J. Gibson, 1982, 1988; J. J. Gibson, 1966, 1979), is to emphasize the relation between the properties of the environment and the capabilities of the organism. For humans who possess several modes of action, we need to consider whether the landmarks used in the spaces entailed by different actions share similar characteristics. Additionally, by attending to different action–environment systems, we can broaden the range of contexts where it makes sense to speak of landmarks and can at the same time be much more precise about the properties of landmarks inherent in such systems.

An ecologically based view also has important developmental implications. As children develop, new modes of action become available to them. E. J. Gibson (1988) has suggested that changes in the available action systems during the first year bring along changes in the affordances of the environment and in how infants explore and exploit them. In a similar vein, I will consider how the properties of landmarks change as new action systems develop.

Eye–head movements

In environments defined by eye and head movements, landmarks typically have fixed locations to mark a target's location. For younger infants, these landmarks are often in close proximity, not distal from, a target (Acredolo & Evans, 1980; Pick, Yonas & Rieser, 1979). This is not surprising, because infants' lack of mobility for at least the