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Environmental perception and spatial behavior : A brief overview of cognitive mapping research

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Environmental perception is qualitatively different from object perception which has been the traditional subject of perceptual psychology. Environmental perception involves "cognitive mapping" which serves to guide human as well as animal behavior within the real environment. In recent years, the concept of cognitive mapping has been used increasingly in several fields including cognitive psychology, environmental psychology, developmental psychology, animal psychology, neuropsychology and behavioral geography. In this essay, some representative studies of cognitive mapping in adult human subjects and certain methodological problems were briefly discussed. Developmental, animal and neuropsychological studies on spatial cognition also reviewed to help to understand how individuals acquire and use spatial knowledge about their environments.

Keywords: environmental perception, cognitive mapping, spatial behavior, methodological problems, developmental studies, animal studies, neuropsychological studies.

I. Introduction

The perception of the environment has been neglected in the traditional study of perception, which emphasizes the perception of the object (e.g., Baird, 1970). Ittelson (1973) has contrasted enviromental perception with object perception in the following way. "In the history of experimental psychology the overwhelming bulk of perception research has been carried out in the context of object preception, rather than environmental perception, with the findings of the former providing the basis for the latter. Virtually every major school of psychology in the past 100 years has investigated its perception problems in the context of object perception; has developed its theory of perception from the results of these studies; and has then transferred the explanatory system thus derived into the context of environmental perception. As a result, the investigation of perception has lost the essential esthetic unity without which any pursuit leads to chaos, rather than resolution (p. 3)." "The distinction between object and environment is crucial. Objects require subjects — a truism whether one is concerned with the philosophical unity of the subject — object duo, or is thinking more naively of the object as a 'thing' which becomes a matter for psychological study only when observed by a subject. In contrast, one cannot be a subject of an environment; one can only be a participant. The very distinction between self and nonself breaks down ; the environment surrounds, enfolds, engulfs, and no thing and no one can be isolated and identified as standing outside of, and apart from, it (pp. 12-13)." Furthermore, Ittelson (1973) listed the following seven properties of the environment which the object does not possess. (1) The envrionment cannot be observed but explored. (2)

The environment is always multimodal. (3) Not only central (i.e., focus of attention) but peripheral (i.e., outside the focus of attention) information about the environment is important. (4) Environmental information is rich and redundant. (5) Environmental perception always involves action. (6) The environment provides symbolic meanings and motivational messages. (7) The environment has an ambience or atmosphere which involves social activities, and esthetic and systemic qualities.

These vast differences between object perception and environmental perception suggest that traditional theories of the former cannot be helpful in explaining phenomena of the latter. The problem of environmental perception has recently been studied by investigators of such new disciplines as environmental psychology (e.g., Proshanski, Ittelson, & Rivlin, 1976) and behavioral geography (e.g., Gold, 1980). These areas have been concerned with man's interactions with his environment and have tried to explain his spatial behavior in terms of his perception of that environment.

The key concept frequently used in these investigations is the concept of "cognitive mapping" which may be defined as "a process composed of a series of psychological transformations by which an individual acquires, codes, stores, recalls, and decodes information about relative locations and attributes of phenomena in his everyday environment (Downs & Stea, 1973, p. 9)." As a result of this mapping process, the individual forms a cognitive map of his environment which helps him to orient and navigate in that environment efficiently. The usefulness of the cognitive mapping notion is not limited to those areas described above. The notion has also been used in such areas as the developmental psychology of spatial cognition, the psycholgy of animal navigation and spatial learning, and the neuropsychology of spatial abilities. This essay also reviews major studies on cognitive mapping in these areas.

II. Cognitive mapping research

(1) Some properties of the cognitive map

The term "cognitive map" was coined by Tolman (1948) who used it metaphorically to describe the efficient behavior of rats in learning various spatial maze tasks. He suggested "that in the course of learning something like a field map of the environment gets established in the rat's brain..... and it is this tentative map, indicating routes and paths and environmental relationships, which finally determines what responses, if any, the animal will finally release (1948, p. 192)." In other words, the animal uses his cognitive map of the environment (maze) to locate the goal and to reach there. Two functions of the cognitive map become clear (see Downs & Stea, 1973). It answers the questions of (1) where certain valued things are, and (2) how to get where they are from where the individual is.

In order to perform these functions the cognitive map should process and store certain types of information. First, it should provide information about spatial locations of things (objects, events, or phenomena) relative to each other and to the individual. This locational information should contain both direction and distance of a given object with respect to a reference point. In addition to the locational information, the cognitive map should provide attributional information which tells what *kinds* of objects are located in certain places. Attributes are either descriptive (e.g., red house) or evaluative (e.g., cheap restaurant).

Viewed in this way, the cognitive map of an environment resembles the cartographic map of the same environment. However, this is rarely the case. For example, cognitive maps are often incomplete in the sense that not all places and their attributes are represented in them. Cognitive maps may be distorted in terms of distance and/or direction, such that an individual's subjective geometry deviates from the Euclidean view of the real world. In terms of distance distortions, Lee (1970) has indicated that, given two urban facilities equidistant from an urban resident, one located on the downtown side is considered closer than the one which is away from the city center.

(2) Some methodological issues

The major methodological problem in cognitive mapping research is concerned with how to externalize the individual's internal (cognitive) map of the environment. Basically, two types of methodology have been employed. The first type uses sketch maps drawn by subjects to represent their cognitive maps. This method was first used systematically by Lynch (1960) in his classic study on environmental cognition. Lynch simply asked residents of three US cities (Boston, Jersy City, and Los Angels) to draw rough sketch maps of their cities. Analyses of these maps and interview data revealed that cognitive maps of urban settings included the following five key features: paths, edges, districts, nodes, landmarks. This taxonomy of urban elements of cognitive maps has been applied to many other cities (e.g., Appleyard, 1969).

There are several serious problems with this method. First, as Golledge (1976) indicates, individual differences in drawing ability may confound sketch map output. In other words, sketch map data might underrepresent a person's knowledge about the environment due to his poor drawing ability. This is particularly likely when young children are involved in the study. Few data are available on the effects of graphic ability on sketch maps of the actual environment. Second, it was indicated (Beck & Wood, 1976) that the individual's experience of reading a cartographic map of an environment enhanced the accuracy and complexity of a hand-drawn sketch map of that environment. However, many reported studies using this sketch map methodology did not consider map experience as an important factor. Finally, it is suggested that the scale of the sketch map may be important in how various elements are represented (see Evans, 1980).

The second type of methodology uses small models and photographs to simulate the individual's experience of large-scale, real environments. Since small-scale models and photographs preclude motoric experience, they cannot examine the role of actual locomotion in the real environment in cognitive mapping. For example, in Laurendean and Pinard's experiment (1970, cited in Moore, 1976) the child was required to position several toy persons at certain places on a model landscape consisting of a road, railroad tracks, fire houses of different sizes and colors. The question is whether this experiment can tell anything about the child's ability to do the same thing in a real (corresponding) environment. It is already demonstrated that the size of the model affects how various elements are recognized and used (e. g., Acredolo, 1977).

However, there are several studies indicating the validity of using small-scale models. For example, Kozlowski and Bryant (1977) presented a fragmentary map of a campus to university students and asked them to indicate various buildings on that map. It was shown that the ability to locate the buildings accurately was correlated with the self-assessment of the individual's sense of direction. Furthermore, since the self-assessment was also shown to be correlated with one's performance in a maze orientation task (i.e., real environment), it is possible that the small scale mapping task can reveal certain aspects of one's spatial ability in the large-scale environment.

(3) Some representative studies

As stated earlier, one of the major functions of the cognitive map is to provide locational information which consists of the distance and direction of a given object or place with respect to a certain reference point (in many cases, this is where the idividual is located). Several studies have been published on how human beings estimate distance and direction in large-scale environments. In Baird, Merrill, and Tannenbaum's study (1979), graduate students were asked to represent (recall) the relative locations of buildings in a familiar campus setting by pairwise distance judgements on a 100-point scale and by direct mapping of locations on a cathode ray scope terminal. The use of the scope terminal was presumed to minimize the effect of individual differences in graphic ability. The pairwise judgements were analyzed by multidimensional scaling (MDS) and the buildings were located on a two-dimensional map. Comparisons between the map directly presented on the scope and the map derived from MDS indicate that although both agreed closely with each other and with the actual spatial relations, the former is closer to the actual map of the campus setting. Interestingly, the subjects felt that their direct map was more accurate than the actual map. These results suggest that the cognitive representation of a familiar environment as revealed by direct mapping and pairwise comparisons is faithful to the actual spatial relations within that environment.

In a related study, Sadalla, Burroughs, and Staplin (1980) asked students to rate 20 locations on a university campus and in a larger metropolitan area on three 9-point scales selected to measure the salience and importance of each location. Their hypothesis was that the estimation of the distance between two locations varies depending on the saliency of or subject's familiarity with these locations. More specifically, they hypothesized that a highly salient location, when paired with a nonsalient location, would serve as a reference point for the nonsalient location. The students were asked to make pairwise comparisons of the locations by locating two points on a sheet of paper (one point was always located at the origin of a semicircular grid). The results indicated that when one member of a location pair was more salient than the other, the distance between the former (reference location) and the latter (nonreference location) was estimated as significantly less than the distance between the nonreference location and the reference location. A similar observation was described earlier (Lee, 1970). This asymmetry of distance estimation suggests that the strict Euclidean rule cannot be applied to the cognitive map. Furthermore, they indicated that when the subjects were cognitively located in reference locations, their distance and direction estimation of other locations was quicker (i.e., short reaction time) than otherwise. These results suggest that so-called reference points exist in spatial cognition and that these points provide an organizational structure that facilitates the estimation of adjacent locations in space.

The reference points may be related to the notion of landmark, which refers to the discriminative features of an environment that guide navigational decisions in that environment. The role of landmarks in cognitive mapping was examined by Allen, Siegel, and Rosinski (1978). They hypothesized that the traveler stores two types of spatial information during exploration of the environment: (1) specific environmental features which form the basis of landmark knowledge, and (2) the temporal-spatial relations among these features which form the basis of route knowledge. The route may be defined here as a sensori-motor routine that links one landmark to another conceptually. In this study, students were presented with color slides taken at various intervals along walks through urban areas to simulate the perceptual arrays comprising spatial events. The results indicated that subjects' estimates of distance between various points along a pictured walk were related to actual distances and were more accurate when the subjects (1) estimated distances among scenes with high land-mark potential rather than low landmark potential, and (2) viewed the walk twice rather than once. Similar results were obtained when the subjects viewed a randomized rather than logically sequenced slide presentation (note that the slides contained some overlapping elements). This suggests that perceptual continuity is not necessary for the individual to acquire spatial knowledge about specific routes, provided he has sufficient perceptual cues from the route's context.

Although the above study demonstrated the unnecessity of locomotion (exploration) in an actual environment to form judgements about relative distances between scenes (landmarks), it seems likely that exploration of the environment increases the accuracy of such judgements. In fact, a number of studies (e.g., Golledge, Rivizzigno, & Spector, 1976) indicate that the accuracy of subjects' estimates of interlocation distances increases as their experience with environments accumulates.

In summary, the studies described in this section simply suggest that human subjects have cognitive representations of large-scale environments and these representations enable them to accurately estimate distances and directions among places within these environments. Furthermore, these representations are presumed to be essenial for correct navigation in real environments. These representations may be enriched, revised, and updated through repeated experience with the (changing) environments. The studies described above should be taken only as an initial step toward a fuller understanding of the structure and operation of cognitive maps. A number of questions remain to be examined. For example, it is not clear how humans acquire spatial knowledge about their environments. Particularly, since all aspects of an environment cannot be observed simultaneously, the observer needs to integrate different scenes into a coherent whole. Although it is apparent that memory is involved in this integration, no detailed theory exists as to how this integration is carried out.

Recent developmental studies provide some clues to this and other important problems of spatial cognition. In contrast with sophisticated spatial processing in adults, spatial processing in children takes relatively simpler forms and thus can be analyzed more conveniently. Furthermore, since most studies on spatial perception in general have been done in a developmental context, it seems important to examine spatial processing from the developmental point of view.

Ⅲ. The development of cognitive mapping

There are two major models of the development of spatial representations of large-scale environments, one proposed by Siegel and White (1975) and the other by Hart and Moore (1973) and Hart and Berzok (1982). Both models are heavily influenced by the Piajetian perspective on spatial cognition. Hart and Moore's developmental model may be summarized as follows. Initially, young children rely heavily on egocentric cues to orient and locate objects in space (stage Ⅰ —egocentric frame of reference). This stage is followed by the use of fixed objects in space, first singly and eventually coordinating multiple objects' interrelationships to the observer (stage Ⅱ —fixed frame of reference). Finally, comprehension of space as a coordinated system, independent of the object's or person's position, is established (stage Ⅲ—coordinated frame of reference).

Several experimental studies support this model. In an early study of perspective taking, Piajet and his associates (Piajet & Inhelder, 1967) asked children to tell what a doll's view of three, distinctively modelled mountains would be when it was placed at various viewpoints. Younger children (4-6 .5 years) selected from pictures showing various viewpoints the picture corresponding to their own view rather than the doll's view. These younger children persisted in this type of egocentric representation of space, even when allowed to walk around the mountain model and view from the doll's perspective. With the appearence of so-called concrete operations (7-9 years), there is a progressive differentiation of viewpoints. Before and behind are correctly differentiated first, then left and right. Finally, children could be able to perform the task correctly, suggesting that they could master an objective perspective that is independent of their egocentric viewpoint.

In another study by Piajet and Inhelder (1967), children were asked to place objects on a model landscape. The child was presented with a model on which a doll was placed. Then the child was asked to place the doll at the identical location on a second (identical) model which was rotated 180°. To place the doll correctly, the child could not use his own position as a reference point but had to use either parts of the model itself (fixed reference) or some systematic relationships among objects on the model. Very young children (3-4 years) placed the doll on the basis of its proximity to certain salient objects on the model. No recognition of distance, before-after, and left-right was apparent. During the next stage (4-6 years), egocentricism appeared in that children located the doll relative to their own position and disregarded rotation. At the end of this stage, however, children gradually comprehended left-right, and before-after relationships, order, and distance through trial-and-error learning (stage Ⅱ). At stage Ⅲ (6-7 years), model rotation no longer confused the child's judgement and the doll was placed correctly. In summary, these studies indicate that developmentally children first rely on egocentric cues, then on one or a few referents (objects), and finally on a system of coordinated referents.

It should be noted that since Piajet's experiments used small models theories supported by these experiments may not be applicable to larger-scale environments. However, a recent study by Acredolo (1976) suggests the applicability of Hart and Moore's model to these environments. In one of her experiments, 3-, 4-, and 10-year-old chidren were led to a table on their right as they entered an otherwise empty room (a door and a window act as stationary cues), and then blindfolded. Children were then led around the room, with half of them ending their walk at the opposite side of the room from the original entry (door) and half returning to the original entry point. Furthermore, for half of them, the table was moved to the opposite side (to the left of the door) of the room. The blindfold was removed, and the child was asked to return to the spot at which he or she had been blindfolded. Three-year-olds either responded egocentrically, turning to their right regardless of change in bodily position or table positon, or depended on a fixed frame of reference provided by the table. The 4-year-olds used table position predominantly to orient, whereas the 10-year-olds relied on a coordinated frame of reference (consisting of the stationary room cues), correctly locating the original blindfolding point irrespective of their relative body position or the location of the table.

Siegel and White's (1975, see also Siegel, Kirasic, & Kail, 1978) developmetal model of environmental cognition emphasizes spatial representations of large-scale environments as a basis for navigational actions. Their model may be summarized as follows. First, landmarks must be noticed and remembered. The child acts in the context of these landmarks (landmark knowledge). Once landmarks are established, route learning occurs within their context in a point-to-point fashion (route knowledge). Landmarks and routes are formed into clusters, but until an objective frame of reference is developed, these clusters remain uncoordinated with each other. Survey representations appear as a system of routes arising from and embedded in an objective frame of reference (configurational knowledge).

The importance of landmarks in younger children was noted by Acredolo, Pick, and Olsen (1975). In their study, 3-, 4-, and 8-year-old children were led on a walk through a hallway in their school. During the walk, the experimenter "accidentally" dropped her keys in a hallway that had either a few distinctive landmarks (different chairs) or no furniture. The child was asked to return to the location of the key drop after walking through the hall. Younger children (3- and 4-year olds) made more errors than older children when no landmarks were present, but when landmarks were present, no age differences were found. The child's dependence on landmarks during orientation in space was also noted by Acredolo's experiment (1976) described earlier.

Although landmarks are essential to wayfinding in the large environment, they are insufficient for constructing a cognitive map unless they are embedded in a context of effective action, i.e., a method for moving from landmark to landmark. A primary function of a landmark is to help maintain one's passage on a particular route, which is a pathway connecting two landmarks. The environment can be conceptualized as consisting of landmarks connected by routes.

Shemyakin (1962, cited in Siegel & White, 1975) analyzed children's sketch maps of their environments and found the orderly development from route representations to more wholistic survey representations. Six- to 7-year-old children usually drew only those routes over which they actually and frequently travelled but ignored other routes they did not use. Older children produced maps depicting objective routes and their interconnections more systematically.

Finally, Siegel and White (1975) suggested an interesting possibility that adult learning of new environmental layouts migh mimic the developmental stages described above. That is, during an initial encounter with a new environment, an individual notices and learns about salient landmarks and uses them as navigational aids. Then he acquires routes based on landmark knowledge and finally establishes a coordinated frame of reference (cognitive map) based on both landmark and route knowledge.

Ⅳ. Other related studies

(1) Animal studies

Congnitive mapping abilities are not limited to man. Many animals appear to possess cognitive maps superior to man's cognitive maps. For example, many species of birds migrate hundreds and even thousands of kilometers every year to reach their breeding grounds. These birds must have some means to locate themselves and goals in space in order to successfully reach the goals. A number of studies have been done to examine the basis of this extraordinary spatial ability of birds (e.g., Keeton, 1979). The main focus of these studies has been to determine what stimuli are used by animals and how these stimuli are processed to navigate optimally.

Animals could find their way to a goal in several different ways (Griffin, 1955) : (1) piloting, which is steering by familiar landmarks, (2) compass steering, which is heading in a constant compass direction, and (3) true navigation, which is heading towards a specific goal regardless of the original starting place and the direction neccessary to achieve the goal. The first method is not directly related to cognitive mapping, since in piloting movement is controlled by direct perception of environmental features. Three kinds of cues have been identified that birds use for both compass steering and true navigation: the sun, the stars, and magnetic fields.

Birds use the sun to calculate compass direction by measuring its azimuth and calculating whether the sun is located at that time of the day according to their internal biological clock. The best evidendce for this time compensation mechanism comes from studies in which the animal's diurnal clock has been artificially shifted by altering its day-night cycle. In such studies the birds do not fly in the homeward direction when released at a distant site, but head off in a direction consistent with the notion that they are calculating the compass direction of the sun on the basis of their altered internal clock.

The evidence that pigeons use geomagnetic cues comes from studies indicating that they could navigate correctly under overcast skies and that their flight was severely disrupted if magnets are fixed to thier heads. A variety of nocturnal migrants such as buntings are known to use star patterns to determine directions. The time compensation is not required for this process mainly because birds largely rely on the immobile polar star. Several other cues have been found to help birds' navigation: gravitational cues, olfactory cues, infrasonic cues, and meteorological cues (see Keeton, 1979)

As Keeton (1979) indicated, the major remaining problem in this ares is concerned with how the bird integrates these various cues during actual navigation and how such a integrative process develops ontogenetically. In any case, the scope of cognitive mapping research will be greatly extended by considering birds' navigational skills within a larger framework of spatial cognition.

In recent years, another line of cognitive mapping research has been carried out in the area of animal psychology. In a series of experiments, Olton and his associates (e.g., Olton, 1979) have examined the ability of rats to collect food efficiently from several locations. In their experiments, rats were placed on a radial maze with 8 or more radiating arms containing food pellets at their ends. Since each arm was baited only once in a trial, the optimal strategy for the rat was to choose each arm only once. The experiments indicated that rats learned this multiple place task without difficulty and that their performance was not dependent on such strategies as egocentric orientation and the use of some proximate cues (e.g., odor). Rather, it was suggested, that they could use extramaze spatial cues (landmarks) to guide their behavior (e.g. Suzuki, Augerinos, & Black, 1980). Many recent maze studies of this kind emphasize the efficacy of spatial strategies (presumably based on cognitive mapping) as opposed to strict S-R strategies in solving complex spatial problems.

O'Keefe and Nadel (1978) proposed in a neuropsychological context that during exploration of an environment the animal forms a cognitive map of that environment, which incorporates spatial relatinships among various landmarks and places including the animal's own position. The efficiency of the animal's ability to solve apatial problems is considered to be based on its cognitive map of the environment. Interestingly, O'Keefe and Nadel (1978) regard the cognitive mapping strategy as qualitatively different from such strategies as egocentric orientation and simple landmark utilization.

(2) Neuropsychological studies

Neuropsychological studies of spatial cognition have been concerned with the identification of neural systems responsible for processing and storing spatial information. The importance of the right posterior hemisphere for spatial processing has been demonstrated repeatedly in the literature of neuropsychology (e.g., Benton, 1982 ; Ratcliff, 1982). Critchley (1953) documented extensively that the damage of the parieto-occipital region of the right hemisphere produced various disturbances in visuospatial functioning including loss of map-reading ability, visual agnosia (inability to recognize objects), loss of the ability to recognize faces, and construction apraxia (e.g., loss of drawing or construction ability).

Recent studies on sex differences in spatial ability (e.g., Harris, 1976 ; McGee, 1982 ; Newcombe, 1982) suggest that males show superior spatial abilities to females probably because of their greater right hemisphere specialization than females. This conclusion was based on the results of various spatial tasks including visual mazes, tactual mazes, map reading, left-right discrimination, geographic orientation, and Piajetian tasks. It should be noted, however, that since most of these tasks involve the use of small models, they may not be appropriate for testing true cognitive mapping abilities. In fact, most tests done in larger environments have found no sex differences in environmental knowledge (e.g., Maurer & Bazter, 1972) or in locating objects in real space with a sighting tube (Hardwick, McIntyre, &

Pick, 1976).

Related to this is the question of whether the right parietal region is the only site of the cognitive map. According to O'Keefe and Nadel (1978), the parietal area is involved in purely egocentric spatial processing, while the hippocampus serves as a congitive map which processes non-egocentric spatial information. They presented numerous experiments supporting their position. More recently, however, O'Keefe and Nadel's proposal is challenged by Olton and his associates (see Olton, 1982), who stress that the hippocampus is involved in working memory rather than in cognitive mapping.

It should be noted, here, that most neuropsychological studies (with an exception of O'Keefe & Nadel, 1978) have been done without theoretical considerations on the basic processes involved in various spatial tasks. Consequently, it is not clear what kinds of spatial abilities are involved in each spatial task and how they are affected by specific neural systems. Such theoretical models as developed in the area of cognitive development should be considered in the analysis of neuropsychological correlates of spatial cognition.

V. Conclusions

It is necessary for all animals to perceive their environments accurately and behave accordingly in order to survive. It is not surprising to see that most animals and man possess a considerable amount of knowledge about their environments. Particularly, as Kaplan (1973) suggested, man's excellent ability to acquire and use spatial knowledge about his environment seems to have originated from his evolutionary history in which such ability has played a crucial role for survival. The importance of such ability is still recognizable in this civilized world.

Recent studies on environmental perception in adults have mainly focused on describing and classifying certain environmental features important for organizing environmental experience and action. Several psychometric studies on distance and direction estimation about various locations within large-scale settings have revealed that human beings have relatively accurate representations of their familiar environments. However, it has been noted that cognitive maps containing these representations are in many ways different from cartographic maps of corresponding environments. Distortions of distances, directions, and attributes of locations are commonly observed. Yet there is no systematic knowledge about causes and meanings of such distortions.

Most of the available methodologies of studying cognitive mapping processes have serious flaws. For example, it has not yet been established how reliably hand-drawn sketch maps could represent internal cognitive maps. And the applicability of findings obtained with small models to larger, real-life situations is not clarified. Several recent methodological innovations including the use of psychometric techniques (e.g., MDS) and quantifiable orientation tasks (e.g., Hardwick, et al., 1976) may increase methodological rigor which has been lacking in this field.

Developmental research on environmental perception has some success in revealing certain aspects of the internal structure of cognitive maps. Hart and Moore (1973) suggest that young children first use egocentric cues to orient in space, follwed by reliance on relative position to one then to multiple fixed points in space and finally, comprehension of space as a coordinated system. Siegel and White (1975) suggest that children first acquire landmark knowledge, then route knowledge, and finally configurational knowledge (cognitive map). These two conceptualizations of the development of spatial cognition have many points in common. For example, landmark knowledge provides a fixed frame of reference, while configurational knowledge is essential to establish a coordinated frame of reference. The only conceptual difference is whether spatial representations are regarded as constituting a frame of reference or a form of knowledge.

Studies of animal navigation and spatial learning are consistent with human research. All forms of spatial abilities including egocentric orientation, landmark utilization, and cognitive mapping have been demonstrated in animals. According to O'Keefe and Nadel (1978), many animals have all these abilities and which one is used in a particular situation depends on the nature of an imposed task. When tasks demand the use of non-egocentric spatial solutions, animals use cognitive mapping efficiently.

There has been a controversy as to the neurological site of cognitive mapping funcion. Traditionally, it is localized in the parietal lobe, while recently the hippocampus is implicated. According to O'Keefe and Nadel (1978) it is essential to distinguish egocentric and nonegocentric spatial functions in terms of their underlying neural systems. Siegel and White (1975) also suggested that there are parallels between developmental stages and neurological hierarchies in spatial cognition. This view may be substantiated if hierarchical neural systems subserving hierarchical spatial functions show differetial development so that there is a match between the development of a neural system and the emergence of a corresponding spatial function. This view has been partially supported in studies on both the hippocampus and the parietal cortex.

In conclusion, the study of cognitive mapping seems to be able to provide a rare opportunity to establish a truly multidisciplinary enterprise where the relatively small number of concepts and hypotheses could be applied to a large number of empirical domains. If this is the case, then we have common grounds for studying cognitive mapping in perceptual psychology, cognitive psychology, developmental psychology, neuropsychology, animal psychology, environmental psychology, behavioral geography, urban planning, architecture, etc.

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