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Mental Representations and Cognitive Maps in Humans a Review of Research and Theory

Streszczenie

Celem publikacji jest zaprezentowanie dotychczasowej wiedzy, oraz badań na temat umysłowej reprezentacji przestrzeni człowieka w postaci map poznawczych. Zostaną przedstawione teoretyczne rozważania na temat charakterystyki, elementów składowych map poznawczych i błędów popełnianych w trakcie ich konstrukcji. Wskazane zostaną prawdopodobne podmiotowe uwarunkowania związane z mentalną rekonstrukcją przestrzeni. Ze względu na to, że współcześnie, środowiskiem ogromnej rzeszy ludzi jest środowisko zurbanizowane, w artykule wiele miejsca poświęcone zostało opisowi i analizie map poznawczych dokonanych przez Kevina Lyncha. W artykule ustosunkowano się także do pojęcia czytelności środowiska ze specjalnym uwzględnieniem środowiska miejskiego.

Słowa kluczowe: reprezentacje mentalne, mapy poznawcze, elementy map poznawczych, błędy w mapach poznawczych, środowisko zurbanizowane, czytelność środowiska

Abstract

This paper presents the current state of knowledge and research on human mental spatial representations in the form of cognitive maps. Theoretical considerations
about the characteristics and components of cognitive maps, as well as about errors made during their construction, are discussed. The probable individual traits involved in mental spatial reconstruction are pointed out. Because most people today live in urban habitats, the paper devotes a considerable amount of space to describing and analyzing cognitive maps by Kevin Lynch. Also discussed is environment legibility, especially in the urban environment.

**Keywords:** mental representation, cognitive maps, elements of cognitive maps, errors in cognitive maps, urbanized environment, environment legibility

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**Introduction**

Human beings are inseparable from space. Our bodies take up space, we experience phenomena in space, and take actions in it. Throughout our individual lives we gather knowledge in space and about space. This knowledge is multimodal, perceived with sight, hearing, touch, kinesthetic, feedback from the body, and through other channels (Tversky, 1998). It is crucial to survival. Knowing your own body’s alignment in space, and knowing the location of particular objects are fundamental for the efficient functioning of a living, moving organism. Without the ability to find food and (which may seem trivial) to direct it to the mouth, or knowledge about places which can serve as shelter and the roads that lead to them, our survival would be impossible. Moreover, in order to avoid danger, it must be possible to describe and communicate the knowledge about space (Tversky, 1993).

All physical activity is accompanied with sensory activity, or perception. Perception precedes all other actions (Lose, 2012). Tirrasa and associates (Tirrasa, Carrara, and Germiniani, 2000) say that it is inappropriate to talk about spatial behavior, as behavior itself is only an effect of an “actor’s” interaction with a subjectively perceived reality, as seen by an outside observer. All moving organisms have evolved innate nerve structures (cognitive architecture) that serve spatial orientation. They are as complicated as they need to be for gathering individual experiences. Simple organisms do not form mental representations of objects, while humans cannot only create non-egocentric representations of space, but also symbols used for intentional movement; they can also communicate their knowledge through drawings (Tirrasa et al., 2000), gestures and speech (Tversky, 2011).

Because they are so crucial to survival, forms of spatial thinking are fundamental to other thoughts, as demonstrated by the ways in which we speak, make representations, or reason (Tversky, 2008). All human languages include words and expressions like “between”, “beside”, “in front of”, “above”, which describe spatial relations with varying levels of precision. Spatial knowledge is also a fun-
dament of thinking about other phenomena, such as time, mood, abilities, or ideas (Clark and Clark, 1997; Lakoff and Johnson, 1980; in: Tversky, 1998).

This article presents the state of knowledge about mental reflections of space in humans, in other words, cognitive maps. The nature of these maps, the ways they are constructed, errors in cognitive representations of space, as well as possible individual factors, shall be described. Because contemporary human beings take up mostly urbanized space, Kevin Lynch’s classic description and analysis of cognitive urban maps is given a special place in the article.

Cognitive representations of space

Speaking broadly, cognitive representations can be defined as mental counterparts of objects, including those that are real, fictional, or hypothetical. Physical things, persons, categories, or even relations may be represented. Representations take the place of their objects in various mental operations (Nęcka, Orzechowski, and Szymura, 2006). Spatial knowledge comprises (1) objects, (2) frames of reference, and (3) ways people perceive. These effects combine information coming from various observations, modalities, objects, frames of reference, and perspectives. Reconciling various information sources is done by finding similar elements in them, and transforming them into a generalized, abstract scheme (Tversky, 2011).

Each reflection as a mental image includes spatial relations of the imagined object. According to the constructivist view -- which assumes that an object may be represented in many ways depending on the context, acquired knowledge, or the individual’s emotional state --, it is important to emphasize that a representation must physically correspond to the real object if it is to be usable by a person. That, however, does not change the fact that mental images may be distorted or even completely erroneous. Pursuant to Paivio’s hypothesis of equivalence (Sternberg, 2001), we do not construct mental images that are identical to the perceived, but only ones that are functionally equivalent. Because of this cognitive economy, an adaptive necessity, mental representations cannot be mirror images of reality, but rather simple schemes, which are supposed to enable us to function efficiently, and not strain our cognitive resources (Tirrasa et al., 2000). Knowledge about space is not the effect of Euclidean geometric measurement; it is rather a relativistic construct, comprised of things in space, and not space itself (Tversky, 1998). This solution is completely sufficient for navigation. Our surroundings are full of cues that show us the way, or point towards entrances and exits. A pedestrian need not include in his mental representation the exact coordinates, for example, of the entrance to the underground, as the place has proper, semantically under-
standable signs. The presence of a spatial context enables us to omit the exact locations of objects in our spatial maps (Tversky, 2003).

According to Tversky (1998), creating cognitive representations of the inner and outer world depends on natural spatial vectors. We perceive all situations not only as outside observers, but also through our bodies and sensory organs (Tversky, 2008). Mental spatial representations are constructed as extensions of the body’s axis, with objects in relation to it (Tversky, 1998). A human organism has three axes of perception. The vertical is related to the head and the feet alignment. The two horizontal axes are front-back and left-right. The first two axes are asymmetrical, while the last one is much less so. The body’s axes are also related to the axes functioning in the outside world, the vertical closely linked to gravity. The head-feet axis is the most differentiating in regards to spatial relations, as it is related to the most asymmetrical axis of the outside world, the condition of gravity. The front-back axis is the second one that differentiates space, as it decides which objects may be perceived in a given moment, and which are unavailable to our senses and manipulation. The left-right axis causes the weakest differentiation, as it is the least asymmetrical.

According to Appleyard (1970), forming representations is related to the domination of one of the perception types, which are distinguished according to the functions they serve. The first type is based on the operational function, related to performing particular actions. The purpose here is to choose objects which can undergo a certain operation, regardless of their qualities, degree of complication, and so on. The second type -- responsive -- is related to passive reception of signals and symbols. It can be understood as the use of reference points. The third type -- inferential -- consists of analyzing and comparing perceived objects to models that were seen earlier.

In this framework one object may be remembered and recalled in the context of the activity that the individual undertakes in contact with the object, such as an image, name, category, or symbol. Thus our representations are produced by two independent systems of information: coming directly from experience and indirectly from communication. Spatial representations are constructed because we need to understand our own perception and activity, and in order to make perception and activity, including mental activity, possible (Tversky, 2008).

**Cognitive maps**

One type of mental spatial representations is called cognitive maps. There are many definitions and ways of interpreting the notion, many of which are ambiguous. In the seemingly most reasonable sense, a cognitive map is a scheme
located on the general level of structured knowledge in relation to the surroundings (Hauziński, 2010). It is located in the nervous system, and allows us to plot our movements in an area by supplying knowledge about relations between elements in it (Gallistel, 1990). Cognitive maps are personal representations of the environment and objects within it, which enable us to plan action in a particular space (Lewicka and Bańka, 2006). Cognitive mapping was introduced by Tollman (1948), who analyzed the way rats learned to move through a labyrinth.

Cognitive maps are created through numerous mental operations: remembering, coding, and recalling information, planning actions, or anticipating possible situations (Hauziński, 2010). The information comprising cognitive maps can come from primary (personal experience with space, a walk), as well as secondary sources (paper maps, hints from other people, descriptions of trails).

Producing a simplified scheme of space -- a cognitive map -- is an economical solution that enables us to move about effectively and find solutions to problems pertaining to areas that are too big to observe from a single vantage point (Tversky, 2003). Maps are created by combining separate fragments coming from different modalities, which are adequately integrated, scaled, and arranged (Tversky, 2003). Compressing knowledge about a place enables us to choose only those qualities and relations between objects in an area, which hold quintessential information, and lessens the burden on working memory, whose resources are limited (Baddeley, 1990; in: Tversky, 2003). Despite simplifications, cognitive maps perform their function – they help people find their destination. All that is required of a map is information on where to turn and which road to choose.

Moving through space, humans code the way in subcortical memory structures, thanks to receptors of movement (including the vestibular system), and the visual surroundings of the road – through the coupled staminate retina, among other organs. All stimuli are developed into a unified sensory background of way and place (Lose, 2012). A matrix thusly created enables us to move almost mechanically through familiar space. Many times we consciously choose only the way, and when we arrive at the destination we are unable to recall how we got there, because, simply speaking, we did not need to employ our cognitive resources to traveling. The task was carried out without our knowledge by subcortical structures in constant coordination with the staminate retina and the vestibular system. Upon reaching the destination, a crossroads, or upon encountering doubt a quick volitional verification of the present position occurs.

A cognitive map is a relatively fixed mental construct, written into long-term memory (LTM), and weakly influenced by situational conditions; it does, however include many distortions caused by various factors. The precision, structure, number of elements, as well as other cognitive map qualities bear a positive cor-
relation to the number of experiences with the given space (Ramadier and Moser, 1998; Tversky, 2003).

Cognitive mapping has become a popular metaphor for mental representations of our environment. It is not very fortunate, according to Tversky. Cognitive maps are mental constructs similar to geographical maps, and so should be completely coherent and unambiguous in their content. The cognitive map metaphor does not reflect a person’s complex and rich knowledge about his surroundings. Tversky (ibid.) holds that it is more appropriate to use the term cognitive collage, as the information about spatial relations between objects, which comprise mental representations, comes from many modalities and perspectives, and are ridden with cognitive errors, which means that they are often in opposition to each other. For example, the distance between one object and another, which is constant in reality, can seem longer or shorter in the mind, depending on the frame of reference. The notion of a map does not allow for this type of discrepancy; thus the collage metaphor seems more adequate: it takes many different parts coming from different sources having different qualities, is perceived from different perspectives, and combines them into a whole (Tversky, 1998).

Tversky also distinguishes the construct mental models of space, which, unlike cognitive maps, do not include information about distances between objects, and unlike collages, keep their data coherent. They are schematic simplifications of known or uncomplicated spaces based on relations between objects existing in them (Tversky, 1998).

*Drawings as mental representations of space*

Drawing is one of the oldest forms reflecting mental images. People used it as an important communication medium long before written language, as demonstrated by cave paintings, maps, or pictorial languages (Gelb, 1963; in: Taylor and Tversky, 1992). The earliest known maps come from Mesopotamia, and their age is estimated at around four thousand years (Wilford, 1981; in: Tversky, 1998). Drawings were (and still are) used to portray outside reality as perceived and understood by the observer. They are also used as signs. The varied forms of communicating through drawing seem similar in all cultures. A similarity may also be observed between maps drawn by adults and children (Taylor and Tversky, 1992).

Drawings also express non-spatial relations between objects, such as relations of time, number, or quality, as exemplified in genealogical trees, tables of geological periods, diagrams of scientific theories, or schemes of daily meal plans. On drawings and in the mind these relations are depicted while maintaining spatial separation, and with regard to sequencing or meaning (starting with the most important, the biggest, etc.) (Tversky, 1998). But space in the mind is not the same
as physical space: Differences in location (spatial or geographic) are primary, and
objects are placed with respect to those differences. For humans, objects in space
come first in cognition, and frames of reference are secondary constructs, created
in relation to perceived elements (Tversky, 2008).

Creation of cognitive maps

In recent years considerable research has been devoted to the problem of how
mental maps are formed directly from an individual’s spatial perception. Two
theoretical approaches have emerged. The first assumes that the general outline
of space, a limited area surrounding the observer, is perceived at the very start.
The second maintains that in the beginning objects are distinguished, and their
mutual relations are determined (Yeap and Jeffries, 2000). The analyses carried
out by both groups did not yield data sufficient to clearly determine which ele-
ments initiate the creation of cognitive maps.

Another area of scientific research regarding cognitive maps is the infl
uence
of perspective on the resulting mental image. As concluded in Tversky’s research
(2008), people learn the spatial organization of a place when they traverse it them-
selves more easily than when they are guided by someone else. Whether we ana-
lyze space by experiencing it ourselves (as an observer) or by reading maps does
not influence the quantitative and qualitative characteristics of representations
In his research the participants learned faster and more about a new space from
studying a geographical map than from firsthand exploration. He maintains that
cognitive maps created by analyzing cartographical maps are different from those
created through personally experienced space. The former have more adequate
relations between landmarks relatively to the general frame of reference. The dif-
fferences are more quantitative than qualitative, however.

Cognitive maps do not include a single perspective of perception. They are
more like three-dimensional models, which can be perceived from different view-
points, but cannot be perceived comprehensively (and that is why it is inappropri-
ate to call them images). However, this kind of construction makes representa-
tions more flexible and useful. It allows for analyzing surroundings from different
vantage points, for adapting to changes (in the environment itself as well as in
the individual’s position), and even for transposition to new environments (Taylor
and Tversky, 1992).
Types of cognitive maps

Based on the fruits of much research into the sequence of elements depicted on drawings Appleyard (1970) distinguished two types of cognitive maps. Ones dominated by elements that are spatially adjacent – as if they were sequentially encountered on the road through an area – forming a network of main roads, were called linear maps. More spatial ones, emphasizing regions and landmarks, as well as relations between particular objects were called point-oriented maps.

In later years, and also by analyzing sequential elements drawn on sketched-out maps of spaces, Huynh and associates (Huynh et al., 2008) distinguished three types of structuring and organizing elements of cognitive maps: linear, point-oriented, and hybrid. The main types are then divided into subtypes. Objects in space are organized differently in each type, but landmarks and roads are key elements, with complementary roles, in all of them. The types of cognitive maps are related to differences in prioritization and grouping of elements in space. Each organizational level reflects a subjectively perceived significance level of individual elements. Using a certain type of structuring information can influence decisions about behavior in space, and navigation (Banai, 1999; in: Huynh et al., 2008).

The linear model prioritizes elements related to the transportation network (roads) and the borders between areas, as well as frames of reference for the location of other objects, that it creates. The point-oriented model is based on the priority of identifying points in space that are important for the observer (landmarks); these act as anchors or footholds. The third type mixes the first two qualities. The linear model dominates in humans (Huynh et al., 2008). It seems justified since navigation based on landmarks does not necessarily yield the most efficient way between the starting point and the destination of the journey.

Research into cognitive maps

A cognitive map is a mental representation of space. But in order to communicate its contents to another person, be it someone asking for the way or a researcher, one must externalize it.

For research purposes into various aspects of cognitive maps, scientists have produced a wide range of tools to measure mental representations, depending on the chosen research problems. For example, subjects were asked to sketch maps of particular areas, to locate points on a provided map, to estimate distance or direction between a series of locations, to recognize elements on photographs, to describe the route to a particular destination, to find the way in space, or to build models representing a given area (Kitchin, 1996).
For the purpose of systematizing the existing methods, they may be divided into several groups. The first is *graphic methods*. These include *basic sketched maps* (see Lynch, 1960), *normal sketched maps* (which require the subjects to locate certain elements interesting to the researcher), and *longitudinal sketched maps* (the subject draws the map on layers, which show the sequence of the portrayed elements). The second is *partially graphic and reconstructive methods*. They differ from sketched maps in that they only require the subject to mark certain points. These include *marking locations in relation to two given points* (with or without a fragmentary contour map), and *filling in the missing elements* (the subject is to recall what lies in a map’s blank fragments). The third group is *multimodal methods*. These include multidimensional scaling (MDS) and projective convergence; they use the knowledge about distances and paths in order to reproduce structured spatial knowledge. The fourth, and last, group is *recognition methods*. Here the subject is shown several spatial representations, like maps, and he or she is expected to choose the version on which the qualities and configuration of elements are portrayed correctly (Kitchin, 1996).

Unfortunately, none of the methods is perfect; all are analytically biased in one way or another.

Another trend in research into cognitive maps is concerned with how cognition influences learning in space. As concluded in an analysis of urban tourist guides (Tversky, 2003), describing the content and relations between objects on a spatial map may be done from two perspectives: *path* and *exploration*, or a combination of these. The path perspective takes the recipient on a mental journey through the surroundings, presenting objects whose positions change relative to the observer according to his or her movements. The perspective shows space from a bird’s-eye view, describing objects’ positions within unchanging frames of reference, according to their relations, and ignoring the observer’s changing position.

Another interesting technique, linked more to opinions, evaluations, and affective reactions caused by given structures or areas than to cognitive representations of space, is Goud maps, and their Polish modification – *psychocartography*. The subjects are asked to mark areas of a city, which they like or dislike, consider interesting or uninteresting, or which they believe need revitalization, and so on. Later a computer program sums up the particular submissions, and presents them on a map of isolines representing how often this or that area has been encircled (Lewicka and Folland, 2005). This allows for qualitative and quantitative analyses of obtained data.
Errors in cognitive maps

Mental representations are not faithful copies of their subjects, but only abstract schemes. Simplifications often breed mistakes (Tversky, 2003). They come from cognitive processes, individual factors, and culture.

Tversky (1993) distinguished six types of systematic mistakes appearing in mental spatial representations. The first group is linked to hierarchy in representations of space. People do not remember the exact location of all objects, but only rough placements relative to their larger fragmented surroundings. We do not know where particular towns are located, only in which geographical regions they lie, and what a region’s geographical location is in relation to another (Tversky, 1998). Thus, when we are to determine the relative location of two towns to each other, we analyze information about the regions where they lie. Errors are made in regard to direction (research subjects from a university in San Diego declared that Reno is west of San Diego) as well as to distance (subjects declared the distance between buildings performing different functions to be greater than between buildings performing the same function) (Hirtle and Jonides, 1985; in: Tversky, 2003).

Such errors happen because people are quicker to verify distances between different objects (like countries or continents), than between similar ones (like towns). The effect of group asymmetry described by social psychologists operates on the same principle (Tversky, 1998).

Grouping is done through finding similarities between objects, which can be interpreted in many different ways (as observable qualities, but also as induced or other behavior) (Tversky, 2011).

Hierarchical organization means that people have a tendency to divide space into smaller bits, where some elements are seen as related, and others as functioning separately. In urban space large, global characteristics are compared with smaller, local ones. Thus, when a space is presented, elements of one fragment are shown first before another fragment is. Then the background is described through subsequent planes, down to the details (Taylor and Tversky, 1992). Combining segments of space results in a spatial framework, which can be analyzed on varying generalizes levels according to what is needed. Roads and nodes first undergo prioritization and grouping (Golledge, 1948; in: Huynh et al., 2008). Prototype categories include biased stimuli perception (Tversky, 2011). Categorizing an object in a wider group requires subsequent examples of a class to be compared to a remembered prototype. Rosch’s research (1975; in: Tversky, 2003) has shown that people are more likely to consider magenta a color close to red than to consider red a color close to magenta. Similarly, a son is more like the father than the father is like the son. Landmarks seem to define their surroundings and become proto-
types of categories, while plain objects, like unspecific buildings, do not. They are rather included in the surroundings defined by landmarks.

The second type of mistake is linked to perspective of perception. Research has shown that people overestimate the distances between landmarks located near each other, and underestimate the distances between ones that are far apart. Holyoak and Mah (1982; in: Tversky, 1993) asked student groups to imagine that they are on the east or west coast of the USA, and to estimate distances between pairs of American cities. The study demonstrated that persons “looking” from the western perspective overestimated the distances between western cities, and underestimated the distances between eastern cities, while the relation was the other way around in the second group.

The third type of error is related to cognitive points of reference. While describing the position of a known object to another person we often refer to its surroundings. When we want to tell a foreigner where we are from, we can say that our town lies in central Europe; if he or she possesses additional knowledge, we can say southwestern Poland; to someone who knows Wroclaw even a little bit we can tell the name of the district where our house is located. Our information on regions is organized around landmarks (Tversky, 1998). Remembering the positions of less important locales in relation to landmarks causes distortions that are impossible on ordinary maps (it is called the asymmetry of distances). Sadalla, Burroughs and Staplin (1980; in: Tversky, 1998) discovered that people estimate the distance from a plain building to a landmark as shorter than its inverse, the distance from the same landmark to the same building. The distances between landmarks are also estimated as shorter than those between plain buildings.

The fourth type of mistake is the so-called alignment. Memorizing one location in relation to another results in both being grouped by the observer into a gestalt way (according to the law of proximity), and because of this they are remembered as more evenly aligned than they really are (Tversky, 1981; in: Tversky, 1993). Research subjects, when shown different versions of contour maps depicting both the Americas, most often chose a wrong map, which showed South America as smaller and farther to the west than in reality. In the distorted image it looked like a natural extension of North America.

The fifth type of mistake is rotations, which result from memorizing the location of objects relative to some frame of reference (Tversky, 1981; in: Tversky, 1993). American students tested in the above-mentioned study chose the outline of South America which was most in line with the north-south axis, believing it to be the correct one. Also, Parisians, when sketching maps of their city, had a tendency to draw the Seine as much straighter than it is in reality (Milgram and Jodelet, 1976; in:
Tversky, 2003). Thanks to rotation both axes of the area, as well as those making up the frames of reference, are seen by the observer as more coherent than they really are.

The sixth group of systematic mistakes includes equalizations and simplifications of real spatial shapes. And so angles close to ninety degrees are assumed to be right angles (Sternberg, 2001), and roads close to a straight line in shape are assumed to be completely straight. Moreover, roads with numerous turns, intersections, or barriers are estimated to be longer than straight ones (Tversky, 2003). Situational factors also influence perception: a mountainside seems steeper when we are climbing up with a heavy backpack (Tversky, 2011). Other types include errors of quantity, shape, size, or perspective (Tversky, 1992).

The systematic mistakes described above, as well as random ones, appear not only when a person evaluates new or complicated environments, but also when they assess familiar and simple ones. Even when dealing with simple and familiar surroundings, metric relations are often schematic or deformed. Because of mistakes in perception, the knowledge we have is not fully coherent or consistent.

Other types of cognitive errors result from the specific nature of mental schemata, which are abstract and generalized. The cognitive economy of our minds, as well as the constructive (and not reproductive) functioning of memory, may often lead to errors in recognizing places or in mistaken placement of objects (Appleyard, 1970). Lynch (1960) lists three types of mistakes that are made most often: incompleteness, distortions, and extensions.

Errors of incompleteness omit some elements of the environment, from small details, to large or significant fragments. The reasons for these mistakes are varied, and relate to unfamiliarity with a space, or to ignoring elements that the observer considers irrelevant or even dislikes (Lewicka, Bańska, 2008). Information can be defective or just unnecessary (Tversky, 2008).

Errors distorting the real image are related to distances between elements as well as their erroneous placement in space relative to each other. This observation made by Lynch is consistent with Tversky’s research results cited earlier.

The third group of errors is extensions. Lynch understands them as added elements which do not really exist in the given space. The reason for these irregularities is the inference from earlier experiences and content of one’s cognitive schemata. Elements specific to the present scheme are included in the image even if they do not appear in the current example. The phenomenon is called default structuring, and may often make spatial orientation easier (Bell et al., 2004).

The errors described above are not chance results or the observers’ ignorance. Rather they seem to be natural perceptual and cognitive consequences. Thus mistakes are inevitable, but their number may be reduced by local, specific sensory-motor feedbacks (performing concrete actions), and also by local environmen-
tal cues. Navigation and other behavior are a consequence of both these factors (Tversky, 2003). In the end, if we learn that Rome is farther north than Philadelphia, we still will not know the spatial location of Boston or Rio. Learning is a local and specific process, not a generalized or abstract one. After reading this chapter, despite the fact that we gained knowledge about perceptual errors, we shall not cease to make them.

The mechanisms that entail mistakes have many causes, and enable us to adapt to many perceptual situations. Navigation based on a framework of cognitive representations is adequate and effective in most cases (Tversky, 2003).

**Individual traits and cognitive maps**

Personal traits also influence the outlook of cognitive maps, not only traits like intellect, but also ones like gender (Everitt and Cadwallader, 1972; Orleans and Schmidt, 1972) and the differences in visual and spatial abilities (Moir, Jessel, 1989), as well as in cognitive styles of field dependence or independence (Nosal, 2008; in: Strelau, Zawadzki, 2008), which it entails; the place where one was raised also plays a part. Some researchers have shown that social class (Goodchild, 1974; Karan et al., 1980), familiarity with the city (Evans et al., 1981), as well as one’s age (Francesato and Mebane, 1973, in: Hospers, 2010), may cause differences in produced cognitive maps as well.

Possible inter-gender differences in mapping ability was not, despite considerable research, completely resolved. Many studies show differences in cognitive functioning between men and women, but these differences are related either to quantitative traits (weak and strong sides in some regard), or to qualitative traits that do not affect proficiency.

The thesis that men show better visual and spatial abilities is widely acknowledged. This fact has various explanations. Witkin (Kimura, 2006) linked these abilities to perceptual style, called field dependence/independence, which says how strongly perception is determined by the field. Field-dependent people (more often women, according to Witkin) are slower to distinguish figures from the background, have difficulty structuralizing information, and use a more passive, dispersed style, all of which is reversed in regard to field-independent persons.

Other research has show that the influence of sex hormones on the brain and nervous system is responsible for differences in gender roles, interests, and cognitive styles. Benbow and Stanley (Moir and Jessel, 1989) have proven that the level of testosterone positively influences the development of visual and spatial abilities, while female hormones stunt the growth of these abilities. This may also result from the lateralization of cognitional centers in the brain. In women, structures responsible for verbal abilities are distributed more evenly between hemispheres, while
in men verbal abilities “are located” in the left hemisphere, and spatial abilities in the right (Brannon, 2002). There is no conclusive evidence, however, that lateralization influences mental abilities. Also pointed out is the traditional socialization role, as well as high social acceptance for masculine and feminine stereotypes, both of which mediate gender differences in spatial abilities (Mandal, 2003).

The validity of the above conclusions is called into question by the fact that research into spatial abilities seems to depend on situational factors, including expectations, context, test procedure, and the researcher himself (Brannon, 2002). It has been proven, for example, that changing only the instruction to one that did not reveal the purpose of the test resulted in a significant increase in average scores achieved by women (Brannon, 2002). Other research suggests that what we call spatial abilities might indeed be a group of different abilities. One such ability might be imaginary rotation, where gender differences were most strongly demonstrated (Kimura, 2006; Mandal, 2003). When memorizing and later reconstructing from memory are measured, women do better than men (Kimura, 2006).

Gender differences in widely understood spatial abilities may be reflected in modes of navigation preferred by each group. Women prefer to find the way based on landmarks, because they know more of them than men. When drawing maps they also start with marking the first significant point of reference more often. Men in their turn prefer to navigate based on spatial orientation and directions; they more often refer to the road network and relations between regions (Foo, Warren, Duchon, and Tarr, 2005). The variety may result from different everyday activities of men and women (Orleans and Schmidt, 1972).

Another variable interesting from the viewpoint of inter-group differences is place of upbringing. It may be analyzed with regard to rural-urban differences, or to ethnic groups. The environment where one mainly resides may influence certain strategies of orientation, meaning sensitivity to particular stimuli (including the environmental and the semantic). Mobility and travel may also be a factor in creating varied, coherent cognitive maps (Bell et al., 2004).

**Cognitive maps in urbanized space**

In order to better understand the importance of cognitive maps, we have to realize what it means for a person to function within an environment – especially an urbanized one.

Architecture emerged in history when urban life developed; it required the construction of abodes, and as a result – shared spaces and workplaces. One can look at the cities and villages around us and see the human need to live together and mutually assure one another’s security in the chosen place. A settled community provides us and our offspring with greater chances to survive; it also assures a bet-
standard of living than if we dwelled by ourselves or in a small family or tribe. In all human settlements that shaped over the millennia, regardless of cultural, historic, racial, or climatic differences, men and women sought the same thing – safety and contact with other people.

Real urbanization means a constant attachment to territory despite changes in its potential. It is constant adaptation of humans to an area, and a constant re-shaping of the area (Lose, 2012). Centuries of tribal existence endowed their members with experience needed to survive. Subsequent generations operated the same way their fathers did. This vital experience -- primal knowledge of the world -- was imprinted deeply, becoming instinctual knowledge in the course of evolution.

These considerations correspond to some degree with the savanna hypothesis, which says that some human behavior, related to choosing landscape preferences and a place for living, is a result of evolutionary adaptation by our species for living on the plains of the savanna. People have a tendency to prefer spaces that allow them to see the distant horizon, as well as spaces that have some irregularities, hiding places next to sources of water (rare on savannas: settling near them increased survival chances) (Buss, 2003).

Knowing a territory’s structure and how to function in that space, as well as in society, gives people a sense of security. We gain this knowledge from the beginning of our lives.

"Early childhood is very important for creating a world image. This phase brings with it the activation and final formation of sensual perception, as well as mechanisms of emotional evaluation (...). The experiences of early childhood shape our brains in an irreversible way. (Poppel and Edingshaus, 1998, p. 107)."

The matrix we are talking about, the urban matrix, includes canons pertaining to language and society, to territory, space and time, to economic matters, as well as cultural forms that exemplify the canons (Lose, 2012). Communities in a given territory build their own matrices.

It is important to remember that humans remain biological and social beings, and their ability to memorize and recognize structures of territory and space is limited, especially when the space is amorphous or unstable. Thus, creating a stable place is necessary for proper development. According to Martin Heidegger, having a safe place where we have at least partially tamed the forces of nature gives us a sense of freedom and is a starting point for effective and creative functioning (Lose, 2012).
The importance of a familiar, safe, and comprehensible place is underlined by the fact that in all times, cultures, and communities banishment has been applied as punishment for breaking laws or customs. Animals also die often when they are deprived of their territory.

Building blocks of urbanized space

Kevin Lynch’s research, described in his work “The Image of The City” (1960), has been an inspiration for many cognitive map studies. This American urban planner’s goal was to find laws governing human impressions and behavior regarding the environment they live in, and use the knowledge to design cities, for example. He tested denizens from three American cities: Boston, Jersey City, and Los Angeles, created a methodology for studying cognitive maps of urbanizes spaces, and built a system that describes the contents of these maps.

Based on his research, Lynch distinguished five basic categories of elements that make up cognitive maps, and the elements are common to most individual representations of urbanized space. These are paths, edges, districts, nodes, and landmarks (Lynch, 1960).

Paths are just roads that we can, at least potentially, move along. They can be streets, sidewalks, passages, canals, or even transit lines. In Lynch’s research they were often said to be the most important elements of cognitive maps. The probable reason for this is that we experience space when moving along paths, and other objects may be seen as subservient to them (Lynch, 1960). According to the data gathered by Lynch, paths are considered distinctive when they are extreme in some way, when they are, for example, very narrow or very wide (the latter are seen as main roads). Other distinctive paths are house facades, a concentration of objects performing a particular function (commerce, culture), or if they are somehow different than others in the city. Without distinctive features it is difficult to create a cognitive map. A clear beginning and end also makes a path easier to identify and integrate into a general picture, especially in a structure as large as a city.

The second distinguished element is edges. They are linear elements of the landscape that are not thought to be paths. They are borders separating or linking parts of a town. Their central quality is that they break continuity. They can be river banks, sea or lake shores, moats, or walls. Edges can become points of reference and play vital roles in organizing space.

Another element is districts. Lynch defines them as medium-sized parts of cities that have distinct, observable qualities which set them apart from others. It gives the observer a sense of entering a new neighborhood.

The next category is nodes. They can be defined as strategic points of space that may be entered. In cities they can be intersections, train or bus stations, squares,
or street corners. These are often places that concentrate large numbers of people and/or functions, distinguishable for their outward qualities or purposes.

The last element noted by Lynch is landmarks. Like nodes, they are points of reference, but they are different in that an observer has no direct access to them. Landmarks are usually physical objects that are easily recognizable for their physical characteristics (Lynch, 1960). Some elements are naturally more distinct than others (Tversky, 2008). These can be large objects (skyscrapers, mountains), close together or far apart, standing out from the surrounding space (monuments, memorials, fountains), or things giving the area its own character (signs, signboards, unusual facades). Thus, landmarks are objects with qualities that are distinct and easily observable, be it to all people or only to a particular group that understands their semantic meaning. Moreover, some landmarks are placed in locations where they are indispensable, for example to prevent people from falling down stairs.

The hierarchic organizations of cognitive maps which were described above suggests that paths form the skeletal infrastructure of space which allows us to penetrate our surroundings, whereas edges are other linear elements are not paths. Edges delineate districts, and nodes are strategic points, differentiating the space along paths and edges. Landmarks (objects that serve as cognitive and physical points of reference) are added to make surroundings more diversified, and make spatial orientation easier (Hyunh et al., 2008). These elements overlap and flow into each other (Lynch, 1960).

**Legibility of urbanized space**

One main goal of scientists researching cognitive maps was (and still is) to find a group of environmental qualities that are not only important for users in the space, but also make it more legible. There are, after all, places where we like to spend time, but also ones that we run away from, or ones we purposefully steer away from on our daily journeys, because we seem to lose our way in them.

Legibility relates to just such a group of qualities sought. According to Lynch’s definition (1960), legibility is an environmental quality that makes it easy to learn and remember, which in turn makes navigation effortless, can influence emotional reactions and make the space seem attractive and beautiful (Bell et al., 2003). In other words: a city is legible when it is easily created cognitively and when one finds his way around it (Lewicka and Bańka, 2008). Lynch maintains that legible space (or, from a planner’s perspective, a well designed space) is easy to memorize thanks to well known objects in it (symbols), is widely recognized and has easily available roads (Hauziński, 1998). Optimal architectural space ought to contain elements that clearly express their functions and supply stimuli
with varying intensity; it should also express the views of social groups living in that space (Hauziński, 1998).

Other research has shown that people prefer spaces that are open, orderly, clean, rich in historical value, and with considerable greenery. Well known, traditional architectural solutions are also preferred (Lewicka and Bańka, 2008).

Today there are still many places around the world, also in its highly urbanized part, that lack efficient and clear organization, even though thousands of years ago there already were social entities which were efficiently managed, with legible public and private space (Lose, 2012).

Lack of legible space causes difficulties in finding one’s way around one’s surroundings, which causes stress, as in the case of danger. Stress appears when there is an imbalance between environmental demands and human resources (Evans and Cohen, 1987; in: Evans and McCoy, 1998). Proper sensory stimulation is necessary for effective functioning, because too much or too little stimuli do not support it. Environmental qualities such as strong lighting, an unusual or strong smell, loud noise, or bright colors, cause a dangerous rise in the level of stimulation, just as crowding does, which violates personal space (Berlyne, 1971; in: Evans and McCoy, 1998). At the same time, objects that are boring, lacking mystery or diversity, do not meet the requirements of optimum stimulation. Too much causes disorientation, too little triviality.

Legible urbanized space takes the form of regular, geometrical shapes of buildings (Weisman, 1982) and diverse signs in interiors (Evans, 1980) as well as open spaces outside (Garlining et al., 1986; in: Evans and McCoy, 1998). Extensive research into path finding has shown that landmarks placed in nodes also make space more legible (Evans, 1980). Another quality that influences legibility is to have the functions of spatial elements clearly marked (Heft, 1997; in: Evans and McCoy, 1998). Responsiveness, perceiving feedback as the effect of actions taken in space, also affects spatial legibility; lack of such feedback causes a sense of helplessness, especially in children (Cohen et al., 1986; in: Evans and McCoy, 1998).

Evans and McCoy (1998) distinguished five groups of factors which influence spatial legibility. They include stimulation levels caused by the environment, accessibility of objects, sense of control over the environment, and restorative qualities. Optimizing these traits makes assimilation to the place easier, and thus lowers stress, correlating positively with the person’s health there. People are not able to construct an adequate representation of space when information about the space comes from sources that are vague, poorly organized, and generally hard to describe (Tversky, 1992).

In the approaches presented above, legibility is mainly seen as a physical spatial trait, which is an extension of a hypothesis saying that surroundings directly influ-
ence space perception (Lynch, 1960) and that mental representation of space is isomorphic with its physical structure (Kosslyn, 1975; in: Ramadier and Moser, 1998). In this understanding, spatial legibility of is equal to the degree to which architectural space facilitates navigation within its borders. However, this approach ignores the fact that architectural elements are only a part of urbanized social diversity; it is also full of codes and signs, which are mass produced and shared by groups.

Most research separates social and cultural relationships between people and their environment. According to Ramadier and Moser (1998), it is experience and conferring personal meaning that organize cognitive maps of space, not only the space’s physical attributes. Mental representations are based on general knowledge, which is socially shared and stored in semantic memory. A city’s image or some space in general is not just an analogous reflection. Thus, physical legibility must be considered alongside social legibility. Social legibility affects the ease with which individuals, using social and physical traits of the environment, are able to create and internalize spatial meanings. Various groups in the same environment may endow the same objects with different meanings, and see them as legible to different degrees. Analyzing cognitive map drawings of Afro- and Anglo-Americans has shown differences in their structure between the groups. Afro-American drawings were less exact spatially (Evans, 1980; in: Ramadier and Moser, 1998), which demonstrates, among other things, that social codes are not universal.

The above approach seems worthy of attention, if only for the fact that ignoring social and/or cultural characteristics between humans and their environment leaves us in danger of creating meaningless spaces for many social groups that dwell within them, which in turn can affect the types of spatial representations they create, and thus their behavior. According to Ramadier and Moser (1998), a space’s failure to adapt to the group’s needs that live there may cause vandalism.

Considering many human behaviors without their spatial context is impoverishing and leads to false observations (Lose, 2012). Objects in themselves do not have any meaning; people grant meanings in interactions with these objects.

Looking at the problem from yet another perspective, we must note that while moving through space we reduce stimuli through the mechanism of attention. But when we are stationary, reduction is no longer possible. Therefore, places must be adapted to our natural, physiological perceptions so that we can function without disturbances (Lose, 2012). Space that allows us to group objects in it, to prioritize them, and to link them together, is itself easy to understand and memorize (Taylor and Tversky, 1992). Legibility in this approach is the degree to which the environment is diversified, as this diversity allows the observer to categorize the space, making its recognition more automatic (Kaplan, 1983; in: Ramadier and Moser,

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3 Stanisław Lose writes more on this in his book “Ku Urbanologii”.

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1998). Spatial uniformity, which rids it of any orientation points, not only makes the environment poorer aesthetically, but also makes navigation impossible, makes space harder to learn (Ramadier and Moser, 1998), and severely burdens a person’s attention.

**Summary**

Speaking about humans we must not omit the spatial context of their activities. People are in constant interaction with their surroundings. Adjustment to the environment, through physical spatial traits and through an individual’s personal traits, make it possible for people living in an area to function effectively and creatively. The influence of spatial context is also confirmed by numerous linguistic connections appearing in gestures and drawings across all cultures. All beings capable of independent movement have developed various ways to navigate space. The more advanced species represent objects cognitively. In humans these representations include cognitive space maps that personally represent allowable environments (Lewicka and Bańka, 2006).

Cognitive maps express the complexity of human perception combined with a constant urge to organize one’s environment and surroundings (Lose, 2012). These mental representations are important for creating a comprehensible and safe field to carry out complicated and diverse actions. Cognitive maps are not a homogeneous construct. They are built differently for different people, though three general types may be distinguished: linear (dominated by the position of roads), spatial (with landmarks and relations between them as a basis for the scheme), and hybrid (combining qualities of both of the above).

We must not omit the fact that cognitive maps do not contain information only about physical traits of space, but also about objects with social meanings. The latter is not culturally universal. Individual differences, including gender, education, or place of upbringing, according to the cited research results, affect the outlook and content of constructed maps.

Cognitive maps, like other cognitive representations, are subject to the laws of perception, and thus contain many mistakes and omissions, and are strongly schematic in their composition. Despite these shortcomings they are sufficient for the tasks set before them. The use of schemes limits the use of cognitive resources for navigation. Only in the case of problems or finding discrepancies with a remembered image is volitional analysis briefly employed.

Knowing the structure, their construction, and analyzing the data gathered in them, cognitive maps may be useful in many spheres of human life – architectural planning, modern navigational systems, and emergency medical services.
Knowledge about the effects of spatial conditions – a building’s shape, its material or color – on the mental comfort and adaptation of people to that space is invariably important, for example when it comes to designing schools (Bać, 2003), or hospitals that are “user friendly” (Hall, 2009).

Research and analysis of cognitive maps is important not only as it can be applied by urban planners or administrators of housing estates. It also contributes to the psychological knowledge about the ways space may be represented, allowing us a better insight into understanding human cognition.

References


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