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Polish Cartographical Review
Vol. 47, 2015, no. 4, pp. 179–190
DOI: 10.1515/pcr-2015-0017

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Map perception: theories and research in the second half of the twentieth century

Abstract. Until the 1990s map perception research was one of the main parts of cartography as a scientific discipline. In the last years of the century map perception research fell out of favor as cartographers turned their attention to the new computer technology. In the first decade of the 21th century the problems of map perception became more frequent in cartographic journals.

The article recaps the main problems, theories and research conducted in the twentieth century. The main concepts connected with map perception are discussed: use, utilization, reception and interpretation. These terms are used differently in different research orientations. The author assumes that the terms: reception, reading and perception are unambiguous and perception should be treated as a complex of active and highly interactive processes, leading to identification and understanding of the visible image. The relation of perception research with theory of cartography are presented in three stages of development of the research. In the first, intuitive stage, very important role played eminent cartographers Max Eckert and Karl Peucker, who appreciated the role of human perception in cartography. The second stage began with the research initiated by A.H. Robinson in the 1950s. In the stage perceptual research contributed to the physical aspects of cartographic signs and the psychophysical orientation emerged. Perception has been accepted as an element of cartographic communication theory, modeling theory and cartographic semiotics. The third stage of perceptual research emerged as a result of criticism of empirical research effects. Cartographers turned to methods and theories of cognitive psychology and cognitive orientation was a main paradigm of the research. Perception is perceived as one of the elements of the human cognitive system and considered in the context of higher lever cognitive processes, participating in cartographic information processing. Two methodological approaches can be set apart: theoretical and experimental. In the theoretical approach the processing succession is considered and some models of cartographic processing models were presented. The first decade of the 21st century opens a new stage of perceptual research. It can be named cognitive-digital as the research is based on computer software and is concentrated on cognitive aspects of map perception.

Keywords: percepction, map reception, cartographic research orientations

1. Map perception – concepts

The process of map reception and related activities are discussed using a variety of terms such as map use, reception, reading, perception or interpretation. The same terms are applied in reference to various actions and processes, and the same operations or processes are often addressed using different terms, depending on traditions and research orientations. L. Ratajski (1970, 1978) used the terms *reception* and *reading* to describe the deliberate act of map use and treated them as synonyms. A.H. Robinson and B.B. Petchenik (1976) distinguished between the concept of map *recipient*, *user* and *reader*, linking them to different levels of intellectual engagement in the process. The *recipient*, or map user at the lowest level of involvement, obtains information just by viewing a map, without any clear impact on his/her geographical knowledge. The *user* utilizes maps for a particular purpose, such as reading or calculations, while the *reader* examines maps in order to search for specific information and expands his/her scope of knowledge or changes pre-existing ideas about the environment depicted on the map.

In this paper, I assume that concepts of reception, reading and perception are synonymous because perception is an active process, with a high degree of interaction, where all the elements leading to identification and understanding of the image take place simultaneously.

2. Map perception in cartographic research orientations

Approaches to the phenomenon of map perception and utilization of methods and concepts developed in other scientific disciplines have been shaping for over 70 years. There are four stages in which map perception has been associated with different research orientations: intuitive, psychophysical, cognitive (knowledge acquisition) and cognitive-digital stage.

2.1. The intuitive stage

The first stage lasted well into the fifties of the last century and must be recognized as the *intuitive stage* because it was the time when map creation was guided by intuition and principles derived from practical experience – although the importance of psychological factors in cartography had already been observed and stressed in the fundamental work of M. Eckert *Die Kartenwissenschaft* (1921, 1925). Eckert believed that good maps take into account psychological mechanisms and map understanding relies on mental transformation of separate pieces of information in to one comprehensive picture. Aiming to facilitate this process by an appropriate map design was the elemental task of cartography. For the first time in cartographic history of cartography, another Austrian cartographer K. Peucker in 1898 (source: S. Pietkiewicz 1930) relied on the knowledge of physiology while investigating the effects on the human eye of basic properties of colour (valour, saturation and hue) in hypsometric color schemes and used the results to define his own colour scheme for relief representation.

2.2. The psychophysical stage

The second phase of interest in problems of map perception began after the World War II, when in connection with the development of regional atlases, and statistical maps being their important components, a need arose for the use of cartographic methods and research on the formalization of principles of cartographic presentation. One of the major issues addressed in these efforts became the possibility for objective determination of the size of graduated symbols in cartograms and the value of shading used on choropleth maps. In his innovative book, *The Look of Maps* (1952), American cartographer A.H. Robinson referred to the achievements of nineteenth-century psychology, and particularly research psychophysical E.H. Weber[1] and G.T. Fechner, as well as the work of M. Eckert. A.H. Robinson initiated a series of psychophysical experiments aiming to establish principles for the design of cartographic symbols. Studies conducted by American cartographers were based on behavioral assumptions of psychology of perception and targeted primarily the effectiveness of various symbols used on maps. Embracing these principles contributed to the development of psychophysical orientation called the *perceptual cartography* by American cartographers.

At this stage, which can be described as psychophysical, map perception was viewed response to cartographic symbols (especially their size and intensity) as stimuli invoking reactions in the form of visual sensations. These studies were based on the views of E.H. Weber and G.T. Fechner[2] assuming that reactions in the mind of recipient do not follow a simple linear function of the actual symbol intensity (brightness or size) of symbols (R.S. Woodworth, H. Schlosberg 1963). It was assumed that the relationship between the actual magnitude of the stimuli and their perceived value follows the S.S. Stevens' (1957) power law $J = k\, I^{w}$ saying that a stimulus J produces a response I that follows a power function with an exponent w, meaning that the perceived size or intensity of symbols is smaller than their actual values. Perceptions of different types of

[1] E.H. Weber (1795–1878) – German anatomist, physiologist and psychologist collaborating with G.T. Fechner.

[2] G.T. Fechner (1801–1887) – founder of psychophysics and research on psychological phenomena. Together with E.H. Weber, Fechner formulated the law stating that psychological respons of value increase is proportional to the logarithms of actual intensity values. The Weber-Fechner law provided foundation for the field of psychophysics.

stimuli (cartographic symbols) follow different exponents and the closest to the directly proportional reception is the magnitude assessment of distance and length (P.H. Lindsay, D.A. Normann 1984).

The Stevens' power law gave rise to assumptions that increasing the size of symbols in proportion to the exponent of related power functions would compensate for the underestimation of their value. Determining the exponent values for different symbols became one of the main targets of studies in perceptual cartography that were carried primarily by R.L. Williams (1956), J.J. Flannery (1956) and P.V. Crawford (1973). The results of these studies were inconsistent because they yielded different values of the coefficients (K.T. Chang1977, I. Frączek 1983)[3]. Nevertheless, coefficient of 0.5716 as determined by J.J. Flannery was then adopted for so called *psychophysical scaling* of the size of circle diagram maps.

The psychophysical research extended also to the perception of grey tones, i.e. relationships between the actual and perceived intensity of grey shading. The value estimation grey patterns was initially believed to follow the Fechner's law[4]. Research on this problem was undertaken by R.L. Williams (1956), P.V. Crawford (1973) and A.J. Kimerling (1975), who designed the gray scales with different value increments. Eventually though, R.L. Williams (1958) concluded that the curve describing visual perception of value increase is inconsistent with the Fechner's law. As in the case of scaling of the size of graduated symbols, these studies have produced different effects, depending on the experimental method and the structure of the tested areal patterns (raster density).

Psychophysical studies targeted also other methodological problems such as distinction among point symbols (P. Grohman 1975, E. Vaněček 1980, J. Bolzman 1981), selection of type sizes and faces (B. Bartz 1970), or the rules for use and perception of colour in cartography (J.S.Keates 1962, A.H. Robinson 1967, A. Makowski 1967, C.A. Brewer 1992).

The main achievement of psychophysical studies on map perception was establishing that evaluation of cartographic symbols – both the size of graduated circles as well as of grey shades – is always fraught with error and magnitude assessments are made on the basis of linear dimensions of shapes rather than their areal extent. Inconsistency in research results and discrepancies arising with the type of questions posed to experimental subjects also attracted criticism of both their basic assumptions as well as the employed methods of research.

2.2.1. Map perception in the theory of cartographic communication

The popularity of research on map perception attracted attention of cartographers occupied with the theory of cartography. The functioning in the sixties research orientations (J. Ostrowski 1984, J. Pasławski 1984) – such as the theory of cartographic communication, cartographic modeling and semiology – embraced the existing at the time knowledge about map perception. The leading proponents of the theory of cartographic communication, A.H. Robinson and B.B. Petchenik (1976) and L. Ratajski (1978), incorporated it into the cartographic models of communication, while J.L. Morrison (1981) highlighted the close relationship between the processes of map perception and map design, adding the reinforcing feedback that occurs between these two processes.

In the scope of cartographic communication, map perception was regarded as a step in the process of information transfer, and therefore a process of reading understood as the relationship between stimulus and response. It was assumed that information acquired during map processing was retained in the "memory storage" and the encoding that occurs in the course of map reading is a subject to quantitative changes, described by L. Ratajski (1977) as gains and losses. Although associations with the obtained in that process knowledge were noted, they were not subjected to deeper analysis in the communication approach.

A. Moles (1971), Ch. Board (1978) and L. Ratajski (1978) distinguished two levels in the process of map reading: the *map perception*, i.e. the process of visual acquisition, decoding, verbalization as well as the *map interpretation* that through processes of visualization, measurements, analysis and verification leads to

[3] I. Frączek's work includes a detailed discussion of research on the magnitude perception of cartographic symbols.

[4] Since Stevens' and Fechner's laws are equivalent, they are often combined under the label of Stevens-Fechner's law.

the formation in the recipient's mind of ideas about the reality depicted on the map. These ideas correspond to the concepts of mental maps or maps "in the mind" functioning in behavioral geography. W. Grygorenko (1982) placed mental maps at the center of processes of cartographic communication as a separate entity interactively linked to the structures of memory, knowledge and experience – and with effects of evaluation and human behavior. However, he did not specify the structure of that entity and did not explain the nature of those interactive linkages.

2.2.2. Map perception in semiological and modeling theory approaches

Another approach to map perception was associated with semiological orientation. Based on the linguistic analogy, map perception was treated as a process similar to the reading of written text and map was viewed as a system of signs or codes. This approach was initiated by J. Bertin (1967), the creator of *semiology of graphics*, the concept based on the properties of perceptual processes. The language analogy aroused a number of objections deriving from the obvious differences between natural languages and maps (A.H. Robinson, B.B. Petchenik 1976). Map perception is a contemporaneous in nature while text reading is a sequential activity – moreover, the map language has no clearly defined units of language, and the syntactic relationship also differ from natural languages. Proponents of linguistic analogy, L. Ratajski (1971, 1976, 1978) and A.A. Lutyj (1984), devoted much attention to the issue of units and the syntactic relationship in the language of maps but they didn't link them with perceptual processes.

In turn, K.A. Salistchev (1975), who combined the concept of cartographic method of research with the theory of modeling, proposed the epistemological approach. He believed that the map is a model of reality, and therefore can be studied as a substitute for the actual object of study, i.e. the geographic space. From this it follows that real phenomena are the starting point of the process of map perception. Transfer of information from the model to the modeled object is made possible owing to the similarity between certain characteristics of the map structure as a model and the modeled real phenomena. Therefore, K.A. Saliszczew regarded map perception as the elements of cartographic methods of cognition, without tying them to cognitive psychology and cognitive research.

An important contribution to our understanding of the cognitive aspects of maps use made A. Czerny (1994), who identified basic cognitive procedures related to various stages of map perception in the system approach to cartographic modeling. At the first stage, reading or measurements provide primary information that after processing and interpretation yield derivative information used for the research purposes and enriching knowledge of the map user. A. Czerny believes that this process follows the "bottom-up" path and in the process of map reading, elemental relations are cognized first, followed by the regional and more general relationships. However, he invokes no theories of cognitive psychology[5] whatsoever that explain the flow od perception processes. The second stage involves using conversion of the primary information into derivative information through the methods of morphometric statistics and mathematical analysis. The third stage is interpretation, or reasoning that involving the transition from premises to conclusions.

2.2.3. Criticism of psychophysical orientation

The psychophysical research did not meet the expectations of providing the opportunity to explain the principles and nature of map perception becoming the subject of multifaceted criticism. Behavioral basis of psychological research and their subjectivist philosophical fundaments have been criticized by the founder of epistemological orientation K. A. Saliszczew (1982). But despite appreciating the importance of research on the psychological aspects of cognition, neither he nor his successors – A.F. Aslanikašvili (1967) and A.A. Lutyj (1984) – did carry any empirical research, or had proposed other methods of research.

A.H. Robinson and B.B. Petchenik (1976) performed the most thorough analysis of the theory of communication and the results of psychophysical research. In their view, the

[5] Sub-discipline of psychology that studies the cognitive processes and structures, as well as the general principles of functioning of the mind.

human cognitive system was not properly investigated within the framework of communicative approach as it failed to adequately take into account the importance of map perception and other cognitive factors affecting the map reception. They proposed to begin research into the cognitive and perceptual aspects of the activities of customers, users and map designers, and put forward the proposal for changing the research paradigm. Underestimating the role of map user's was identified as the fundamental reason for the limitations encountered when using psychophysical research to explore the process of cartographic communication. B.B. Petchenik (1983) criticized the use of isolated symbols, disregarding the map context, while according to B.G. Shortridge and R.B. Welch (1980), the influence of procedural instructions on the experimental results was also not taken into account.

In the first work devoted entirely to the issues of perception and map understanding, J.S. Keates (1982) drew attention to the ambiguity of such terms used in communication as "map maker" and "map user", as well as the differences in the reception maps in various tasks. For the first time in the cartographic literature he characterized the human visual system as well as the process of visual perception and its effects in the context of map reading and understanding its contents. Like Ch. Board and L. Ratajski, J.S. Keates also distinguished between two stages of reading that lead to map understanding. The first one, *visual perception*, includes perception, discernment, identification and recognition of symbols. The next stage, *interpretation*, serves the goal of performing specific tasks. When describing the process of map interpretation, J.S. Keates accepted, however, the popular then in psychology model of memory storage that did not take into account all aspects of the information processing at various levels of brain structures.

Critics of the theory of cartographic communication pointed also to other causes of failures in psychological research. According B.B. Petchenik (1977), the process develop a process of map design has is synthetic in nature that differs from the naturally analytical processes of map processing. Therefore, the conceptual apparatus used in the process of mapping the conceptual apparatus is fundamentally different from the mental strategies used during the reap use. This difference is a root cause of incorrect assumptions about the usefulness of research on the use of maps and, therefore, disappointing effect of psychophysical tests. J.M. Olson (1975, 1976, 1979) and J.R. Eastman (1985ab) also shared these views.

2.3. The cognitive stage

Criticism of research on map perception and its role in cartographic communication gave rise to the emergence of new approach referred to as the cognitive orientation (knowledge acquisition and processing) associated with the third stage of perceptual research. The late eighties witnessed the merging of research on map perception with the methods of cognitive psychology and cognitive science. The new orientation was based on the paradigm of information processing and in many respects accepted assumptions of epistemological orientation, and particularly the cognitive function of maps and map functioning as a model. Cognitive orientation was resting on assumptions consistent with views accepted in cognitive psychology (M. Materska, T. Tyszka 1997):

1) The perceptual experience is not just a consequence of reactions to stimulus – it is also an effect of a series of operations occurring simultaneously at different level of information processing;

2) Processing is limited by the capacity of channel transmitting information as well as the experience and abilities of the recipient;

3) The perception process is active in nature because the recording and storage of information occurs at all processing stages and therefore, studying the process has to take into account also the processes of attention and memory.

Subsequently, cognitive orientation treats map perception as part of the human cognitive system associated with acquisition of map content and considers it not just in terms of reaction to stimuli, but also in the context of higher order cognitive processes that take part in cartographic information processing and solving of various tasks that lead to the creation of spatial representation and spatial knowledge. In this orientation, M.W. Dobson (1985) distinguished two methodological approaches that

differ in the nature of research hypotheses: theoretical and experimental.

2.3.1. Theoretical approaches

In this approach, research into the mechanisms of cognitive processing of information, strategies, and cognitive phenomena of attention and memory, is based on theoretical assumptions defined as a theory of cognitive information processing as well as models of memory and knowledge as defined by psychologists (P. Thorndyke and B. Hayes-Roth 1982, T.P. McNamara 1986, B. Tversky 1992, A. Nowak 1991).

According to M. Blades and Ch. Spencer (1986), building a good theory of cognitive cartography by cartographers in close cooperation with psychologists is a prerequisite for the conducting experiments probing the mechanisms of cartographic information processing. On the one hand, cartographers use theories proposed by psychologists, on the other hand psychologists penetrate into specific aspects of cartographic information processing. A manifestation of interest in those aspects are outstanding researchers in experimental and cognitive psychology, who have had an impact on research and views in cognitive orientation (P.P. Gilmartin 1984).

Considering the means of spatial knowledge acquisition, T.P. McNamara and P. Timothy (1986) distinguished between two basic groups of theories of mentally representing spatial relations: *non-hierarchical theories* based on the assumption that representations are based on networks and *hierarchical theories* alleging that spatial knowledge is organized at different hierarchical levels in accordance to the level of regions or units constituting elements of that knowledge. For example, exploring the mechanism of memorizing and reproducing spatial information, M.P. Peterson (1987) relied on the so-called Selfridge's Pandemonium[6] utilizing the state of Texas in the USA.

Two contradictory assumptions function in cognitive psychology with respect to the process of perception that differ in terms of the order and function of the basic stages. Theories of the first group assume that in the initial stages of visual perception, information processing is boils down to splitting image information into elementary visual impressions that are put back together in the second stage of perception. The second group of theories rests on assumptions of the Gestalt theory of form (shape) asserting that perception of the whole picture in the primary stage of perception precedes the second stage of perceiving its individual components and does not constitute a sum of perceived parts. Therefore, the whole form of the image and what creates the "shape" the result of interaction between the figure and its background has an crucial impact on the image interpretation. J. Bertin (1967) agreed with this view while recommending that the map information should be conveyed "in one glance".

Many psychologists accept the assumption of hierarchical memory structure, including A. Stevens and P. Coupe (1978), T.P. McNamara (1986) and B. Tversky (1981, 1992). D. Navon (1977) found that spatial representations resulting from map perception have a hierarchical structure, while the analysis of local characteristics precedes the perception of general character of the image structure. S.E. Palmer (1977) also found that in the process of creating of sensory representation, information is encoded in the structure of hierarchical networks. Certain subsets of the image are encoded as integral, structural units of the image called by S.E. Palmer "bites" (chunks).

Palmer's hypothesis has been confirmed experimentally by R. Eastman (1985b), who observed that subjects learning map content tend to divide the map image into fragments. He drew attention to the fundamental role of the map's graphic organization played in the process of perceptual grouping of its elements and showed the vital part that regionalization and hierarchy of regions plays in assimilating information about location. Among the factors facilitating the grouping of spatial information he named the position of objects' names, objects' proximity, the internal cohesion of group, linear connecting objects with lines and consistency of categories.

According to A. Stevens and P. Coupe (1978), the hierarchical structure of spatial representation causes systematic distortions of spatial

[6] One of the methods for analysis of imaging features proposed by O. Selfridge. The system consists of the successive levels of the Selfridge's Pandemonium that record the characteristics of image, moving from the general characteristics to specific ones (P.H. Lindsay, D.A. Norman 1984).

relationships because the assessment of directions among geographic objects lying in lower-level units is subordinate to the overriding relationships between higher-level units. R. Lloyd (1989) confirmed the validity of these hypotheses in research on mental maps distortions.

The problem of distortion maps of actual and mental maps caused by the operation of certain mental processes examined also B. Tversky (1981, 1992). She found that they have systematic nature and arise as result of arrangements of objects along lines and their rotation. In her view, these procedures include the mechanisms of simplification and schematization that distort memorized systems in the direction of a certain "ideal". These hypotheses were confirmed by R. Lloyd (1989). W. Żyszkowska (1996) also found a tendency to set the objects on mental map in a line. The notion of systematic distortion confirmed P.W. Thorndyke and B. Hayes-Roth (1982), T.P. McNamara (1986, 1992) and R. Lloyd (1989), who demonstrated differences in spatial knowledge acquired from maps and direct navigation in the terrain.

Experimental studies of remembering and recall of map content took also into account various factors that may affect these processes. P.P. Gilmartin and J.C. Patton (1984) analyzed the impact of gender and P.P. Gilmartin (1986) examined also the effects of age and education. The study by W. Żyszkowska (1999) also showed some differences between men and women in the ability to identify and memorize the spatial information.

2.3.2. Models of cartographic information processing

Laying down the development directions of cognitive orientation, M. Blades & C. Spencer (1986) pointed out that its theoretical basis requires the formulation and testing of hypotheses pertaining to the course, strategies, and phenomena of cognitive activities. Explaining any of the aspect of map perception – in both low-level tasks (e.g. seeing symbols) and upper (memorizing) level of processing is not possible without relating them to the entire information processing system. Theories of cognitive psychology pertaining to the processing of visual information in perceptual processes agreeably assume that visual perception is not a uniform process and one can distinguish in its course two stages: general and specific. Two groups of opposing theories assume conflicting assumptions about the order and function of both stages. Some are based on the "top--down" scheme, while other stick with "down--up" direction (K. Najder 1997).

Formulating the theory of cartographic information processing requires taking one of these sides or another. Due to the fact that these theories describe the structure of the process, they commonly assume the shape of models. According to M. Blades and C. Spencer (1986), these models can be used as foundation for formulating the theory of cognitive mapping. J.R. Eastman (1985) distinguished among them two types: *system models* that define the functional components of the system and *perceptual-cognitive processing models* that describe the sequence of processes running during cognitive acts. The first models of this type were developed by J.R. Eastman and H.W. Castner (1983), J.R. Eastman (1985), M.W. Dobson (1979a, b, 1985) and C.G. Head (1984).

The models proposed by J.R. Eastman and H.W. Castner (1983) and J.R. Eastman (1985) make a reference to the hypotheses of hierarchical structure representation developed by Navona D. (1977) S.E. Palmer (1977) and A.Stevens, P. Coupe (1978). Map content is processed through the grouping of map components, while the map's visual-spatial characteristics i.e. its graphic organization, has a significant effect on the way in which these elements are grouped. The Eastman's model of cartographic information processing consists of five components (mechanisms): recorder, perception, central processor, long-term memory and the organizer of the answers.

M.W. Dobson (1977, 1979a, b) proposed the model of visual scanning showing the contribution of attention as well as focal and peripheral vision. Assuming that the processing of visual information is controlled by thoughts based on individual semantic experience (CGS – cognitively guided search), he linked perceptual and cognitive aspects together. In the case of absent experience, information processing is controlled by the nature of data. H.W. Castner and J.R. Eastman (1984, 1985) conducted similar studies using the same method to determine the relationship between map perception and map complexity.

C.G. Head (1984) developed his model of information processing basing it on the analogical

model of natural language. Taking into account the differences existing between the processes of reading a map and reading a printed text, C.G. Head put forth a hypothesis that map reading follows a scheme similar to the reading of printed text is carried out according to the scheme similar to the processes of reading printed text, except that in the case of maps arrangements of symbols function as sentences arrangements.

2.3.3. Experimental approaches

Experimental studies in cognitive orientation are largely a continuation of the psychophysical testing, while rejecting their behavioral assumptions. The change in assumptions helped to explain the reasons for the difficulty in finding an exponent of power function in estimating the size of graduated circle diagrams. And so, C.W. Cox (1973) based on the adaptation-level theory established that each symbol is perceived in the context of the resultants of the surrounding signs. This means that magnitude evaluation of each symbol determines not only the Stevens' law but also the mechanism of adapting to the provided key. The phenomenon of underestimate the size of small symbols and overestimating the size of large symbols C.W. Cox (1976) explained as the "anchor effect" with legend keys that determine the level of adaptation. The phenomenon of adaptation makes the assessment size of diagrams dependent largely on the size of key symbols in the legend, and the extent of evaluation errors can be reduced by placing several differently size key symbols in the legend (I. Frączek 1983), rather than by size exaggeration of map symbols. M.W. Dobson (1985) believes that research should be based on the so-called "prediction" i.e. assumptions about the basis and the expected results of experiments.

Deeper insight into the process of map perception provided research on eye movements and eye fixation systems, called often the visual search[7], that deal with recording eye movements and their duration in particular areas or sections of the map. Eye movement is a physiological phenomenon, but to certain extent reflects the processing of visual information. Location, frequency and duration of fixation points and the formula, how to create a map of eye movements reflect the arrangement of the reader's attention focused upon the individual elements or parts of the map. Such system can be viewed as a space-time map reading pattern.

G.F. Jenks (1973), H.W. Castner and D.W. Lywood (1978) and H.W. Castner and J.R. Eastman (1984, 1985) found that visual scanning is indeed an individualistic process but depends also on the type of tasks used to engage subjects' attention. A.A. De Lucia (1976) demonstrated the dependence of fixations on the graphic characteristics of map and the type of tasks employed, while H.W. Castner and D.W. Lywood (1978), and H.A. Sanford (1980) observed that the strength of attention depends also on the type of contexts in which the map is used, and distinguished between task-less situations versus those involving task performance. M.W. Dobson (1979) and H.W. Castner (1979) also demonstrated that peripheral vision plays important role in the distribution of fixation points. The course of maps perception, including the visual screening process, it is also highly conditional on the degree of map complexity on both the graphic and intellectual level. This issue was also the subject of analysis and research in the context of map perception (A.M. MacEachren 1982, W. Żyszkowska 1993).

The emergence of computer technology in the nineties of the last century for some time diverted attention of cartographers from the themes of map perception. Fascination with new possibilities on the one hand, and doubts about the usability of perceptual research results in cartographic practice on the other made the subject almost disappear from cartographic publications. Nevertheless, a very important work by A.M. MacEachren (1995) was published in the mid-nineties, summarizing all the achievements in experimental and cognitive cartography, and in which the author has entered the discussion of how maps are 'seen' and how they are 'understood'.

2.4. The cognitive-digital stage

In recent years, the problems of map perception again evoke more and more interest,

[7] It was determined in the Polish psychological literature as the so-called "eye movement", but recently the term "eye-tracking" is used. These methods are used in a variety of areas, including medicine, marketing and advertising.

especially in the context of the effectiveness of various types of computer maps, presentations, three-dimensional, animated maps and navigation systems. A new wave of research on the functioning of human brain in the process of map use rests on the concept of cartographic visualization (A.M. MacEachren 1995) and is intended to explain the effectiveness of various types of geovisualisation as communication tools.

In connection to the research on information storage and processing as conducted in the nineties, problems associated with eye movements and attention phenomena are again subject to analysis. What is new is the application of rarely employed in cartography research methods such as protocol analysis, exploration of decision-making processes, assessment of data quality and confidence in maps.

Currently, we are thus dealing with the fourth stage of research on map perception, which for lack of a more appropriate term can be described as cognitive-digital and similarly a new cognitive--digital research orientation. After all these new research developments pertains primarily to computer maps, while the latest numerical methods and new hardware allow us to focus on the processing of information, memories and images.

These new trends refocus interest from the lower-level tasks associated with visual perception, to the higher-level tasks associated with knowledge creation and spatial decision making with the use of maps. An important improvement is that computer technology makes it possible to carry out this kind of experiments but also to record users' reactions. The newest studies thus make it possible get insight into previously inaccessible ways in which map users "read" the map and into the factors that influence the process. Oculography (eye-tracking) seems to enjoy particular interest although T. Opach (2011) is no doubt right asserting that although thanks to oculography we can now identify the parts of maps that attract the eyes of map user but factors influencing the processes of looking at the maps still await exploration.

The popularity of research of this new stage needs a separate discussion, so I will return to these issues in subsequent articles.

3. Conclusions

The intuitive mapping decisions and design principles based on practical experiences of the map makers dominated cartography until the fifties of the last century. The new approach, to which the greatest contribution made undoubtedly an American cartographer A.H. Robinson, relied on the introduction to cartography discussions of the methods of cartographic presentation and the ways in which the map recipient reacts to its picture. A.H. Robinson (1952) not only initiated a whole series of experimental studies but with his colleagues and students modified the research approach, guided is on the new tracks (A.H. Robinson, B.B. Petchenik 1976). D.R. Montello (2002), who in the article on the cognitive aspects of map creation, discusses both the development of research on map perception from the beginning of the nineties of the last century believed that the study of map perception was at that time the most important problems facing cartography as a science.

The perception of maps has been long recognized as an important component and factor in both the theory of cartographic communication and cartographic modeling. Studies in map perception adopted methods and approaches used in modern psychology, initially linking its research with the experimental psychology and then with cognitive psychology. This gave rise to the emergence of two research directions in our discipline: experimental cartography and cognitive mapping. The most important role in first orientation played research by J.J. Flannery (1971), G.F. Jenks (1973) and B.B. Petchenik (1977).The second orientation included M.W. Dobson (1977, 1979a, b) J.R. Eastman and H.W. Castner (1983), J.R. Eastman (1985a, b), J.M. Olson (1975, 1976, 1979), J.S. Keats (1982) and A.M. MacEachren (1995). Although it is hard to conclude that research conducted in these fields have produced results of practical application, they have still highlighted the importance of map perception in cartographic communication and visualization, as well as provided methodological basis for further research.

Issues related to the efficiency of solving various problems with the use (perception, reading) of maps have become particularly important in the twenty-first century, as the result

of increased popularization of map and their increased availability of the Internet as well as the emergence of new forms of maps and methodological solutions. Numerous publications of articles and papers at conferences mapping that report results of recent studies indicate the formation of a new, fourth stage of research on map perception maps that can labeled the cognitive-digital stage.

With new tools at the disposal, and at the same time taking advantage of the rich legacy of research in cognitive mapping within the scope of relations between the map and its recipient, modern cartography can deepen knowledge about the processes involved in map perception. These topics become again one of the important subjects of research in our discipline.

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