Summary

Cartography, as a scientific and practical domain, has been undergoing intensive changes for several decades because of dynamic technological developments. Due to new means of expression and available solutions, opportunities have been created but problems and challenges have also arisen. An example of a solution that has resulted from technological developments is and a new approach to working with spatial information is coordinated and multiple views (CMV) tool. This consist of several views, presented simultaneously and connected interactively. Each view presents (spatial) data in a different way, and this includes maps, graphs, diagrams and spreadsheets. Such tools are considered by some authors to be one of the most promising geovisual solutions, although there are also opinions on their low usefulness.

CMV represents a huge potential for the effective exploration of large and complex data sets, but like any new tool, it needs to be appropriately assessed. Among other things, its critics have pointed to the problem of its limited use, so understanding how new users learn to use this type of tool, and how they can be helped, seems to be of high importance for its popularization.

This study aims to relate the investigation of CMV with cartographic semiotics, for which important design issues include: selecting input data; explaining the meaning of signs in the legend – which is particularly relevant to semantics; and getting users to understand the presented data via CMV – the subject of pragmatics. The *cognitive aim* of this research is to assess the usefulness of redundancy (presenting the same input data in various views) in CMV. The *methodological aim* of the study is to develop the methodology of eye tracking data analysis in the empirical study of CMV tools; in particular, to identify new areas of application of the eye tracking method, thus expanding its potential. The *practical aim* is to investigate the process of inexperienced users learning

an unknown CMV tool. On this basis, guidelines have been formulated for designers of this type of tool, and its training and tutorial materials.

To achieve the goals, theoretical considerations in the field of cartography and related disciplines were taken into account; then empirical research was conducted. This allowed for the formulation of conclusions of both a practical and theoretical nature. As the context of cartographic semiotics was considered, general conclusions were formulated, allowing for dimensions to be distinguished to help design CMV tool interfaces. The set of methods of data collection applied – eye tracking, interaction logs, thinking aloud, and response accuracy – allowed for the collection of diverse data and an analysis of the process of working with CMV geovisualization tools from many angles and, therefore, for the formulation of conclusions.

Consequently, the effects and goals achieved include not only organizing the existing knowledge, but – thanks to its theoretical basis – formulating new synthetic approaches. The result of the work is a model of learning a CMV tool, which is the basis of an extended approach to legends in such tools. Apart from traditionally understood symbols, the legend of a CMV tool can cover interactive elements of the layout. Another result of the study that was achieved through conducting empirical research, among other things, is the proposal of a new approach to the analysis of data obtained using the eye tracking method. In the applied approach, two dimensions of applied analysis are distinguished: including interactivity (or not); and applying temporal information with regard to eye tracking data. Moreover, the conducted empirical studies allow for the assessment of the usefulness of a CMV tool for inexperienced users and the formulation of recommendations for designers of this type of tool. Such empirically proven clues are valuable because during their design work, the authors of CMV geovisualizations can choose from many solutions that only seemingly can be of similar utility.

The work consists of eight chapters. In the opening chapter, I outline the current place of cartography in the context of several related scientific disciplines. I also emphasize the role of semiotics in cartography; in particular, I draw attention to the possibility of using cartographic semiotics in the design and analysis of CMV geovisualization research. In the next chapter, I introduce the concept of CMV geovisualizations, and point to problems related to their design. In chapter three, I deal with the need for usability research in cartography and geovisualization, with particular emphasis on those that apply the eye tracking method. Another three chapters contain a description and analysis of the empirical research I conducted, and aim to verify theoretical considerations and

answer the research questions posed. At their center, I put the process of learning an unknown CMV and the usefulness of redundancy in such tools. In the course of the conducted analyses, emphasis has been put on cartographic semantics. Due to the research being conducted with users of CMV, the pragmatic aspect of these analyses is of particular importance. In turn, in chapter seven, I presented conclusions formulated in a new context based on the obtained results and analyses. This made it possible to formulate an extended approach to the legend of the CMV geovisualizations and to propose a model of learning this kind of tools. The work ends with a summary in which I assess the importance of cartography as a discipline in the study of CMV geovisualization tools, and point to the need for further research.

Keywords: coordinated and multiple views; CMV; cartographic semiotic; user study; eye tracking; cartography; geovisualization

Słowa kluczowe: geowizualizacje wieloelementowe; semiotyka kartograficzna; badania użyteczności; *eye tracking*; kartografia; geowizualizacja