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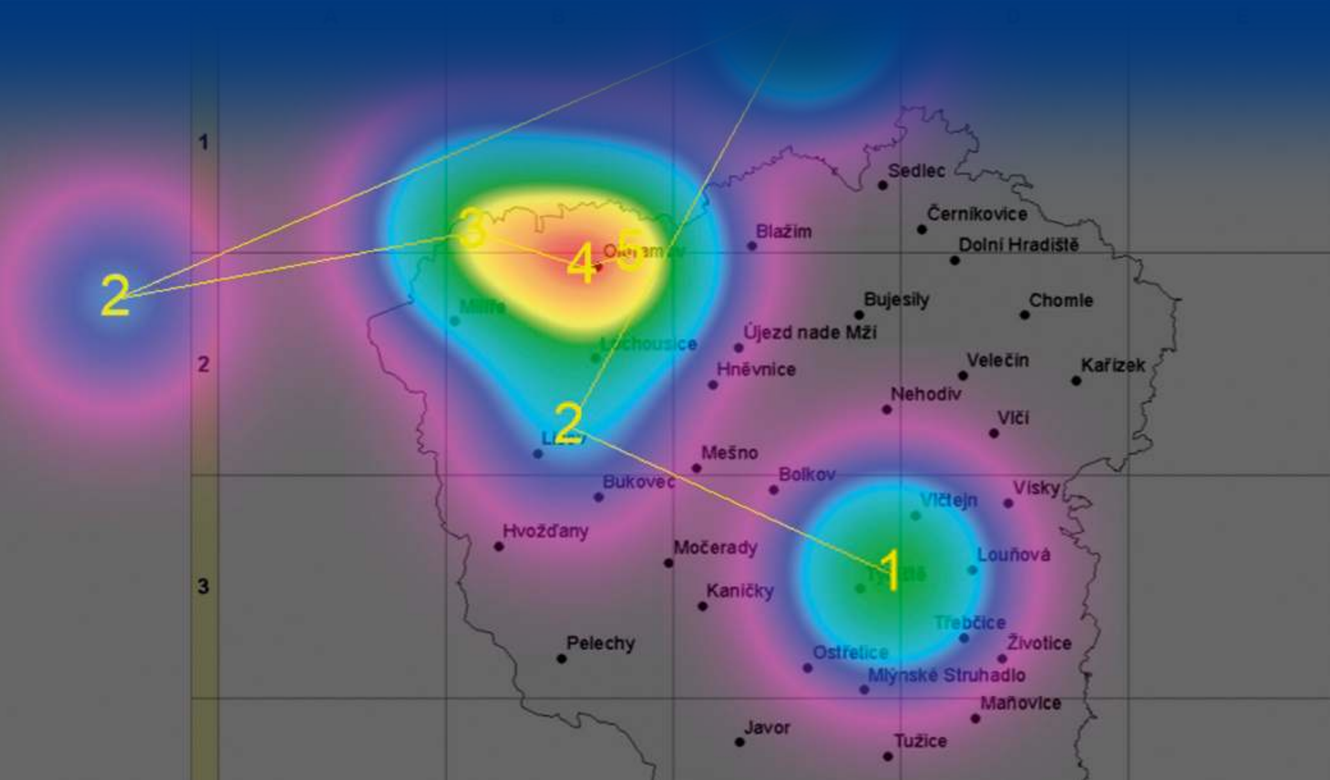

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Preface

In recent years, cartographic research has placed increasing emphasis on the study and evaluation of the process of communication of information between the map (or visualization in general) and the user. Increasingly, even cartographers themselves deeply ponder the practical usability of their products, the target group of users, and possibly the methods by which these aspects can be monitored and evaluated. This interest in the professional cartographic community has been largely emphasized thanks to numerous activities of the International Cartographic Association (ICA), which considers aspects of user research in cartography as one of its action goals. All of the activities related to the implementation of this objective are then successfully coordinated, mainly into two commissions of ICA, through the Commission on Cognitive Visualization and the Commission on Use and User Issues. Both commissions create an effective platform in the field of theoretical and applied research activities and outputs of these two committees can therefore, in any case, be recommended for those interested in further knowledge in this area.

One of the specific aspects of user studies in cartography is its interdisciplinary nature, which uses a large number of methods and techniques known, for example, from psychology, and the relatively young field of cognitive psychology. This book lucidly summarizes selected topics related to experimental testing of cartographic visualizations. In addition to selected methodological aspects of experimental research in cartography, it outlines possibilities of using knowledge and research practices in cognitive psychology, which can help in interpreting the evaluation of some aspects of cartographic products' usability. It should be noted that the reader will not find all mentioned specifics of this issue here, nevertheless, in most cases, the book will offer a signpost to other relevant literature and other applicable resources. This book lucidly summarizes some of the activities in which the authors have been focusing on in recent years within various research projects. In this connection, it is important to mention the written and defended dissertations dealing with interdisciplinary cooperation in the evaluation of cartographic products. Selected outputs of these (namely the work in the field of cartography and geoinformatics "Objectification and optimization of the evaluation of cartographic symbology for maps in crisis management," the author: Zbyněk Štěrba, 2012, and the work in psychology "Interindividual differences in perception of space and maps," the author: Čeněk Šašinka, 2013) together with outputs of related research projects undertaken at the Department of Geography and the Center for Experimental Psychology and Cognitive Sciences at the Masaryk University in Brno, are described in detail and summarized below. Due to its linguistic processing (unlike some previously elaborated Czech outputs), this publication is available to a wider professional audience.

The first part of this publication deals with theoretical aspects of the evaluation of cartographic products. Existing evaluation approaches of cartographic products are described, from strictly subjective evaluation methods to objective methods focusing on the very applicability of the cartographic visualizations. The obvious emphasis is put on psychological aspects, which can have a significant effect on the communication of information between the map and the user. From this point of view, there has been a detailed discussion of the phenomenon of cognitive style, which brings the possibility of studying individual differences among users of cartographic products. Options for testing cognitive styles among users, and of course, also, in connection with the activities associated with work on the map, are then presented in this sense. The second part of this publication is focused on the practical use of newly developed interactive testing software Hypothesis, which has been used in experimental research in cartography. Simple examples present the functionality of this tool, which enables the implementation of objective and subjective evaluation methods and testing the user's performance on the map, according to the requirements of the specific research project.

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1. Introduction

1.1. Overview

An integral part of the creation of cartographic products should always be a sequence of several steps, from specifying the purpose, through the collection and evaluation of data to the actual visualization (Voženílek, 2005). All cartographic works are necessary not only to create, but also, critically evaluate to see to what extent they meet the purpose and requirements imposed by users. Nevertheless, before any similar evaluation, it is generally necessary to know exactly what to evaluate and what properties (which should always be to some extent reflecting the user's requirements) should the evaluated object have (a cartographic product, in our case). An important factor will be the overall methodical approach to evaluation and importance, which is attributed to each of the criteria, which will be taken into consideration during evaluation. Equally, it is necessary to consider the user, too, since the use value of the map might be in fact deduced only by examining its relationship to the user. To that effect, it is important to realize a possibility of examining the cartographic product with regard to inter-individual differences in its perception by different users on the basis of various relevant parameters, such as age, expertise or cultural environment, in which the individual is, or grew up.

Study and detail evaluation of interaction processes between the user and the map also necessarily require close monitoring of cognitive processes, which occur when observing information on the map. For this reason, it is important to view the whole issue of experimental testing in cartography also from the point of view of psychology, which has generally extensive and long term experience with research methods focusing on the given issue. Examining the way that users work with the map, within the interdisciplinary cooperation of psychologists and cartographers, we will always deal with two levels of description.

- On the cartographic level, we focus on the user's map skills and types of resolved tasks on maps.
- Psychological analysis should be aimed deeper and detect mechanisms and cognitive processes, which are evoked during these operations. It is necessary to find corresponding terms from psychology theory, and vice versa, in order to be able to describe a specific situation when working with the map on the cartographic level. The prerequisite for reaching a certain level of cartographic skills is an adequate (minimal) level of cognitive functions and the individual's knowledge, as well. Solving a specific task on the map also evokes various cognitive processes. The quality or organization of partial cognitive processes thus defines the effectiveness, which the cartographic

tasks will be performed with. The aim of this publication is to present existing procedures of examining and evaluating cartographic products with methods of experimental testing, with using knowledge of cognitive science, which might, in some cases, offer a suitable methodological frame of examining and resulting interpretations.

The mentioned principles will be also demonstrated on the examples of existing batteries of tests, which were administered with the special interactive software called Hypothesis.

1.2. The basics of examining of cartographic products

A map is an objectified human idea of the space and phenomena in it (see Mark, 2003). We are not capable of experiencing the world as such directly; we are not even capable of understanding the world as a whole. We can only make assumptions about how the world and things in it look like and relate to each other. These assumptions might be, in case of the space, externalized through maps. From this point of view, maps are thus image representation of our inner mental representation of the space or spatial phenomena. Importantly, a map also functions as a means of communication. A person with fair knowledge of a certain phenomenon tries to communicate this information through the map, so that the recipient could interpret the given information in accord with the sender's intention (see, for example, a model of cartographic communication in Koláčný, 1977), in order to minimize communication noise. Cartographers use various means of cartographic expressions to describe data designated for communication. The same phenomenon, the same data might be communicated a different way, and it is our intention to monitor how the chosen form will influence understanding and interpretation of the communicated information.

The method of visualization is not the only factor influencing the effectiveness of communication. Another important intervening variable, which affects the way we work with the map and the resulting effect, is the context of the situation. Understanding the map and interpretation of the phenomena expressed in it might be especially influenced by the context of the situation, in which the user works with the given cartographic product. Thus, in such cases, cartographers reflect the purpose of using the map and try to adjust its contents and form to the given context of usage. Users might have different requirements for the cartographic work, whether it should be used to resolve emergency situations, or, for example, whether it should serve to historians for various analysis of already realized events.

Similarly, an important aspect is certainly the medium itself, which is a bearer of the cartographic work, i.e., whether it is an analogue or traditional map in particular, and what level of interaction is offered to the user. Digital products relate to a possibility of technological processing of the user interface, which is one of the most important aspects determining overall use of all geo-information tools (in fact, it is a major influence on the user's quality of decision-making processes). Optimization of technological processing is certainly an important moment in the creation of usable cartographic products and this issue should not be overlooked in any case. However, this publication also rather observes possibilities of optimization of cartographic processing itself, and its evaluation.

Finally, when creating a map, it is necessary to take the end user's qualities into consideration, as we need to suitably adjust used cartographic methods and overall form of the final visualization according to them. End users, or recipients of information, as mentioned above, might have different experience in working with maps, varying education or personal predispositions (e.g., Slocum et al., 2001). Therefore, we deal with an interaction of two variables. On one hand, there are the contents of the message, which may have various forms, but on the other hand, there is a group of end users, who naturally vary in many aspects. One of the steady psychological concepts, which observes inter-individual differences, is a cognitive style. The cognitive style is both a construct following typical differences in individual people's perception, cognition and thinking, and a relational theoretical frame, which our work is based on as well, and will be discussed further in the text.

Work with cartographic works is not possible to reduce only to moments when the individual can already understand and interpret graphically coded information on the map. In order to understand a person's ability to read, understand and work with maps, it is necessary to understand the issue in the broadest perspective possible. The way in which people perceive time and space and are able to have a sense of it, is certainly included in this area of examining, as well. Another fundamental area of the research is a unique ability of humans as a kind to operate on the symbolic level. Maps also reflect this human ability in historical perspective and the map can be generally defined as a symbolic representation of time-spatial relations. The user's intention is always shown when using a map. Except for a situation, when the map is treated as a work of art, then the map is not used, but perceived aesthetically (see Bláha, 2011). However, the map is mostly used for a certain purpose and functions as a tool to reach set targets. Maps and cartographic works are also used under various circumstances, which influence the way the map is handled. At a certain point, the map can be a key source of information, which is available to us and our survival might depend on our ability to use it properly. In other cases, the map is one of the sources of clues and our decision is based on the combination of alternative information sources, which are available at the moment.

As wide as the range of areas defining and explaining our work with the map is, so is the field of research topics, which we can deal with. In the psychological perspective of examining, it is possible to stay on the micro-level, focusing on elementary cognitive processes and functions, which are involved when perceiving maps or their parts. In this case, we can, for example, monitor qualities of cartographic (generally graphic, too) processing of point or linear map symbols and their readability and mutual differentiability on various underlays (see Knapp, 1988). A typical method of this level is an experiment, or reactometry, when test subjects determine the presence of the reference symbol or try to locate it on the exposed map. On the rather complex level, we can also deal with associativity (intuitiveness) of symbols and differences in the interpretation of maps, or expressed spatial distributions of the reference symbol there, which are caused by various methods of cartographic visualization (Stachoň et al., 2010).

On an abstract meso-level of scientific examination, we can sequentially monitor the user's use of the map when following instructions by their nature corresponding with tasks, usually completed by the user in the real conditions. In this case, it is a sequence of above mentioned operations, which represent real activities when working with a map product. In laboratory conditions, we can therefore simulate a possible solution to crisis situations to monitor the procedure when planning optimal supply and escape routes, or marking danger areas (e.g., flood-prone areas, etc.); similar examples are claimed by Štěrba et al., 2015 or Konečný et al., 2011). This level can also include examining working with the map in natural conditions with the use of field experiments, where individual participants are not taken out of their environment and ecological validity is thus much higher. Such experiments might involve, for example, monitoring the way the orienteering runner works with the map directly in the terrain (see Seiler, 1996), the way the user works with interactive web maps (Skarlatidou & Haklay, 2006), or again examples of crisis management simulating the dispatch of responders during fictive model situations (e.g. Kubíček et al., 2009). Research on the meso-level might differ from the micro-level in terms of the range of ecological validity, for example, or complexity of solved tasks, nevertheless, still have one common element. We focus on activities on the individual's level and monitor his/her behavior when using one cartographic product or their system.

On the macro-level, however, we leave the level of the individual and his/her immediate context and also focus on the level of social interactions, using all of the information sources and equipment available, and also examine the nature of institutions, where monitored actions take place. At this point, the map or geographical information system (GIS) becomes one of the component variables, which enable us to understand the human behavior in all its variety. Similar complex situations are possible to observe again in the mentioned environment of the crisis management, which represents rather difficult and quickly changing situations requiring the user's high requirements for work efficiency. The authors have covered this area before when working on the project called "Dynamic geo-visualization in crisis management," where one of the main points was to verify the user's efficiency and way of work with designed cartographic works and systems (Konečný et al., 2011; Kozel & Štampach, 2009). A part of the mentioned project was also research focusing on monitoring the activity of operators of regional emergency operations centers and the way they use current geographical information systems designed for crisis management (see Šašinka et al., 2010). In the mentioned partial study, the research focus shifted gradually from the research of interactions between the user and GIS to examining the system of higher level, where using GIS and its available map documents is only one of the ways when meeting required targets. Without not reflecting the broader context of the operator's work (his/her knowledge, experience or current requests), we could misinterpret his/her way of using given cartographic visualizations (within GIS).

All the above mentioned examples of cartographic research are possible to meet the requirement for the largest objectification possible of used evaluation methods, which would further bring improvement and optimization of the communication process of relevant information to users (with the feedback of this evaluation back to the cartographer and consequent optimization of the given cartographic visualization).

2. Information value of the map

When evaluating the quality of maps, it is also necessary to consider their information value, which is one of the important factors while using the map. It is appropriate to use techniques of information science for studying information value of the map and ways of communication. Information science deals with information transfer in the society, a way of communication, and describes information from the contents point of view (Souček, 2009). As Šašinka et al. (2010) further claim, it also includes an analysis, collection, classification, manipulation, storing, obtaining and spreading information. As Shuman et al. (1992) observe, information science also examines information transfer, including possibilities for its effectiveness. This issue is possible to view from the point of view of the study of information behavior, which we use to try to explain a variety of individual's behaving depending on available information sources and information channels providing the transfer (Wilson, 2000). Information behavior includes both the form of communication and also the way of obtaining requested information. From the general standpoint, it is possible to describe the way of the map user's work as interactive obtaining of information, which is based on a dynamic search for information currently needed to solve the given problem (Robins, 2000). Thus, it is obvious that applicable tools should allow the user to obtain information quickly from available sources by means of effective technological solution and appropriate visualizations, which allow quick and accurate perception of individual elements on the map. Cognitive load of such visualization should distract the user's attention as little as possible, which, in fact, leads not only to higher perceptual speed of looking up the requested information, but also to lower error rate in the result.

2.1. Graphical space-filling and complexity of the map

Obtaining information from the map is surely influenced, to a certain point, by the amount of the information on the map, where such information might have dual nature from our point of view. First, it is requested information, a subject of perceptual search (from this viewpoint, it is an attractor of our perception) and other information, which overload the whole image representation and reduce perception of relevant elements (we talk about distractors of image field). Therefore, the cartographer should try to reduce the amount of present distractors, which overload the user's attention while maintaining maximum informativeness of the map (given by the specific subject matter). This can be done by reducing graphical space-filling of underlay information, which are distractors in most cases, making perception of the figure harder. Obviously, the relationship between the information background and the figure is strongly determined by the purpose of the map.

It is generally true that a map's readability is largely determined by the possibility of distinguishing a figure from background, while we can list a few rules supporting this fact. As Bertin (2010) claims, it is necessary to make sure that there are no areas with too large or too small graphical space-filling on the map. Regarding topographic maps, the maximum graphical space-filling is around 30% of drawing and labeling on the map (e.g., Drápela, 1983). Regarding electronic maps these days, it is not a problem to meet this requirement, which is possible, in relation to the concept of context visualization (see Reichenbacher, 2004; Nivala & Sarjakoski, 2005; Kozel & Štampach, 2009), to emphasize by transferring some irrelevant elements to other contexts. At the same time, it is important to provide good readability by cartographic representation of individual elements on the map by maintaining the minimal size of graphic entities by depicting important elements (elements of the figure) in distinctive contours (according to so-called Gestalt principle, see xx) – intuitive distinction of all elements is provided this way, which leads to their quicker perception (Bertin, 2007; Cuenin, 1972).

The issue of graphical space-filling of the map is closely related to its map complexity, which is dependent on the combination of mutual arrangement of individual graphical elements in the map field, which might lead to a rapid complication of the map's readability in some cases (MacEachren, 1982). Map complexity depends (if not considering the difference implicitly resulting from the given scale) both on the space layout of the represented objects and phenomena and on the way of their cartographic visualization. Obviously, the main emphasis on reducing the overall influence of complexity on the usability of the given map is exactly on the correct visualization of individual elements on the map (spatial layout is in this case invariable, independent on the cartographer; influential by only various methods of generalization to a certain point).

As Fairbairn (2006) states, we can distinguish the map complexity on the intellectual and graphic (or visual) complexity. While the first type includes the complexity resulting directly from the used cartographic symbolism (in terms of complicated interpretability of some map symbols due to their ambiguity, or their insufficient association value), graphic complexity refers directly to spatial differentiation of individual graphic elements on a map field (Brophy, 1980). Generally, we can assume that with increasing map complexity (similarly to its graphical space-filling), the overall usability is decreasing (see the next chapter).

2.2. Relation of graphic variables and map's usability

As the technology development progressed, needs to create more specific cartographic visualizations also changed (as well as concerning crisis management in the form of context visualization). This trend is also visible these days, when it is obvious that maps in all forms are and will be used in the future. Yet, it is clear that technologies are fundamentally changing together with transferring spatial information (e.g., web map portals, navigations, etc.)

Sliviaková et al. (2009) claim that rapid development of information technology, which took place at the end of the last century, significantly influenced a wide range of fields of human activities, and cartography was no exception. At present, typical cartography output is a representation of geographical data in digital form on the computer screen, possibly on a portable digital device, with various degrees of interaction. Considerable reducing of technical and financial intensity of creating map outputs has brought an important change in the approach to creating maps. Traditional maps were static, typically used for various tasks, thus it was necessary for them to include as much information as possible because they mainly functioned as an analytical tool. The only restriction was the upper limit of permissible graphic space-filling, i.e., to ensure the map's readability. The overall usability of the map (its specifics and individual aspects are dealt with in the following text) therefore depends not only on its contents and the amount of represented information, but also on its graphic qualities, i.e., readability. We may assume that the utility value of the map is possible to represent schematically by the relation in figure 1, i.e., that the increasing amount of represented data also broadens the overall usability of the map but at the same time graphic space-filling increases as well. Nevertheless, the map's readability and its potential usability for the given purpose decrease from a certain level of graphic space-filling.

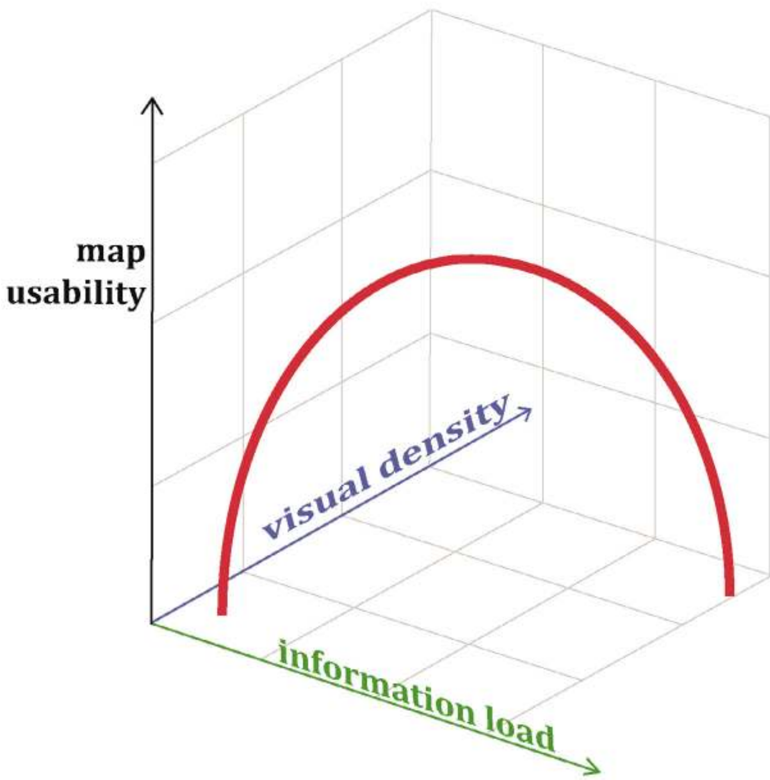


Fig. 1. The map's usability depending on the amount of its space-filling and information richness.

Sliviaková et al. (2009) further claim that cartographers make an effort to individualize maps these days, i.e., to create various map outputs for various tasks and user groups. A map should include only a minimal amount of information (suitably represented) necessary for the user to be able to interpret conveyed information quickly and correctly in the first place. While working with traditional maps assumed a rather high level of the user's knowledge, complicated analytical operations are run partly or completely automatically today and the user is provided with information in the form of corresponding with his/her individual level of knowledge.

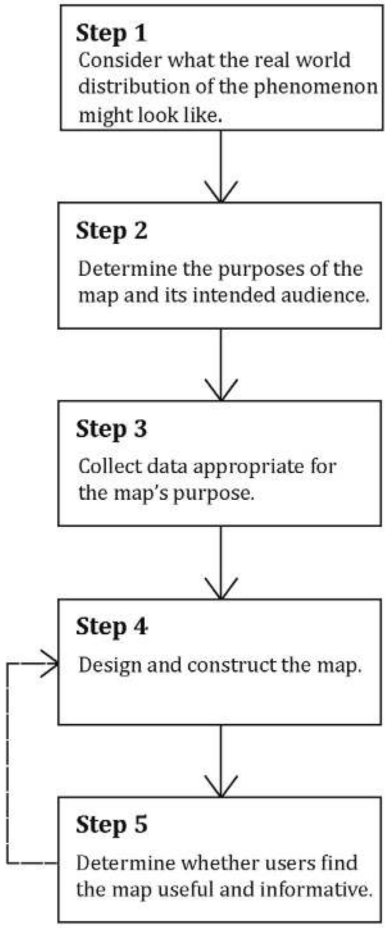
This is the part where one should pay attention and see the difference in how the described issue is understood by various fields of study. While cartographers might tend to put the user in the context and thus "reduce" his/her role to the level of hardware equipment, psychology will apparently always be interested in the subject of activity, which overlaps the limited context and situation of using the map by its intentional activity and ambitious behavior. The individual's general intention, which overlaps the activity itself when working with the map, is always primary in this case. It is also necessary to carefully observe and understand differences in the meanings of used terminology. An example might be the term "visualization," in psychology usually defined as an ability to create new visual images. Cartographers, however, understand this term as representing data on a map by various technical means.

3. Evaluation methods in cartography

The quality of decision-making processes on maps, meaning the speed and accuracy of deciding when dealing with various situations (from a common problem when finding the shortest route to dealing with huge, complicated crisis situations) in particular, depend largely on the quality of used visualization of spatial data. The quality of used cartographic visualization, whether it is topographic underlay information or thematic overlay, surely influences the user's judgment and subsequently his/her decision. This fact might be shown even more when working with maps in the process of crisis management, for example. One of the basic requirements for maps created for crisis management purposes is a possibility to make a quick judgment. The reasons mentioned above therefore indicate that it is necessary to keep improving all of the processes of map creation, which will lead to the improvement of used cartographic visualizations.

As mentioned before, evaluation and analysis of created maps, or all cartographic products for a fact, are considered to be a very important part of the whole process of their creation, which brings valuable feedback possible to use for further increase of their usability. This chapter will also focus on some existing methods and approaches, which are possible to include into the evaluation process of cartographic works, while the main emphasis will be put particularly on questions related to the overall usability of the map (as a strictly objective criterion), which should be a determining aspect of this area when evaluating quality of cartographic visualization.

Map specifics have been discussed in previous chapters the way that they are perceived from the point of view of cartography and psychology, including the basis for their evaluation. This chapter will briefly pay attention to the most used methods for map evaluation. To explain the issue of map evaluation better, it is also suitable to briefly outline the issue of the map creation process and see the sequence and relation of creation and evaluation of a given map. In this connection, Slocum (2005) offers a linear process of map creation (see fig. 2) where it is obvious that assumed confrontation of the user and product takes place after the complete production of the product. Feedback is shown there, indicating that if the cartographic product is not quality enough, it will be made over. For example, Dostál (2005) elaborates the product mentioned above and describes the process of creation in a more complex way (compare with fig. 3). In his multi-dimensional model, he emphasizes that the reader might be included in the process of map creation (or its individual elementary parts, e.g., cartographic symbolism for individual themes) in its early stages. In this case, the author monitors the interaction among the cartographer, user and reality simultaneously on various levels and thus offers a possibility to closely inspect the issue of map creation and areas of knowledge, which the map creator must have.



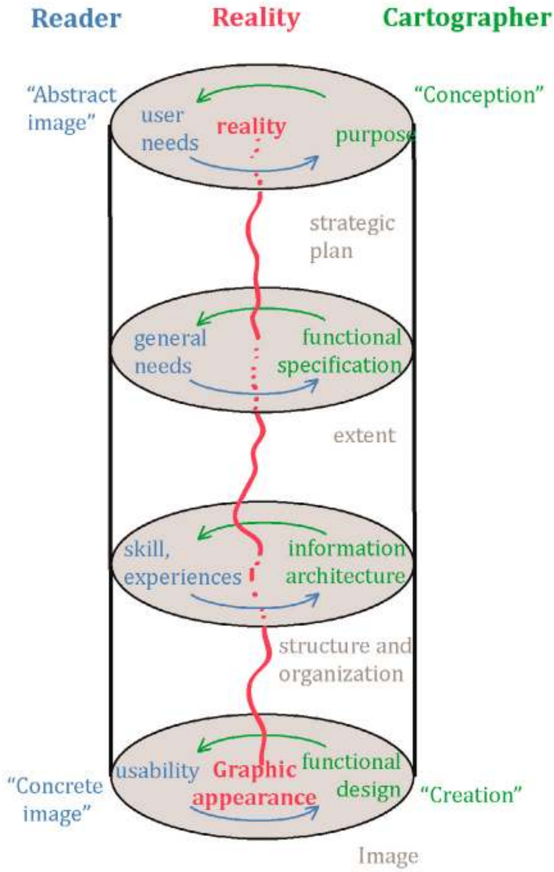


Fig. 2. Process of map creation; adjusted according to Slocum (2005).

Fig. 3. Informational level of map creation; adjusted according to Dostál (2005).

3.1. Principles of research methods and techniques

Searching professional literature and results of previous research of authors (Štěrba et al., 2011 & 2014), it is possible to find several approaches to evaluation of map products, which are able to provide useful feedback. Each of these evaluation techniques might be beneficial for cartographers while creating maps, but each of them offers various specifics. In practice, various methods are usually combined and completed to meet relevant requirements, which are resulting from the purpose of a given cartographic product or the cartographer or publisher's requirements. This part will partly focus on more detailed description of methodology of perception and cognition research, which are commonly used in cognitive psychology and in recent years also widely applicable in empirical research in cartography. Their use in study of usability of map products is one of the aims of the International Cartographic Association, which associates its activities in this area through the Commission on Use and User Issues and the Commission on Cognitive Visualization.

These days, research in the field of cartographic products evaluation naturally uses more research methods and techniques, which have been, and still are, developed by psychology fields. However, it is important to point out that research methods and procedures used in psychology have been historically influenced by natural sciences to a certain point, which have achieved significant results with the help of exact methods in the history. To this effect, Smutný & Řezníček (2012) claim that tendencies strictly applying more precise explanation, which is typical for exact sciences, have appeared in the area of inexact sciences. Also, it was important to somehow reflect a restriction resulting from the nature of research in psychology, i.e. studying various internal psychological processes. Nevertheless, these are examined and interpreted on the basis of the demonstrated behavior only.

At present, there are various research methods and techniques of data collection available, which are also used in research of cartographic works. Basically, these methods can be divided into qualitative and quantitative methods according to the data collection and its analysis, and also into subjective and objective methods considering the nature of collected data and its evaluation (see fig. 4). For example, Svoboda (2010) sees the objectivity of the psychology test as the impossibility of intentional misinterpretation by a person who is investigated, and also, independence of results on a person who evaluates the test. This principle might be also extended to the area of cartographic products evaluation. When evaluating the quality of cartographic work, we often focus on the efficiency and effectiveness, with which the user is able to work with a given product. The ideal way of monitoring these parameters is achieved when the performance is objectively measured. Subjective assessment of their own performance by the user in this case is not the optimal way, even though subjective experience in working with the map is an important indicator of the quality of maps (see overview of subjectively oriented methods). In the field of engineering psychology (or usability engineering), three parameters are often simultaneously monitored: the effectiveness, efficiency and satisfaction. The effectiveness and efficiency are suitable to monitor by objective methods; satisfaction reflects the user's experience when working with the product. More specifics on these aspects, which are crucial for the overall usability of the product, will be discussed further.

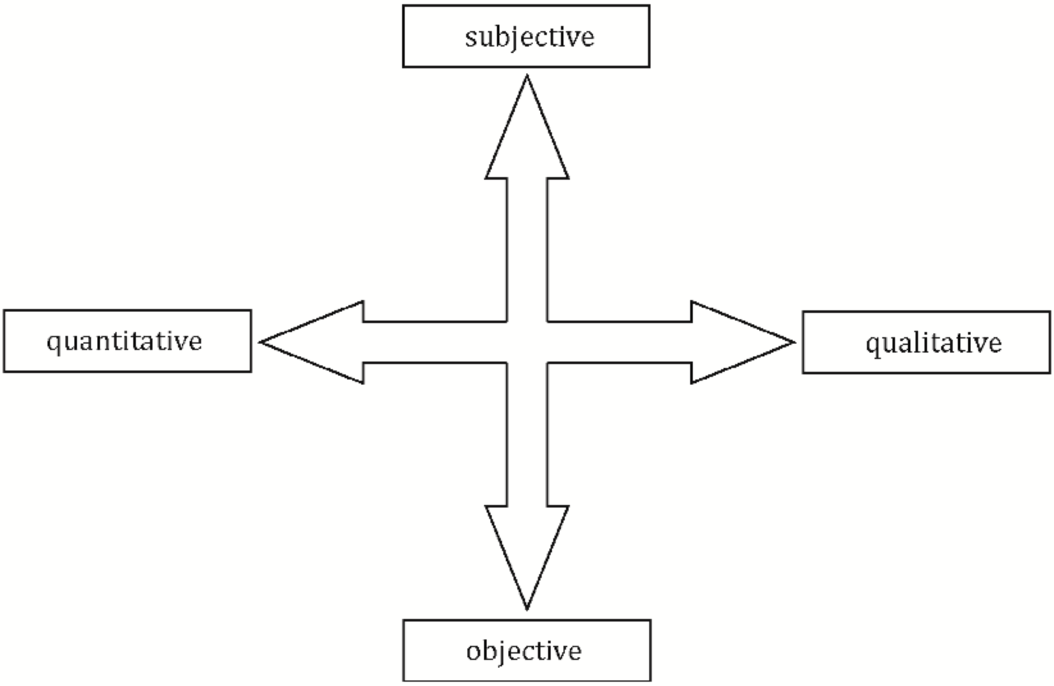


Fig. 4. Schematic division and relation of each research method and procedure.

In connection with the following text, at this point, it is necessary to emphasize the importance of the concept of qualitative and quantitative research, as they are also used in this book. It is believed that two perspectives are taken into account in the qualitative approach. First and foremost, it is the researcher's point of view, which includes, for example, what research goals he/she sets, what research tools and methods to use, what procedure leads to his/her findings, as well as how he/she defends their progress. The second aspect is represented by the respondent's own perspective, or the participants of the experiment.

A critical moment of qualitative research is just the sheer importance, which is attached subjectively to the situation by the participant, as he/she interprets the situation. From the psychological point of view, experiments in cartographic research are focused mainly on ways of exploring cognitive processes, which are engaged in the work of the individual with cartographic visualization, and hence, pursues the issue of human behavior on the molecular level. In this perspective, the examined phenomena are considered to be objective entities, and therefore relatively independent on the subjective meaning. For this reason, we are now working with the concept of qualitative research in the strict sense, with particular emphasis on the first standpoint. By qualitative research in map evaluation it is thus understood that the researcher's working process, where no hypotheses are defined in advance and there is no attempt to verify statistically assumed relations. By contrast, the researcher uses appropriate techniques and tools to obtain empirical data, whose in-depth analysis and exploration could lead to findings previously not reflected relations and patterns.

In the quantitative research, there is primary data collection, which is then precisely quantified and processed using statistical analyses. Appropriate interpretations are then made on their basis.

Although there are quite significant differences in the concepts of quantitative and qualitative research, it is possible to find consensus allowing interconnection of both approaches (Trafimow, 2014). Johnson & Onwuegbuzie (2004) complete this fact by claiming that both approaches use empirical observation to solve the set of research questions. From this point of view, both approaches can effectively complement each other (Sechrest & Sidan, 1995), which seems to be a promising approach especially in the area of testing the usability of cartographic visualization.

3.2. Subjectively-based evaluation methods

According to their nature, one group of evaluation methods is possible to consider subjectively based, these methods are principally based on a rather subjective view of the evaluator and therefore, they are largely dependent on him/her. In our division of individual research methods and procedures, we can identify examples of combinations of subjective methods in terms of qualitative-quantitative point of view.

First, it is possible to experience using a method of so-called expert evaluation or, on the contrary, a method of subjective evaluation carried out by users themselves. In these cases, we speak about a simple and quick way of evaluation of a given work, which is, however, more or less burdened with its subjective nature (also within expert evaluations, some conclusions are drawn without objective basis, which would support these views enough). Principally, we speak about a method of review opinion of a given work, which might be “objectified” in a certain way by partial criteria. Therefore, the results of such evaluation are often dependent on the selection of the expert (or the circle of evaluators and their knowledge, experience, etc.). The usual output of expert evaluation is usually a list of qualities of a given work, or their positive and negative features, values or other parameters (Bláha, 2010). This method is generally used as a primary step in the complex evaluation process, which might be helpful in its further direction. From this point of view, an introductory phase of the planned experiment might also be considered expert evaluation, while hypotheses are set, specific methods, independent and dependent variables are selected. In certain cases, conclusions of expert evaluations of a given cartographic visualization might be used for its further optimization. It is necessary to point out that these conclusions are always suitable to be verified with the use of more objective methods, possibly through an experiment.

In the case of the users' evaluation of a cartographic product, usually various types of questionnaires are used, which mostly provide a certain level of attraction of the evaluated product (thus, we may consider them quantitative and subjective research methods). Users collectively complete a set of selected questions, assessing selected aspects of a map or their performance with it. Depending on the type of a cartographic product (analogue or digital map, thematic or topographic, etc.), a suitable target group of potential users is selected so that relevant conclusions might be drawn from obtained results (Martin, 2007). Using a suitable set of questions, or simple tasks on the map, it is possible, from such research, to deduce certain weaknesses (possibly strengths, too) of a given product, which might be developed in the process of further creation. The disadvantage of such an approach is obvious. The result is largely dependent on the evaluator's ability of introspection; this subjective result might be in contradiction with objectively achieved results. Another exploration tool, which might still be put into this category, is semantic differential (see Osgood et al., 1957). The observed phenomenon is evaluated on the dimensions with bipolar terms, such as readable/unreadable, comprehensible/incomprehensible. To a certain point, this method also prevents so-called *neutral response effect,* thus we might be able to suppress the respondent's tendency to select the neutral response option (see, e.g., Biemer et al., 2011).

However, a questionnaire method might be considered objective in some cases. Certain ambiguity of including these methods into the subjective quadrant will then show, for example, at the point when the aesthetic quality of the map should be evaluated in terms of beautiful/awful. At this aspect, a subjective response might be regarded as an objective indicator of the monitored feature. Subjective evaluation methods of cartographic products (mainly from the user's point of view) are, for its relative time undemanding character in particular, a rather suitable method for commercial products, e.g., road books, tourist maps, etc., or possibly also for products for the public, including school atlases, geographic educational web pages or other educational products.

Combining subjective and qualitative research methods, a method of unstructured interview could be mentioned (Schraagen et al., 2000), for example, or also the so-called think-aloud technique (Hartson & Pyla, 2012). In the unstructured conversation, the user can influence or focus on the next direction of the researcher. The boundary between the researcher and researched is blurred. Think-aloud protocol arises directly when doing an activity with the map or immediately afterwards and it is used, for example, in research of working with the map in orienteering, when the use of other techniques is rather limited. Mapping research methods used in the research of cognitive processes in orienteering, in his paper, Seiler (1996) claims that research in this sport discipline has its own specifics. The athlete's behavior, apart from other disciplines, is not possible to monitor while being performed, even though it is possible to monitor the athlete's movement with a GPS device, practically it is not possible to monitor other aspects of his/her performance, especially ongoing cognitive processes influencing the mental aspect of his/her performance. Again, it is a subjective response influenced by the participant's ability of self-reflection. Johansen (1991) carried out a study in research of cognitive processes in orienteering, combining think-aloud technique with a follow-up unstructured conversation. Gilhooly et al. (1998) used a think-aloud technique for research of strategies, which distinguish beginners from experts when remembering information from a map. However, the resulting protocol of think-aloud technique is also possible to analyze as monitored behavior and assign marked features into previously defined categories, which is again similar to the objective way of research.

A certain level of objectification of cartographic work evaluation is possible to see in complex multi-criterial approaches, resulting mainly from basic user functions of cartographic works. As Miklošík (2005, 2002) claims, these methods try to encompass previously specified functions of evaluated maps, on the basis of which then set the main evaluation criteria. According to Miklošík (2005), the basic and relatively independent criteria, which have a direct impact on the level of user functions' performance, might include the evaluation of the map content in particular, accuracy of elements displayed on the map, importance of depicted landscapes from the user's point of view, currentness of depicted information, technical design and aesthetic level. In the context of these proposed basic set of criteria, then we might set effective partial criteria according to specific evaluated cartographic products and their purpose. Due to this system, we can objectify the whole process of evaluation to some extent, subjective features are only limited to partial criteria specification and setting their weight (which might, on the other hand, influence overall evaluation results to some point). Compared to other methods, a disadvantage of this method might be its time-demanding character, which is related to setting all the criteria, their values and then applying the designed system to evaluated maps. Results of this system are very difficult to interpret regarding the use of a given cartographic product when put into place, thus expressing rather certain assumptions and hypotheses applicable in further phases of evaluation process. This fact might be found, for example, in various specific maps with a very specific purpose, for example, maps for crisis management, where criteria including positional accuracy, currentness, etc., are a necessary condition for their successful usability. Yet, it is not possible to precisely predict their factual usability on their basis when put into place.

The above mentioned method (as one of the potential criteria) might also include processes evaluating mainly aesthetic qualities of cartographic products, which have already been mentioned in the case of the user's subjective evaluation. These methods are particularly focused on various aspects of attractiveness of map products, which are related to both user friendliness and an aesthetic function of the map, which is primarily dependent on perceptual attractiveness of the map (more, for example, Bláha, 2011). This kind of evaluation is again completely applicable, especially with commercial products designed for the public since the attractiveness is the significant feature in most cases (to the exclusion of basic functions of the map) increasing its marketability. Evaluation of attractiveness and user friendliness result from basic principles generally existing in graphic design, which are applicable in cartographic visualization, too. First, we can discuss, for example, evaluation of used colors in the given map, the whole color compositions included. The color might not only influence the readability to some level but also the attractiveness of the whole product and therefore it is necessary to pay attention to it (see Bláha & Štěrba, 2014).

On the other hand, map works designed for experts need to focus on completely different aspects, which determine their overall usability in the end (discussed in detail below). These aspects might include characteristics such as clarity of cartographic expression of objects and phenomena, differentiability and associativity of used cartographic symbols, clear arrangement of individual types of objects and phenomena and map's readability in assumed conditions of its use. For this reason, it is necessary to focus on specific criteria, which are important for work, with maps designed for a very specific group of users. In most cases, it is necessary to focus on variables, which might directly or indirectly affect the applicability of given cartographic products. Therefore, in accordance with the previously mentioned studies, we can mention, for example, evaluation of potential effectiveness of cartographic symbology through its definiteness, non-interchangeability, memorability and a degree of association value (associativity) of individual map symbols, it means characteristics, whose quality directly influences the performance of user functions of a given map (e.g., Jarosz et al., 1982). In her work, Tajovská (2011) focused on measuring similar variables, concentrating on determining the level of acceptance of designed cartographic symbology by users themselves. Particularly, she emphasized the need to avoid map symbols, which might lead to a misunderstanding of their meaning or mutual confusion to a certain degree. These specifics might therefore lead to a higher error rate and lower efficiency, which is the result of higher cognitive load. Hence it is obvious that the main aspect, which should be taken into consideration when evaluating maps for specialized professionals (e.g., operators, street workers, etc.), is usability while all of the factors mentioned above have an immediate influence.

3.3. Objectively-based evaluation methods

The above mentioned methods, which are more or less based on subjective evaluation of a cartographic product, are, from the factual point of view of usability, possible to consider only as indicative information, which might only suggest the weak points of a given product. In comprehensive evaluation, however, it is necessary to focus on the entire process of objectification, which could better identify potential communication noise in communicating important information on the map. For this reason, it is suitable to use objective evaluation methods, which focus on the practical performance component of working with the map and help to identify the incorrect or insufficient use of cartographic methods, design of a cartographic product or non-fulfilment of the overall required purpose. By comparing the performances of future users (or a similar target group) we can evaluate required levels of usability of a given cartographic product.

In the context of the method division into two mentioned dimensions, we can also identify their various combinations. An example of an objective and quantitative approach is the use of various applications, which enable testing various tasks on the map, while the main objective is monitoring and ability of exact quantification of at least basic aspects of usability (see further). Authors use these techniques in the cartographic research the most then (see Konečný et al., 2011; Štěrba et al., 2011;

Stachoň et al., 2013), while the whole testing (with the option of creating, editing, collecting and resulting data evaluation) takes place in the computer environment. In our case, it is using the research software MUTEP (see Šašinka & Morong, 2012; Štěrba & Šašinka, 2012), also the software Hypothesis in particular, which is described in detail in the following text (chapters 9, 10 and 11). Both of these tools have been developed by the Department of Geography and Department of Psychology at Masaryk University for the research of cognitive aspects and usability of cartographic products. During a computer testing, the participant completes a relatively exact assigned kind of tasks and his/her performance is immediately recorded and then evaluated (semi) automatically (depending on the type of the task). An example of tasks might be marking point elements, choosing an optimal route and its drawing or marking a certain area (see Konečný et al., 2010; Stachoň et al., 2009; Zbořil, 2010). Mostly, the correctness or speed of the answers is monitored, but we can also monitor the frequency of a specific variant of the answer in case there is more than one correct option. An example of such a type of testing might be a task where the participant is asked to find an optimal route. Possible examples of using these methods in the Hypothesis software will be discussed in details in the practical application of this publication (see chapter 10). It is not possible to evaluate all of the aspects of a cartographic product through this method, for example, content accuracy, currentness or positional accuracy (the same as with multi-criteria approaches, e.g., Miklošík, 2002), however, it is very suitable for evaluation of various cognitive aspects of the process of obtaining information from the map, which are very difficult to do by other means.

In the past, researchers from the Department of Geography and Center for Experimental Psychology and Cognitive Sciences at Masaryk University dealt with very extensive research in the field of evaluation and testing of cartographic products (with an obvious emphasis on the map in crisis management) using tools MUTEP and Hypothesis. In the context of the previously mentioned research project, several sets of symbology have been developed for different purposes (points of interest, map features for flood context, transportation of hazardous waste, etc.). The design and creating these sets was obviously related to their resulting evaluation. As Štěrba et al. (2011) claim, the most suitable method for the purposes of evaluating above mentioned sets of cartographic symbology is a multi-phase measuring of the users' performances when working with the map, which had been earlier dealt with by Sedlák et al. (2010) to a limited extent. This evaluation consisted of several parts, which focused both on the individual map features of a particular symbol set, as well as to the user him/herself. The evaluation of perceptual and cognitive aspects has been included, as well as the evaluation of their association value (associativity), significant added value can be found in the span of psychological view of the whole evaluation, which should not be overlooked in the evaluation of cartographic products (see chapters 7 and 8 for more details).

As the last method, a method of qualitative and objective research can be mentioned. Particular techniques of video-recording or eye-tracking (see Duchowski, 2007) are used in cartographic experiments. Although testing using eye-tracking systems is usually used for quantitative data collection and subsequent analysis, the analysis can be conducted also in a qualitative way (e.g. Štěrba et al., 2015) to observe the elementary cognitive strategies selected by the user of the map to cope with such challenges (including, for example, monitoring the frequency of using selected predefined elements on the map, sequence of using the map legend, etc.).

The above mentioned objective approaches mainly use various qualitative or quantitative testing methods of usability of cartographic visualizations (in this context, Stachoň et al., 2013; Brychtová et al., 2012; Cöltekin et al., 2010 can be named, for example). These methods use modern computer technology for testing users, enabling objective quantification of selected aspects of usability. In any case, the division in fig. 4 is certainly not unambiguous and it is not possible to view it quite rigorously, but it suffices to create a basic idea of the pros and cons of research methods. In practice, a combination of several of these techniques is often used (so-called mixed research design), for example, through the use of qualitative techniques in the context of the pilot study, which builds on data collection using quantitative techniques with resulting statistical processing. The combination of these methods and testing procedures, which bring together quantitative methods for testing the effectiveness and efficiency of the user and to monitor cognitive strategies using eye-tracking system can be successfully compared with the results of the parallel psychological testing focused on inter-individual differences between users (respondents); see Štěrba et al., 2014; Kubíček et al., 2014 and Stachoň et al., 2013. Current possibilities for such testing, including observation of the personal characteristics of users of cartographic visualizations, will be further described in the following text (chapter 8).

3.4. Mixed-research design

Large variability is apparent from the above mentioned evaluation methods, which can be used. During experiments, such variability may have a relatively significant influence on obtained results and their validity, depending on the evaluation methods used and the structure of the proposed design (Olson, 2009; Wolfe et al., 2004). One may believe that with combining more methods, it is possible to achieve an objective procedure for obtaining usable results. In some cases, when proposing the research, using only a qualitative or quantitative type of method is not sufficient; therefore, it is necessary to combine those methods, enabling their suitable completion, obtaining more valid results and achieving better interpretation.

For this reason, combined methods of so-called *mixed-research design* are widely reasonable in research of usability of cartographic products. Johnson & Onwuegbuzie (2004) define mixed-research methods as the "third research movement, where the researcher mixes or combines quantitative and qualitative research techniques, methods, approaches, concepts or language into a single study". In addition, they claim that their main feature is their methodological pluralism and eclecticism in particular, and the aim to connect strengths of both approaches in order to achieve relevant and accurate results, and minimizing weaknesses on the contrary. Hence, both approaches are applied within one study or experiment. Methods of mixed-research design therefore offer an objective procedure, while quantitative methods enable effective interpretation of a large amount of data and qualitative procedures explain partial processes in their creation, to a certain degree. Their effective combination thus enables a better understanding of cognitive strategies of respondents to a large degree, as well as a deeper understanding of quality of monitored and evaluated cartographic visualizations.

As Olson (2009) notes, the design of research combining quantitative methods with qualitative ones is often neglected in cartography. Similarly, Griffin (2012) and Hegarty et al. (2010) point out the highly complex character of cartographic stimulus material, and therefore, it is necessary to construct rather complicated designs of proposed experiments, in some cases, adequate pilot studies included. This fact is based on the nature of the cartographic visualization as such, whose form is determined by geographical distribution of individual elements, to a large degree. For the more precise and objective interpretation of results of the experiment, it is therefore necessary to prepare a rather massive design of the entire test in most cases, which would include a greater number of various types of tasks on various map segments. Accurate defining of the issue, including the target group of users and the nature of the evaluated cartographic work, is a prerequisite for usability testing (Slocum et al., 2001). Mixed-research design of the experiment based on interdisciplinary methodological foundations is one of the ways in which to deal with the complexity of cartographic stimulus material (Jabine et al., 1984). Using a combination of several methods, overall results can be considered more interpretable. In cartographic experiments, it is generally necessary to collect a relatively large amount of data for subsequent analysis, which precedes a confrontation of hypotheses, which were set in advance. Valid and useful results can only be obtained with a sufficient number of respondents and when using appropriately defined tasks.

One of the first ones highlighting the necessity of mixed-research design in the proposition of general experiment was Buttenfield (1999), who used several complementary methods of quantitative but also qualitative nature in her research. As already mentioned, it is necessary to emphasize the structure and design of a test (Olson, 2009). From this point of view, various available interactive tools are a valuable instrument for quantitative experimental research enabling efficient collection of quantitative and qualitative HCI data, its simple analysis and subsequent interpretation. The second part of this book will focus on one of these tools, the software, Hypothesis. It offers a very fast and flexible environment for measuring effectiveness and efficiency of respondents in created test batteries (more information about various similar aspects are discussed in the following chapter).

Despite the obvious importance of quantitative metrics, which are, for example, response times or error rate (Wolfe et al., 2004), it is necessary in some cases to proceed the qualitative type of research (which would enable an easier description of cognitive strategy of respondents), which corresponds to obtained results. This specification then leads to significantly better interpretations and other applications. A certain form of qualitative research in cartography is provided by an eye-tracking system, which can, within a certain qualitative analysis of some metrics, thoroughly explain behavior and strategy of certain groups of users by comparing some metrics (Popelka et al., 2013 & 2012). Similar procedures allow cartographers to better understand the way the chosen visualization is perceived.

Qualitative analysis by testing using eye-tracking may be used in two cases, from this point of view (Štěrba et al., 2014):

- It is possible to understand integrating qualitative analysis using the eye-tracking system in the form of a pilot study examining a certain design of the experiment. The preparatory phase monitors partial results obtained in individual parts of a given test and the course of solution of individual tasks – strategy of the solution, comprehensibility of instructions, intuitiveness of managing the test, etc. Based on a similar study, the whole experiment can still be improved. The design can be finalized for real testing using the software for quantitative data collection (e.g., the previously mentioned software, Hypothesis). Similarly, it is possible to further specify set hypotheses based on the pilot study. A huge advantage of such qualitative analysis used this way is relatively a small time consumption of data collection in particular, and mainly the optimization of design of the experiment for the resulting quantitative analysis. The analysis is not necessary to carry out using eye-tracking equipment, which requires a rather high time consumption for the researcher and participants.
- The second option for using a qualitative approach is, on the contrary, its application after obtaining a sufficient amount of quantitative data. It is not possible to interpret exactly the obtained total or partial results at certain moments (parts of the test, certain types of tasks or individual items). The main reason is the fact that we do not know the accurate strategy of respondents when completing these tasks. Results obtained by quantitative collection (e.g., using the software, Hypothesis) do not enable closer view on the nature of resulting data; this is so-called a *black box* for us, where we cannot interpret the cause of the cumulative effect and its structure correctly. The second part of the research can be successfully applied for similar results, and even involving only a few participants in the qualitative phase of the research enables the uncovering of certain patterns in solving certain types of tasks. Particularly, various elementary cognitive processes leading to solving set tasks and causes of some errors and inaccuracies in responses might be uncovered. This date further enables more detailed and accurate interpretation of obtained results and a more accurate comparison of set hypotheses. Analysis using eye-tracking can also be used for subsequent specification of certain results with adjusted or changed types of tasks with a fewer number of respondents (Manson et al., 2012).

An experiment designed this way might specify obtained results during the research to some extent but also increase efficiency of the whole course of evaluation. Using a quantitative phase, it is possible to collect a lot more data from participants than in an eye-tracking experiment. On the contrary, eye-tracking can only be used in an emergency and only in specific tasks, which require more detailed analysis. Selected examples of application of mixed-research design are described in detail by Štěrba et al. (2014).

4. Usability of the map

The issue of usability, as a relevant criterion for evaluating maps, has been mentioned in the text a few times before. In this chapter, we are going to briefly focus on the basics of the meaning, its understanding and use in the map evaluation. Rubin (2008) generally defines usability as a quality of a product, which is present in some cases and, sometimes, we might observe its insufficiency. Generally, usability is monitored by various metrics, which are possible to accurately quantify (Tullis & Albert, 2008). These characteristics might be monitored and described with products, which have user interface. According to web pages of the UsabilityNet project (*www.usabilitynet.org*), however, usability is generally related to the fact of how users are able to master a product successfully in order to achieve their goals and how they are satisfied with this process. A rather large amount of standards and recommendations (for overview, see Bevan, 2006) deal with all the aspects of usability, their testing included. These available documents are primarily focused on various areas of Human-Computer Interaction (HCI). An area of HCI might also include evaluation of usability of cartographic products, where we can also monitor an interaction between the user and a given product through user interface (on the computer screen, tablet, etc.). Therefore, procedures common in HCI are also relevant for evaluation of usability of cartographic products.

An ISO standard 9241-11: Guidance on Usability from 1998 defines usability as "*the extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use*". User Experience Professionals Association (UXPA, *uxpa.org*), however, focuses on the process of product development: *"Usability is an approach to development that incorporates direct user feedback throughout the development cycle (human-centered design) in order to reduce costs and create products and tools that meet user needs and have a high level of usability (are easy to use)".* As Dumas and Redish (1999) or Sedlák et al. (2010) further comment, while functionality is related to what we can do with a given product and how it works, usability is concerned with the way in which a product can be used effectively. It is important to say that correct functionality does not guarantee good usability of any object or product – it only gains importance in the interaction with the user.

4.1. Aspects of usability

Usability of examined products or systems is not only understood as a one-dimensional feature of user interface, but it is also possible to find more partial parameters, which determine the extent of usability to a certain degree, depending on the purpose of a given product. As Rubin (2008) claims, a "usable" product (or service) should meet certain criteria depending on a given purpose and target group of users. These criteria then define the overall user's objective regarding usability of a given product, which is mainly a possibility of its easy use for a specific purpose set in advance, without any ambiguity and vagueness in its use. This approach can also certainly be applied to evaluation of maps, which should have the above listed features (described in detail by Štěrba et al., 2014).

Usability, as a feature of a certain object or product, might be divided into individual attributes. Nielsen (1993, 1994) lists these attributes: learnability, efficiency (corresponding to the level of the expert's performance at the moment when the line of learning levels off); memorability (how easy or difficult it is for the occasional user to remember and use the system); errors (any action, which does not lead to a set objective, error rate is defined by a number of small actions during performing a specific task); and satisfaction. Quesenbery (2011) offers different classification: effectiveness (to reach the target successfully without any errors or failure); efficiency (speed during correct solutions); engaging (the level of satisfaction; solution which meets expectation and needs of the user); error tolerance; and the learnability. Main aspects of usability, which can be considered essential during evaluation of a cartographic product, might be described in detail the following way:

The aspect of *usefulness* is concerned with the fact of whether a used object will enable the user to reach the target. Real utility value is very important from this point of view. The object might be used easily, might be easy to remember, however, if it does not enable the user to meet his/her requirements (i.e., if it is not *useful*), it becomes useless. Usefulness is one of the most overlooked aspects when comparing various tests and experiments. From the cartographic point of view, it is mainly about primary assessment of a given map regarding the factual ability to be able to meet the stated purpose. Therefore, this aspect should always be evaluated in the first phase. Its carrying out is then based on various subjective methods, which were described in the preceding chapter, and expert evaluation of the given map in particular.

The following chapters then focus on objectively based aspects, whose resultant interpretation is directly related to overall objective usability of a given product. Particularly, these aspects might also include *effectiveness* and *efficiency*, which might be considered two of the most important aspects of the map's usability in the interaction between the user and the map (Rubin, 2008). These aspects are possible to quantify, analyze and interpret precisely with quantitative features. These features correspond to the user's speed of response (or response time) in individual acts (which in our case corresponds to the aspect of efficiency), the second important aspect is then the error rate, which is monitored during the user's use of the product (the above mentioned term "effectiveness" is then used for this feature). Aspects of effectiveness and efficiency therefore determine how quickly and easily the user obtains the desired information. Both parameters are used most often in cartographic research because they can describe the user's interaction with the map accurately. While testing effectiveness, resulting conclusions can be comprehensibly quantified in most cases; for example, in a specific task on the map, users' error rate might range to 10%, etc. Evaluation of these aspects uses these previously mentioned objectively-based methods, nowadays most often using special high-technology equipment. These methods are described in detail in the following chapters of this publication.

An aspect focusing on the detailed analysis of elements, determining overall usability, is *memorability*. Memorability is related to the user's ability to work with a subject of a certain qualification, which has been gained from the previous experience (thus, also possible to understand it as a factor influencing the resulting effectiveness of the user). In cartographic symbology, memorability generally refers to correct or incorrect conception in its creation, while a symbol, which is easy to remember, increases its usability to a certain level. Therefore, the form of cartographic symbols should correspond to its meaning as much as possible, i.e., according to the principle of isomorphism, a given cartographic symbol should refer to a depicted object or phenomenon (Pravda & Kusendová, 2007). Association value of given cartographic symbols is closely involved with easy memorability, which makes it easier for the reader to read relevant information. For example, as Jarosz et al. (1982) state, the level of association value of cartographic symbols might gain positive (the symbol is attributed correct or similar meaning), negative (meaning is incorrect to a large degree) or zero values (the user is not able to understand the symbol in any specific meaning without the use of map legend. It is obvious that strongly positive association values for most of the symbols might also rapidly increase overall usability of a given product – the user can perceive individual meanings quickly and correctly without using (or frequently using) other map elements. In this regard, it is, however, necessary, when evaluating cartographic symbology, to focus on potential conflicts in recognizability of symbols, regarding their confusion. On the contrary, these may reduce usability of the map.

Satisfaction represents the user's subjective view on a subject and perception of a subject or product. Satisfaction expresses the user's feelings, which are caused by using a given product. When evaluating a subject, satisfaction is very difficult to describe for its subjective nature. At a moment when we should somehow quantify an object or product as precise as possible, questionnaire or oral results might be confusing. Regarding the issue of the feature of satisfaction, Tullis & Albert (2008) add a fact that despite the above, some authors distinguish between usability of a subject and the user's experience. Usability itself does not include a broader view on the user's interaction with an examined object but it only corresponds to the user's ability to complete a given task. Satisfaction, i.e., the user's subjective feelings, is not possible to be included in usability. This specification might also apply to some areas of cartography, where such a great (or none) emphasis should not be put on the user's subjective opinion. For example, in crisis management, the effectiveness is surely a more important feature then satisfaction itself, which will be dealt with later.

In conclusion, usability is defined as a set of one to all mentioned features. However, to carry out objective quantification is principally very difficult and some aspects of this issue might only be solved by comparative evaluation of given products or objects. Nevertheless, based on monitoring users' performances in variously designed experiments, it is possible to determine the potential level of usability of these maps in practical application.

5. Usability testing of cartographic visualizations

The topic of this book, as well as the whole field of cartography, treads a thin line between the basic and applied research. That is why it is suitable to mention both concepts and approaches, which relate to research in the applied area. The term "usability", which we dealt with in theory in the previous chapter, is popular and widely used in information technology these days. This term primarily relates to the quality of tools and systems created by humans, which are used to achieve desired human objectives. Thus, the term is used to describe ease or difficulty, with which the user is able to use given tools. The terms "usability engineering" or "usability testing" then relate to methods of research and evaluation of user issues of these tools. In the context of working with computers, research of user issues focuses on ways of displaying information on computer screens and its control devices. Usability engineering might be included in the applied field with a long-time history in engineering psychology. Blum (1952, in Stanton, 1996) claims that engineering psychology deals with adjusting equipment and environment in order to meet human needs, or their psychological capacity and limitations. Another related term is also "ergonomics", whose first historical reference dates back to the Hellenistic period in the 5th century BC, when in his book, Hippocrates described how a surgeon's environment should be organized.

Usability engineering and related disciplines have developed a methodology and practical approaches of research and improving the performance of various systems. In this context, an interaction including both a human and technology is regarded as performance of the system. Endsley et al. (2007) mention the term "mental effort", which also includes a study of mental load and relates to its monitoring and reduction in a complex and stressful environment, such as aviation. Some of the applied psychological approaches, which are concerned with cognitive engineering and decision making (CEDM), focus on screen designs and multi-modal interface and are based on multiple resource theories (see Wickens, 2008). Also, they try to reduce mental load by improving designs of experiments used from the perspective of this theory. Wickens (2008) believes that the individual does not have only one cognitive source to choose from to process information when completing a task, but he/she has various types of sources available which can be simultaneously used. Depending on the type of the task, processing is either sequential, if only one source is used, or parallel in time, in case the nature of the task allows using multiple sources. Wickens (2008) further states three basic stages, which use differential sources.

- The stages of processing distinguishing between perceptual and executive processes assuming that both stages use different sources.
- The codes of processing distinguishing between a cognitive spatial and verbal linguistic activity.
- The modalities dimension attributing various sources for auditory or visual perception.

Endsley et al. (2007) further claims that cognitive engineering and decision making processes include the study of cognitive work and the application of findings for designing purposes and technological development. These concepts and research specializations belong to the main pillars: decision making in natural environment, "ecological interface design" (according to Rasmussen and Vincente, 1989, it is partially based on the works of Gibson and the ecological psychology approach), mental constructs, computer modelling of cognitive processes, automation and collaborative work.

Using contemporary maps is often connected to geographic information systems. Therefore, research methods and the theoretical frame of usability engineering and related disciplines are also suitable to use in this application field. In this regard, it is necessary to mention that the International Cartographic Association (ICA, 2010) listed the issue of user issues as one of the topics on their research agenda. According to this agenda, maps should always be user-centered in design, based on fair knowledge of its principles. In addition, the need to conduct usability testing, using both qualitative and quantitative methods, for various types of maps or visualizations, was emphasized. Konečný et al. (2011) also emphasizes the importance of research of the way of working with different types of maps, as well as the necessity to complementarily examine users' cognitive maps and the way users perceive geographical space. Wachowicz et al. (2005), Montello (2002), Nivala et al. (2007) and Dvorský et al. (2009) also deal with the these topics in cartography.

Contemporary maps are often not only digital, but also interactive; therefore, users are able to obtain data dynamically from databases and also display them dynamically on screens or portable devices. Bandrova & Nikolova (2005) demand that cartographic information should be depicted differently for different groups of users. Contemporary technology already enables the representation of cartographic data for a specific user or a group of users. A map can be adjusted and designed with respect to needs, abilities and personal preferences of the user, who himself/herself can then choose between various types of visualizations. These days, there are conceptual and technological solutions of similar contextual ways of visualization (see Konečný et al., 2011; Reichenbacher, 2004; Nivala & Sarjakoski, 2005; Kozel & Štampach, 2009).

Research of usability of cartographic products may be simply divided into two main areas: individual maps as forms of representation and complex geographic information systems, which include both cartographic representation and the overall technological approach. Principally, the first area is focused on the evaluation of various cartographic methods in connection with the purpose of resulting visualizations (in accordance with the context, etc.) and a target group of users. We are concerned with questions such as how a specific map or its part is perceived, interpreted by the user, and how it influences his/her behavior. The second domain already includes the way of manipulation and interaction with cartographic products, or generally with geographic information systems. We are interested in the way in which the user works with a geographic information system, what functions and control tools are used (including analysis and functionality evaluation of the given application). At this moment, we would like to point out that the main topic of this work is the first area which, as we mentioned, means the way that it is possible to measure reading performances and working with the actual cartographic visualization. Monitoring visible behavior when working with only the map is not satisfactory, therefore, the major effort is to understand and explain the cognitive processes that are involved in this activity.

5.1. Types of tasks on the map

When working with a map, various types of tasks may be distinguished, from rather simple ones to highly complex issues. An example of an elementary task at one end of the imaginary continuum is verification of the presence of an object or phenomenon on the map or displayed area. For example, it may be locating a petrol station in the final destination. A more difficult task is to locate a given phenomenon and determine its other attributes, such as the rate of unemployment in the region. On the other end of the imaginary continuum, maps are used as a primary source of information for creative analysis or synthesis. Such a case might be using a map for creating original theories or work with old maps, where data on the map serves to interpret historical events and phenomena. An example of this would be forestry maps which are used for defining borders of property owners. Roček (2008) claims that "unlike today's arrangement of our landscape, where we can see the separation of forests from open fields, in the past borders between forests, fields, and pastures used to be unstable in some cases. At that time, it might have been difficult for village and city dwellers to answer the question where the forest starts and ends."

Ogao (2002) tries to find a psychological level of description for various types of tasks and activities with the map and applies the Neisser's (1967) definition of cognition, who defines this term as all the processes, which transform, reduce, process, store, recall, and use sensory input. According to Ogao (2002), sensory inputs referring to maps can be explained with the above mentioned processes; in cartography, they are defined in relation to localization and attributes of phenomena in the space. Medyckyj-Scott & Board (1991) state that research of cognition in cartography focuses on active processing of the map by the individual. Therefore, focusing specifically on the ways that cognitive structures and processes, such as memory, thinking, imagination, motivation, and attention are included into this process. Lobben (2004) claims that map makers' attention shifted from questions of physical (external) representations processing to questions of efficiency/effectiveness, with which maps are used. Lobben (2004) further claims that the issue of the way that the information is interpreted on the map is currently understood as an integral component of communication process. Cognitive processing is emphasized as well as cartographers' attention is focused on abilities and skills of the user.

Kubíček (2012) states that cartographic literature offers multiple taxonomy of task types concerning maps and outlines a conception of Wehrend & Lewis (1990), who offer one of the most extensive, taxonomy of tasks on the map, regarding the number of items. From this point of view, the following categories may be distinguished (ranked according to the degree of difficulty):

- *Identify*: identification of general (visual) feature, which can distinguish individual objects.
- *Locate*: locating items of certain value and recognizing absolute or relative location. Where is it? Is on the left or right?
- *Distinguish*: recognize or tell two elements apart. This is a common discrimination of individual elementary visual elements in the map field, which should be easily distinguishable for the user (from each other, or from the underlay base).
- *Categorize*: creating specifically defined categorization or classification, for example, based on the color, size, location, and type (shape) of an object.
- *Cluster*: making groups of clusters based on the same, similar or related type of graphic quality.
- *Spatial distribution*: description of the whole spatial pattern. This task is closely related to clusters and also to location and identification, however, it is more complex by its nature. The aim of locating clusters is to detect individual groups of clusters, while spatial distribution also requests a detailed description of overall cluster organization.
- *Ranking*: requests creating of order or position with respect to object of a similar type (according to an attribute set in advance).
- *Comparison*: process of finding similarities, differences or order.
- *Association*: connecting graphical elements based on a certain relation.
- *Correlation*: creating a direct connection.

One of the approaches explaining work on the map is Amy Lobben's conception. The author observes not only partial cognitive processes but also emphasizes a strategic level of completing tasks on the map. Lobben (2004) claims that different people use different strategies to complete the same tasks on the map. The key difference between a strategy and cognitive processes is that different individuals engage the same processes in completing a task but they differ in the extent of effectiveness and abilities of their utilization. For example, individuals without a high level of visual memory do not rely on this cognitive function very much and they would rather work with direct sensory inputs from the map. Also, individuals who did not develop an ability of mental rotation will physically rotate the map while navigating. The reasons for different ways of work with the map might be found both in the structure of the brain and influence of the environment. The way that different strategies of completing cartographic tasks are presented by Amy Lobben is parallel to a psychological concept of cognitive styles, which also considers cognitive processes and also explains them on the molar level. The concept of cognitive styles, including their potential influences on perception of cartographic visualizations, is described in detail in chapter 7.

Lobben (2004) further claims that tasks realized on the maps may be divided into smaller units, and offers example tasks regarding navigation. The user chooses a global strategy, how to complete a task and also selects a process of partial phases, for example, decoding the meaning of a symbol, planning a route, self-location, rotating a picture or text on the map, etc. A task analyzed this way already offers the researcher a possibility to define anticipated elementary mental processes (in psychological terminology) and, also, it is the first step for their operationalization. In this context, Allen et al. (2006) used simple maps designed for weather forecast and examined processes of obtaining information. They examined the degree of users' knowledge concerning the given domain but they primarily focused on cognitive processes. It was assumed that general visual-spatial abilities of the individual are an important consideration in given tasks. According to Allen et al. (2006), these abilities consist of four partial abilities or processes:

- *Spatial scanning*: ability to scan large or complicated patterns quickly and accurately.
- *Flexibility of closure*: ability to detect figures disturbed by noise or put into a complicated visual context. Searching for target information which is a part of a complex pattern of other data.
- *Speed of closure*: ability to identify related figures or phenomena despite the fact that they are not complete or only their parts are observed.
- *Visual memory*: remembering a relative position of visually presented phenomena.

Prior to an experiment, it is obviously not easy to estimate what cognitive processes are engaged in the given task and what cognitive abilities are responsible for the resultant performance. The situation becomes even more complicated because a lot of intervening variables are included in completing the task. More importantly, the map itself is a very complex phenomenon, therefore, very specific stimulus material. Also, it is necessary to critically say that a lot of experiments might be and are designed in a way so that it is possible to apply available psychological tests or tasks. In other words, it is only possible to measure phenomena, where measuring instruments are available to do so. In their research, Sholl & Egeth (1982) focused on cognitive abilities, which were assumed to be of a great importance and are a prerequisite for map skills. Contrary to expectations, they found out that visual-spatial abilities and functional specialization of hemispheres were not correct predictors of map skills in the given tasks. On the contrary, a connection was proven between performance in tasks on the map and a vocabulary test and a test of mathematical abilities.

It is believed that in order to fully understand map skills and performances when working with the map, it is also suitable to examine the phenomena holistically, apart from monitoring partial processes and mechanisms. Reading the map is not only a summation and expression of partial cognitive abilities, but their dynamic organization as well as connection with executive processes are also concerned (see Švancara, 2007, 2006). Nevertheless, research of partial cognitive processes, or functions evoked when working with the map are certainly reasonable and can help to better understand the way that geographic information is graphically coded.

5.2. Structural model of solution of cartographic tasks

Based on the previously presented approaches, it is possible to create our own structural model, which would reflect important variables that influence the way of working with the map and the way of its use. Three main variables define the user's behavior when working with the map, or his/her quantitative and qualitative performance. In this context, the quality is understood as different opinions, decisions or interpretations, which users might come to, based on using the same information source, or the map. This structural model could be the first step to create a functional (computer) model, which would be able to reflect the dynamics of the phenomena as well.

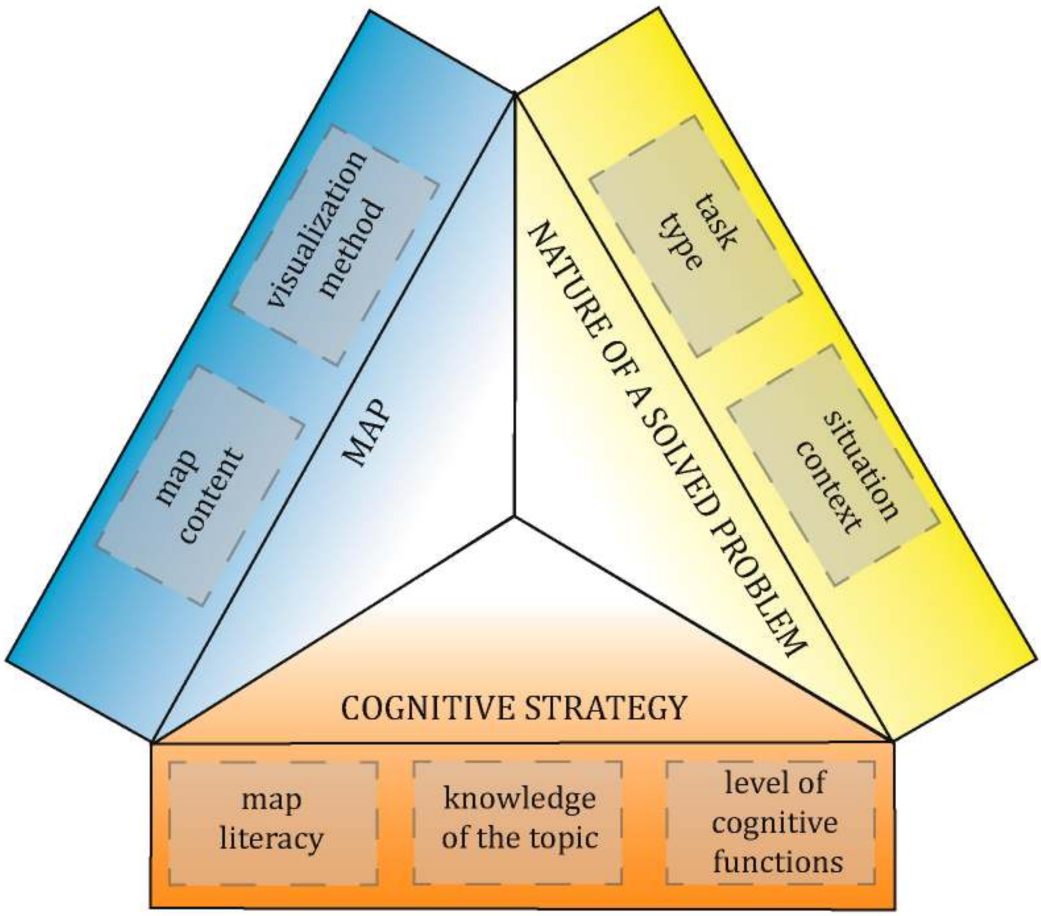


Fig. 5. Structural model of solution of map reading tasks.

The term cognitive strategy is understood as a way in which the individual chooses to solve a given problem. The individual adjusts a cognitive strategy to the nature of a problem and also to a specific form of representation of information, which is used to deal with a given problem. Thus, a cognitive strategy is not stable across various situations but may change depending on the quality of the two mentioned external variables. A cognitive strategy, or its specific expression, is defined by three relatively independent areas at the same time. First, its map literacy in terms of the level, which the individual is able to use information depicted on the map. If the map offers specific information to solve a problem situation but the individual is not able to use it, he/she must necessarily use an alternative way and change his/her strategy. Second, knowledge of the topic or problem domains also influences the selection of the strategy and the way in which to resolve the situation. If the individual is educated about the topic, then most probably he/she will choose a systematic procedure than use a strategy of finding a random solution. The level of cognitive functions and their organization define global "fluid" potential of the individual for resolving the situation. To make it easier, the model does not include any conative or emotional components, which also influence executive processes.

The nature of a solved problem is a term mainly concerned with specific types of tasks which the individual solves. A connection to cognitive strategies is obvious. To solve various types of tasks, it is naturally necessary to involve different cognitive processes, nevertheless, the individual may also choose, for example, based on his/her cognitive style, different strategies. Also, the context of the situation where the task is completed influences cognitive strategies. For instance, time pressure, which may influence the given strategy, is an example. Exactly here, we might see the direct connection to emotions. Other information sources are included in this situation context that may influence the way of solving a problem. Differences can be expected in using the map, for example, if the individual is in an environment with a lot of landmarks for navigation. This aspect is also directly connected to the quality of the map, i.e. to what extent a visual representation of phenomena adequately and accurately represents the given phenomena and enables to solve a specific type of tasks. From this point of view, for example, a road map will not be a good option for solving tasks in terms of hiking.

The last variable in the described model is the map itself. Obviously, it depends on the method of cartographic visualization and the quality of the map design. At the same time, the availability of information is also influenced by the interaction between the method of visualization and actual content of the map. Last but not least, it is important to say that different individuals might prefer various types of information representation. Thus, if the form of representation corresponds with the way of the individual's thinking, his/her cognitive style, we might expect optimal performance. These inter-individual differences, including all other relevant psychological aspects, are discussed further in the following chapters.

6. Psychological aspects of working with the map

In recent years, research in cartography has also been focusing on the study of cognitive processes when reading maps (see the mentioned agenda of the ICA Commission on Cognitive Visualization). As previously mentioned, when creating a map, the purpose should not only be considered, but also the user's personality and his/her cognitive skills (see the structural model on fig. 5). The following chapters will outline the influence of the user's characteristic features on perceiving the map in detail. This knowledge could, in relation to other extraneous influence, draw some relatively important conclusions for cartographic production.

The issue of inter-individual differences of individuals (or various groups), which can also quite significantly influence their work with the map, has been reflected on in works of many authors before. In psychology, inter-individual variability is dealt with not only by experts in psychology of personality, but also in other fields of psychology. Research in differences (in terms of expertise, cultural differences, sex, age or visual limitations) is an important consideration to understand general principles of peoples' experiencing, cognition, and behavior (see, for example, Cole, 2003; Kitayama et al., 2003). In various situations, users' opinions and sequentially their decision making process are influenced by the quality of a map in many cases. For this reason, a continual improvement of all of the parts of map creation and developing new methods, which might use knowledge from other fields, is very important. A huge contribution in recent years seems to be a connection of traditional cartographic methods with methods and approaches from psychology. As it is apparent from the previous chapter, it is essential to consider cartography as an interdisciplinary science and that is why conclusions and methods from other areas of human cognition must be taken into account. This chapter will explain in detail the potential relevant psychological aspects, which join the process of cartographic communication, the influence of individual users' cognitive style will be discussed in chapter 7.

During all of the phases of creating cartographic works, as well as when evaluating their usability, it is very important to also consider various psychological specifics, which might influence perception of information on the map in some respect. Each user of the map is an independent personality with rather various character features which influence reading the map as well. For that matter, this phenomenon is also possible to deduce from existing models of cartographic communication (see Koláčný, 1977; MacEachren, 2004). Basic components of information transfer from the source to the receiver of this information were defined in information theory. According to Zbořil (2010), these components include the source of information itself, an encoder, transmitter, communication channel, receiver, decoder, and a final target of information transfer. In the process of decoding information, it is possible to see the influence of inter-individual variability of users, which might cause a different final form of such information, even with the same source (Robinson & Petchenik, 1977).

Individual aspects influencing the above mentioned decoding of information are discussed in detail by Koláčný (1977) in his theory of cartographic communication. In the described theory, the map is basically understood as a communication channel while reading the map itself might bring some noise and an information filter, both by the cartographer and certainly by the user – the reader of the map. The overall understanding of the information depicted on the map by the cartographer is then transformed to an idea of the user. This idea is, however, influenced both by knowledge or experience on one hand and by user's abilities (perceptual and cognitive) on the other hand. Such influenced and changed mental model of the user is different from the reality, which was intended to be described by the cartographer. It is important to say that even cartographer's "reality" is different from the objective reality, which is caused by similar aspects as on the user's part.

6.1. Perception of visual information

Pictorial representation might be considered the oldest possible way of transferring information. Even today, this way of communication is an integral part of all kinds of media and we encounter it in all aspects of everyday life. Similarly, one of the oldest cartographic communications can be traced back to the period of 25,000 years BC (Drápela et al., 2004). Also, it is obvious that the potential of various cartographic products of modern contemporary cartography is increasing (especially in relation to the potential of its technology). One aspect is, however, common to all these representations, and that is the way that it is perceived by the user. As suggested in the previous chapter, some external representations describing the same objective reality transfer rather different or opposing information to the individual.

According to the Oxford English Dictionary, perception may be defined as a process of awareness and understanding the surrounding environment through processing sensual information. Therefore, perception includes a primary reaction to stimulus, especially its finding, and understanding its optical properties or a relative relation to ambient subjects. Understanding this process is essential for studying, reading and perceiving maps. It is important to say that studying perception should also include a whole range of other psychological processes, which influence the result in a certain way (Sternberg, 2002). To make the picture complete, it should be noted that by perception we understand visual perception, in this case.

Human senses, visual sense included, used to be considered passive sensors for a long time, however, proper study of illusions and optical illusions has proven that the brain tries to make sense of every received information, also including information, which does not depict the outside world objectively. This phenomenon bears its consequences to cartography. There might be a common optical phenomenon when reading the map which may lead to misinterpretation (Štěrba et al., 2011). Various ways of the cartographic visualization thus may cause uneven visual perception, which might lead to wrongly acquired knowledge. MacEachren (2004) claims that in cartography it is also important to focus on understanding the way maps are perceived, not only on the cartographic creation itself. Therefore, it is essential to consider causes, which might produce similar interpretations.

6.2. Locating and recognizing objects

In actual fact, a map can be considered a very complex pictorial representation that consists of many elementary parts (individual map symbols), which are assigned a meaning in the map legend (see Thorndyke & Stasz, 1979; Edler et al. 2014). Legibility and comprehensibility of any representation is given by the individual's ability (map user) to locate, recognize, and distinguish from the environment and interpret correctly (in an analogical way, with which we try to understand a speaker's speech in case of auditory perception). Therefore, in some cases, the cartographer's effort might also be conscious emphasizing of certain features on the map in order to fulfil the purpose of the map. Locating and resultant recognizing individual elements is influenced by various perceptual and cognitive processes, which may also be applied to reading the map and may be explained for what reasons its legibility and comprehensibility sometimes decrease.

During visual search, a given environment (map field) is searched in order to find certain symbols whose location is unknown (Sternberg, 2002). An important consideration of this process is the presence of other items in the given area (or map field), which make locating more difficult and decrease overall legibility. These items are also, besides the searched ones, so-called distractors, i.e., such entities that distract our attention by being very similar to searched items – attractors. When searching the map field, all of the items with similar optical properties and thus comprised of similar map morphemes, will be distractors. In other words, one can say that, for example, when locating a point symbol, a majority of other semantically different point symbols will also be distractors because they tend to be of the similar size. It is obvious, however, that the same colorization or texture will proportionally increase the level of the distraction. This fact is proven in their research by Wolfe & Horowitz (2004), Connor et al. (2004), Rauschenberger & Yantis (2006) or Garlandini & Fabrikant (2009) who further specify that the most important graphic variables attracting our attention are mainly the size, color (brightness and saturation included), orientation, movement (e.g., in dynamic maps), shape or stereoscopic depth (created, for example, by thermal color contrast; see Bláha & Štěrba, 2014). Most of these variables are considered to be features of the cartographic symbol, which means that it is very important to precisely choose morphographic operations when creating a symbol set in order to minimize the possibility of confusing individual symbols, at least among different semantic groups.

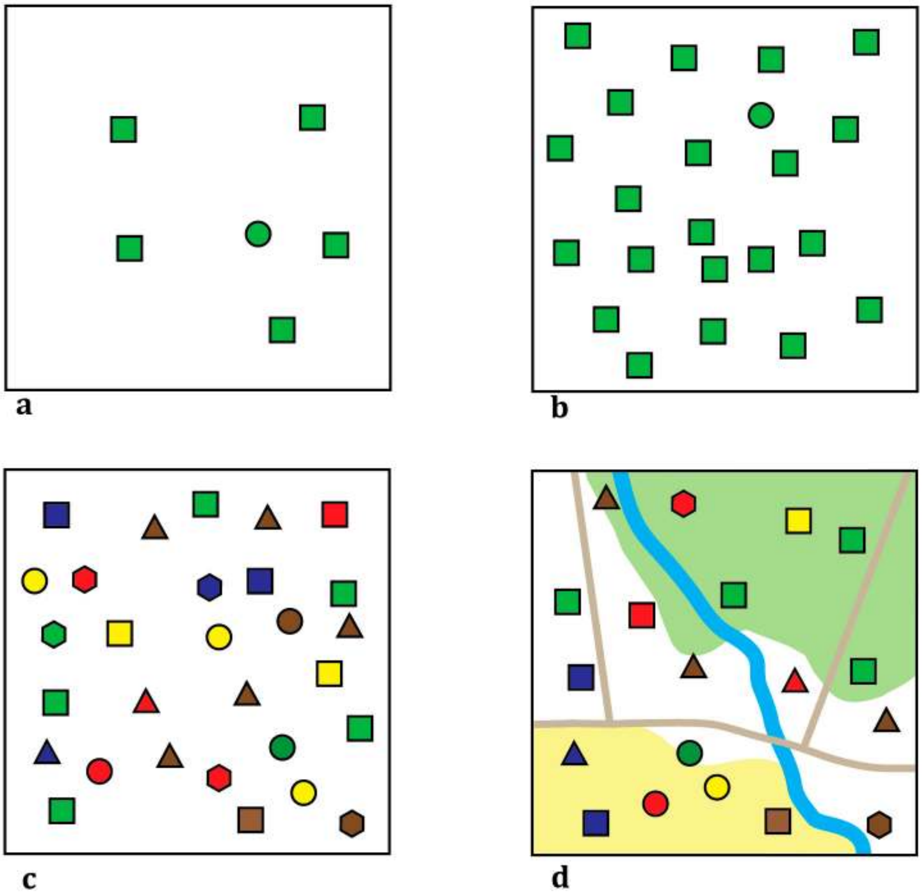


Fig. 6. Depiction of the influence of various diverting stimuli when locating an attractor (green circle): (a), (b) – frequency of depiction of individual distractors decreases legibility and lengthens the process of locating an attractor; (c), (d) – frequency and variability of other items (with different optical properties from an attractor) increases graphical space-filling and decreases legibility (e.g., meaning all the other symbols in the map field).

As Sternberg (2002) further points out, the efficiency of locating a symbol is dependent on the frequency of distractor depiction. In this context, one may say that the more distractors present in the map field, the worse efficiency of locating desirable symbols (Duncan & Humhreys, 1989). This statement generally applies to other items, which might not be considered distractors (they greatly differ in their features from a target object) but given the increase of overall graphical space-filling of monitored field, their influence on efficiency of locating is apparent (see fig. 6). This effect might eventually show not only in higher response times but certainly also in the error rate, thus in very important aspects determining overall usability of the given map.

The process of locating a given object depends on the overall context of the ambient space, to a certain degree, which might disrupt perceptual constancy when monitoring. In certain points in the map field, our adaptive mechanisms might wrongly interpret some effects, which originated from optical illusions (Eysenck & Keane, 2008). Their implications might be some mistakes made when perceiving depicted information, for example, based on the confusion of some map symbols). These influences mainly include various illusions of color contrasts resulting from uneven perceiving of different color shades or distorting the size of the item depending on the size of the ambient objects (see fig. 7).

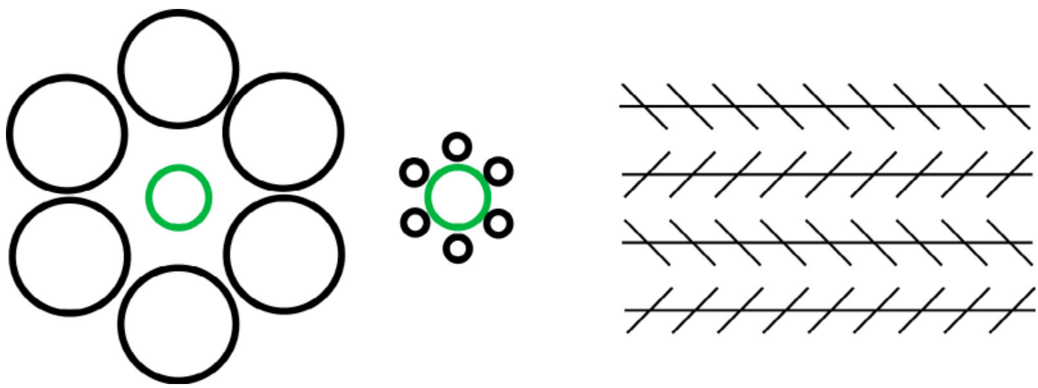


Fig. 7. Examples of optical illusions influencing perceptual constancy when locating and recognizing objects: in the picture on the left, the size of the green circles appears relatively different depending on the ambient objects – so-called Titchener's circles; on the right picture, four parallels make seemingly divergent impression, under the influence of shorter crossed out lines, which distort the final impression – so-called Zöllner's illusion (adjusted according to Fujito, 2008).

Apart from the above mentioned regularities, Eysenck & Keane (2008) state a few more main processes which participate on the recognition of objects. One of the main phenomena is overlapping, it means a decision where an object starts and where it ends. When looking at the map, it is important to prevent the confusion of different map symbols caused by their incorrect differentiation or blending, which might be prevented by using correct cartographic means of expression and visualization methods. Another factor influencing recognizing objects is an angle and distance of observing a given object. It is obvious that a certain distance is the most effective for observing, and when drawing near or distancing the object, its perception will be gradually decreased which also applies to the angle, by analogy. In this regard, Eysenck & Keane (2008) claim that a phenomenon of constancy, which represents perception of the same size and shape of objects where the distance and angle of monitoring change (i.e., even though the picture on the retina goes through changes), is perceived as the same observed object. All of the facts above mean that when perceiving information from the map, the distance and angle, which we use when looking at the map, are equally important. The observation angle of the map should be perpendicular, or at least approximate, to the map. Apparently, when using digital or interactive maps shown on the display, the ability to distinguish individual items is reduced because of the possible reflection of the ambient light. The distance when monitoring the map is also dependent on its format (analogue map vs. digital map and their size), the nature of the solved task (the size of the observed spatial context) or visual abilities of the individual. The factor of the distance and angle of observing the map implies utilization of cartographic processes when creating map visualizations. This factor might be minimized by adjusting the size and color of specific map symbols.

When perceiving information on the map, it is possible to identify all of the processes mentioned above, which have their share on the final perception. The user performs a certain combination of locating and recognizing graphical symbols. One of the cartographer's tasks is to additionally distinguish all of the relevant graphic items on the map. In connection with the following text, it must be emphasized that an integral part of the whole process of communicating the visual information is certainly the user him/herself. Therefore, possible differences among users (or defined relevant groups of users) must be taken into account as well, and a given cartographic visualization must be adjusted as much as possible to these needs (or parameters).

7. Inter-individual differences in visual perception

Observed processes of perception and cognition of visual information (including cartographic visualizations) do not proceed the same way with all individuals. Cognitive sciences consider various parameters which might potentially influence perception and processing visual information. In their research, cartographers frequently consider and explore factors such as, for example, age, sex, education, expertise, cultural background, etc. (for more, see Slocum et al., 2001). However, they tend not to notice individual differences in cognitive abilities of individuals. In cognitive psychology, this phenomenon is examined in the long term thus the following parts of the text are focused on using already existing concepts in cartographic research. First, this subchapter will deal in detail with basis of inter-individual differences, which will be later worked on.

7.1. Cognitive style

One of the possible ways reflecting individuals' inter-individual differences in perception is the concept of cognitive style, which represents a typical individual's approach to learning and solving a given problem. The concept of cognitive styles focuses on differences in the way in which people process information and what form of information representation they prefer. The research of cognitive styles has its origins in the study of perception and personality (Isaksen & Puccio, 2008). Cognitive style describes the way that the individual thinks and perceives information or his/her preferable approach to using this information when solving a problem. Gardner et al. (1959, in Biggs 2001) defines cognitive style as a developmentally stabilized form of cognitive control, which is invariant in various situations. He develops this point of view further and claims that rooted cognitive style is adapted or used for solving a whole range of various tasks, such as school tasks. Cognitive style is essentially a kind of typology and represents the way cognitive functions are typically organized with various groups of individuals. Thus, cognitive style refers to cognitive processes and to the personality of the individual on his/her general level of expression as well.

The concept of cognitive style describes and explains inter-individual differences in perception and thinking of individuals even through their development stages. Witkin et al. (1967) have examined the stability of cognitive style from the development point of view and have come to the conclusion that there was no change of cognitive style (while examining field dependence/independence of individuals), with individuals at the age of 17-24; therefore, it might be considered an individually relatively stable way of functioning, which individuals show in perceptual abilities. Cognitive style describes a way in which people think, receive information or preferable ways to solve problems as well.

The concept of cognitive style (or the style of thinking) explains differences in how individual people process information (how people think, perceive and remember) and what form of information presentation people prefer. Therefore, cognitive style is a typology and represents a typical way of organization of cognitive functions with a group of individuals. This typology may be used in cartography, at some point, mainly in creating alternative methods of visualizations in order to meet the needs of users with various cognitive styles (see Štěrba et al., 2011; Konečný et al., 2011). When orienting in the environment, individuals mostly use only some of the clues from a large amount of clues available, and one can expect that the ways of their locating might be different according to their typical cognitive dispositions or their cognitive styles. A similar effect may be expected when working with the map, which is an objective representation of geographical environment and mentioned cognitive processes are employed when using the map.

Rayner & Riding (2000, 1997) emphasized that cognitive style needs to be perceived as a psychological construct, which we use to describe individual differences in psychological structures of individuals, or in monitored behavior associated with their typical way of functioning. Kozhevnikov (2007) claims that G. S. Klein was the first to define cognitive style as regularities in the way of adapting to the external world, which regulate the individual's cognitive processes (in Klein, 1951). Kozhevnikov (2007) further believes that cognitive style represents heuristics, which the individual uses when processing information about his/her environment and that the heuristics might be detected both on elementary and automated, and on complex and conscious levels of perception. It means that the individual, who is, for example, analytically oriented (as opposed to the globally oriented individual) will automatically pay attention to details on a displayed picture. At the same time, when consciously solving a problem situation, he/she will rather focus on partial aspects and relations and will make his/her decision based on them. Kozhevnikov (2007) also claims that cognitive style has an adaptive function as well.

A difference between cognitive style and cognitive abilities, as distinguished by some authors (Grigorenko & Sternberg, 1997; McKeena, 1983, and others), should be noted. Cognitive style might be understood as a way that partial cognitive abilities are related and organized. On the contrary, cognitive abilities refer to the amount of certain skills and their potential that the individual has; for example, memory or ability to think abstractly. From this point of view, cognitive style does not explain differences in performance as such but only determines the way that the task was solved. In other words, individuals with similar cognitive abilities will hypothetically solve the given task equally efficiently but in a different way. McKeena (1983) states that the Wittkin's concept of the field dependence/independence should not be considered cognitive style because the test scores strongly correlate with scores in a standardized intelligence test. Similarly, other authors (Sternberger & Grigorenko, 1997; Ridding & Cheema, 1991) consider the field dependence/independence one of the aspects of intelligence. In his approach, Pask (1976) talks about cognitive strategy (instead of cognitive style) which implies that the individual might influence and choose a way to solve a problem based on the nature of the problem. A similar assumption can also be found in K. R. Hammond's concept, which states that the nature of the solved problem and context of the situation may evoke different strategies of its processing (Kostroň, 1997). We believe that the individual might really adjust the way of solving the problem to the nature of the problematic situation to a certain degree. However, we also believe that the user is biologically or by his/her own previous experience determined to prefer and use a certain way of solution, which is typical for him/her. If the nature of task corresponds to a typical cognitive strategy of the individual, or his/her cognitive style, the higher performance might be expected in the given task.

Cognitive style is not a clearly defined construct nor in its content; however, in addition, there are differences in its application to different levels of personality system. Kozhevnikov (2007) states that the original research on cognitive style focused on exploring individual differences in perception and basal cognitive processes. However, the focus was subsequently on higher hierarchical units and the concept of cognitive style has been used to explain the inter-individual differences, for example, in problem solving, decision making, learning or explaining causes of life events. Thus, there are concepts of decision making styles, cognitive styles, styles of thinking and learning. Since this work, or the research part, has been solely focused on the level of cognitive processing of visual representations and their interpretation, the issue of using concepts of cognitive styles, for example, in social psychology, is beyond the center of our attention. Nevertheless, we critically view a possibility of straightforward generalization and interpretation of some of the performance test results on the hierarchically higher level of the individual's personality.

7.2. Characteristics of cognitive styles

According to Kozhevnikov (2007) and Riding & Cheema (1991) who have carried out an analysis of existing concepts of cognitive style, one may assume that these concepts include and compare two rather general dimensions. On one hand, there is a verbal-image dimension finding out the individual's preference to process rather verbal or image-coded information. According to Sandler-Smith (2001) verbalizers prefer and store information in the form of word associations. On the other hand, imagers prefer information in the form of mental images. The verbal-image dimension reflects the individual tendency to a certain type of representation in the memory in the course of thinking. The verbalizer perceives information which is being read, heard or seen as words or word associations. On the other hand, the imager, when reading, listening or observing perception, considers information "a coherent, spontaneous mental image" (Riding & Sadler-Smith, 1997). However, Blazhenkova & Kozhevnikov (2009) emphasize that in the case of imagers, we can further distinguish two subtypes. Thus, they distinguish object imagery, spatial imagery, and verbal dimension (see fig. 8). Object imagery orientation supposes a preference to create vibrant, specific, and detailed images of individual objects, on the contrary, spatial imagery preference uses an image to schematically represent spatial relations among objects. Blazhenkova & Kozhevnikov (2009) question the traditional concept of visual-verbal cognitive style as one bipolar-dimension and they suggest understanding this cognitive style as three-dimensional.

The second group of these approaches distinguishes the individual's orientation in terms of analytical-holistic dimension. By this, we mean orientation to details or a global context of the image field (more, for example, Allison & Hayes, 1996). Thus, it corresponds to preferences in the way of structuring information (detail orientation, or creating larger units or images). The individual with global cognitive style, corresponding to the term itself, tends to observe given situations in a more complex way, he/she considers a broader perspective and takes the context of the situation into account. On the contrary, the analytically oriented individual perceives a situation as a set of partial elements and often focuses only on one or two at a time, while not considering the rest of them (Rezaei & Katz, 2004). The overall analytical dimension mainly deals with organization and arranging information. This dimension is primarily based on the study of inter-cultural differences in visual perception. For example, Ji et al. (2000) realized an experiment where performances among populations of Asians and Americans in so-called "Rod and Frame test" (RFT) were compared. Witkin used this test to measure his concept of cognitive style, which he called field dependence or independence. Field dependence (Witkin & Goodenough, 1981) is defined as a general dimension including individual differences no matter how easy or difficult it is for the individual to separate an item from an organized field or to exclude a hidden item from the context. Berry (1991) claims that individuals that are relatively independent on the visual context are, in comparison to individuals depended in the field, able to "break" or deconstruct an organized field. They focus on the relevant content within the context and distinguish a signal from noise. Ng & Houston (2009) further believe that individuals independent in the field are more independent and self-aware and when processing information, they rely on their own inner frame of reference. Ji et al. (2000) have concluded that Americans, in comparison to Asians, made fewer mistakes in Rod and Frame test (RFT), which indicates that they are generally less dependent in the field. Kitayama et al. (2003) emphasizes that these findings are even more remarkable because RFT does not have any obvious overlaps to social areas and thus confirms that cultural experience might influence cognitive processes even out of the context of a social situation.

Based on the mentioned facts, one might assume that global processing of input does not mean an ability to grasp more information at once but find a regularity in the stimulus material on a more general level, thus emphasizing partial attributes of lower structures and integrating them into a higher unit based on certain rules. For this reason, one cannot perceive a concept of global cognitive style only as a tendency to perceive phenomena on a more general level or higher units but this concept covers partial cognitive processes and dispositions. These may include greater flexibility of perception and the ability to take mental leaps, the ability of processing input information loosely, the ability to deconstruct patterns and understand new reconstruction, parallel processing of information, "intentional" ignoring of attributes of partial elements, etc. Some of the processes might be stressed by researchers and they might base their concepts of cognitive styles on them.

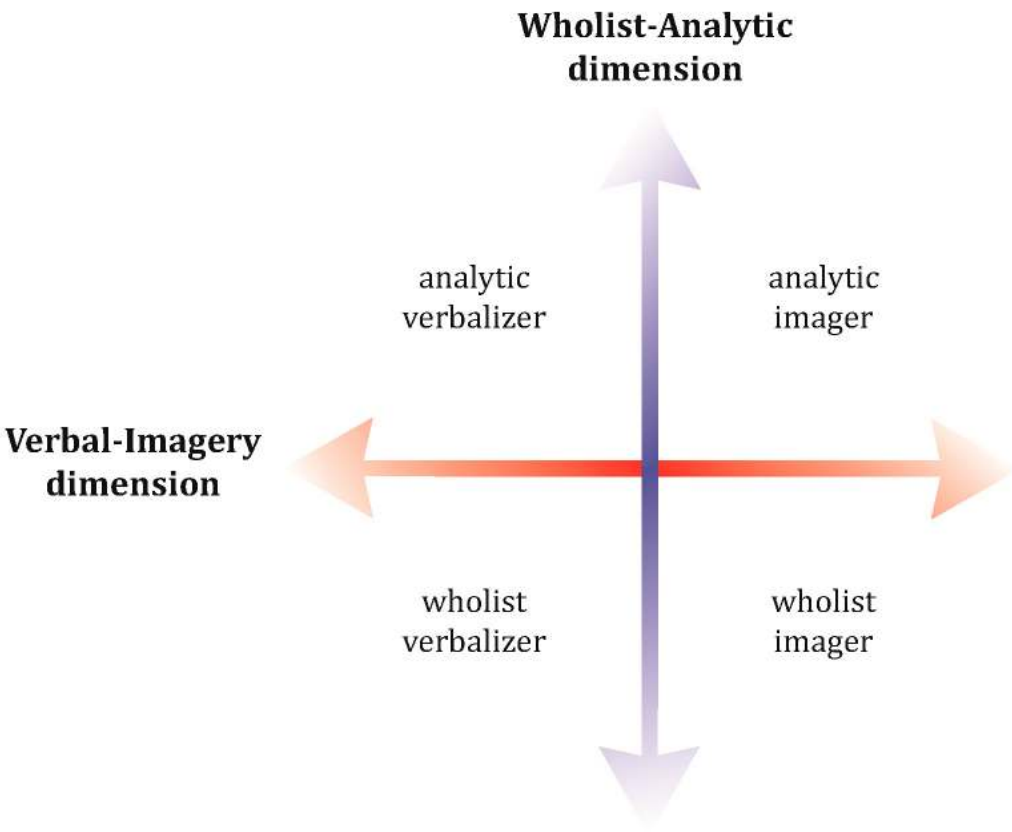


Fig. 8. Scheme of main dimensions of cognitive styles (adjusted according to Riding & Sadler-Smith, 1997).

In addition, we state a fact that some authors then emphasize a wide range of other qualities of cognitive processes and offer their own standpoints about how to grasp a concept of cognitive styles. For example, Blazhenkova & Kozhevnikov (2009) even distinguish within the traditional approach in the verbal-visual dimension between object imagers and spatial imagers. Brigham et al. (2007) claim that cognitive style is a pervasive bipolar dimension which is stable in time and is possible to examine with psycho-metric methods. They further claim that cognitive style describes differences in cognitive processes rather than their absolute level. It must be said that there is not only one concept of cognitive style, but a whole range of more or less different approaches which might partially overlap. As an example, Rayner's (2000) concept of personality, such as levellers or sharpeners, is provided. While levellers tend to assimilate new events or phenomena in order to correspond with previously stored events or phenomena, sharpeners stress the differences of new phenomena and store them in their memory discretely from existing ones. Kirton (1989) comes up with a concept of personality of adapters or innovators. Pask (1976) distinguishes holistic or serialistic cognitive style, and, for example, Kagan (1965, in Lucas-Stannard, 2003) distinguishes reflective and impulsive cognitive style.

7.3. Cognitive style in cartographic research

Cognitive style might be reflected in the individual's behavior within the social context, however, we are mainly interested in the description, which is directly related to the way of processing primary sensory inputs and differences in organization of other mental operations and speeches in the performance area. Hence, we are interested in expressions of cognitive style in relation to the use of the map, when completing tasks on the map. We are interested in differences in perception, understanding and interpretation of cartographically communicated information. We generally focus on how the individual's cognitive style influences his/her performance with the map. The above mentioned concepts are considered to be a suitable frame, where we can examine the issue of perceiving the space and maps in perspective of inter-individual differences. Therefore, the following parts deal with the mentioned concepts and are related directly to the practical application of this work. The issue of cognitive style might also be successfully applied to crisis management, while individual tendencies within the first dimension mentioned will have some influence, for example, with (self)locating tasks; results obtained from the second dimension – analytical-holistic dimension – might suggest more about dependency of the individual's cognitive style on reading the map. Especially when applying principles of context cartographic visualization, it is important to find out possible consequences of changes in the visualization of spatial data on the individual's perception.

Some of the stated characteristics (quantified with the tests listed in the following chapter) will be applied when evaluating a performance in solving general tasks on the map. A traditionally conceived verbal-image dimension is further elaborated by some authors (as mentioned in previous part), distinguishing between an "object-imagery" division and "spatial imagery" division (Blazhenkova & Kozhevnikov, 2009), which is closely related to the topic of alternative cartographic methods of visualization. Individuals who are rather object-oriented, are able to perceive and create vivid, concrete, and detailed images of individual objects (i.e., painters might be typical representatives of this cognitive style). On the other hand, spatial visualizers act more analytically and prefer more schematic image representations concentrating mainly on spatial relations among objects as well as in cognitive processing, implementing rather complex spatial transformations. A widely used questionnaire OSIQ (Object-Spatial Imagery Questionnaire) has been created to measure preferences defined in this way. In cartography, the questionnaire might be applied in testing the association value of symbol sets depending on the individual's cognitive style. In the case that given map symbols differ in characteristics like level of schematization or colors, one might expect a certain correlation between established cognitive style and performance in working with the specific symbol set. Similar research, carried out by Stěrba et al. (2011), found out that spatial visualizers need more time when solving perception tasks (locating and recognizing symbols), which are focused on brightly colored and iconic map symbols. Thus, for schematically oriented users, a symbol set composed this way might worsen the performance, possibly for the reason that it attracts more attention and lowers a continuity of processing visual information.

One of the potentially most sophisticated cognitive styles is then the field dependence/independence. The author of this concept is H. A. Witkin, who argues that dependence or independence in the field is an individual ability, which enables the user to perceive objects in image representation as independent elements (Cassidy, 2004). From this point of view, Witkin et al. (1962) distinguished between individuals who are able to break free of the spatial context of the reference image (spatially independent) and those whose perception is rather common in a global manner – individual elements are rather an integral part of the field (spatially dependent). The application of this concept in the study of reading the map is based on this idea. One may assume that spatially independent individuals will easier divert their attention between figures and background, and therefore, will obviously achieve better results in more complex tasks, which include locating more information on the map. Also, a hypothesis might be made that spatial independence will also correlate with an ability of adaptation to a change of visualization, which comes, for example, with a change of the cartographic context or transitioning to different map scale. Dependence in the map field might be assumed to some degree, for example, by a method of so-called FLT test (framed-lined test; Kitayama et al., 2003), whose results then might be interpreted by the degree of the individual's filed dependence (see further).

All of the above mentioned ways of testing cognitive style represent another aspect of evaluation of usability of cartographic visualizations enabling a more detailed view of how the given map (or cartographic symbology) is perceived and identification of potential problems for certain users (or a group of users).

8. Possibilities of testing differences between users

In psychology, there are several methods known for finding individuals' cognitive styles depending on the specific observed personal characteristics. Especially in recent years, the development of these methods is more apparent in relation to technology development, which brings the possibilities of automation of such testing and easier and more efficient evaluation of results. This chapter will briefly introduce some suitable tests for finding cognitive style of the user (according to previously described dimensions) of a cartographic experiment. All of the listed tests may be applied in cartographic research in the environment of software MUTEP and Hypothesis (see chapters 9 and 10).

8.1. Object and spatial imagery tests

Nowadays, there are a few standardized tests or test batteries available that are aimed at object and spatial imagery. For example, in their publication, Zacks & Tversky (2005) introduce a few experiments and believe that given findings support an assumption that in case of spatial imagery, there is not only one global process but various types of independent processes are involved depending on the nature of the task. The authors distinguish object-based transformations and transformations with a perspective. Besides performance tests, there are also questionnaire methods, which measure the mentioned concepts.

One of these methods is a questionnaire OSIQ (Blazhenkova et al., 2006) containing performance tasks focused on the object and spatial dimension. The whole method is based on the standardized questionnaire, which consists of 30 questions using suitably defined wording to find out preferences of the test subject within the context of the defined spatial range, or spatial focus (Kozhevnikov et al., 2006). Vidláková (2007) claims that the original OSIQ test is composed of a range of object imagery and range of spatial imagery. The whole questionnaire comprises of 30 questions, which are divided into two parts – 15 for each range. The questions are formed in statements in the first person singular, evaluated on the scale of five points (from strongly disagree – 1 to strongly agree – 5) by the respondent.

8.2. Tests of global-analytical dimension of cognitive style

Also, in the case of global-analytical cognitive style, there are more tests judging the given construct. For example, the Rorschach's test pays close attention to the way the test subject deals with the stimulus material. Overall and detail orientation is monitored. However, one of the most known tasks focusing on measuring the global-analytical dimension, are the so-called hierarchical Navon figures. In his work, Navon (1977) used results of experiments with this stimulus material in order to support the theory of global precedence. The original Navon's research battery consisted of three types of figures: consistent, neutral, and conflict figures. Test subjects were asked to determine large, global figure or small, local figure (see figure 9). Nowadays, there are more variations of the original Navon's hierarchical tests differing, for example, in the way of administration. Peterson & Deary (2006) have examined performances of test subjects in two tests of global-analytical cognitive style, reaching the conclusion that the items of both tests (Wholistic Analytic Inspection Time "WA-IT" and Extended Cognitive Styles Analysis-Wholistic–Analytic extended "CSA-WA") dependably determined the individual of a different type. However, at the same time, the results pointed out that the performances of both tests do not mutually correlate. Peterson & Deary (2006) claim that WA-IT is composed of relatively simple tasks focusing on discrimination and information processing already proceeds the elementary level of perception. Extended CSA-WA comprises of rather complex types of tasks or stimuli material. Ehrman & Leaver (2003) assume that tests focusing on surveying the global-analytical style might be focused on a different level of cognitive processes (e.g., detail analysis, attention paid to the context, etc.) and that might be the reason for the low level of their mutual correlation.

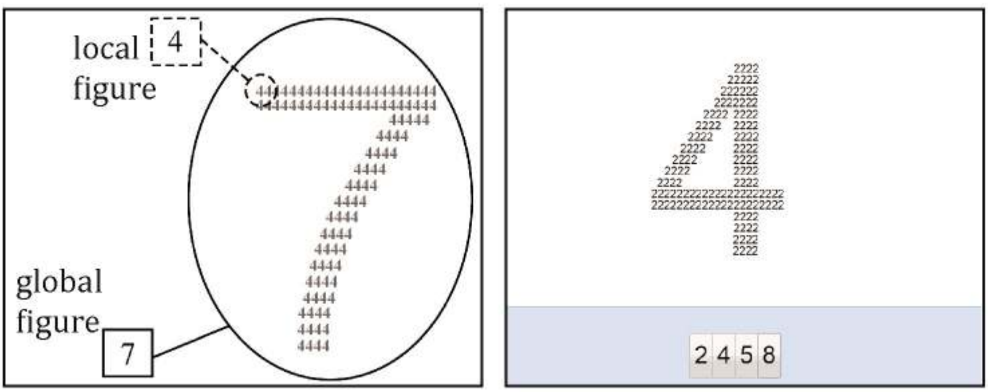


Fig. 9. The principle of the Navon's test – participants are asked to determine global or local figure (on the left) and an example of a slide implemented in Hypothesis.

Another method used to measure dependence in the field is also a so-called test of hidden figures, sometimes briefly labeled with an abbreviation EFT (Embedded Figure Test; see Witkin et al., 1962). This test is based on locating requested hidden figures on a relatively complicated field in the shortest time possible. Individuals reaching better results in this test might be, based on this, considered spatially independent because they can separate given objects from the ambient disturbing context.

Dependence on the spatial context might also be monitored by a method of the so-called FLT test (Kitayama et al., 2003). In the course of the whole test, the test subject is presented with a model always containing a line, whose length changes in various tasks. This line is put into a random geometric figure representing the background of the whole image field in this case. The test subject is then asked to draw a line according to a given parameter: either a line of the exact same length, as in the model, is requested or a line in the relatively same proportion to the size of the figure, which was observed in the model. Thus, there are two types of tasks alternated in the test: an absolute and relative estimate of the length of the line (see fig. 10). Results of this test might be then interpreted with the degree of the individual's dependence in the field. In this case, interpretation of the results will be based on the error rate in both types of tasks in the way that notably higher error rate in tasks requiring the absolute estimate of the line, the individual will be rather dependent in the field (i.e. he/she perceives the whole spatial context more). On the contrary, if higher error rate in relative tasks is observed, such individuals might be considered independent in the field. This result might be interpreted the same way; therefore, map users with such cognitive style will be more successful when solving more difficult tasks requiring frequent attention and switching between a figure and background.

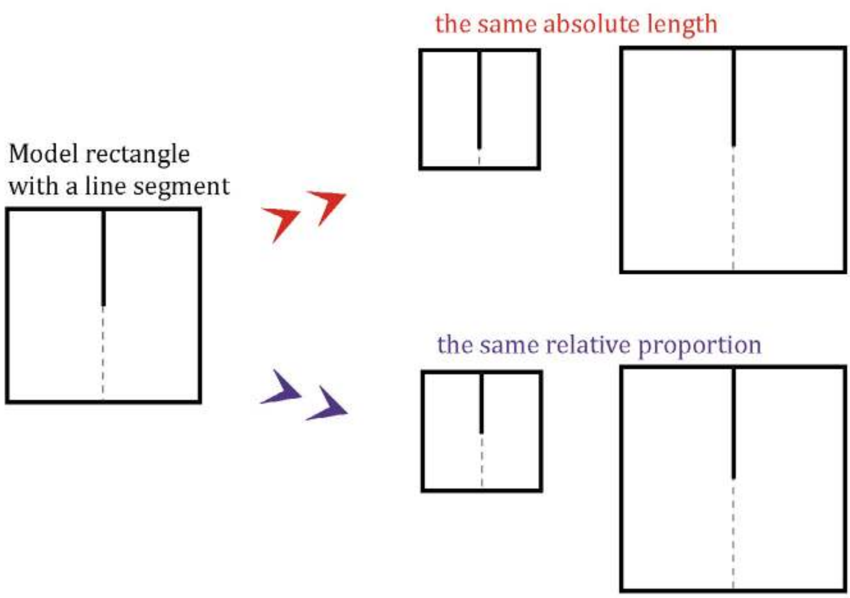


Fig. 10. The principle of the FLT test; a line of requested length is marked in the figure according to the model: the same absolute length (upper part of the picture), or in the same proportion to the given figure (bottom part of the picture); a deviation from the correct solution is evaluated in both cases.

9. Research software Hypothesis

For the purposes of experimental research and evaluation of cartographic works by objective methods, a design of new research software MUTEP (multi-variant testing program; see Konečný et al., 2011) was designed by a team of authors (Č. Šašinka, Z. Stachoň, and P. Kubíček) within the project "Dynamic geovisualization in crisis management". This concept was later realized in close cooperation with an external programmer, Kamil Morong. The software MUTEP was successfully used for research purposes (for example, Stachoň et al., 2013 or Štěrba et al., 2015) but after some time, its limitations were obvious, not allowing the sufficient development in the future.

After ending the above mentioned project, the next step was to invent a design of a new platform so that it would be possible to develop the software progressively in many ways in the future. This concept was collaboratively designed by Kamil Morong and Čeněk Šašinka based on the experience from the previous version. The platform was then further developed under the name SW Hypothesis in collaboration with the Department of Psychology at Masaryk University (Center for Experimental Psychology and Cognitive Sciences) and the Department of Geography at the Faculty of Science at Masaryk University (Laboratory on Geoinformatics and Cartography) for the purposes of postdoctoral projects of Čeněk Šašinka (project "Interpretation of graphical representation of information and maps evaluation from the user's perspective and his/her personality characteristics") and Zbyněk Štěrba (project "Evaluation of digital cartographic products for crisis management from the perspective of users"). The architecture of the new platform, Hypothesis, allows computer adaptive testing, expanding the functionality through the additional external modules, precise exposition of the stimuli material in dozens of milliseconds with a specialized type of component, potential native connection with external devices such as the eye-tracking system, as well as the use as a multiplayer platform, among others.

The main objective was to examine work with electronic maps or related cognitive processes, such as visual perception, decision-making, planning, etc. Since the objective was always to keep examining new maps and completely different types of operations, the maximum emphasis was put on variability of the software. It means that the researcher is able to change the content effectively (various map layers etc.) and allow and combine necessary functions, allowing the examination of various types of operations or cognitive processes.

SW Hypothesis is installed on the server and the preparation of research battery of tests and test administration itself are processed online. The administrator's (researcher) access is protected by a password, as well as individually created test batteries are accessible through the authorization of the particular user (certainly, it is possible to make them freely accessible on the web page of the application). The main philosophy behind this software is to allow researchers, not only from the field of cartography and GI, UX developers and those interested in graphic products and interface testing, to precisely monitor users working with the given product. Carrying out the research with the software Hypothesis has considerable potential for preparing not only original research designs but also, in our opinion, it is an important step forward in the way of publishing and presenting scientific findings. Principally, the researcher is free to publish both results and his/her own research equipment, or the test itself. The professional public therefore gain a possibility to directly control the methodological quality of the given research, as well as expand the database of experiment results on other subjects or repeat the experiment with deliberate modifications.

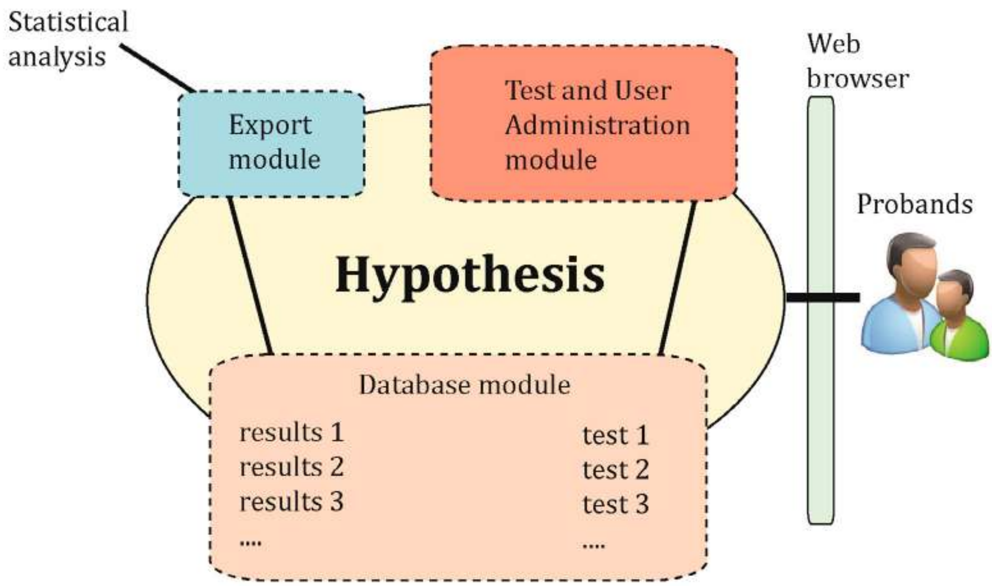


Fig. 11. The scheme of the Hypothesis environment.

Although the software is primarily designed to be used in research, it has great potential in psychodiagnostic practice. Currently, the software is used as a research tool not only in cartography but also in psychology. A typical research design used in the mentioned projects is an experiment (subsequent monitoring of two groups) in combination with a correlative study comparing a relation between the performance in a cartographic (map reading test) and psychological part of the given battery of tests (see the design scheme, fig. 12). In some cases, two or more cartographic methods of visualization in combination with a psychology test or tasks (a test of cognitive style) might be compared. Using this matrix way, it is possible to find out not only differences in efficiency and effectiveness of processing alternative cartographic methods of visualizations or products in general, but also the performance achieved in tasks on the map might be related to psychological concepts such as intelligence or cognitive style, etc. There is a possibility to effectively adapt various original psychological tests (e.g., the previously mentioned FLT test, etc.) and in some cases, the administration on this platform is much more efficient than ad-hoc creating a test battery in the electronic environment or formerly used “paper” versions of given tests, in our opinion. The previously mentioned FLT test (see fig. 10) might be given as an example, where test subjects had to mark the length of the line with a pencil in the original paper version. The version adapted to the software Hypothesis not only allows the group administration precise storage of performance figures of individual respondents (response time and estimate accuracy), but also fully automated evaluation.

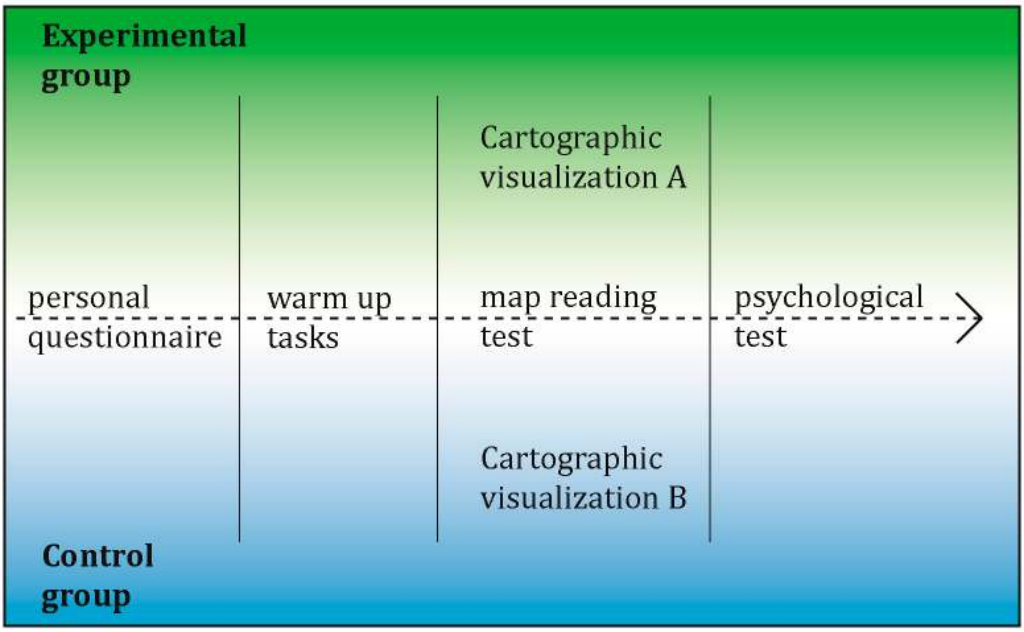


Fig. 12. Typical design of experiment combining map reading and psychological tests.

9.1. Technology

Hypothesis is a web application for preparing a test battery and subsequent processing and evaluating performance tests. The application has been developed using modern technology of the dynamic web page. The application core and user interface are built on the framework Vaadin 7; work with the database is provided by ORM Hibernate, and PostgreSQL in version 9.1 (and higher) is used as a primary database system.

The architecture of the application is three-layer; a client, server, and database. The client part is designed for communication and interaction with the user and its operation is provided by a standard system web browser (thin client) or a special browser distributed in the application package – Hypothesis Browser. This browser is based on Standard Widget Toolkit components and ensures more strict conditions for running tests. The client part communicates on the background with the server through the technology Ajax RPC (remote procedure call).

The server part is implemented as a servlet of the application server (e.g., Apache Tomcat) processing the client's requests and updating the user interface. The servlet then communicates with the database system by methods of object mapping of entities through the Hibernate library. This library allows the connection to all commonly used database systems (PostgreSQL, MySQL, MS SQL, Oracle, etc.) based on the united interface.

Individual test batteries (packages) are structurally stored in the database. The package comprises of branches which contain one or more tasks and each task contains at least one slide. The slide consists of a template and content. After starting a test, a selected package is loaded from the database to the server application and a new test is created. During the test, branches are scanned according to defined conditions which are evaluated on the basis of results of the test subject's interaction or system variables. The branches consist of a set of tasks which are linearly scanned and contained slides are gradually exposed. Every interaction of the test subjects (e.g., pressing the button, etc.) is recorded into the event log. After completing a slide, correctness of the solution is evaluated.

The task consists of a set of individual slides. These slides might be scanned in the linear or random order or, it is possible, to adjust the next slide by the user according to evaluated conditions.

The slide is comprised of individual components (buttons, images, fields, and other elements), which are divided into a template and content. The template is suitable for general parts, definition of the structure, and functionality (e.g., common for several slides) and the content is suitable for attributes of elements, which are unique for the given slide. For example, the template might define position and functionality of the buttons and other elements of the slide, while texts and descriptions are defined in the content. Both parts of the slide are written in XML format. When building the slide, both parts are put into one XML file, according to which, elements of the user interface and their responses to the interaction with the user are created.

The following parts explain how XML test configuration files are created. These are, however, often very long and complicated. That is why only shorter segments of XML are used as an example, explaining specific elements. It is possible to receive examples of complete and complex templates and contents and consult directly with the team of authors. There are prepared XML documents of templates and contents available for users.

9.2. Database structure

The test battery consists of data included in the individual tables, which make a hierarchical structure. In this structure, the highest table is *tbl_pack* (test battery), the second is *tbl_branch* (branch) table, then there is a table *tbl_task* (task) below, followed by a table *tbl_slide* (slide) and on the last level, there is a table *tbl_slide_template* (template).

An entry in the table *tbl_slide* represents a slide and contains a link to *uid* (unique identification) of the template in the table *tbl_slide_template* and proper content of the slide. An entry in the table *tbl_task* represents a task, which comprises of 1..n slides and this relation is saved in the join table *tbl_task_slide*. Using a column randomized in the table *tbl_task*, it is possible to set up the random order of the slides in the task. An entry in the table *tbl_branch* represents the branch and contains 1..n of tasks joined by the table *tbl_branch_task*. An entry in the table *tbl_pack* represents a test battery consisting of 1..n branches with relations in the join table *tbl_pack_branch*.

The course of the test, meaning the test subject's taking the test, is saved to the hierarchical structure in the tables *tbl_test* and *tbl_event* with the join table *tbl_test_event*. An entry in the table *tbl_test* represents one course of the test, an entry in *tbl_event* represents a certain event, which happened when taking the test. There are events performed by the user (e.g., pressing the button) and by the system (e.g., loading a new slide). One slide receives more events in the table *tbl_event*. An event may include specifying and additional information in XML format in the column *xml_data*.

The tables *tbl_role*, *tbl_user*, *tbl_user_permission*, *tbl_user_role*, *tbl_group*, *tbl_group_permission*, and *tbl_group_user* are for user administration and authorization. The table *tbl_slide_order* is for recording the order of slides in the test taken. It is used only when the slides are set up to be used in the random order. The table *tbl_branch_trek* is used for the definition of the program branch. The table contains an item key (user-defined key), which helps to identify the next branch (*next_branch_id*) for the given combination *branch_id* and *pack_id.* This key is then used in the *xml_data* definition for the given branch in the table *tbl_branch*. Information about the content of individual tables is in appendix 1.

10. Functionality of the software Hypothesis

As mentioned before, the Hypothesis platform allows for the creation of various test batteries, which are administrated online. The actual test battery comprises of individual slides that are defined by their content and permitted functionality. This means that each slide might contain completely different content and type of task. Due to such variability, the actual software might be considered multi-variant, allowing the administrator to create various types of tests. When the test subject takes the test, all of his/her actions (currently the movement with the mouse is not monitored) and their time (i.e., the user's response time) are recorded into the database.

An example might be the way of FLT test administration (see principle on fig. 10). At the moment, when a model is exposed (e.g., a square with a line of the certain length), the countdown starts. The test subject is then allowed to look at this model in the time limit previously set by the administrator. After this time limit, another slide is displayed where the test subject directly marks the line in of the certain length. At the moment, when the test subject starts marking the final line by drawing the polygonal line (e.g., finished by a double click), this action is recorded together with the time data. After drawing the line, the software displays another slide. The administrator can also reduce the time limit for answering, i.e., drawing the line. In the case of not completing the task in time, the slide is automatically finished (the timer function) and the test subject will automatically proceed to the next slide. All of the actions are recorded, which means that the researcher has all of the data about the test subject available. For example, whether the final line was drawn in the correct place, how accurately this line was drawn (in pixels), and saving the total time of drawing the line.

The actual version of the software has these functions, among others, which can be combined in order to create unique tasks: the timer (i.e., after the time limit, the software will end the given slide and proceed to the next task in the battery of tests), buttons selection (the test subject is asked to click one or more buttons corresponding to various options of answers), association of the button and click in the image (after clicking on the button, there is an adequate answer in the map field; further details to come on this), dialogue window, line selection, drawing the line, one-point marking (marking just one element in the given slide), multi-clicks (marking more elements in the given slide), and text field for writing, combo boxes and scales.

Individual key words, which are used to create individual test slides, are written in *italics* in the whole chapter. The whole segments of XML codes, where slides are defined, are then written in a different font, which is also highlighted in color.

10.1. Description of XML configuration files

A slide comprises of individual components, which are divided into templates and content. A template is suitable for general parts (e.g., common for several slides) and it is a kind of a frame for the whole slide. On the contrary, the content is suitable for elements that are unique for the given slide. For example, location and functions of individual buttons and other elements of the slide may be defined in the template, while texts and specific captions on the buttons in given slides, etc., are defined in the content. Both parts of the slide are described in XML format, while XML files are recommended to be created in UTF-8 coding. The heading of each file then contains a standard XML definition, coding included.

Slide template

The first XML document, which makes the slide, is a slide template. The root element of the slide template must be called *SlideTemplate* and it has a mandatory *UID* parameter, which represents an arbitrary unique identifier. To guarantee uniqueness, it is recommended that one generate an *UID* string using an internet generator of unique identifiers (for example, *http://createguid.com* or *http://www.guidgenerator.com*). The identifier of the given slide will be in XML code written in the following way:

```
<?xml version="1.0" encoding="UTF-8" ?>
<SlideTemplate UID="CA442B90-6C6B-11DE-8769-03E855D89593">
 ...
</SlideTemplate>
```

The root *SlideTemplate* element must contain the *Viewport* element, which represents the screen, then there are optional elements available:

- *Windows* – to define pop-up windows (applicable, for example, for opening the map legend, help, etc.)
- *Timers* – to define timers
- *Variables* – to define variables
- *Actions* – to define actions
- *Handlers* – to define the event operation and *OutputValue* – to define the overall result of the slide

The *Viewport* element then contains elements of individual components which make the slide, for example, *Panel*, *VerticalLayout* or *Map*, which is described in the following parts. The way that these elements are noted might be shown on the following example of the XML code:

```
<SlideTemplate UID="CA442B90-6C6B-11DE-8769-03E855D89593">
 <Viewport>
   <Panel Id="p1">
     ...
   </Panel>
   ...
 </Viewport>
 <Windows>
   <Window Id="w1">
     ...
   </Window>
   ...
 </Windows>
 <Timers>
   <Timer Id="t1">
     ...
   </Timer>
   ...
 </Timers>
 <Variables>
   <Variable Id="v1">
     ...
   </Variable>
   ...
 </Variables>
 <Actions>
   <Action Id="a1">
     ...
   </Action>
   ...
 </Actions>
 <Handlers>
   <Init>
     ...
   </Init>
 ...
 </Handlers>
 <OutputValue>
   ...
 <OutputValue>
</SlideTemplate>
```

Description of individual sections of the template slide

The component *Windows* is designed to define independent windows that might be displayed on request in the testing slide; as mentioned before, they might include help or the map legend, for example. Mutual connection of other sections *Viewport*, *Variables*, *Actions* and *OutputValue* is described in the next example, which defines the appearance and function of the button panel (the *ButtonPanel* element), from which the test subject must choose one by clicking the mouse.

Fig. 13. The example of the final appearance of the ButtonPanel (displayed from the following example).

```
<SlideTemplate UID=“CA442B90-6C6B-11DE-8769-03E855D89593“>
 <Viewport>
   ...
   <ButtonPanel Id=“selection“>
     <Properties>
       <Width Value=“60%‟ />
       <Height Value=“100%‟ />
       <ChildWidth Value=“90%‟ />
       <ChildHeight Value=“100%‟ />
     </Properties>
     <Handlers>
       <Click>
         <Expression>buttonIndex=ComponentData->getButtonIndex()</Expression>
          <Call Action=“buttonSelect“/>
       </Click>
     </Handlers>
   </ButtonPanel>
   ...
 </Viewport>
 <Variables>
   <Variable Id=“result‟ Type=“Integer‟ Value=“0‟ />
   <Variable Id=“buttonIndex‟ Type=“Integer‟ Value=“0‟ />
   <Variable Id=“rightSelection‟ Type=“Integer‟ Value=“0‟ />
 </Variables>
 <Actions>
   <Action Id=“buttonSelect“>
     <If>
       <Expression>buttonIndex==rightSelection</Expression>
       <True>
         <Expression>result=1</Expression>
```

```
      </True>
    </If>
    <Call Action="nextSlide" />
  </Action>
  <Action Id="nextSlide">
    <Expression>Navigator->next()</Expression>
  </Action>
 </Actions>
 <OutputValue>
   <Expression>result</Expression>
 </OutputValue>
</SlideTemplate>
```

Now, individual parts of the code will be analyzed in detail. The code in the *ButtonPanel* element defines the appearance of the actual button panel. The parameters *Width* and *Height* are for the whole panel, in our case, it takes 60% of the width and 100% of the height that is available. The parameters *ChildWidth* and *ChildHeight* are for the individual buttons, which take 100% of the panel height but only 90% of the panel width, while the empty space is evenly distributed among the individual buttons.

Besides the appearance, the code of the template also defines functionality in the *Handlers* element, especially using the *Click* element, which defines the reaction to the user's click. All of the buttons react to the click, but each of them represents a different value. The function *getButtonIndex ()* will thus find out which button was selected, will record its order to the *buttonIndex* variable and after that the *buttonSelect* action will be called (see the code example below).

```
<ButtonPanel Id="selection">
 <Properties>
   <Width Value="60%" />
   <Height Value="100%" />
   <ChildWidth Value="90%" />
   <ChildHeight Value="100%" />
 </Properties>
 <Handlers>
   <Click>
     <Expression>buttonIndex=ComponentData->getButtonIndex()</Expression>
     <Call Action="buttonSelect"/>
   </Click>
 </Handlers>
</ButtonPanel>
```

The following part of the template code explains how to further work with the order of the button recorded into the *buttonIndex* variable. Within the action *buttonIndex*, this value is compared to a *rightSelection* variable. It is obtained from the slide content and contains the correct answer – the button number, which should have been selected. If the two values are the same (the correct button was selected), then the *result* variable is set up to the value 1. Otherwise, the *result* variable stays on the value 0, which indicates not choosing the correct button. Originally, all of the variables are set to the value 0 (see their definitions in the *Variables* element).

Whether the *result* variable is set to 0 or 1, the action *nextSlide* is always activated. Its code will ensure the transition to the next slide. The *result* variable is set up as the result of the whole slide (in the *OutputValue* element). Therefore, after completing the slide, it will be recorded in the database, into the table *tbl_event*.

```
<Variables>
 <Variable Id="result" Type="Integer" Value="0" />
 <Variable Id="buttonIndex" Type="Integer" Value="0" />
 <Variable Id="rightSelection" Type="Integer" Value="0" />
</Variables>
<Actions>
 <Action Id="buttonSelect">
   <If>
     <Expression>buttonIndex==rightSelection</Expression>
     <True>
       <Expression>result=1</Expression>
     </True>
   </If>
   <Call Action="nextSlide" />
 </Action>
 <Action Id="nextSlide">
   <Expression>Navigator->next()</Expression>
 </Action>
</Actions>
<OutputValue>
 <Expression>result</Expression>
</OutputValue>
```

Slide content

The second XML document is the whole slide for a given task comprised of is the slide content. The root element of the slide content must analogically be called *SlideContent* and has a mandatory parameter *TemplateUID*, whose value must correspond with the parameter *UID* in the slide template. When building the slide, values of the parameters *UID* and *TemplateUID* are compared and in the case that they do not match, the slide is not created. The heading of created template thus has the following form:

```
<?xml version="1.0" encoding="UTF-8" ?>
<SlideContent TemplateUID="CA442B90-6C6B-11DE-8769-03E855D89593">
 ...
</SlideContent>
```

The root *SlideContent* element must include the *Bindings* element, which contains 0..n *Bind* elements.

```
<SlideContent TemplateUID="CA442B90-6C6B-11DE-8769-03E855D89593">
 <Bindings>
   <Bind>
     <ButtonPanel Id="selection">
       ...
     </ButtonPanel>
   </Bind>
   <Bind>
     <Panel Id="p1">
       ...
     </Panel>
   </Bind>
 </Bindings>
</SlideContent>
```

The *Bind* element contains an element of some types of the components which make the slide (e.g., the *ButtonPanel* and *Panel* in the example above). The following part discusses some of the components in detail. An element of any of these components contains a parameter *Id*, whose value (e.g., *selection* in the *ButtonPanel* element) corresponds with the parameter *Id* of the given element in the slide template. The consistent *Id* parameters then create the slide.

Slide compilation – combining the template with the content

When building the given slide, the content of the slide template element is then combined with the content element from the slide content to the resulting element using the consistent *Id* parameter. Thus, it is necessary to always define at least the empty component element with the given *Id* parameter in the template.

If the element of the given component (e.g., the *ButtonPanel* element from the component of the button panel) contains the *Properties*, *Actions* or *Layers* elements in the template, then individual sub-elements *Property*, *Action,* and *Layer* are compared to the same sub-elements in the slide content. In the case of finding a consistent parameter in the template and content (the *Width* element in the following example), the value from the template is overwritten by the value from the content. The slide content is thus superior to the template, which applies to all of the cases. In other cases, when the given parameter is defined only in the template (in the example of the *Height* element) or only in the content (in the example of the *Captions* element), the parameter is only copied to the result.

The template:

```
<ButtonPanel Id="selection">
 <Properties>
   <Height Value="90%" />
   <Width Value="90%" />
     ...
 </Properties>
 ...
</ButtonPanel>
```

The content:

```
<Bind>
 <ButtonPanel Id="selection">
   <Properties>
     <Width Value="80%" />
     <Captions Value="'3','5','7','žádné'„ />
     ...
   </Properties>
   ...
 </ButtonPanel>
</Bind>
```

The result:

```
<ButtonPanel Id="selection">
 <Properties>
   <Height Value="90%" />
   <Width Value="80%" />
   <Captions Value="'3','5','7','žádné'„ />
   ...
 </Properties>
 ...
</ButtonPanel>
```

The above mentioned facts imply that the convenient way is to insert the elements, which do not mutually differ from each other in similar slides (e.g., location and functions of the buttons, the size of the images), into the template. On the contrary, the slide content should then include mutual differences among similar slides, which are based on the similar template (e.g., explanatory texts, button values, actual images). This way, it is possible to define two similar slides using the different content, as the template will be common for both slides.

From this point of view, the following two button panels will have a common template and the slide content of each of them will only contain the *Captions* element – buttons captions. This way will also ensure that a change of the common template will influence both slides, which makes the collective adjustment of test batteries with many slides easier.

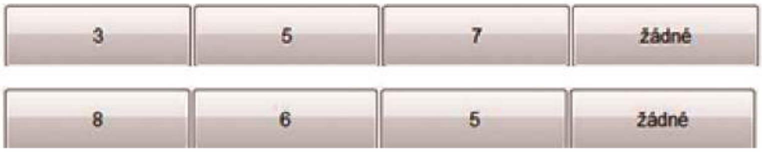


Fig. 14. An example of two button panels, which share a definition in the template and different definitions in the content.

The following chapters discuss individual elements use and examples of XML code, which should explain the setup of individual parameters of given elements. Thus, these examples will not distinguish, whether the given code is located in the template or slide content, the given parameter would work in both cases. It depends on the test creator of a specific test, whether the given parameter is located in the template or slide content. Certainly, the above mentioned suggestion for their creation needs to be taken into account. For better understanding of the structure of the code notation and for other examples, the reader may contact authors of the publication.

10.2. Types of components, which can compose a slide

A slide comprises of various components – panels, buttons, columns, pictures, etc. Each of these components has its element, which can define its appearance and function. These elements are put into the *Viewport* element in the slide template. The previous example used, for example, the *ButtonPanel* element, which defined the button panel component.

This part provides an overview of other components for the slide creation and relevant elements for their definition. The components are divided into container components, which were mainly designed for placing elements within the slide, and action components, which mainly ensure some activity (i.e., the interaction between the user and the slide). Besides them, there are special components with extended functionality and a very complicated structure, from which the component "map" is listed in this publication.

Tab. 1. Elements for creating container components.

Panel	draws the basic panel
VerticalLayout	non-visual component dividing the content vertically
HorizontalLayout	non-visual component dividing the content horizontally
Window	dialogue window
FormLayout	designed for locating various component – part of the form

Tab. 2. Elements for creating action components.

Button	simple button
ButtonPanel	panel with more buttons
Timer	timer (stopwatch)
TimerLabel	panel displaying the time from the timer
Image	image
ComboBox	selection field
TextField	text field
TextArea	text field for a longer text
DateField	field for setting a date
SelectPanel	panel for selecting from more options
Label	description, text
Video	inserted image object
Audio	inserted audio object

Tab. 3. Elements, sub-elements, and their hierarchy for creating a specialized map component.

Map	map or image with an option for drawing
- *ImageLayer*	map layer – raster image
-*ImageSequenceLayer*	map layer – several raster images are gradually switched
- *WMSLayer*	map layer – map obtained via Web Map Service
o *Pan*	to ensure shifting the map with the mouse
o *Zoom*	to ensure a change of the scale by the mouse scroll wheel
- *FeatureLayer*	map layer – a possibility to draw and define vector geometry

o *Feature*	FeatureLayer part – vector object
o *DrawPoint*	to ensure drawing points to FeatureLayer
o *DrawPath*	to ensure drawing lines to FeatureLayer
o *DrawPolygon*	to ensure drawing polygons to FeatureLayer
o *Style*	to ensure the appearance of Feature and FeatureLayer

All the components have various parameters defined by the *Properties* element containing individual elements of characteristics.

10.3. The *Map* element – an image with functions for receiving feedback

The basic description of XML definition of templates and slides was introduced in the previous chapter (see 10.1. Description of XML configuration files). All of the elements defining individual items of the test template, for example, the *Map* element, are put in the *Viewport* element. The following portions of the text and code examples try to explain some functions above all, which enable the receipt of the test subject's feedback in the test (for example, drawing points or lines). Therefore, the *Map* element and its subordinate elements are described in particular because it allows drawing in question. It is a complex element with a complicated structure and many parameters and its own library of functions. The *Map* element is also very often used to create various map reading tests, usability tests of various map visualizations or psychological tests, which assume a certain user interaction with a given visual stimuli material.

However, the software also provides a number of easier elements, for example, windows, panels, buttons, text fields for input values, images, etc. Their overview was described in chapter 10.2. Their advantage is that they do not have such a complicated structure. Thus, they might easily be used in case of not necessarily requiring the test subject's feedback in the form of drawing, but it is sufficient to record his/her reaction in the form of clicking the button or filling the text field. Due to the limited space, it is not possible to deal with all of the available easier or more complex elements. Those interested in the overview of all of the functions are recommended the software Hypothesis documentation (real examples of various complete XML templates and slide contents are there with commentary) or a consultation with the authors.

The *Map* element is one of the elements that can create the content of the test slide, the map, in this case (generally, it is visual input). For this reason, it is put into the *Viewport* element in the slide template. It is a rather complicated element, which comprises of many subordinate elements and other parts. Therefore, the name in the template code and slide content must also include the name of the name space – *maps:Map* (see the example below). The *Map* element has a wider range of use then the name suggests. It does not only have to be a "map" in terms of an image depicting a certain area. In actual fact, this element may contain any image (e.g., a photograph) that might also be defined by the easier *Image* element. However, unlike that, the

Map element has many more possibilities, among others, receiving the test subject's feedback in particular. One may click and draw in the image defined using the *Map* element, as well as define individual image layers and put one over another, insert other symbols into the image, etc. These actions are not possible with the simple *Image* element.

The following table (Tab. 4) describes permitted parameters of the *Map* element which can be defined in its sub-element *Properties*. Not all of them are used in the following examples.

Tab. 4. Parameters of the ImageLayer element, adjustable in the Properties element.

Name	**Permitted values**	**Meaning**	**Starting value**
Width	text (100%, 230px, 230)	width	
Height	text (see Width)	height	
Alignment	tl, tc, tr, ml, mc, mr, bl, bc, br	alignment, combination of values of vertical (Top, Middle, Bottom) and horizontal alignment (Left, Center, Right)	mc
CRS	Codes from the EPSG list. Source: http://www.epsg-registry.org/	A coordinate system. It must be defined if the *WMSLayer* will be used in the map.	
BoundingBox		Bounding box of the map, the coordinates in order minx, miny, maxx, and maxy. It must be defined if the *WMSLayer* element will be used in the map.	

Except the *Properties* element, the *Map* element must also include one additional mandatory element called *Layers* which must contain at least one layer definition (see below).

- ***Layers*** – individual map layers. It may have values such as *ImageLayer* (raster image), *ImageSequenceLayer* (sequence of raster images) or *WMSLayer* (layer of the web service WMS, usually used for the underlay), and *FeatureLayer* (vector layer, it is possible to draw in it, for example).

Other elements can be used to ensure additional functionality or visual settings:

- ***Controls*** – items for editing objects of the layer and using the map. It may have values such as *DrawPoint* (drawing a point), *DrawPath* (drawing a path), and *DrawPolygon* (drawing a polygon). The tools *Pan* (shifting the map) and *Zoom* (changing the map scale) are also part of this group.
- ***Styles*** – visual styles of map items.

The following example defines the complete map (element *maps:Map*) with the given size in the template, the content of the *Layers* and *Controls* elements will be explained in the following parts, the content of the *Styles* element can be found in the software Hypothesis documentation.

```
<?xml version="1.0" encoding="UTF-8"?>
<SlideTemplate
 xmlns:maps="http://hypothesis.cz/xml/maps"
 UID="EC28FE19-9D33-4501-9156-909280B867C3">
 <Viewport>
   ...
   <maps:Map Id="map">
     <Properties>
       <Width Value="990px" />
       <Height Value="585px" />
     </Properties>
     <Layers>
       ...
     </Layers>
     <Controls>
       ...
     </Controls>
     <Styles>
       ...
     </Styles>
   </maps:Map>
   ...
 </Viewport>
 ...
</SlideTemplate>
```

The following fig. 15 shows a map with two layers. The underlay image is created with a layer *ImageLayer*. Above it, there is a transparent layer *FeatureLayer*, which is designed to draw red points (or crosses), yellow polygons, and blue lines with using the mouse.

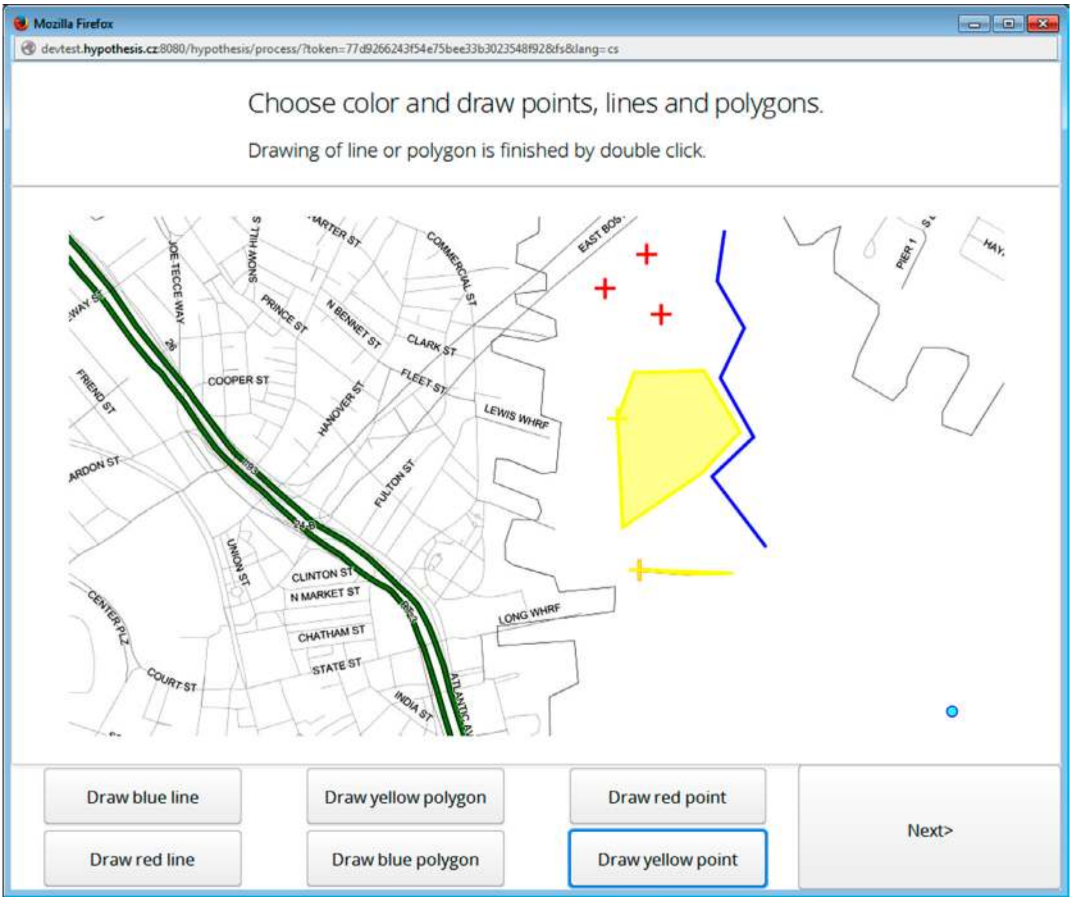


Fig. 15. An example of a map with an underlay layer ImageLayer and layer FeatureLayer designed for drawing points, lines, and polygons. The ring on the right is a mouse pointer used for drawing.

10.4. Sections of the element *Map: Layers*

The *Layer* element makes a list of map layers while more types are possible. This part will describe only two examples, which will be used in the examples of the codes.

ImageLayer

An *ImageLayer* type is one of the kinds of layers that creates the map. It is located in the *Layers* element. The layer consists of a raster image saved at the address included in *Url* parameter. Layers do not have the *Width* and *Height* parameters. Their area is always the same as the map area, defined by parameters of the *Map* element. It is possible to specify the reaction of this layer to two types of events; the moment when the image of the layer is loaded (event *Load*), and a clicking the mouse into the picture (event *Click*). Handling these events can be set in the *Handlers* element.

Tab. 5. Parameters of the ImageLayer element adjustable in the Properties element.

Name	Permitted values	Meaning	Starting value
Url	text	url address of the image creating the layer	

Tab. 6. Events, which the ImageLayer element may handle in the Handlers element.

Event	Meaning
Load	loading the layer to the slide
Click	click by the mouse into the slide

An example:

The following slide code shows a case where the *Layers* element contains one *ImageLayer* layer using the *Click* element to handle a mouse click and reacts to the click by starting up an action *nextSlide*, which loads the following slide (coordinates and time of this click are then recorded into the database again).

```
<maps:Map Id="map">
 ...
 <Layers>
   <ImageLayer Id="image_layer">
     <Properties>
       <Url Value="http://hypothesis.cz/01a.png" />
     </Properties>
     <Handlers>
       <Click>
         <Call Action="nextSlide" />
       </Click>
     </Handlers>
   </ImageLayer>
 </Layers>
 ...
</maps:Map>
...
<Actions>
 <Action Id="nextSlide">
   <Expression>Navigator->next()</Expression>
 </Action>
</Actions>
```

FeatureLayer

This element is one of the layer types forming a map. It is located in the *Layers* element. This layer is "vector"; it contains individual items (polygons, polylines, points) that are defined using *Feature* elements united in the *Features* element. The whole layer of *FeatureLayer* itself is the same size as the *Map* element, thus, there are no *Width* and *Height* parameters. This type of layer can react to a mouse click.

Tab. 7. Parameters of the FeatureLayer element adjustable in the Properties element.

Name	**Permitted values**	**Meaning**	**Starting value**
Style	text	Definition of the visual style of the layer elements. It refers to a style defined in the *Styles* element.	
HoverStyle	text	Style (which is used for a selected or highlighted item).	

Tab. 8. Events that can be handled by the FeatureLayer element in the Handlers element.

Event	**Meaning**
Click	mouse click into the layer

Other elements defining the *FeatureLayer* element – listed outside of the *Properties* element:

Features – element joining the definition on individual items (polygons, lines, points) that form the layer *FeatureLayer*.

An example:

The code listed below shows how other elements using the *Features* element are defined in the layer of *FeatureLayer* (the name is *FeatureLayer*). This will be dealt with in the following pages. The item, which is called *target,* is defined here.

One should note that there are two *Handlers* sections in the code handling a mouse click. The whole *FeatureLayer* has its own *Handlers* section, as well as its sub-part – *Feature* "target". The section belonging to the *FeatureLayer* element is highlighted in bold and italics. It handles all of the clicks anywhere in the whole layer, which is always the same size as the actual map, and it will display the next slide. On the contrary, the *Handlers* section belonging only to the *Feature* element (marked with a regular font in bold) handles only the click into the space of the actual *Feature* "target" and starts an action called *rightAnswer* – it will set up a variable *result* on the value 1. However, this *Feature* is also a part of the whole *FeatureLayer*, therefore, the same click will also activate the *Handlers* element of the whole layer. It means that whenever one clicks into the map, the next scene is displayed, but only when clicking on the *Feature* "target" will it record that it is the correct answer. This can be used when distinguishing correct and incorrect reactions when map testing.

The code also includes the *Style* and *HoverStyle* elements defining the appearance of the layer *FeatureLayer*. These refer to individual appearance definitions within the *Styles* element. Its detailed description can be found in the relevant section of the documentation of the software Hypothesis.

```
<maps:Map Id="map">
 ...
 <Layers>
   <FeatureLayer Id="featureLayer">
     <Properties>
       <Style Value="redCross" />
       <HoverStyle Value="greenCross" />
     </Properties>
     <Features>
       <Feature Id="target">
         <Geometry Value="POINT (300 100)" />
         <Text Value="A">
           <Offset X="0" Y="-20" />
         </Text>
         <Handlers>
           <Click>
             <Call Action="rightAnswer" />
           </Click>
         </Handlers>
       </Feature>
     </Features>
     <Handlers>
       <Click>
         <Call Action="nextSlide" />
       </Click>
     </Handlers>
   </FeatureLayer>
 </Layers>
 ...
 <Styles>
   ...
 </Styles>
</maps:Map>
...
<Variables>
 <Variable Id="result" Type="Integer" Value="0" />
</Variables>
<Actions>
 <Action Id="rightAnswer">
   <Expression>result=1</Expression>
```

```
 </Action>
 <Action Id="nextSlide">
   <Expression>Navigator->next()</Expression>
 </Action>
</Actions>
```

Feature

The *Feature* element is designed to define individual items of the layer *FeatureLayer*. It may be a point, line, polyline, or polygon. The *Feature* element is set as visible in the default setting, using the *Hidden* parameter, which is set to *False*. In this case, the given item is visible on the map. It is possible to set the *Hidden* parameter to *True*, which makes the item invisible. This may be used for situations such as defining the area where the test subject should click correctly (this area needs to be defined only for the purposes of evaluation of correct answers; there is no need to present it visually within the whole slide). The *Style* and *HoverStyle* elements are then designed to set the way of visualizing.

The type of geometry (a point, line, polygon) and coordinates are defined in the *Geometry* element in the format of Well Known Text (WKT), which is the standard ISO/IEC 13249-3:2011 for the text notation of vector geometry. As well as the whole layer *FeatureLayer*, the individual *Feature* element can react to a mouse click as well.

Tab. 9. Parameters in the Feature element, adjustable in the Properties element.

Name	**Permitted values**	**Meaning**	**Starting value**
Style	text	Definition of the visual style of the feature. It refers to a style defined in the *Styles* element.	
HoverStyle	text	Style (which is used for a selected or highlighted item).	
Hidden	True/False	Item is or is not invisible.	False

Tab. 10. Events that can be handled by the Feature element in the Handlers element.

Event	**Meaning**
Click	mouse click into the item

Other elements defining the *Feature* element are listed outside the *Properties* element. These are the *Text* (item label) and *Geometry* (geometry coordinates) elements. Within the *Text* element using the subordinate *Offset* element, the actual location of the label (or its left bottom corner) is defined using the X and Y coordinates, and a relative position to the described geometry. The coordinates X increase to the right and coordinates Y increase downwards; the units are in pixels.

An example:

The coordinates of the label X are the same as the coordinates of the labeled point, minus coordinates Y mean that the left bottom corner of the label is 20 pixels above the labeled point – see the following figure.

```
<Text Value="START">
 <Offset X="0" Y="-20" />
</Text>
```

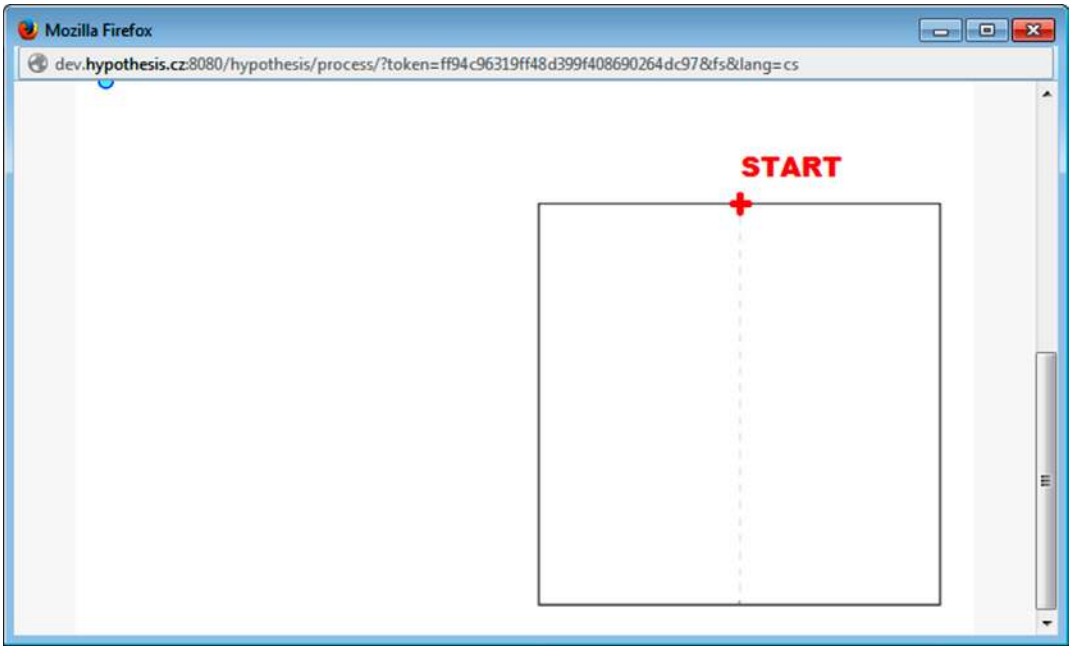


Fig. 16. An example of the label location of the point defined by the Feature element.

In case of the *Geometry* element, WKT definition and its geometry is used, the coordinates are stated in pixels. The beginning (i.e., coordinates 0 0) is in the upper left corner of the map. The coordinates X therefore increase to the right and the coordinates Y increase downwards.

Examples:

The definition of the point and polyline:

```
<Geometry Value="POINT (30 10)"/>
<Geometry Value="LINESTRING (30 10, 10 30, 40 40)"/>
```

The coordinates of the first and the last point of the polygon must be identical.

```
<Geometry Value="POLYGON ((30 10, 40 40, 20 40, 10 20, 30 10))" />
```

The polygon may also include an inner border (inner-block):

```
<Geometry Value="POLYGON ((35 10, 45 45, 15 40, 10 20, 35 10), (20 30, 35 35, 30 20, 20 30))" />
```

The software also accepts even more complex geometries – MultiPolygon, MultiLineString, MultiPoint, GeometryCollection, while their description can be found in the documentation for the standard ISO/IEC 13249-3:2011.

An example:

The following code is identical with the example from the previous chapter regarding the *FeatureLayer* element; however, only the part belonging to the *Feature* called "target" is highlighted in bold. Italics then highlights the definition of the reaction to the mouse click, which is started by the *Click* element of this element. After the click, the variable *result* is then set to the value 1. Using the *Hidden* element, the *Feature* is set to invisible (see above) and will not be visible in the final map, however, clicking on it will be recorded. Using this element, it is then possible to precisely define the area of interest where the test subject should click correctly. If it is clicked into this area of interest, the variable *rightAnswer* will set up to the value 1 (i.e., correct answer).

```
<maps:Map Id="map">
 ...
 <Layers>
   <FeatureLayer Id="featureLayer">
     <Properties>
       <Style Value="redCross" />
     </Properties>
     <Features>
       <Feature Id="target">
         <Geometry Value="POINT (100 300)" />
         <Text Value="A">
           <Offset X="0" Y="-20" />
         </Text>
         <Properties>
           <Hidden Value="true" />
         </Properties>
         <Handlers>
           <Click>
             <Call Action="rightAnswer" />
           </Click>
         </Handlers>
       </Feature>
     </Features>
     <Handlers>
       <Click>
         <Call Action="nextSlide" />
```

```
      </Click>
    </Handlers>
  </FeatureLayer>
 </Layers>
 ...
 <Styles>
   ...
 </Styles>
</maps:Map>
...
<Variables>
 <Variable Id="result" Type="Integer" Value="0" />
</Variables>
<Actions>
 <Action Id="rightAnswer">
   <Expression>result=1</Expression>
 </Action>
 <Action Id="nextSlide">
   <Expression>Navigator->next()</Expression>
 </Action>
</Actions>
```

10.5. Sections of the element *Map: Controls*

This section of the *Map* elements defines editing options, or options for drawing into the given map. Beside the elements described here such as *DrawPoints* for drawing points and *DrawPath* for drawing polylines, there is also the *DraPolygon* element for drawing polygons. Its functionality is analogical to those two mentioned above.

DrawPoint

The element defining drawing points *DrawPoint* is one of the ways in which to draw items into the layer *FeatureLayer*. The actual definition of the element is written into the *Controls* element. A parameter of this element is the *LayerId* element. It describes which layer will be used for drawing. The *CursorStyle* element then defines the appearance of the drawing cursor. Using the *Draw* event, it is possible to handle the moment of drawing a point into the map and define a relevant reaction.

Tab. 11. Parameters of the DrawPoint element, adjustable in the Properties element.

Name	Permitted values	Meaning	Starting value
LayerId	text	Layer *FeatureLayer*, which is drawn into.	
CursorStyle	text	Appearance of the drawing cursor.	

Tab. 12. Events that can be handled by the DrawPoint element in the Handlers element.

Event	Meaning
Draw	Finish drawing the item.

An example:

Locating the *DrawPoint* element into the *Controls* element determines that the drawn items will be points. The attribute *LayerId* determines which layer of the *FeatureLayer* is included in the *Layers* element; a new point will be drawn into – it is the *featureLayer* in our example. The *Cursor* element then defines the appearance of the mouse cursor, which is used for drawing. It is a circle in the right bottom corner in the fig. 15.

However, the appearance of the actual drawn items (i.e., points in the example) is not set in the *Controls* element, but it is defined in the *Style* element in the *FeatureLayer* (i.e., the layer, which is drawn into). In the example, this layer is called "featureLayer" and its appearance is set using the *Style* element on the value "red". The *Style* element is described in detail in the documentation of the software Hypothesis.

Drawing items must be activated first therefore the *Variables* element defines a variable *drawPoint*, which refers to the *DrawPoint* element itself (see the example below). This variable *drawPoint* is used in the *Action* element called *activatePoint*. This element includes a code activating drawing points – *drawPoint>activate()*. The *Handlers* element called *Show* then handles the moment of complete loading of the slide and it is designed to start an action (the *Action* element "activatePoint") after loading the slide and therefore activate drawing using the *DrawPoint* element. Please note that the *Show* element belongs to the *Handlers* element of the whole template because it reacts to loading of the whole slide. On the contrary, the *Draw* element is located in the *Handlers* section of the *DrawPoint* element because it only handles the event of drawing a point. The example also includes an action "drawFinished", which displays the following slide from the test battery after drawing new items.

```
<maps:Map Id="map">
 ...
 <Layers>
   <FeatureLayer Id="featureLayer">
     <Properties>
       <Style Value="red" />
     </Properties>
     ...
   </FeatureLayer>
 </Layers>
 <Controls>
   <DrawPoint Id="drawPoint">
     <Properties>
       <LayerId Value="featureLayer" />
       <CursorStyle Value="cursor" />
     </Properties>
     <Handlers>
       <Draw>
         <Call Action="drawFinished" />
       </Draw>
     </Handlers>
   </DrawPoint>
 </Controls>
 <Styles>
   <Style Id="red">
     ...
   </Style>
 </Styles>
 ...
</maps:Map>
<Handlers>
 <Show>
   <Call Action="activatePoint" />
 </Show>
</Handlers>
<Variables>
 <Variable Id="drawPoint" Type="Object">
   <Reference>
     <Component Id="drawPoint" />
   </Reference>
 </Variable>
</Variables>
<Actions>
 <Action Id="nextSlide">
   <Expression>Navigator->next()</Expression>
 </Action>
 <Action Id="drawFinished">
```

```
   <Call Action="nextSlide" />
 </Action>
 <Action Id="activatePoint">
   <Expression>drawPoint>activate()</Expression>
 </Action>
</Actions>
```

DrawPath

The *DrawPath* element is designed for drawing polylines, which are another way of drawing items into a certain layer of the *FeatureLayer*. As well as in the previous case, this element is defined within the *Controls* element as well. The *LayerId* then describes which layer of the *FeatureLayer* will be drawn into and the *CursorStyle* element defines the appearance of the drawing cursor. Using the *Draw* element, it is possible to handle the moment of drawing a point into the map and define a relevant reaction.

Tab. 13. Parameters of the DrawPath element, adjustable in the Properties element.

Name	Permitted values	Meaning	Starting values
LayerId	text	Layer *FeatureLayer*, which is drawn into.	
CursorStyle	text	Appearance of the drawing cursor.	
StartPointStyle	text	Appearance of the starting point of the polyline.	
LineStyle	text	Appearance of the line of the polyline.	
VertexStyle	text	Appearance of the vertex.	
FinishStrategy	AltClick, DoubleClick	The way of finishing drawing the line (either by pressing Alt key together with a click or double click).	AltClick

Tab. 14. Events that can be handled by the DrawPath element in the Handlers element.

Event	Meaning
Draw	Finish drawing an item.

An example:

Locating the *DrawPath* element into the *Controls* element determines that drawn items will be lines, including polylines. The attribute *LayerId* then determines which layer of the *FeatureLayer* is included in the *Layers* element; new lines will be drawn into – it is the layer called "featureLayer" in our example. The *CursorStyle* element determines the appearance of the mouse cursor, which is used for drawing. The *StylePointStyle*, *VertexStyle*, and *LineStyle* then set the appearance of the starting point, vertices and the appearance of the actual drawn polyline. In the following picture, the starting point of the line is a ring in the upper end of the line on the crossing roads; the line is marked in the cyan color with small rings as vertices and the mouse cursor is depicted by a larger ring on the other end of the line (in the south part of the map field by the pond).

The *FinishStrategy* element defines the way that the actual process of drawing the line is finished. This element is not included in the example at all, which means that the default setting is applied. In this setting, the last point is drawn by clicking a left mouse button together while pressing the Alt key on the computer keyboard.

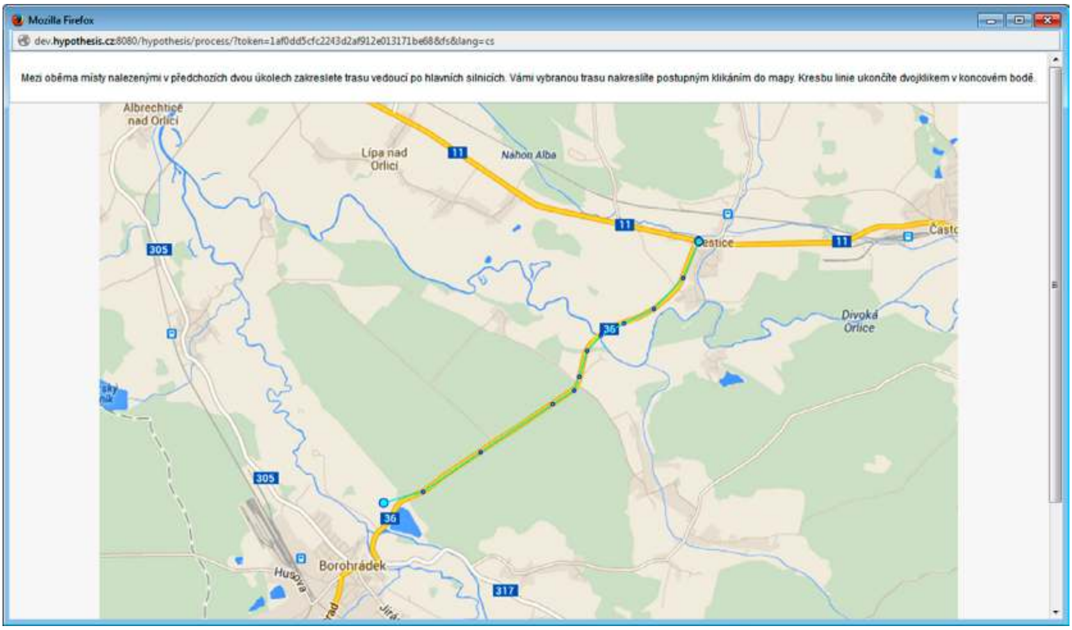


Fig. 17. The slide with the drawn line, which should copy the road.

Drawing lines must be, as in the previous case, activated first. For that reason, the variable *drawPath* is defined (by the *Variable* element) and refers to the *DrawPath* element itself. The variable drawPath is used in the event *Action* called "activatePath", which includes a code activating drawing *drawPath>activate()*. The *Show* element then handles the event of loading the slide and is designed to start the relevant event (*Action* "activatePath") after loading the slide and therefore to activate drawing. Please note that the *Show* element again belongs to the *Handlers* element of the whole template because it reacts to its loading. The *Draw* element is again analogically defined in the *Handlers* element belonging to the *DrawLine* element because it handles the event of drawing the line. Our example also includes the *Action* "drawFinished", which will display the following slide.

```
<maps:Map Id="map">
 ...
 <Layers>
   <FeatureLayer Id="featureLayer">
     <Properties>
       <Style Value="redLine" />
     </Properties>
     ...
   </FeatureLayer>
 </Layers>
 <Controls>
   <DrawPath Id="draw_path">
     <Properties>
       <LayerId Value="featureLayer" />
       <CursorStyle Value="cursor" />
       <StartPointStyle="start" />
       <LineStyle="line" />
       <VertexStyle="vertex" />
     </Properties>
     <Handlers>
       <Draw>
        <Call Action="drawFinished" />
       </Draw>
     </Handlers>
   </DrawPath>
 </Controls>
 <Styles>
   <Style Id="cursor">
     ...
   </Style>
   <Style Id="redLine">
     ...
   </Style>
   <Style Id="line">
     ...
   </Style>
   <Style Id="start">
     ...
   </Style>
   <Style Id="vertex">
     ...
   </Style>
 </Styles>
 ...
</maps:Map>
<Handlers>
 <Show>
```

```
   <Call Action="activatePath" />
 </Show>
</Handlers>
<Variables>
 <Variable Id="drawPath" Type="Object">
   <Reference>
     <Component Id="draw_path" />
   </Reference>
 </Variable>
</Variables>
<Actions>
 <Action Id="nextSlide">
   <Expression>Navigator->next()</Expression>
 </Action>
 <Action Id="drawFinished">
   <Call Action="nextSlide" />
 </Action>
 <Action Id="activatePath">
   <Expression>drawPath>activate()</Expression>
 </Actions>
```

This chapter showed the possibilities of how to create test batteries using the software Hypothesis. Some of the selected examples from available functionality were chosen to show that it is possible to create any tasks focused on testing various visual inputs. The creator him/herself defines both the content of the slide and the form of what the user will see on the computer screen. This feature allows modification of various types for the purposes of specific testing which gives the user relative power to objectify the whole process. The aim of this chapter was not to include all of the available functionality that is at the user's disposal, but to illustrate the philosophy behind the creation of the test and introduce this special software in general. All of the detailed information is available in documentation for the software Hypothesis.

11. Hypothesis Manager

For administration of all of the created test batteries, the Hypothesis Manager is available for the user (see fig. 18 with an introductory page of the application). This application, which is available through the web interface, is designed to start and administrate tests, administrate user accounts, and export test results from the database. The user may enter the web interface by logging in with his/her username and password, which must be first created by another user. One can enter the interface through the "guest" account without having to log in. Using the guest account only allows the user to start tests that are set as public; he/she is not allowed to perform any operation with created tests (e.g., export test results from the database).

There is a list of tests on the *My packs* card which are assigned to the registered user. At the same time, the bookmark Public shows all of the tests which are marked as public (i.e., tests accessible for all unregistered users). The tests may be started in the *featured* or *legacy* mode. The former allows more controllable conditions when taking the test; for example, it is not possible to end it prematurely or switch to another program. This mode is suitable for bulk testing more users and ensuring more controllable conditions. A requirement for starting the test in this mode is to install Java Runtime Environment (JRE). The second mode, *legacy,* is possible to be run in any browser and there is no program installation requirement.

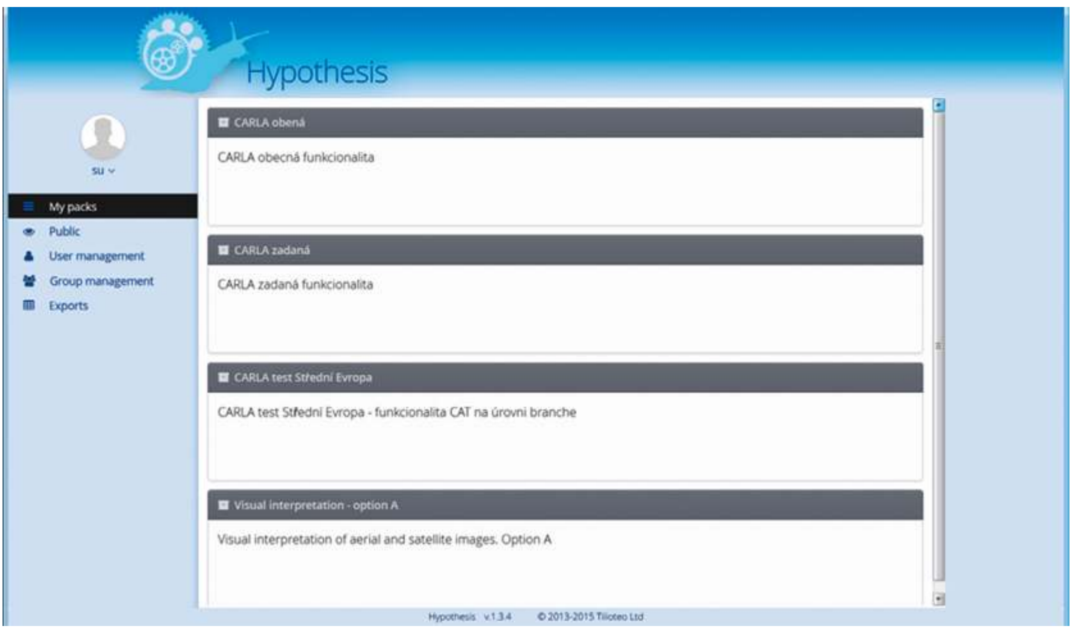


Fig. 18. Web user interface Hypothesis with the menu for starting tests.

A bookmark *User Management* (see fig. 19) is designed to administrate user accounts. It is possible to set up a name, password, and the level of user rights for each user as well. From this point of view, these types of users might be distinguished into the following: superuser (full rights), manager (administrates user groups), and user (no rights to administrates accounts). Each user might be assigned to tests where he/she is authorized to perform and export the results. Afterward, these tests will be shown in the bookmark in his/her card *My packs*. Individual users might be put into groups via the bookmark *Group Management* (fig. 20); then, it is possible to configure their user rights collectively.

The actual data might be gained from the menu *Export* (fig. 21), where it is necessary to select a type of the test. The user is allowed to export test results only of the tests for which he/she has permission. Within the context of the next parameter, it is essential to set a time interval for which the results of the given test are requested to be exported (e.g., one may use it to filter only selected results from a certain testing day, etc.). After pressing the *Show Tests* button, a list of results corresponding with given conditions is shown. Every entry listed is marked with a note as to whether the test was successful or ended prematurely. Due to this, only the successful tests will be exported. The actual export is completed by pressing the *Export* button. Requested results are available in .xlsx format (Microsoft Excel).

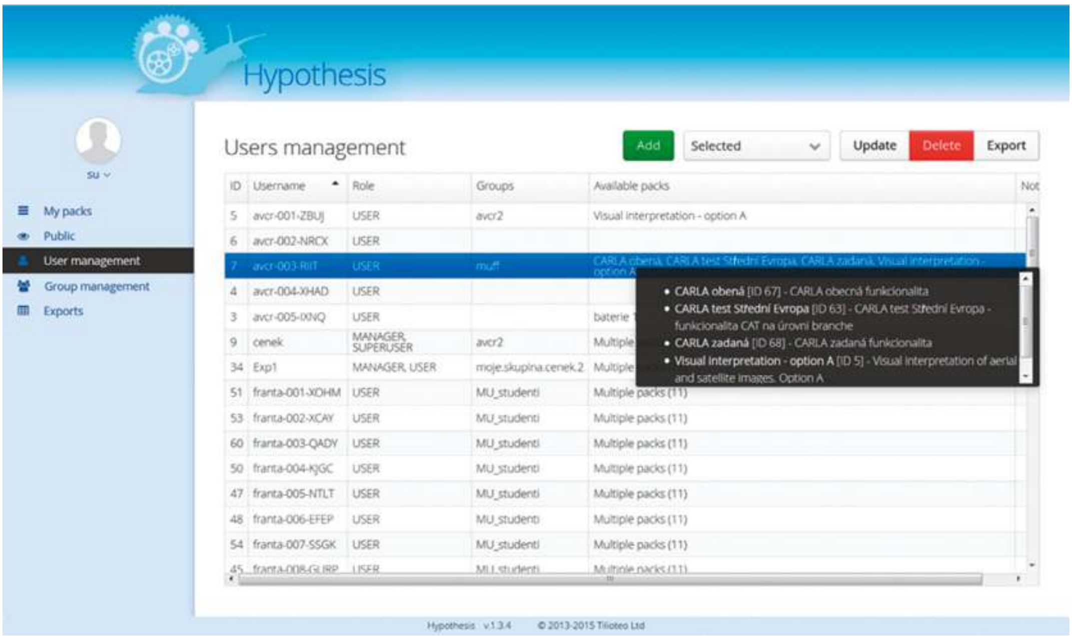


Fig. 19. Web user interface Hypothesis with the menu for user account administration.

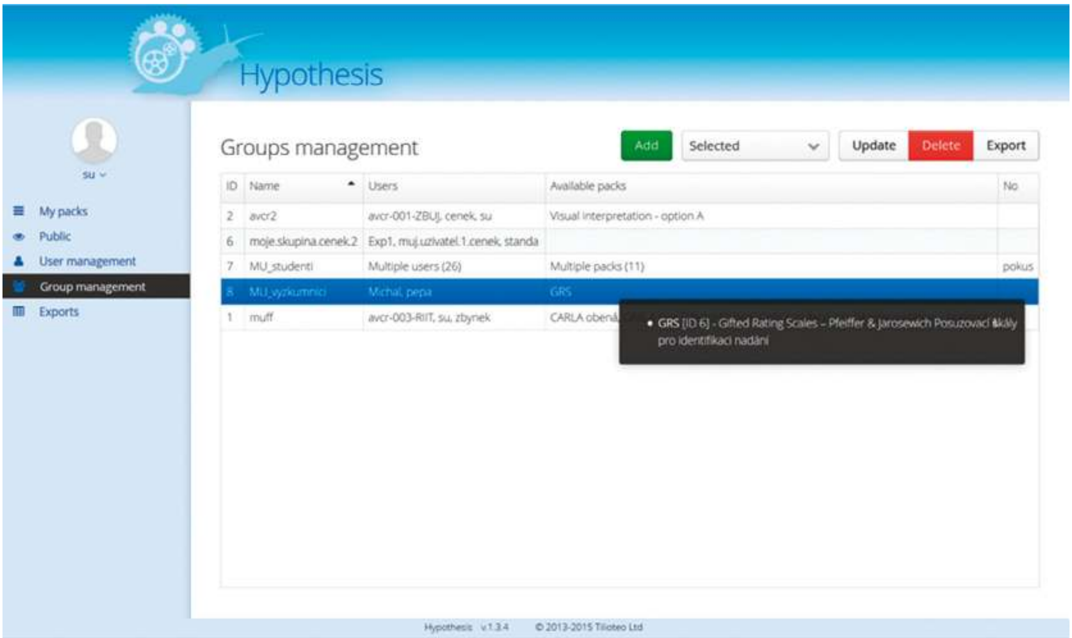


Fig. 20. Web user interface Hypothesis with the menu for user groups administration.

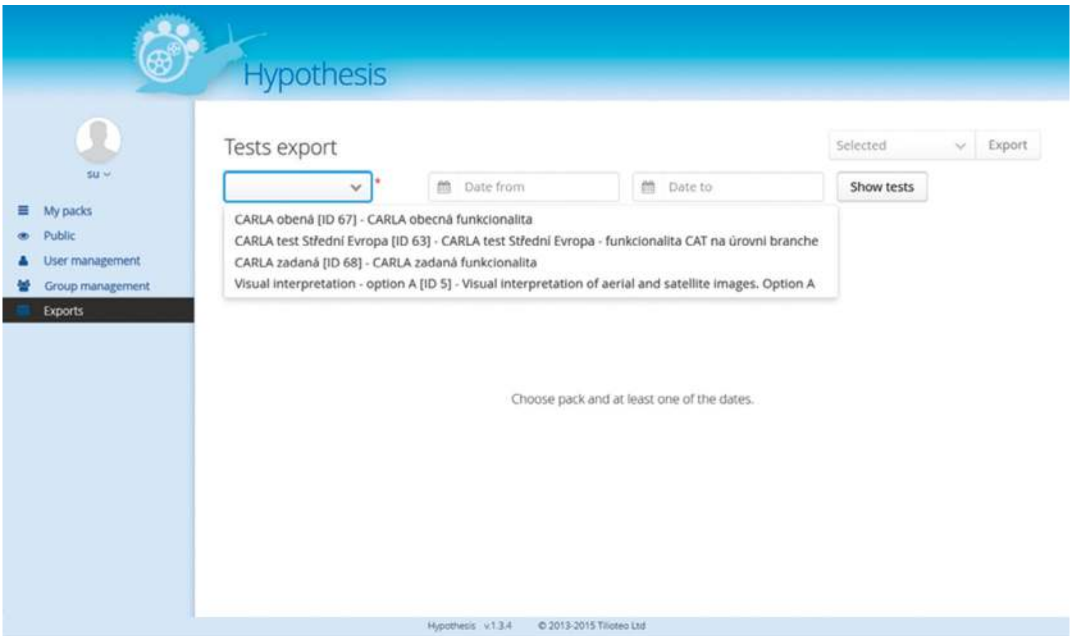


Fig. 21. Web user interface Hypothesis with the menu for exporting test results.

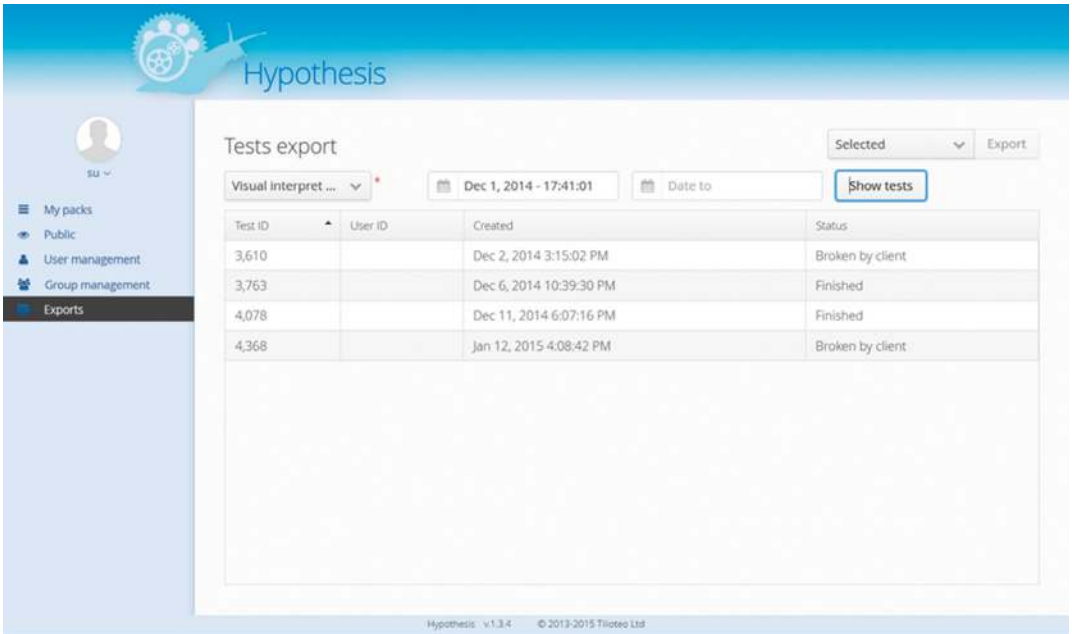


Fig. 22. Displayed found test results corresponding with the given test and start date.

The analysis and interpretation of obtained results is certainly not finished with the actual export of the rough data from Hypothesis. The next step is to select the required relevant data by gradual filtering. If more than one test result is selected during the export then the file will surely contain more tests at once. In this case, one might use a simple filter in the Excel environment to select required data, which may further be processed in detail and evaluated with one of the statistical analyses (using Excel application or some other specific statistical software).

From this point of view, one must emphasize that individual columns in exported xls table (see fig. 23) correspond with individual tables in the database of Hypothesis and might simply be used when selecting required final data. For example, using columns *test_id* and *date,* one can select the data from the given test and the column *slide_id* and *slide_name* identifies the rows referring to one slide (one slide has more rows including all of the events in this slide). Each row contains some event (meaning alternative slides, end of the slide, pressing the button, click into the picture, drawing geometry, etc.). This specific type of the event can be found in the column *event_name*. The columns *event_timestamp* and *event_time_diff* are important for result evaluation as well. The former contains the time of the event in milliseconds since starting the test and the latter contains the time difference since the previous event. These data allow the user to find a time lag between displaying the scene and the proband's reaction by clicking the mouse.

The actual results of each event are saved in the column *event_data*. All of the variables relating to the event are saved there. For example, the name of the button designed for the button click event, coordinates of the mouse click event, etc. The most important entries for the test evaluation are the entries labeled with the value "FINISH_SLIDE" which marks the event of finishing the given slide (i.e., the moment of the user's reaction, which is usually the data of our interest). Evaluation of the whole slide including all of the variables (values of evaluators evaluating accuracy of the answers, etc.) is usually saved there. One must mention that this entry can often be very long and complicated for complex slides (in the form of a string of all of the results available), therefore, it is suitable when creating a given slide, to define specific variables which contain the most important data for evaluation of the given task. These variables are then saved to specific columns when exporting the results in order to be easily found and processed.

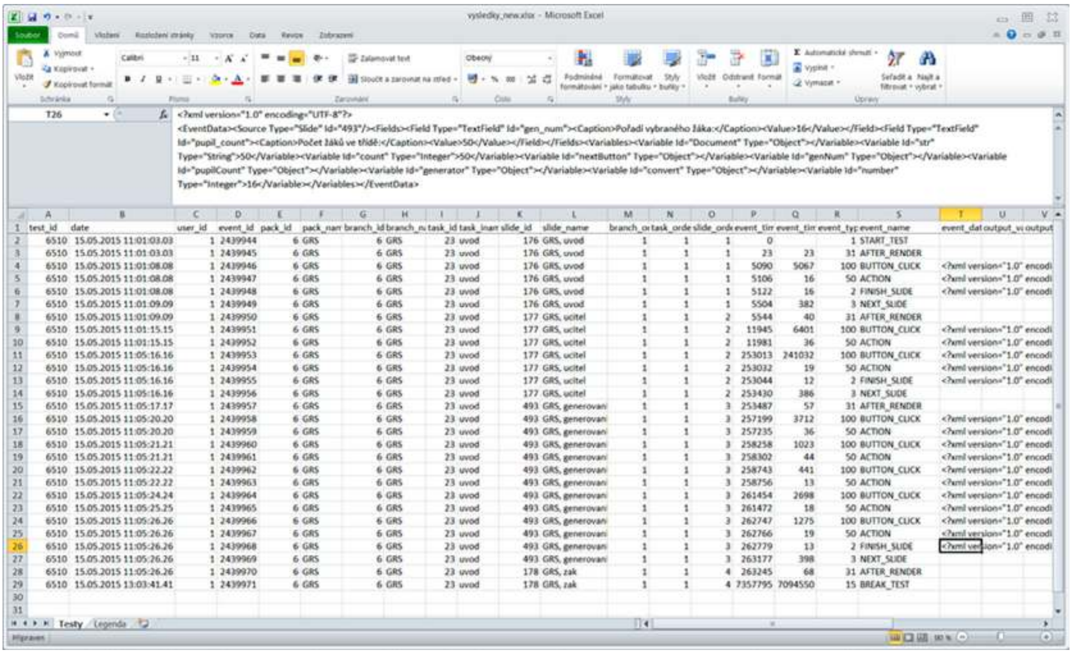


Fig. 23. The file with exported results; selected cell contains an example of complicated entry of the results of the whole slide.

12. Conclusion

Evaluation of cartographic works is a very important part of the process of creating maps, atlases or other cartographic products, which provides the author with valuable feedback on the way in which the purpose of the given map is achieved. It is not possible to create maps successfully usable in practice without thinking hard about reasons that predetermine the satisfaction of the purpose. The issue of optimization and objectification of the process of evaluating cartographic visualizations has been an object of research at the Department of Geography and Department of Psychology for several years, within a lot of projects either in progress or already finished. In the process of their solution, various procedures and pieces of knowledge were implemented in research. Some of them had not been frequently used until that time, especially the study and deeper involvement of cognitive aspects in actual evaluation of cartographic visualizations. It is obvious that besides a given cartographic product (or its potential to transfer depicted information), it is necessary to also observe aspects of the specific user or reader of this product (and his/her ability to receive this information). This publication is therefore focused on selective map specifics, particularly focusing on optimization of methods of evaluating the degree of its usability.

One of the main objectives was to identify and describe all of the major influences affecting the perception of information via maps. The evaluation process of the cartographic work was then viewed through the inter-disciplinary approach, where a connection of traditional methods of cartography with processes borrowed from cognitive psychology might be considered a great contribution. Thus, relatively great emphasis was put on cognitive aspects influencing perception of image representations in the case of maps which significantly participate in the process of the communication of cartographic information. The issue of inter-individual differences of users was also included, as it seems to be one of the important factors influencing the perception of visual information on the map. Selected available psychological tests were also commented on from this perspective, as they can observe and evaluate this phenomenon. Strong emphasis was put on describing possible consequences of cognitive differences between users in terms of usability of given cartographic products. Another described approach included examples of possible combinations of objective testing methods of usability with detailed examination of users' cognitive abilities. In this context, the authors emphasize the importance of the user in the whole process of transmitting information on the map and the necessity to pay attention to user aspects of map creation.

Theoretical information and methodical approaches in questions were then employed in the practical application of this publication, which introduces special new software Hypothesis for creating test batteries. Selected functionality of this software was chosen to illustrate an example of creating various types of tasks focused on verifying set hypotheses for map reading tasks and psychological tests. This tool, which has been developed at the Masaryk University in the long term, represents a significant contribution to further development of research in usability testing and the study of cognitive aspects in cartography.

In conclusion, one should mention that one of the partial benefits of processing this topic in recent years has been establishing an efficient inter-disciplinary team of research workers from the field of cartography and psychology, with the connection to the national and international centers dealing with related topics. Certainly, it would be beneficial to continue developing this well-established cooperation in standardizing empirical evaluation of cartographic works and verifying basic theoretical approaches of cartographic creation. The authors are aware of the increasing interest in this issue in the international community, which is associated mainly under the auspices of the ICA – Commission on Cognitive Visualization and Commission on Use and User Issues. For this reason, we hope for further cooperation and development of the tool Hypothesis within this community.

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Appendix 1 – database tables information

Tables for test creation:

A1-1. Table *tbl_pack*

Field	**Type**	**Meaning**
id	bigint	primary key
description	varchar(255)	test description
name	varchar(255)	test name
published	bool	test is/is not published
note	varchar(255)	note

A1-2. Table *tbl_branch*

Field	**Type**	**Meaning**
id	bigint	primary key
xml_data	text	XML description
note	varchar(255)	branch name

A1-3. Table *tbl_task*

Field	**Type**	**Meaning**
id	bigint	primary key
note	varchar(255)	task description
name	varchar(255)	task name
randomized	bool	slides are/are not randomized

A1-4. Table *tbl_slide*

Field	**Type**	**Meaning**
id	bigint	primary key
slide_content_id	bigint	content ID in the table *tbl_slide_content*
note	varchar(255)	slide name

A1-5. Table *tbl_slide_content*

Field	**Type**	**Meaning**
id	bigint	primary key
xml_data	text	XML content definition
note	varchar(255)	name
slide_template_uid	varchar(255)	template ID in the table *tbl_slide_template*

A1-6. Table *tbl_slide_template*

Field	**Type**	**Meaning**
uid	bigint	primary key
xml_data	text	XML template definition
note	varchar(255)	name

A1-7. Table *tbl_pack_branch*

Field	**Type**	**Meaning**
pack_id	bigint	test ID in the table *tbl_pack*
branch_id	bigint	branch ID in the table tbl_branch
rank	int	branch order (must be defined)

A1-8. Table *tbl_branch_task*

Field	**Type**	**Meaning**
branch_id	bigint	branch ID in the table *tbl_branch*
task_id	bigint	task ID in the table *tbl_task*
rank	int	task order

A1-9. Table *tbl_task_slide*

Field	**Type**	**Meaning**
task_id	bigint	task ID in the table *tbl_task*
slide_id	bigint	slide ID in the table *tbl_slide*
rank	int	slide order

Tables used for test branching:

A1-10. Table *tbl_branch_trek*

Field	Type	Meaning
Field	**Type**	**Meaning**
id	bigint	primary key
key	varchar(255)	key defined by the user; used in the column *xml_data* in the table *tbl_branch*
branch_id	bigint	branch ID in the table *tbl_branch*
pack_id	bigint	test ID in the table *tbl_pack*

A1-11. Table *tbl_branch_branch_trek*

Field	Type	Meaning
branch_id	bigint	branch ID in the table *tbl_branch*
branch_trek_id	bigint	ID in the table *tbl_branch_trek*

Tables for storing the test results:

A1-12. Table *tbl_test*

Field	Type	Meaning
id	bigint	primary key
created	timestamp	time of upload of the test (by web browser)
started	timestamp	time of start of the test (by user)
broken	timestamp	time of prematurely ended (broken) test
finished	timestamp	time of successfully ended test
last_access	timestamp	time of the last access of the test to the database
production	bool	Yes (it is a test ready for an experiment); No (preliminary version)
status	int	test status: 1- test uploaded 2- test started 3- test successfully ended 4- test prematurely ended (by user) 5- test prematurely ended (by software)
last_branch_id	bigint	id of the last branch in the test run (*tbl_branch*)

last_task_id	bigint	ID of the last task (*tbl_task*)
last_slide_id	bigint	ID of the last slide (*tbl_slide*)
pack_id	bigint	ID of the test (*tbl_pack*)
user_id	bigint	ID of the user user who started the test (*tbl_user*)

A1-13. Table *tbl_event*

Field	**Type**	**Meaning**
id	bigint	primary key
xml_data	text	XML events description – clicks coordinates, buttons names etc.
name	varchar(255)	event name – START TEST, BUTTON CLICK etc.
branch_id	bigint	branch ID in the table *tbl_branch*
task_id	bigint	task ID in the table *tbl_task*
slide_id	bigint	slide ID in the table *tbl_slide*
timestamp	bigint	time of the event
type	bigint	event type (code)

A1-14. Table *tbl_test_event*

Field	**Type**	**Meaning**
test_id	bigint	test ID in the table *tbl_test*
event_id	bigint	event ID in the table *tbl_event*
rank	int	order of the event in the test

A1-15. Table *tbl_slide_output*

Field	**Type**	**Meaning**
id	bigint	primary key
xml_data	text	XML event description
output	varchar(255)	XML event description – output value
slide_id	bigint	slide ID in the table *tbl_slide*
test_id	bigint	test ID in the table *tbl_test*

A1-16. Table *tbl_slide_order*

Field	**Type**	**Meaning**
id	bigint	primary key
xml_data	text	order of the slide
task_id	bigint	task ID in the table *tbl_task*
test_id	bigint	test ID in the table *tbl_test*

A1-17. Table *tbl_branch_output*

Field	**Type**	**Meaning**
id	bigint	primary key
xml_data	text	XML event description
output	varchar(255)	event description – output value
branch_id	bigint	branch ID in the table *tbl_branch*
test_id	bigint	test ID in the table *tbl_test*

Tables for user administration:

A1-18. Table *tbl_user*

Field	**Type**	**Meaning**
id	bigint	primary key
password	varchar(255)	password
username	varchar(255)	user name
enabled	bool	user is/is not enabled
expire_date	timestamp	expire date of the user name
note	varchar(255)	note
owner_id	bigint	user ID of the user name creator

A1-19. Table *tbl_role*

Field	**Type**	**Meaning**
id	bigint	primary key
name	varchar(255)	role name (user, administrator etc.)

A1-20. Table *tbl_user_role* – user's role

Field	Type	Meaning
user_id	bigint	user ID
role_id	bigint	role ID of the user

A1-21. Table *tbl_user_permission* – user's permission

Field	Type	Meaning
id	bigint	primary key
enabled	bool	user permission is/is not enabled
pass	bigint	max. number of test runs for the user
pack_id	bigint	pack ID of the enabled pack
user_id	bigint	user ID enabled for the pack

A1-22. Table *tbl_group* – group of users

Field	Type	Meaning
id	bigint	primary key
name	varchar(255)	group name
note	varchar(255)	note
owner_id	bigint	user ID (in the table *tbl_user*), group owner

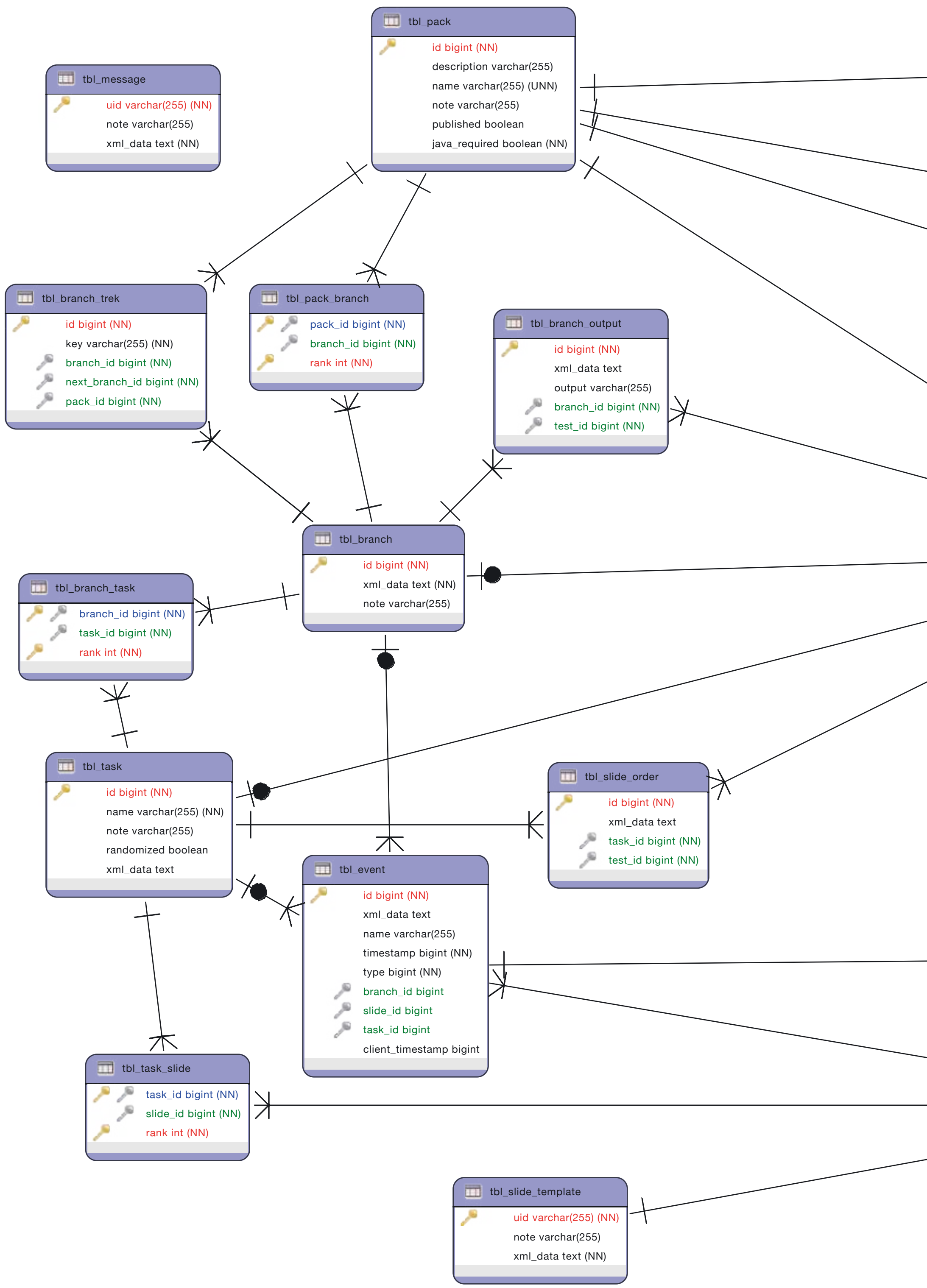
A1-23. Table *tbl_group_permission* –mass processing of users' permissions

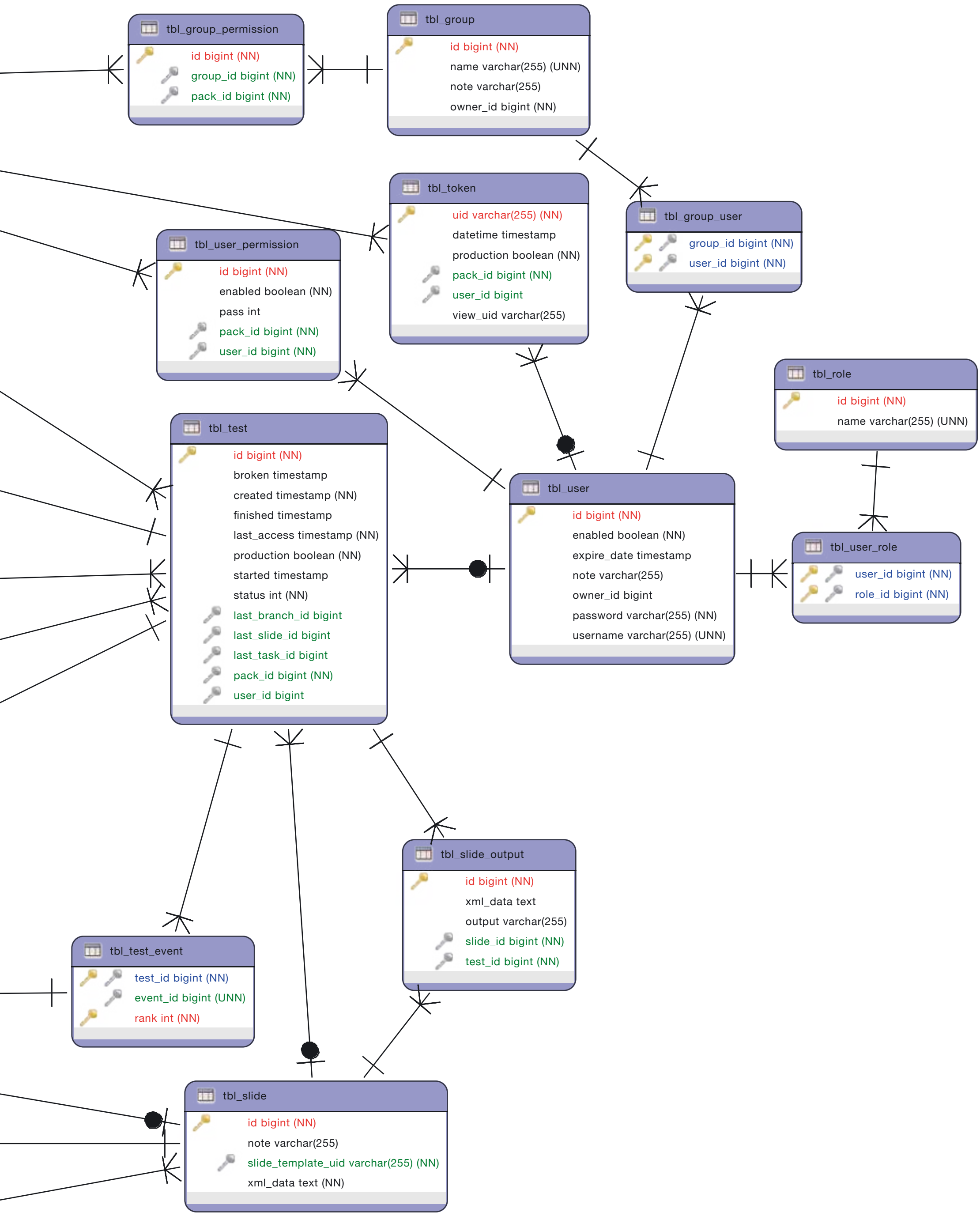
Field	Type	Meaning
id	bigint	primary key
note	varchar(255)	note
owner_id	bigint	group owner

A1-24. Table *tbl_group_user* – group administration

Field	Type	Meaning
group_id	bigint	group ID the table *tbl_group*
user_id	bigint	user ID in the table *tbl_user*

Appendix 2 – database ER diagram




tbl_group_permission
id bigint (NN)
group_id bigint (NN)
pack_id bigint (NN)
tbl_group
id bigint (NN)
name varchar(255) (UNN)
note varchar(255)
owner_id bigint (NN)
tbl_token
uid varchar(255) (NN)
datetime timestamp
production boolean (NN)
pack_id bigint (NN)
user_id bigint
view_uid varchar(255)
tbl_group_user
group_id bigint (NN)
user_id bigint (NN)
tbl_user_permission
id bigint (NN)
enabled boolean (NN)
pass int
pack_id bigint (NN)
user_id bigint (NN)
tbl_role
id bigint (NN)
name varchar(255) (UNN)
tbl_test
id bigint (NN)
broken timestamp
created timestamp (NN)
finished timestamp
last_access timestamp (NN)
production boolean (NN)
started timestamp
status int (NN)
last_branch_id bigint
last_slide_id bigint
last_task_id bigint
pack_id bigint (NN)
user_id bigint
tbl_user
id bigint (NN)
enabled boolean (NN)
expire_date timestamp
note varchar(255)
owner_id bigint
password varchar(255) (NN)
username varchar(255) (UNN)
tbl_user_role
user_id bigint (NN)
role_id bigint (NN)
tbl_slide_output
id bigint (NN)
xml_data text
output varchar(255)
slide_id bigint (NN)
test_id bigint (NN)
tbl_test_event
test_id bigint (NN)
event_id bigint (UNN)
rank int (NN)
tbl_slide
id bigint (NN)
note varchar(255)
slide_template_uid varchar(255) (NN)
xml_data text (NN)

SELECTED ISSUES OF EXPERIMENTAL TESTING IN CARTOGRAPHY

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