Design Guidelines for Pictographic Symbols: Evidence from Symbols Designed by Students

Jari Korpi, Paula Ahonen-Rainio

Department of Real Estate, Planning and Geoinformatics, School of Engineering, Aalto University, PO Box 15800, FI-00076 Aalto, Finland

Abstract. Pictographic symbols are widely used in different kinds of environments because of their potential for delivering complex messages efficiently. However, if they are not properly designed they fail to deliver the intended message. In this paper, we formulate a set of graphic and semantic qualities that contribute to the overall quality of the symbols. We concretize the qualities by analyzing pictographic symbols designed by students from different countries on a cartography course and by identifying typical design errors made by the students. The resulting list of errors can be used as a check list of things to be avoided when designing pictographic symbols.

Keywords. Pictographic symbols, Map symbols, Icons, Design guidelines, Symbol design, Novice designers

1. Introduction

Pictographic symbols are commonly used in several environments, including tourist maps, cell phones, instruction manuals, automobile dashboards, traffic- and safety signs, and airport wayfinding systems, and they define much of the usability of the products or systems they are part of. For this reason, the symbol designer must have good knowledge on the qualities that are needed for creating successful symbols. The advantages and limitations of pictographic communication are studied in several fields, such as semiotics, perceptual psychology, ergonomics, human-computer interaction, cartography, and graphic design. Several qualities that the symbols should possess have been introduced for different purposes of use, such as user interface icons and warning pictorials. Also guidelines have been given for achieving these qualities.

ICA European Symposium on CARTOGRAPHY
VIENNA, 10–12 NOVEMBER 2015

Published in "Proceedings of the 1st ICA European Symposium on Cartography", edited by Georg Gartner and Haosheng Huang, EuroCarto 2015, 10-12 November 2015, Vienna, Austria

In paper maps, the pictographic symbols have played an important role for decades and today mobile devices equipped with high resolution displays and GPS receivers are able to visualize map mashups where different kinds of points-of-interets nearby the user are shown on a map. Still, symbol design represents only a fraction of the process of map design and production. Because of this, symbol design is not among the core contents of cartographic education. Therefore, even professional cartographers, let alone growing number of self-educated amateur map makers may lack the knowledge and skills required for designing successful symbols that the professional graphic designers do have. This kind of occasional designers need practical guidelines to design proper symbols. However, there are no solid list of symbol qualities or design guidelines for pictographic map symbols. In this paper, we aim at tackling this problem by 1) collecting a general list of symbol design qualities from different disciplines and 2) formulating a set of concrete guidelines for achieving these qualities. The general symbol qualities describe the desirable characteristics of pictographic *map symbols*. However, the qualities are aimed to be applicable to different contexts of use of pictograms, and therefore seek to benefit professional graphic designers in addition to cartographers. The concrete guidelines describe the list of dos and don'ts and seek to benefit map designers that are not fully trained in symbol design.

In the next two sections we first present a brief overview of the motivation and characteristics of pictographic symbols, and then, introduce a list of general symbol qualities composed from the related literature. We then present an evaluation and analysis of map symbol designs by university students in order to concretize the qualities by examining how the qualities tend to be violated in practice. Finally, the limitations of the results are discussed and the conclusions are drawn.

2. Pictographic Symbols

Pictographic symbols (also referred to as icons, pictograms, and pictorials) are small graphical pictures that are used to present information (Wogalter et al. 2006), and they are often used to replace textual presentation. The advantage of pictographic symbols over text is that they are language-free (Pappachan & Ziefle 2008), they are more robust to changes in scale, reading speed and distance (Nakamura & Zeng-Treitler (2012), and require less space (Wogalter et al. 2006). The well-known example of the power of pictographic representation is the Isotype system by Otto Neurath. He and his team used pictographic symbols to make statistics more attractive and memorable to less educated people (Burke 2009). In cartography picto-

graphic symbols are used in maps for general public, such as tourist maps, because pictographic map symbols are, if not intuitive, easier to learn and remember than abstract map symbols.

Comprehension of symbols is explained through the semiotic concept of sign introduced by Peirce (1931-58). In semiotics sign is a product of a three-way interaction between the „representamen" (i.e. the symbol), the „object" (i.e. the referent that is represented) and the „interpretant" (i.e. the mental representation of the object), and sign is a sign only when it represents something for someone. Identification of pictographic symbols can also be explained through the processes of object recognition introduced in perceptual psychology, e.g. by Biederman (1987), and by the terms used by Keates (1982). In symbol identification, bottom-up and top-down processes are used simultaneously. Perceptual bottom-up processes allow a symbol to be detected from the background. The symbol is further identified to depict something familiar, for example, a „police car" on a map. The meaning is then interpreted, for example, the police car is interpreted as standing for the location of a „police station". In the identification and interpretation phases top-down processes are incorporated under the influence of semantic knowledge and goals of the user and the context (Pappachan & Ziefle 2008). For example, the goal of a map reader might be to find the location of the nearest police station in the map, and he or she may have an idea of what kind of objects are depicted in the map (e.g. services on a city map).

Pictographic symbols are generally categorized in terms of their visual abstractness and the relation between the symbol and the referent. Visually symbols can be placed on a continuum of abstractness starting from geometric shapes and ending with highly realistic pictures of real world objects (MacEachren 1995). Pictographic symbols can be categorized further on the basis of how the symbol (i.e., the visual representation) is linked to its meaning (i.e., the referent). Nakamura & Zeng-Treitler (2012) provided a taxonomy of representation strategies of pictographic symbols. In their taxonomy, the representation strategies of the symbols were categorized at the general level into arbitrary convention, visual similarity, and semantic association. In representation through visual similarity, the referent is represented by depicting its visual characteristics, for example, a symbol depicting an elephant in a map of a zoo pointing out the location of the elephants in the zoo. In arbitrary convention the symbol is attached to the referent by a convention, for example the Red Cross or the Rod of Asclepius standing for health services such as first aid point in the zoo. In representation through semantic association, the connection between the referent and the symbol is „mediated" by depicting concepts that are semantically close to the referent, for example a coffee cup standing for cafeteria or a knife and a fork standing for a restaurant in the map of the zoo. Semantic association

can be further divided to a number of different subclasses such as comparison, exemplification, semantic narrowing, physical or temporal decomposition, body language, metaphor or different types of contiguities (Nakamura & Zeng-Treitler 2012).

Pictographic symbols possess different qualities that define their success, and the goal of symbol design is to maximize these qualities in the symbols. The symbol qualities can be reviewed from the viewpoint of reading the symbols and from the viewpoint of designing them. From the viewpoint of reading the symbols, the qualities of the symbols relate to the efficient (bottom-up) processing of the symbol and to the correct interpretation of the meaning of the symbol that requires higher-level cognitive processes. In addition, the qualities may relate to more sophisticated processes, such as the aesthetic response (i.e., what is felt to be good-looking) and the sensitivity of a symbol (i.e., what is felt acceptable and appropriate). From the viewpoint of designing the symbols, the qualities of the symbols relate either to the graphical representation of or to the (semantic) design idea for the symbol (i.e., the concept(s) chosen for visualizing the referent). For example, the design idea for a „police station" can be a „police car" or a „sheriff's star".

Design guidelines can be classified into descriptive guidelines detailing the characteristics of the end result and into procedural guidelines instructing the design process. Design guidelines are suggested for different uses of pictographic symbols, and several methods are used in achieving the guidelines. Huang et al. (2002) collected the opinions of graphic designers in order to collect the factors affecting the design of computer icons. Apple (2015) gives practical guidelines for designing icons for applications for the iOS platform. McDougall and her colleagues studied how different symbol properties affect the efficiency of symbol identification by organizing several experiments (McDougall et al. 2000, McDougall et al. 2006, Isherwood et al. 2007). In cartography different sets of goals are developed to help design a symbol set for a specific map use, e.g., for mobile maps (Stevens et al. 2013), for humanitarian demining (Kostelnick et al. 2008), and for crisis management (Korpi 2008) but these sets mostly concentrate on the purpose-of-use specific guidelines. Because of the differences in the research methods and in the considered contexts of use of the symbols, different qualities are emphasized in different sets of guidelines. By combining guidelines from different sources, different aspects such as efficiency, aesthetics and cultural aspects can be considered.

3. Survey on the Qualities of Pictographic Symbols

We conducted a thorough literature review to identify the general qualities and guidelines for successful symbols. Guidelines were collected concerning symbols for various purposes of use, such as map symbols, interface icons, warning signs and traffic signs. The materials used were various, as we included studies based on measured performance of the symbols as well as design books and practical design guidelines. Material was included from the past thirty years. Guidelines varied in terms of their format (narrative or listed form) and in terms of their level of detail. We used similar method than Friedman and Bryen (2007) in analyzing the guidelines. All guidelines and qualities were put in a table. Procedural guidelines (e.g. test-before-use) and context-specific guidelines that are not relevant in other purposes of use of symbols were excluded. The remaining qualities and guidelines were sorted according to their contents. Duplicates and closely described guidelines were combined, and the remaining guidelines were categorized. There were a few guidelines that were descriptive and potentially relevant across contexts, but could not be categorized into any categories and were not mentioned in other sets of guidelines. This category of "others" was considered to consist of rarely mentioned guidelines that do not have significant contribution to overall quality of symbols.

The qualities and guidelines can be subsumed under ten categories. We divide these qualities into graphic and semantic qualities on the basis of whether the quality primarily deals with the graphical representation or the semantic content of the symbol (i.e. the design idea). Graphic qualities include simplicity, clarity, visibility, consistency, distinctiveness and aesthetic appeal. Semantic qualities include concreteness, semantic closeness, familiarity, and acceptability. The qualities are explained below with references to earlier studies or practical recommendations. Figure 1 shows examples of high- and low-quality designs according to each quality.

3.1. Graphic qualities

Simplicity

The visual complexity of a symbol refers to the intricacy of the edges, the number of elements, and the level of detail in the symbol (Forsythe et al. 2003). Simple symbols are located more efficiently in a visual search task than complex symbols (McDougall et al. 2006) and are more legible (Wogalter et al 2002, Wogalter et al. 2006). In addition, simplicity in general is noticed to be an appreciated attribute of a range of products among the users (Blijlevens et al. 2009). Therefore, the symbol should not include small details. However, in some situations complex communication of in-

formation is necessary for correct interpretation of the intended meaning (McDougald & Wogalter 2014).

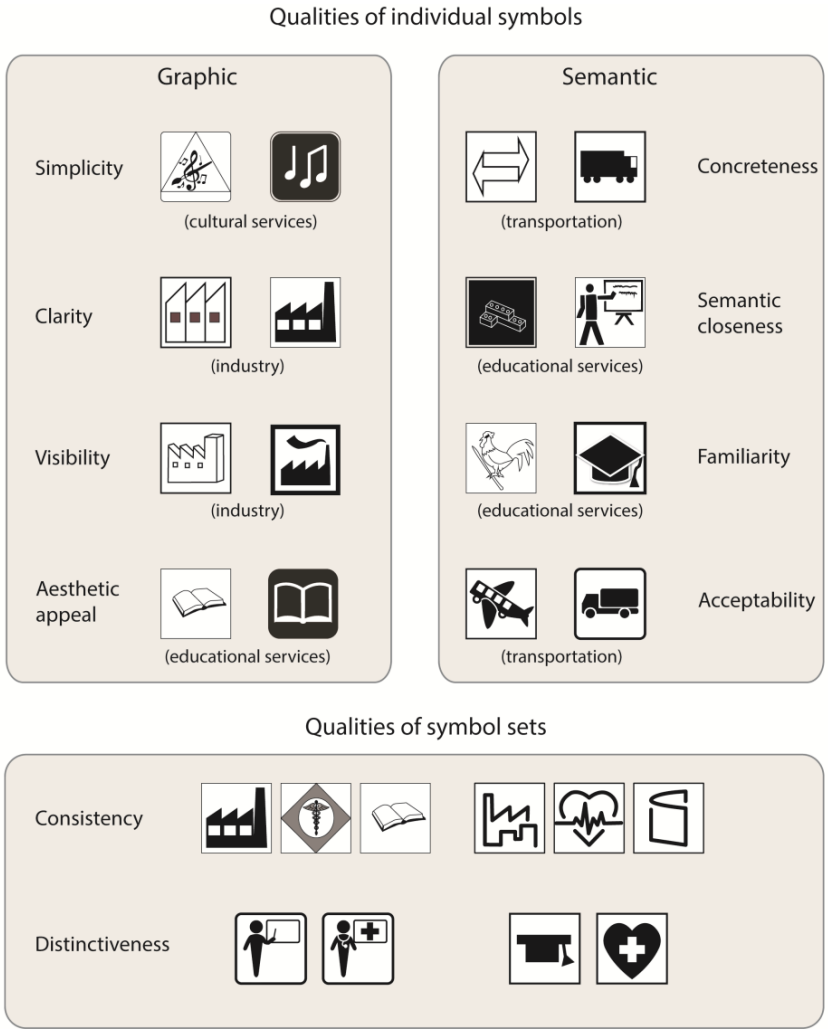

Figure 1. Low-quality (left) and high-quality (right) examples of symbols designed by students for each of the nine qualities.

Clarity

Clarity refers to the ease of recognition of the contents of the symbol unambiguously. For example, in Figure 1, it is difficult to recognize the factory

that is used to represent industry. The symbols should be easily recognizable (Huang 2002) when the context is known (Wolff & Wogalter 1998, Goonetilleke et al. 2001, Hsu & Lin 2011). Too many details in the symbol hamper the efficiency of its recognition, whereas the absence (or poor visualization) of the typical elements of the object hampers the accuracy of the recognition (Bruyas et al. 1998, Wogalter et al. 2002). Therefore, the essential parts of the object that contribute best to its recognition should be enhanced, whereas unnecessary elements should be removed (Adams et. al 2010, Tyner 2010, Pettersson 2011, Zender 2006). The symbol may represent only the characteristic parts of the objects because of the human ability to recognize partially occluded objects (Korpi et al. 2013).

Visibility

The visibility of a symbol refers to the ease of detection of the symbol from the background. The contrast between the symbol and the background and the contrast between the pictogram and the frame should be large enough (Huang et al. 2002, Shieh & Huang 2004, Wogalter et al. 2006, Rousek & Hallbeck 2011). If the background is light in color, the symbols should be dark so as to maximize the luminance contrast (Stevens 2013). However, a common problem especially in case of maps and mobile device menus is that the symbols may be used with multiple backgrounds (Korpi 2008, Apple 2015). This problem may be overcome by designing the symbols to be generally distinctive by framing the pictogram or by having a thick enough edge weight. If the symbols include frames, the contrast between the frame and the pictogram should be large enough to distinguish the pictogram. This can be done by using filled figures (Pettersson 2011, Medynska-Gulij 2008) that have a large enough luminance contrast with the frame, or by having bold lines (Wogalter et al. 2006).

Consistency

Consistency refers to the extent to which the symbols designed to a purpose form a visually uniform set. Therefore, consistency is a quality of the symbol set instead of a quality of the individual symbols. Symbols in a set should employ a consistent and unified style and visual appearance so that the symbols look as though they belong to the same set (Horton 1994). This can be achieved by using similar stroke weights, arcs, circle sizes, and perspectives in all symbols (Zender 2006, Korpi 2008, Apple 2015). In addition, when a set of symbols is used together in a display (e.g. map symbols), saliency differences between the symbols should be avoided, if the objects they represent lie on the same level of semantic importance. Visually heavier symbols tend to attract attention (Forrest & Castner 1985), as well as a symbol that is simpler than the other symbols in a display (Huang 2008).

Therefore, the symbols meant to be used together in a display should be consistent in terms of their visual weight (Korpi 2008) and complexity (Stevens 2013). Apple (2015) advise ensuring a consistent perceived size in all the symbols.

Distinctiveness

Distinctiveness of symbols refers to the easiness of discriminating the symbols from each other (McDougall et al. 2000). Also the term discriminability is used from this quality (Huang et al. 2002). Symbols should vary in terms of their global characteristics to ensure the efficiency and effectiveness of visual search of a symbol in a display (Williams 2000, Wiedenbeck 1999). However, distinctiveness is difficult to measure (McDougall et al. 2000).

Aesthetic appeal

In addition to be effective and efficient, symbols should be appealing and aesthetically pleasing in order to give an impression of quality (Korpi 2008, Wogalter et al. 2006). Aesthetics guidelines of symbols are mentioned in literature only broadly, probably because graphic design is commonly considered to be an artistic process that is difficult to guide in practice (Wang & Hsu 2006). Pettersson (2011) states that the horizontal and vertical elements, as well as the dark and light ones, in any information material should be in good balance. The layout of elements in an icon could affect icon quality (Huang et al. 2002).

3.2. Semantic qualities

Concreteness

The concreteness of a symbol refers to the extent to which the symbol depicts real objects, materials, or people (McDougall et al. 1999). A Symbol that is depicted by a geometric form, such as the Red Cross emblem, is visually abstract, whereas a symbol, such as the Rod of Asclepius is concrete, because it depicts real objects, a snake and a staff. Concreteness affects the accuracy of identification (Chan & Ng 2010, Chan & Chan 2013). This suggests that concrete design ideas should be used as far as possible.

Semantic closeness

The semantic distance is the closeness of the symbol to the referent that it represents (McDougall et al. 1999). We use the term semantic closeness after Chan and Ng (2010). The representation is semantically closest to the referent when the symbol physically resembles the referent, i.e. the representation strategy of visual similarity according to Nakamura and Zeng-

Treitler (2012). The representation is semantically longest when the referent is represented through an arbitrary convention that must be learned before in order to be correctly interpreted. Semantic closeness is stated to be the best predictor of symbol interpretability (Ng & Chan 2007, Chan & Ng 2010, Chan & Chan 2013). Therefore, semantic closeness is generally highly advisable for ensuring the correct interpretation of the symbol (Morrison & Forrest 1995, Korpi & Ahonen-Rainio 2010, Stevens 2013, Medyska-Gulij 2008, Huang 2002), and ambiguity, i.e. the possibility to connect the symbol to multiple meanings in the context, should be also avoided (Goonetilleke et al. 2001). In addition, the symbol should cover the whole concept that is intended to be represented, and not just a single sub-concept (Wogalter et al. 2006, Korpi & Ahonen-Rainio 2010, Nakamura & Zeng-Treitler 2013). However, this may be impossible to reach in case of conceptually broad referents.

Familiarity

McDougall (1999) defined the familiarity of the symbols as the frequency with which they are encountered. Frequently encountered symbols are identified generally more accurately than unfamiliar ones (Ben-Bassat & Shinar 2006). Isherwood and McDougall (2007) defined familiarity as also meaning the familiarity of the connection between the symbol and its meaning, e.g., that a book is a well-known symbol for a library. The familiarity of the symbols has a strong effect on the speed and accuracy of symbol processing (Isherwood & McDougall 2007, Chan & Chan 2013), and familiar symbols tend to be preferred by users (Oh et al. 2013). In their practical guidelines, Apple (2015) suggest using “universal imagery that people will easily recognize”. In other words, established conventions should be used in symbol designs (Chi & Dewi 2014). However, historical reference itself does not guarantee the correct interpretation for new users (Rousek & Hallbeck 2011). In addition, the designer should take into account the cultural differences when considering the familiarity of the symbols (Piamonte et al. 2001, Shinar et al. 2003, Pappachan & Ziefle 2006, Korpi & Ahonen-Rainio 2010, Blees & Mak 2012).

Acceptability

Acceptability of a symbol refers to the subjective suitability of the design idea for the referent. Users may consider a symbol unsuitable for its referent even though they would correctly identify it (Böcker 1996). For example, two design ideas may be understood equally well as a depiction of a referent, but the users may generally prefer the first over the second. Then the first design idea is considered more appropriate than the second. Design ideas that are acceptable in one culture may be unacceptable in anoth-

er and some design ideas may even be felt offensive in some cultures (Korpi & Ahonen-Rainio 2010). Respectively, the acceptability of a symbol can be increased by adding desirable elements in the design, such as a helmet on a bicycle rider to promote a desired behavior (Oh et al. 2013).

3.3. Discussion on the qualities

We see the ten qualities as a valid set of design goals that help designers implement successful map symbols. However, the qualities were not defined in equal levels of generalization and agreement in the literature. Simplicity, concreteness and familiarity were examples of qualities that were explained consistently and concretely. Aesthetic appeal was an example of quality that was mostly referred to only vaguely. Semantic closeness was a quality that was defined variable ways. Some sort of semantic association to the referent was the most frequently mentioned quality in the literature, and different terms were used and different points were raised, e.g. "A symbol that evokes different interpretations across objects is ambiguous" (Wogalter et al. 2006), "The meanings of the icon should be consistent with users' mental models" (Huang et al. 2002), and "The icon's implicit meaning should be close to the intended ones" (Huang et al. 2002). We classified all such statements under semantic closeness, but the semantic connection between the representation and the referent seem to be more complex issue than a single quality. For example, semantic reliability is a quality that might be reasonable to be separated from semantic closeness. Semantic reliability refers to the danger of linking the meaning to an unwanted referent. This might happen if the symbol is semantically close to more than one possible referent.

We categorized the qualities into graphic and semantic qualities on the basis of whether the quality deals with the graphical representation or the semantic content of the symbol. In addition, the qualities can be divided on the basis of which phases of the symbol reading process they contribute to. Visibility is important in the early stage of bottom-up processing whereas semantic closeness relates to the interpretation phase. Aesthetic appeal and acceptability may contribute a little to the efficiency and effectiveness, but are more important when the user forms an opinion of a product.

Symbol qualities presented here are somewhat universal, i.e. the same qualities are useful for most of the uses of pictographic symbols. However, different qualities are emphasized in different contexts according to the constraints typical for the context. In maps and mobile device menus the space available for the symbols or icons is limited, and in maps the (background) map and e.g. crowding of the symbols affect the perception of them. In traffic signs the time available for reading the sign is limited (Oh et al. 2013). In

safety signs the correct interpretation of signs is vital, and critical confusions must be avoided above all (Wogalter et al. 2006). Furthermore, different user groups may require an additional emphasis on some qualities. For example aging causes cognitive changes in attention, language, and memory that lowers symbol reading and comprehension abilities (Lesch et al. 2011, Handcock et al. 2004). Therefore, contrast (Nivala & Sarjakoski 2005), clarity, concreteness, and semantic distance (Lesch et al. 2011) especially are suggested to be taken care of when designing symbols for older adults. Also, cultural background of users may affect the relative importance of different qualities (Blees & Mak 2012). At least, familiarity and appropriateness, as the two most culture dependent qualities, should be considered with care when the intended users come from different cultural background. In addition to maximizing the general qualities, the purpose of use may dictate specific needs for the visualization. For example, Stevens et al. (2013) applied skeuomorphic cues to give an appearance of being touchable for interactive symbols.

3.4. Reliability and validity of survey of the qualities

The literature survey was based on 18 sets of guidelines that were from a long period of time and originated from different disciplines. Some of the studied guidelines were explaining earlier guidelines. This kind of second hand guidelines were used if the original was not accessible, but double collecting of same guidelines was avoided. The sets of guidelines were reinforced by research results that concentrate on a specific quality or characteristic of symbols. Besides the materials used, there are probably a number of guidelines available, but it is unlikely that additional sets of guidelines would introduce „new“ guidelines that would be considered as generally applicable. We used a systematic process for formulating the qualities from the collected guidelines and qualities. However, slightly different interpretations of the qualities are possible.

4. Analysis of Symbols Designed by Students

4.1. Material and methods

We analyzed map symbols designed by students to concretize the qualities in practice and to get more information on the variables of symbol design. The symbols that were analyzed originated from a symbol design task that was one of the assignments of an annually organized Master‘s program course „Visualization of Geographic Information“. The symbols were designed by students in four years (2009 and 2011-2013). A little more than a half of the students were Finnish, and the rest came from several countries

in Africa, Asia and Europe. The educational background of the students varied but the majority had a major in cartography or geoinformatics. The rest had practical interest in cartography and some studies in the field. None of the students had design background. The task was to design pictographic symbols to represent eight given activity areas of regional planning. The areas varied slightly from year to year, and in total designs for ten areas of regional planning were covered, namely: „agriculture and forestry", „industry", „administrative services", „health services", „social services", „transportation", „cultural services", „educational services", „commercial services", and „environmental care". The students were allowed to design manually by using pen and paper or use design software such as Adobe Illustrator or Autodesk. The students were instructed to design framed pictograms so that the symbols would be detectable from a background map. The size of the symbols was restricted to 1 cm size. Other design parameters were not fixed. The task was given after a lecture and classroom exercises on symbol design.

In the initial analysis of the symbols, many of the manually designed symbols were found to be visually complex and were considered more as drawings than as real map symbols. Therefore, the evaluation of the graphical quality of the manually designed symbols was not expected to provide any meaningful results and manually designed symbols were excluded from the analysis. In addition, the designs that did not follow the instruction on framing the symbol were excluded from the analysis. The remaining 216 symbols (i.e. 27 symbol sets each consisting of eight symbols) were then analyzed by three independent reviewers. The authors acted as two of the reviewers and the third one was a doctoral candidate from the research field of cartography. The symbols were analyzed both individually and as sets of eight symbols. Each symbol (216) and symbol set (27) was given a written report of including problems, if any were found.

4.2. Results of the evaluation

We analyzed the results of the evaluation by the following process. First, the individual problems were separated and generalized from the reviews. For example, the review: "the ear of wheat is lighter than other elements in the symbol, and thus difficult to recognize. It is also too small" was rewritten as two problems: "too light elements in the design" and "too small elements in the design". Next, the individual generalized problems were collected in a table and frequencies for different problems were recorded. In total, 48 different problems were identified. Similar problems were further categorized. For example, problems such as "thin lines used in the frame", "thin lines used in a specific element of the pictogram" and "entirely drawn by using thin lines" were combined into "thin lines used in the design". Com-

ments that appeared only once were excluded, because they were assumed to not be general problems occurring in symbols designed by novice or occasional designers. Most frequent problems were “too detailed presentation” and “thin lines used in the frame or in the pictogram”. Finally, the resulting list of 21 remaining problems were classified under different symbol qualities by comparing the problem descriptions with the definitions of the qualities. At least one problem was identified for each of the qualities. The problems are listed and arranged according to the qualities they violate in Table 1.

4.3. Discussion on the evaluation results

The 21 problems found can be used in concretizing the qualities into descriptive guidelines simply by reading the problems as a list of things to be avoided when designing symbols. Pointing out typical mistakes can help the novice designers to pay attention to issues that they might otherwise fail to consider. For example, the problem of “thin lines used in the frame or in the pictogram” can be converted to a guideline by rephrasing it to: “use filled figures or thick lines”. However, the problems or resulting descriptive guidelines themselves are, to some degree, generalizations that leave room for interpretation. For example, two judgments of whether a design idea for a referent is “generally well-known instead of local one” may differ vastly due to individual and cultural differences. This is especially a characteristic of the semantic qualities. Therefore, procedural guidelines, such as “test the symbols before use” or “apply participatory methods for design ideas”, are needed to ensure the overall quality of the symbols. Aesthetic appeal was also a quality that was sometimes difficult to concretize. In addition to concrete problems such as “not enough space between the pictogram and the frame” there were problem descriptions such as “not aesthetically pleasing”. Also, the guidelines do not give exact measures for example for the amount of space needed between the frame and the pictogram, because the measures may depend from the case. Therefore, the guidelines can only be used to draw the attention of the designer to the respective design issues.

Simplicity	• Complex design idea used (i.e. design idea requires detailed representation) • The pictogram consists of several redundant elements (i.e. several pictograms in one symbol)
Clarity	• Unnecessary details that do not contribute to the recognition • The visual representation lacks detail/visual characteristics that would have been needed in consistent recognition
Visibility	• Thin lines used in the frame or in the pictogram with respect to the planned size of the symbol • The luminance or color contrast between the pictogram and the frame is too weak for efficient communication
Consistency	• Visual weight: over- or under-emphasized symbols in the set (e.g., darker vs. lighter); • Complexity: very detailed and very simple designs in the same set • Style: symbols look stylistically different (e.g. different line weights used)
Aesthetic appeal	• Misplaced elements: the pictogram is not in the center of the frame • Not enough space between the pictogram and the frame • Elements placed uneconomically resulting in empty areas • Unrealistic proportions in elements or between different elements
Concreteness	• Visually abstract and unfamiliar design idea used
Semantic closeness	• Unidentified connection between the pictogram and the referent • A single sub-concept is used so that the symbol gets understood too narrowly • The pictogram can be connected to an unplanned referent in the context
Familiarity	• Too local, i.e., not generally well-known, design ideas for symbols used
Acceptability	• Culturally dependent design ideas used (i.e. objects referring to a certain culture are used) • Abnormal or weird design ideas used
Distinctiveness	• Two or more symbols in a set look too similar (i. e. varied only by small detail)

Table 1. The problems identified in the symbols designed by the students.

When evaluating the symbols, we found that the introduced qualities are interrelated and inseparable so that one quality affects others, which is also reported before (McDougall et al. 1999). Therefore, the qualities must be reviewed in relation to other qualities. Too complex symbols are not efficiently recognizable. However, symbols may be also too simplified in order to be accurately recognizable. Concreteness is not a problem in case of familiar symbol such of the (red) cross, but abstract and unfamiliar symbol would be difficult to interpret. Also compromises have to be made between different qualities. Graphical consistency and distinctiveness are qualities of symbol sets, and they have somewhat opposite goals to each other, because consistency guides towards similarity of the symbols and distinctiveness towards dissimilarity. There should be enough variation between the symbols to avoid misidentifications, but the symbols should still look stylistically consistent.

Qualities also build on top of other qualities. Symbols should be visible enough so that the contents can be recognized, and the contents must be recognized before the correct interpretation (with the help of semantic closeness and/or familiarity) would be possible. Furthermore, the representation should be semantically close to the referent or the connection between the symbol and the referent must be familiar to the user before the symbol can be considered acceptable.

The motivation for the approach presented in this paper is based on the assumption that guidelines are best when they are served as a list of simple dos and don'ts. Furthermore, we believe that these dos and don's are most effective when they describe errors that the novices naturally make. However, it is still a hypothesis to be tested that whether communicating these guidelines to the novice designers actually help in avoiding design errors.

4.4. Reliability and validity of the evaluation

Although, we consider the descriptive guidelines presented in this paper as a useful list, we do not claim to have listed them exhaustively. The set of guidelines is based only on the problems we were able to identify from the symbols we evaluated. Although the number of symbols included in the evaluation was high, the number of referents they represented was limited in our study. Therefore, it is likely that there exist problems that just did not appear with our set of referents. However, the referents represent reasonably well the range of map symbols, because in addition to relatively easy referents such as „health services" and „transportation" there were more abstract referents such as „administrative services" and conceptually broad referents such as „cultural services". The three reviewers identified problems generally consistently in the designs, i.e. most problematic symbols

were reported by all three reviewers. The reviewers seemed to pay attention to different aspects resulting in different problem descriptions and different frequencies of a specific problems spotted by different reviewers. However, we expect that adding more reviewers would not raise significantly more problems from the symbols. The limitation of the analysis with respect to cartographic applications was that, although the symbols were designed to be map symbols, they were assessed while being located against white background that is not the real environment of map symbols.

5. Conclusions

The cognitive process of reading and interpreting pictographic symbols is complex, and the symbols can fail to deliver the intended message in many ways. Therefore, understanding the different qualities of symbols is important when a new set of symbols is designed or when a set of symbols is chosen for a map or for another communication medium. We identified ten such qualities that can be considered as goals of symbol design. Graphic qualities relate to the visual outlook of a symbol, and they include simplicity, clarity, visibility, consistency, distinctiveness and aesthetic appeal. Semantic qualities relate to the semantic contents of the symbol, and they include concreteness, semantic closeness, familiarity, and acceptability. However, giving precise guidelines instead of general goals or qualities can be helpful in concretizing the qualities for novice designers, and thus, make the qualities more understandable. We concretized the ten qualities by identifying 21 problems relating to them from the set of 216 symbols designed by 27 students of geoinformatics.

References

Adams A, Boersema T, Mijksenaar M (2010) Warning symbology: Difficult concepts may be successfully depicted with two-part signs. Information Design Journal 18(2):94–106

Apple (2015) iOS Human Interface Guidelines. Apple Inc, Cupertino

Ben-Bassat T, Shinar D, (2006) Ergonomic Guidelines for Traffic Sign Design Increase Sign Comprehension. Human Factors 48(1):182–195

Biederman I (1987) Recognition-by-Components: A Theory of Human Image Understanding. Psychological Review 94(2):115-147

Blees GJ, Mak WM, (2012) Comprehension of disaster pictorials across cultures. Journal of Multilingual and Multicultural Development 33(7):699- 716

Blijlevens J, Creusen ME, Schoormans JP (2009) How Consumers Perceive Product Appearance: The Identification of Three Product Appearance Attributes. International Journal of Design 3(3):27-35

Bruyas M-P, Le Breton B, Pauzié A (1998) Ergonomic guidelines for the design of pictorial information. International Journal of Industrial Ergonomics 21:407–13

Burke C (2009) Isotype: Representing social facts pictorially. Information Design Journal 17(3):211-223

Böcker M (1996) A multiple index approach for the evaluation of pictograms and icons. Computer Standards & Interfaces 18:107-115

Chan AH, Chan KW (2013) Effects of prospective-user factors and sign design features on guessability of pharmaceutical pictograms. Patient Education and Counseling 90:268-275

Chan AH, Ng AW (2010) Investigation of guessability of industrial safety signs: Effects of prospective-user factors and cognitive sign features. International Journal of Industrial Ergonomics 40:689-697

Chi C-F, Dewi RS (2014) Matching performance of vehicle icons in graphical and textual formats. International Journal of Industrial Ergonomics 45:904-916

Forrest D, Castner HW (1985) The design and perception of point symbols for tourist maps. The Cartographic Journal 22(1):11–19

Forsythe A, Sheehy N, Sawey M (2003) Measuring icon complexity: An automated analysis. Behavior Research Methods, Instruments, & Computers 35(2):334-342

Friedman MG, Bryen DN (2007) Web accessibility design recommendations for people with cognitive disabilities. Technology and Disability 19(4):205- 212

Goonetilleke RS, Shih HM, On HK, Fritsch J (2001) Effects of training and representational characteristics in icon design. International Journal Human-Computer Studies 55:741-760

Hancock HE, Rogers WA, Schroeder D, Fisk AD (2004) Safety symbol comprehension: effects of symbol type, familiarity, and age. Human Factors 46(2):183-195

Horton W (1994) The Icon Book: Visual Symbols for Computer Systems and Documentation. John Wiley and Sons, New York

Hsu TF, Lin PC (2011) Graphical Symbols: The effects of proximate context and educational background on recognition performance. Information Design Journal 19(1):18–27

Huang K-C (2008) Effects of computer icons and figure/background area ratios and color combinations on visual search performance on an LCD monitor. Displays 29:237–242

Huang S-M, Shieh K-K, Chi C-F (2002) Factors affecting the design of computer icons. International journal of industrial ergonomics 29(4):211- 218

Isherwood SJ, McDougall SJ, Curry MB (2007) Icon Identification in Context: The Changing Role of Icon Characteristics With User Experience. Human Factors 49(3):465–476

Keates JS (1982) Understanding Maps. Longman, London

Korpi J (2008) Designing Pictorial Symbols for Situation Pictures of International Crisis Management. Proceedings of Cartography and Art - Art and Cartography Symposium, ICA, Vienna

Korpi J, Ahonen-Rainio P (2010) Cultural constraints in the design of pictographic symbols. Cartographic Journal 47(4):351-359

Korpi J, Haybatollahi M, Ahonen-Rainio P (2013) Identification of Partially Occluded Map Symbols. Cartographic Perspectives 76: 19-32.

Kostelnick JC, Dobson JE, Egbert SL, Dunbar MD (2008) Cartographic symbols for humanitarian demining. Cartographic Journal, 45(1):18–31

Lesch MF, Horrey WJ, Wogalter MS, Powell WR (2011) Age-related differences in warning symbol comprehension and training effectiveness: effects of familiarity, complexity, and comprehensibility. Ergonomics 54(10):879-890

MacEachren AM (1995) How Maps Work: Representation, Visualization, and Design. The Guilford Press, New York

McDougald BR, Wogalter MS (2014) Facilitating pictorial comprehension with color highlighting. Applied Ergonomics 45(5):1285-1290

McDougall SJ, Curry MB, de Bruijn O (1999) Measuring symbol and icon characteristics: Norms for concreteness, complexity, meaningfulness, familiarity, and semantic distance for 239 symbols. Behavior Research Methods, Instruments, & Computers 31(3):487-519

McDougall SJ, de Bruijn O, Curry M (2000) Exploring the Effects of Icon Characteristics on User Performance: The Role of Icon Concreteness, Complexity, and Distinctiveness. Journal of Experimental Psychology: Applied 6(4):291-306

McDougall S, Tyrer V, Folkard S (2006) Searching for Signs, Symbols, and Icons: Effects of Time of Day, Visual. Journal of Experimental Psychology: Applied 12(2):118–128

Medynska-Gulij B (2008) Point Symbols: Investigating Principles and Originality in Cartographic Design. The Cartographic Journal 45(1):62–67

Morrison C, Forrest D (1995) A study of point symbol design for computer based large scale tourist mapping. The Cartographic Journal 32(2): 126-136.

Nakamura C, Zeng-Treitler Q (2012) A taxonomy of representation strategies in iconic communication. International Journal of Human-Computer Studies 70:535–551

Ng AW, Chan AH (2007) The guessability of traffic signs: Effects of prospective-user factors and sign design features. Accident Analysis and Prevention 39:1245–1257

Nivala A-M, Sarjakoski LT (2005) Adapting Map Symbols for Mobile Users. Proceedings of the 22th International Cartographic Conference. ICA, A Coruna

Oh K, Rogoff A, Smith-Jackson T (2013) The effects of sign design features on bicycle pictorial symbols for bicycling facility signs. Applied Ergonomics 44:990-995

Pappachan P, Ziefle M (2008) Cultural influences on the comprehensibility of icons in mobile–computer interaction. Behaviour & Information Technology 27(4):331-337

Peirce CS (1931-58) Collected Papers. Harvard University Press, Cambridge, CA

Pettersson R (2011) Information Design, Volume 4: Graphic Design. Institute for Infology, Tullinge

Piamonte DPT, Abeysekera JDA, Ohlsson K (2001) Understanding small graphical symbols: a cross-cultural study. International Journal of Industrial Ergonomics 27:399–404

Rousek JB, Hallbeck MS (2011) Improving and analyzing signage within a healthcare setting. Applied Ergonomics 42:771-784

Shieh KK, Huang SM (2004) Effects of pictorial size and circle-slash thickness on glance legibility for prohibitive symbols. International Journal of Industrial Ergonomics 33:73-83

Shinar D, Dewar RE, Summala H, Zakowska L (2003) Traffic sign symbol comprehension: a cross-cultural study. Ergonomics 46(15):1549-1565

Stevens JE, Robinson AC, MacEachren AM (2013) Designing Map Symbols for Mobile Devices: Challenges, Best Practices, and the Utilization of Skeuomorphism. Proceedings of the 26th International Cartographic Conference. ICA, Dresden

Tyner JA (2010) Principles of Map Design. The Guilford Press, New York

Wang RW, Hsu C-C (2006) Study of the design operation of graphic simplification. The Design Journal 10(3):54-73

Wiedenbeck S (1999) The use of icons and labels in an end user application program: An empirical study of learning and retention. Behaviour & Information Technology 18(2):68-82

Williams TR (2000) Guidelines for Designing and Evaluating the Display of in- formation on the Web. Technical Communication 47(3):383-396

Wogalter MS, Conzola VC, Smith-Jackson TL (2002) Research-based guidelines for warning design and evaluation. Applied Ergonomics 33:219– 230

Wogalter MS, Silver NC, Leonard SD, Zaikina H (2006) Warning symbols. In MS Wogalter: Handbook of Warnings. Lawrence Erlbaum Associates, Mahwah, NJ

Wolff JS, Wogalter MS (1998) Comprehension of pictorial symbols: Effects of context and test method. Human Factors 40(2):173-186

Zender M (2006) Advancing Icon Design for Global Non Verbal Communication: Or What Does the Word Bow Mean?. Visible Language 40(2):178-206