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Do navigation maps need a legend? Empirical assessment of the intuitiveness of point symbols on mobile maps

Abstract. Navigation applications and the mobile maps that are integral to them are now widely used all over the world. The most popular applications of this type, such as Google Maps, has more than a billion users a month. To save time, users of navigation applications generally use the maps without referring to their legends, which are not shown in the default settings. In such circumstances, only intuitive symbols are read correctly. Mobile maps often have an extensive system of point symbols (POIs – points of interests), and navigation applications sometimes differ significantly in the symbols they use. Point symbols have been the subject of theoretical considerations and empirical studies of users, but there is a lack of comparative research indicating more and less effective solutions for designing intuitive symbols on mobile maps. This article presents the results of empirical research on the intuitiveness of POI symbols used in selected navigation applications. The study was conducted in the form of a questionnaire with 127 respondents. The results confirmed the hypothesis that the analysed symbols used in navigation applications would differ in level of intuitiveness. In addition, features of design solutions that increase or decrease the intuitiveness of point symbols were identified.

Keywords: mobile map, point symbols, user study, map legend, symbol intuitiveness, navigation applications

1. Introduction

Most travellers use navigation application. So too, in everyday life, people are increasingly using maps for navigation and for a variety of purposes. These range from simply identifying the route to a nearby cafe or shop to the more critical use of indicating an emergency escape route (Griffin et al., 2017). As a result, the most popular applications of this type, such as Google Maps, has more than a billion users a month (Kozłowski, 2020).

Mobile maps are integral and essential to mobile navigation. These maps are categorised as socio-economic maps, which can be subcategorised according to the aspects they present. According to this division, popular and widely used mobile maps are a kind of tourist map, which is classed as a socio-economic map (Ostrowski & Pasławski, 2006). These maps show topographic content, but primarily information of use to tourists (the location of tourist facilities, POIs, public transport networks). One special type of map, which includes the mobile map, is the road map supporting drivers navigating to a destination. Mobile maps are used on devices such as smartphones via navigation applications, *e.g.* Google Maps or HERE WeGO. The navigation map is adapted for optimal legibility while on the move; it reacts to changes in the user's location and is characterised by the cartographic message changing according to location and the conditions in which it is being used (Gotlib, 2012).

During the most common tasks, such as mapping a route to public places and seeking assistance in visiting a foreign city, point symbols are extremely helpful in marking various types of objects. For a symbol to be effective, it must be correctly interpreted by the user (Korpi & Ahonen-Rainio, 2010; Pasławski,

2010). According to Nivala and Sarjakoski (2007): "If the user does not understand the meaning of the map symbols, this may lead to frustration or misinterpretations." (p. 1). It is therefore important that the symbol be well constructed and correctly interpreted by the map user. This has a significant impact on an issue of great importance in the modern world, i.e. speed of access to required information. Users of mobile maps expect to be able to read map content quickly, which is especially important when navigating by vehicle, where reaction times are very important and can affect road safety. In this regard, symbols that are quick to read, i.e. those that can be understood without referring to a legend, are helpful. To check whether a map and the symbols it contains are well designed, cartographers can evaluate them, such as by empirically evaluating the map.

2. Intuitiveness of map symbols

Empirical user studies can, among other things, investigate how users read map content and whether they do so accurately. Using empirical research, cartographers can evaluate the design of various types of cartographic works: static maps (Havelková & Hanus, 2019), animated maps (Cybulski, 2022; Opach et al. 2013) or atlases (Popelka et al., 2021). User studies help to empirically verify theoretical recommendations, e.g. the usability a rainbow colour scale that has been criticised by professionals (Brewer, 1997; Gołębiowska & Çöltekin, 2022). Another issue tested in user studies is symbolisation, on paper maps (Clarke, 1998), in geoportals and interactive applications (Gkonos et al., 2018; Kellenberger et al., 2016; Manson et al., 2012; Nivala et al., 2008; Roth et al., 2017).

Point symbols on maps have also been the subject of empirical studies, including in the context of the intuitiveness of their legibility. Importantly, this has been analysed in various contexts and attending to a range of variables. Nivala and Sarjakoski (2007) assessed the intuitiveness of symbols on a mobile map, and additionally investigated how a seasonally adapted design of mobile map is assessed by users of different ages. The researchers noted that some respondents correctly recognised the image within a symbol, but failed to identify what it was intended to symbolise. For example, the respondents recognised the bicycle symbol, but did not know whether it was symbolising the beginning of a bicycle path or perhaps a bicycle service centre or shop. The authors also noted that the intuitive legibility of the symbols depended on the age and experience of the subjects. For example, all adult respondents recognised the viewpoint symbol, while none of the teenagers participating in the study did.

Empirical testing has also focused on another use case in which intuitiveness of map symbols is extremely important – crisis management (Roth et al., 2011). Using the card sorting method, i.e. a method that requires the user to organize a set of elements by, for example, separating images into appropriate categories, the authors examined a set of map symbols used for crisis situations. The results allowed them to indicate several categories of symbols that were not intuitive to the respondents, and to indicate a recurrent problem of poor categorisation of individual symbols that requires the system of symbols to be revised for better intuitiveness. Another factor that can influence how point symbols are interpreted is cultural differences. This aspect was studied by Korpi and Ahonen-Rainio (2010). They investigated the impact of users' cultural backgrounds on the perception of symbols designed for maps used in international crisis management. They demonstrated that cultural origin influenced the perception of symbols and suggested guidelines for future creators of symbols that were culturally not biased. The authors recommend, for example, the use of pictorial symbols whenever possible, and the avoidance of the standards of one's own culture and environment when developing a symbol to be used on maps intended for an international audience. The context in which the user will read the symbol, as well as cultural differences, can influence the interpretation and understanding of the symbol itself. Wolff and Wogalter (1998) examined the influence of context on the reception of a symbol. They defined context as the presence or absence of photographs of environments in which the symbol would likely be displayed. The authors found that the presence of context increased the understanding of symbols in the tests performed.

The design of point symbols also influences their distinguishability and memorability, which is related to their intuitiveness. Franke and Schweikart (2017) compared labels, and icons to investigate the effectiveness of each in maps. The task involved the subject remembering landmarks marked using the types of symbols placed next to a marked road. The study showed that text symbols were remembered best. The distinguishability of point symbols was analysed in the context of a mobile Augmented Reality system (Halik, 2014; Halik & Medyńska-Gulij, 2017). In these studies, symbols were differentiated according to graphic variables and background. The results were used to determine recommended parameters for symbols. Moreover, it was recommended to use only one graphic variable among those tested (size, transparency, sharpness) to represent a distance relationship.

The issue of design on mobile maps has also been the subject of research of slightly wider scope. T. Horbiński et al. (2020) studied the design of graphic user interface elements, i.e. buttons for measuring, route-finding, searching objects and changing displayed layers in mobile applications. The study covered various types of maps for mobile devices and found a large variation between applications in terms of the accurate recognition of the meaning of buttons for various functions.

The empirical studies has addressed the intuitiveness of symbols on maps, focusing on various aspects and contexts of use. The results have shown that the appropriate selection of parameters for symbols on maps can significantly improve or reduce their intuitiveness for users.

3. Empirical study

3.1. Aim

The aim of the study was to empirically assess the intuitiveness of symbols used on mobile maps in selected popular navigation applications. As a rule, intuitive symbols will not require the user to use a legend, making effective use of the navigation application more convenient and faster. By conducting a survey we aimed at determining the intuitiveness of POI symbols in selected navigation applications, thus indicating the potential for the user to need to use a legend to correctly identify the meaning of the tested symbols.

3.2. Materials

The initial stage included the selection of applications whose symbolisation was to be assessed. This selection was based on several criteria. The research analysed applications that meet the following criteria:

– using point symbols for POIs in the default settings,

– the symbolisation differed between selected applications,

– high popularity in the app store's "navigation" category,

– availability on the iOS platform.

Based on the above criteria, six applications were selected for the study:

1. *Google Maps* (version 5.42),
2. *Maps (iOS)* (iOS version 13),
3. *HERE WeGO* (version 2.0.53),
4. *Sygic GPS Navigation&Maps* (version 18.5.0),
5. *AutoMapa* (version 7.8.6),
6. *NaviExpert* (version 4.4.0).

The applications selected for study can be divided into two groups: free ones (Google Maps, Maps and HERE WeGO) and partially paid ones (Sygic, AutoMapa, NaviExpert) that can be downloaded for free, but for which a license must be purchased to unlock full functionality. The applications also differ in terms of launching year: AutoMapa application was launched earliest (in 2004) and the latest (a decade later) HERE WeGO (2014/15). These applications present data obtained from various vendors. Each of these applications is rated quite highly by users: all analysed applications were rated at above 4.0 in AppStore (maximum is 5 points), with the lowest rating for HERE WeGO (4.1) and the highest for Google Maps (4.7). The basic features of the selected applications is provided in Table 1.

After the initial analysis of the system of symbols adopted to designate POIs, it was found that only some categories of objects were presented in different ways (Table 2). Therefore, the category symbols that differed between applications were selected for intuitiveness

Table 1. The applications selected for testing

	Google Maps	Maps (iOS)	HERE WeGO	Sygic	AutoMapa	NaviExpert
availability	free	free	free	paid	paid	paid
producer	Google	Apple	HERE Technologies	Sygic	Telematics Technologies	Aquart and Geosystem Polska
map provider	*Incl.*, PPWK, Tele Atlas, Transnavicom	proprietary data	proprietary data	TomTom	proprietary data	Emapa / TomTom
year launched	2008	2012	2014/15	2009	2004	2005
rating in AppStore	4.7/5	n.a.	4.1/5	4.6/5	4.2/5	4.1/5

analysis. Thus, categories such as “bus stop” or “petrol station” were omitted from the empirical research, because these objects are symbolised similarly in all selected applications (these are the categories in grey cells in Table 2). Most of the symbol categories tested in the study are used frequently and represent regularly searched objects, such as post office, pharmacy or ATM. For the purposes of the study, the symbols were enlarged to the same, legible size.

3.3. Tasks

The study was conducted as an online survey. For this purpose, an internet application developed at the Department of Geoinformatics, Cartography and Remote Sensing of the Faculty of Geological Sciences, University of Warsaw was used. To assess the intuitiveness of the selected symbols, the respondents answered 43 questions: 19 open and 24 closed.

For the first 38 questions, respondents were asked to define the meaning of a presented symbol. For these questions, symbols from seven categories were selected that differed between between applications: pharmacy, ATM, library, post office, school, gym and auto service (Table 2, symbols marked with a green rectangle). In the first part (1–19), open-ended questions were asked: respondents were required to type in their guess at the meaning of a symbol; the second part (20–38) comprised closed questions for which respondents choose one of five optional answers. The two series of questions (1–19 and 20–38) posed questions about the same set of symbols, allowing the correctness of answers to open questions and closed questions to be compared. The questions from this part of the study allowed more and less successful graphic solutions for individual symbols of different content categories to be identified.

In the next part (questions 39–43), respondents were asked to indicate which of the symbols shown they most associate with a given meaning. Six categories were tested: pharmacy, ATM, library, post office, school (categories in green cells in Table 2). Respondents were asked to indicate one of six different symbols, each from a different application. The answers to the questions in this part made it possible to verify whether any of the analysed applications’ way of presenting point symbols was preferred by users.

Each question was presented similarly: the question and (for closed questions) answer options were presented on the left of the screen, and the assessed symbols on the right of the screen (Fig. 1). After providing an answer, the participant confirmed the answer by pressing the “Next” button at the bottom of the screen, and then the next question was presented. It was not possible to go back or correct confirmed answers.

It was a within-user study, so users answered the same questions about symbols from the six applications. The analysis referred to the provided responses, and for questions 1–38 also their correctness. An answer consistent with

the meaning adopted in the application was taken to be correct. It was decided to abandon analysis of response times due to the online format of the survey, which makes it limited to ensure uniform observance of time discipline for all respondents. Response time was used to exclude outliers responses (as described in subsection 4.1).

Table 2. Symbols from the selected applications

application / category	GOOGLE MAPS	MAPY (iOS)	HERE WeGO	SYGIC	AUTOMAPA	NAVIEXPERT
Pharmacy						
ATM machine						
Library						
Post office						
School						
Gym						
Auto service						
Bus stop						
Petrol station						
Restaurant						
Shop						
Theatre						
Cinema						

Categories marked with a grey fill were excluded from the analysis due to the high similarity of the symbols; symbols with a green outline were included in questions about symbol meaning (questions 1–38), and the categories marked with a green fill were tested in questions about preferred symbols (questions 39–43).

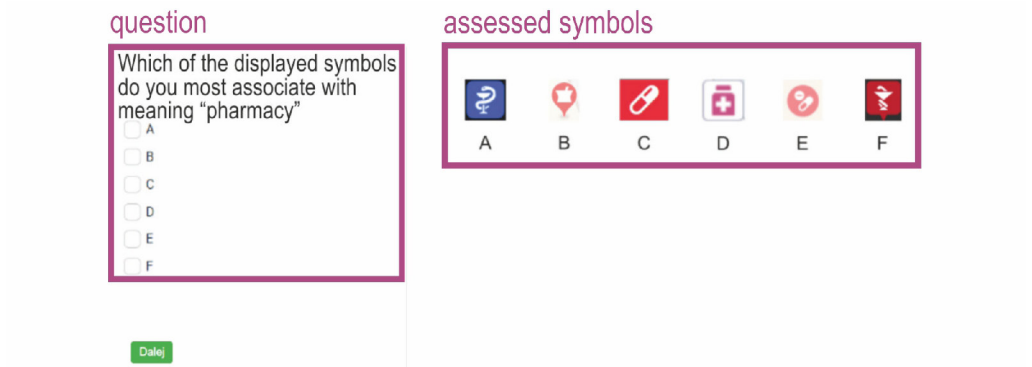

Fig. 1. Screenshot of a question requiring the selection of the symbol most associated with a specific meaning (in this case, "pharmacy")

3.4 Participants

Geography undergraduates at the Faculty of Geography and Regional Studies at the University of Warsaw participated in the study. The respondents were 1st, 2nd and 3rd year students who do not yet have specialist knowledge of map design but do, as geography students, have map-reading experience that they can use to formulate opinions on various types of symbolisation.

The survey was conducted remotely due to the university's distance learning mode cause by the Covid-19 pandemic. The questionnaire was made available to students during classes by teachers. The questionnaire was anonymous, and its results did not affect the grade for the subject on which it was completed. The participants were informed about the anonymity of the survey and the voluntary nature of participation.

One hundred and twenty-seven people took part. Of the people who completed the test, 56% of the respondents were men and 44% women. Of the respondents, 63% were third-year students, 31% were first-years, and the remaining 6% were second-years. The respondents declared that they most often use Google Maps: 79% of users use this application at least once a week (Fig. 2). The remaining applications are used by a much smaller percentage of respondents. More than half of the respondents declared that they had not used the Maps application, and over 80% of users had never used or did not know the AutoMapa, HERE-WeGO, Sygic and NaviExpert applications.

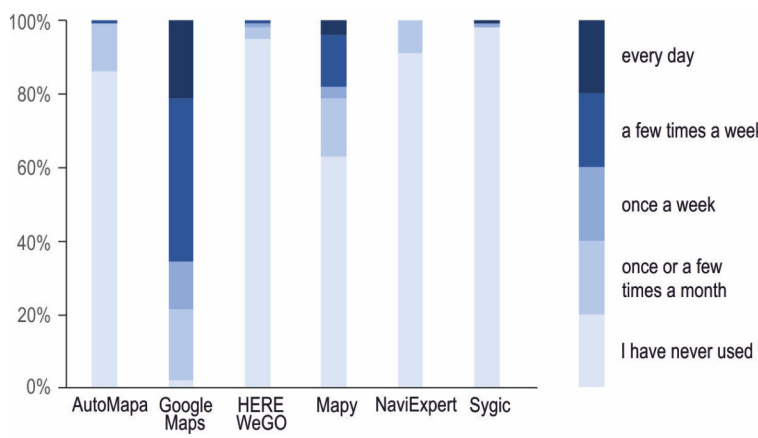

Fig. 2. Frequency of respondents' use of analysed applications

4. Results

4.1. Preliminary data analysis

The study was completed by 102 participants. Twenty-five people did not answer all the questions, so their answers were not taken into account in analysing the results. The next step in the preliminary data analysis was to verify whether there were atypical responses – outliers in terms of response time. This is important because the survey was conducted online, and it was not possible to control participants while it was being completed. Unusually slow responses may suggest low respondent engagement in answering the questions (interrupting the survey with other activities), which may affect the correctness of answers. Of those who completed the entire questionnaire, the results of those with the most outlying average response times were rejected. For this purpose, subjects were rejected whose mean time exceeded three interquartile ranges (IQR). In Fig. 3, the values are marked with an asterisk. The interquartile range, also known as the quartile range, is the "difference between the third quartile and the first quartile of the examined feature. 50% of all observations are between the quartiles." (Luszniewicz, 1973).

The obtained outliers (Fig. 3) resulted in three persons being removed from the dataset. Ultimately, the responses of 99 respondents were taken into account in further analysis.

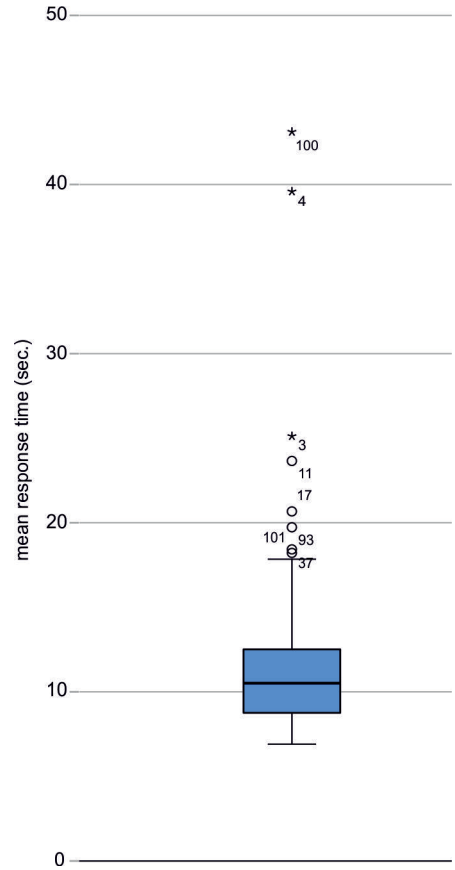

Fig. 3. Average response time of respondents. The remotest outliers (marked with an asterisk) were rejected.

4.2. Correct identification of symbol meanings

The collected answers (Fig. 4) show that the tested symbols differ in level of intuitiveness.

Although the symbols used to mark a pharmacy (Fig. 4A) and ATM (Fig. 4A) were developed in different ways, they were correctly recognised by more than half of respondents, even when not provided with an answer options. However, the remaining categories were represented by symbols that were not understandable to the respondents, especially when the respondents were not supported by an answer options. The percentage of correct answers did not exceed 40% for most of the evaluated symbols from the library and gym category, nor for individual symbols from the school and car service categories. The cause of low intuitiveness can be found in overly abstract drawing of symbols (the green gym symbol in Fig. 4E or the brown symbol for auto service in Fig. 4F), or the use of an object symbol that may be associated with another meaning (the symbol of the pitch or runner was not intuitive for designating a gym in Fig. 4E).

As expected, the meaning of a symbol was easier for respondents to recognise in a closed question where multiple possible answers were shown: correctness of answers for these questions was higher than for the open-ended questions for the same symbol (compare the height of dark and light blue bars in Fig. 4). However, for some of the assessed symbols, even the support given by an answer options did not help significantly. Such editorial solu-

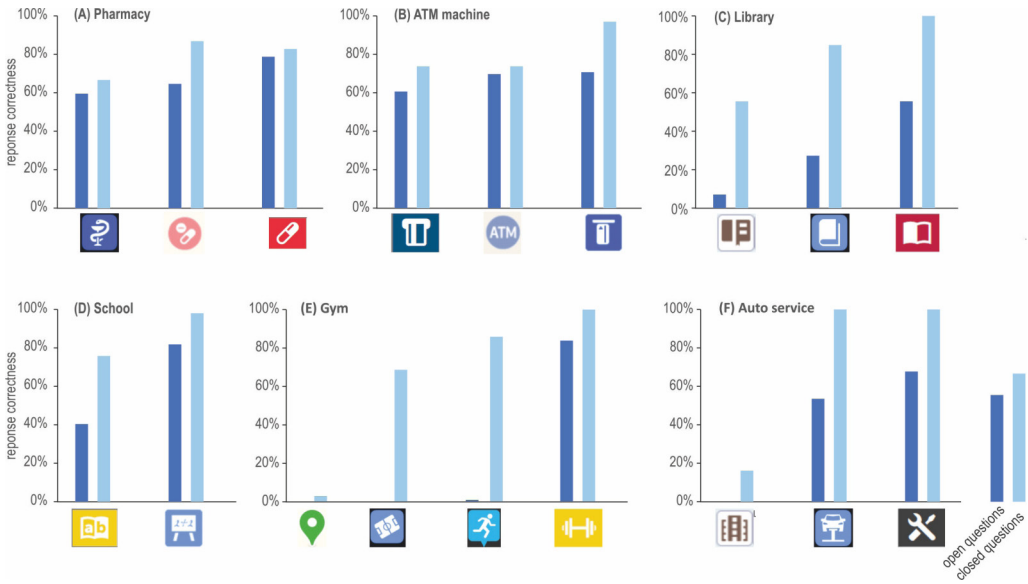

Fig. 4. Correct recognition of symbol meanings

tions can be considered unsuccessful and require the use of a legend.

4.3. Selection of symbol most associated with a category

The answers of the respondents to the questions from the next part of questions made it possible to define the preferred solutions among symbols from five categories: pharmacy, ATM, library, post office, school (Fig. 5).

Note that, of the selected content categories, some are marked in the applications using symbols of similar degrees of intuitiveness: all assessed symbols for ATMs were indicated with a similar frequency by respondents (Fig. 5E). This suggests equally successful solutions, even though the symbolisation differs between the symbols, from the symbol of an ATM card, through the cash symbol, to the English abbreviation ATM and the dollar currency symbol. For the post office symbols (Fig. 5D), there is a preference for the trumpet symbol, which is probably known to users from the Polish national mailing company (Poczta Polska) logo. The results for the remaining three assessed categories allowed symbols very poorly associated with their assigned meaning to be identified. When indicating symbols most associated with pharmacies, respondents referred to the Bowl of Hygieia symbol (in blue, not red), i.e. symbols known to them from experience, being commonly placed in pharmacy windows in Poland. Other solutions, such as the symbol of medicines or first-aid kits, were less preferred. In the case of the symbol for libraries, two were indicated that clearly represented a book. Overly abstract symbols of a book or the thematically loosely related symbol of a graduate's "mortarboard" cap were not considered successful solutions for presenting this category of content. The school category also included several symbols that were rarely indicated as being best associated. Interestingly, in this case, the design choices in presenting the icon seem significant, because both the most and the least often chosen symbols show the same object – the mortarboard. As with the questions about the meaning of individual symbols (subsection 4.1.1), respondents preferred symbols not made uncertain by an overly abstract symbol and that did not employ elements that might be associated with other categories (e.g. in the school category they did not indicate the book symbol that may be associated with a library) or with other objects, such as the envelope symbol that is now associated with the symbol for SMS text messages on smartphones or e-mail.

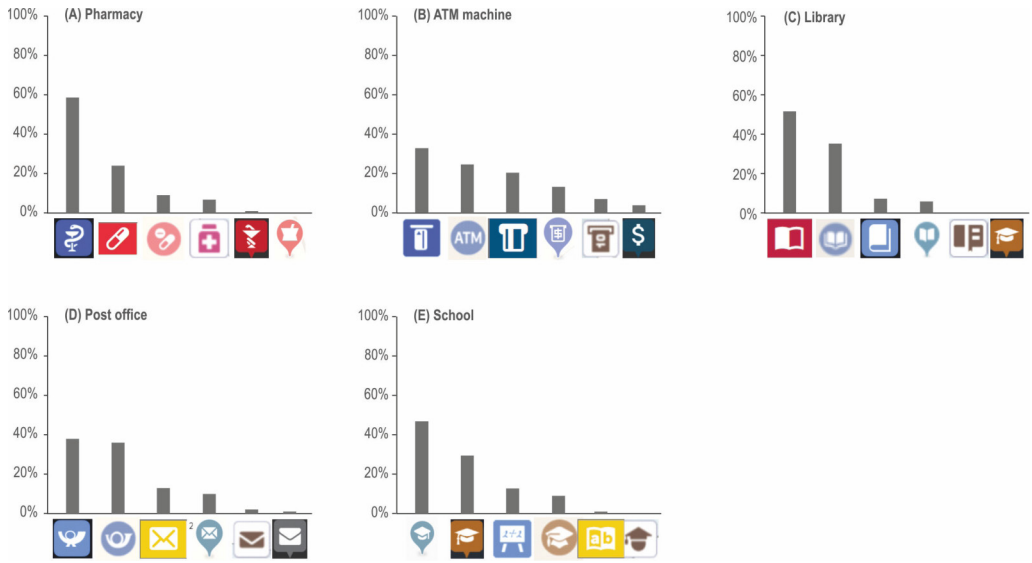

Fig. 5. Frequency with which symbols were indicated to be most strongly associated with their intended meaning

Interestingly, there is a noticeable difference in the frequency with which the symbols of specific applications were most associated with the correct category (Fig. 6). Signs from the AutoMapa, Maps (iOS) and Sygic applications were most associated with their intended meanings.

Importantly, the preferred solutions do not coincide with users' past experience in using a given application. According to the respondents' declarations (Fig. 2), the AutoMapa and Maps (iOS) applications, whose symbols were indicated as most associated most often, were unknown to more than half of respondents. Conversely, Google Maps, the application used by almost 80% of respondents at least once a week, was the fourth most frequently indicated application (Fig. 6). It is also interesting to compare the users' ratings in the AppStore (Table 1) with the preferred symbols (Fig. 6). Again, it turns out that the applications whose symbols are best associated with the given

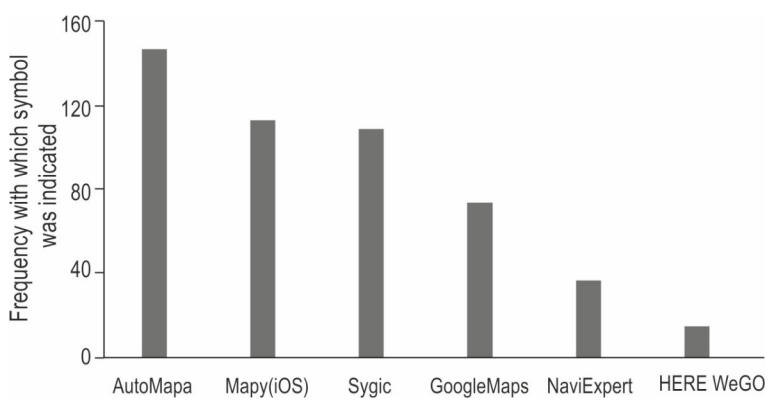

Fig. 6. Frequency of a symbol from a given application being indicated as most associated with the intended meaning

meaning are not reflected by higher ratings. The highest rated applications by users (Google Maps – 4.7/5 and Sygic – 4.6/5) do not contain the symbols most often indicated as the most understandable. By contrast, AutoMapa, which was most frequently indicated by the respondents, obtained one of the lowest average scores among the selected applications, at 4.2/5. This suggests that when giving ratings in the AppStore, users do not follow the criteria of intuitiveness and comprehensibility of POI symbols. However, we note that AutoMapa, which was most often indicated as the application with the most associated symbols, is the application that was launched the earliest (in 2004), while the latest HERE WeGO (2014/2015) was indicated by respondents the least frequently. On this basis, it can be considered whether the time needed for the application to evolve, including its symbolisation, might have affected the intuitiveness of the symbols used in the application.

5. Conclusions

The research has shown that the point symbols used in selected navigation applications are differentiated in terms of intuitiveness of meaning. This confirms the results of Horbiński et al. (2020), who obtained similar results for meaning recognition with regard to interface buttons in popular mobile applications. Based on the results collected in this study, similarly to the study by Roth et al. (2011), it was possible to identify categories that should be improved to increase intuitiveness. Not making such corrections requires a legend use to correctly identify the meaning of some symbols. The preliminary analysis of the symbolization adopted in the applications (Table 2) showed that some categories are symbolised very similarly between the selected applications, e.g. petrol stations or restaurants. The uniform use of symbolisation across cartographic products helps consolidate the meaning and increase the intuitiveness of such symbols, which at the same time removes the need to use a legend on such maps. However, some of the categories in applications are presented with different symbols and – as the results have shown – these solutions vary in how intuitive they are.

The collected data also confirmed the problem identified by Nivala and Sarjakoski (2007): although the respondents recognised the object depicted by the symbol, it was difficult to define what meaning it was intended to represent. For example, a book was not an intuitive symbol for a school for the respondents. Therefore, despite the use of a pictorial symbol, a legend is necessary in such cases. Moreover, the results confirmed the conclusions of research by Korpi and Ahonen-Rainio (2010): these authors showed that, among Europeans, the rod of Asclepius is the symbol most associated with medical facilities.

Looking at the analyses performed, several limitations can be identified, these being inherent in any study. When formulating conclusions, it should be borne in mind that symbols were assessed for intuitiveness as independent symbols, without them being placed in the context of other symbols or in the context of a map. Placing a symbol on a map provides the user many valuable clues on the potential meaning of the icon: depending on the surrounding in which it is located (for example, whether it is a built-up or forested area) and what other symbols it accompanies. As shown in the research of Wolff and Wogalter (1998), context has a clear influence on intelligibility of symbols. For the purposes of the study, to control this impact and thus focus on how to develop the point symbols themselves, it was decided to evaluate the symbols in an abstracted context. Therefore, it would be worthwhile for further research to consider the natural spatial context in which the point symbols are placed. Moreover, the research was carried out on a group of users who varied little in age. It is possible that differences in experience and a changing cultural context (as evidenced by the differences between successive generations, e.g. Generation X, Millennials, etc.) may find a different perception of symbol meanings among users from other age groups (as this affect the map use in general, as demonstrated by Słomska-Przech and Gołębiowska, 2020). This aspect, too, should be taken into account in further research on this issue.

6. Summary

In light of the obtained results, it can be concluded that the symbols used in the tested applications are characterised by different levels of intuitiveness, and therefore the need for

a legend differs between symbols. The intuitiveness of symbols was increased by symbolising POIs through specific items directly related to a given category and used in the facilities they represented (a book for libraries, a fuel dispenser for petrol stations, a dumbbell for gyms). It was also beneficial to refer to symbols used on a daily basis that users encounter in non-cartographic contexts. Examples include logo elements from well-known companies and institutions in Poland (the trumpet in the Poczta Polska logo), symbols appearing directly in these objects (the rod of Asclepius shown in pharmacy windows).

On the other hand, the use of abstract symbols, overly simplified drawings (even of concrete objects), and symbols that are used in practice to represent another meaning were unfavourable to intuitiveness (the envelope symbol is now commonly used as the symbol for SMS or e-mail messages, but it is not commonly associated with hard-copy letters). In such cases, the user needs to refer to a legend to find out the meaning of the symbol.

The results of examining the intuitiveness of symbols show that most symbols do not require a legend, because most users are able to correctly decode their meaning. Also, a certain degree of standardisation of some content categories makes a legend unnecessary. In closed questions about the meaning of a symbol, some achieved 100% correct answers, and only three obtained less than 50% correct indications of the symbol's meaning, which confirms that a legend is not necessary to understand each symbol. However, it should be borne in mind that many of the symbols tested herein were much less understandable without an answer options, and there were also symbols that were correctly matched to their intended meanings only sporadically or not at all. Thus, the development of intuitive symbols is an ambitious challenge that is not always fully achievable.

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