UMEÅ UNIVERSITET

RESOLVING USABILITY ISSUES IN WEBGIS

A Cognitive Science Approach

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Abstract

This study focuses on using cognitive principles in design, trying to resolve four problem areas (PA) found in the map layer panel of Umeå municipality's webGIS. In a first step cognitive findings that could serve as principles for implementing design choices were identified. Four low fidelity (lo-fi) prototypes were created. The lo-fi prototypes were tested using think aloud tasks and a semi-structured interview. Six participants, three expert and three novice users were recruited. Participants' opinions and thoughts were gathered to enable the development of a high fidelity (hi-fi) prototype. The hi-fi prototype was based both on the lo-fi test results and the identified cognitive principles. The hi-fi prototype was again tested using think aloud tasks and a semi-structured interview. Three experts along with three novice participants were recruited. Opinions and thoughts from the test were transcribed and categorized using combined deductive and inductive coding. The results of the analysis were used to answer our research question: does the use of cognitive principles in designing the map layer panel of Umeå municipality's webGIS resolve the previously identified usability issues? While two of the PAs seems to have been resolved in the new design, for the other two there still seems to be some unresolved issues. It can be discussed if the unresolved issues were due to lack of functionality of the prototype or inadequacy of the cognitive principles.

Keywords: webGIS, cognition, design, usability issues

Sammanfattning

Denna studie har fokuserat på att använda kognitiva principer i design, för att försöka lösa de fyra problemområden (PO) som finns i kartlagerpanelen i Umeå kommuns webGIS. En litteratursökning gjordes och identifierade kognitiva teorier som fungerade som principer för att genomföra designval. Fyra low fidelity (lo-fi) prototyper skapades. Lo-fi-prototyperna testades med hjälp av tänka-högt uppgifter och en semistrukturerad intervju. Sex deltagare, tre experter och tre nybörjare användes. Deltagarens åsikter och tankar samlades för att möjliggöra utvecklingen av en high fidelity (hi-fi) prototyp. Hi-fi-prototypen baserades på lo-fi-resultaten och de kognitiva principerna. Hi-fi-prototypen testades med tänka-högt uppgifter och en semistrukturerad intervju. Tre experter rekryterades tillsammans med tre nybörjare. Åsikter och tankar från testet transkriberades och kategoriserades med hjälp av kombinerad deduktiv och induktiv kodning. Resultaten av analysen användes för att besvara vår forskningsfråga: löser användningen av kognitiva principer vid utformningen av kartlagerpanelen i Umeå kommuns webGIS de tidigare identifierade användbarhetssvårigheter som identifierats? Huvudsakligen verkade det som att två problem är lösta, när det gäller de andra två problemen verkade det fortfarande finnas svårigheter. Bland annat, diskuterades det om de olösta frågorna berodde på bristande funktionalitet i prototypen eller otillräckliga kognitiva principer.

Nyckelord: webGIS, kognition, design, användarsvårigheter

Resolving Usability Issues in webGIS
a Cognitive Science Approach

Researchers have for a long time been interested in how people comprehend and understand maps (Bunch & Lloyd, 2006). People process map information through verbal and visual systems. A map can contain a large amount of spatial information and allows for a connection between visual information and specific locations. Maps often display large visual patterns and visually display large amounts of verbal information. Despite an incoherent picture of how users read and interact with maps, the technology has moved forward. This has created maps that are more complex, using the internet and digital media to display spatial information more dynamically and with more options. On their own, maps provide large amounts of spatial information representing complex associations, these developments add further complexity that is not yet fully understood.

One of these more complex developments of a traditional map is webGIS (Geographic Information System). WebGIS is defined as a web-based application providing the user with an online map interface containing geospatial information for the user to interact with (Mwangi et al., 2017). The main goal of a webGIS is to enable the user to easily visualize and analyze spatial information. The scope of webGIS is vast and it is estimated that over 85% of all data has a spatial component (Mwangi et al., 2017), making webGIS a very useful and versatile service that many organizations and individuals could benefit from. With the emergence of the internet, webGIS has grown rapidly and is now used by experts as well as non-experts. The increase in non-expert users has revealed to researchers that many webGIS are inherently difficult to use. This is in part because the developers of webGIS focus more on adding new features than increasing the usability of existing ones. It can also be difficult to employ traditional user testing only, when many users have never encountered webGIS before (Slocum et al., 2001). It is therefore of interest to find ways in which the usability of webGIS can be increased.

Previous studies show that cognitive theories in design and implementation of user interfaces can greatly improve the usability of a computer system (Patel & Kushniruk, 1998). Cognitive limitations and capabilities of the user should be considered when designing a user interface, especially when the interface is as complex and demanding as a webGIS. An example of a limitation to consider is the fact that our working memory has a limited capacity (Baddeley, 1992). Alternatively, there is our advanced capability to detect contrast and groupings of objects (Ware, 2021). Some of the benefits of cognitive-based design in user interfaces and applications have been shown to be improved recall of information, and that they are more satisfying to use and easier to learn (Abdullah et al., 2011). Additionally, cognitive-based design can make applications more efficient. It is believed that the technological enhancements of geovisualization specifically, will be of little use if not developed within a cognitive science framework and iteratively tested using usability engineering principles (Slocum et al., 2001).

The usability of a computer system can be defined in terms of how easy it is to learn, how effective it is, and how enjoyable it is (Sharp et al., 2019). To achieve usability, it can be broken down to six different goals, effectiveness, efficiency, safety, utility, learnability and memorability. Effectiveness is a broad term and implies how good a product is at doing what it is supposed to do. Efficiency refers to how easy it is for a user to carry out their tasks. Safety mainly concerns the user's safety interacting with the product. It also refers to protecting the users from making unwanted mistakes. Utility is mainly the concern of functionality, does the product support the user to carry out

their tasks in their own way. Learnability refers to how easy a product is to learn. Memorability refers to how easy it is for a user to remember how to operate a product once it is learned. Several issues related to these usability goals and definitions were identified in Umeå Municipality's webGIS.

The Current webGIS of Umeå Municipality

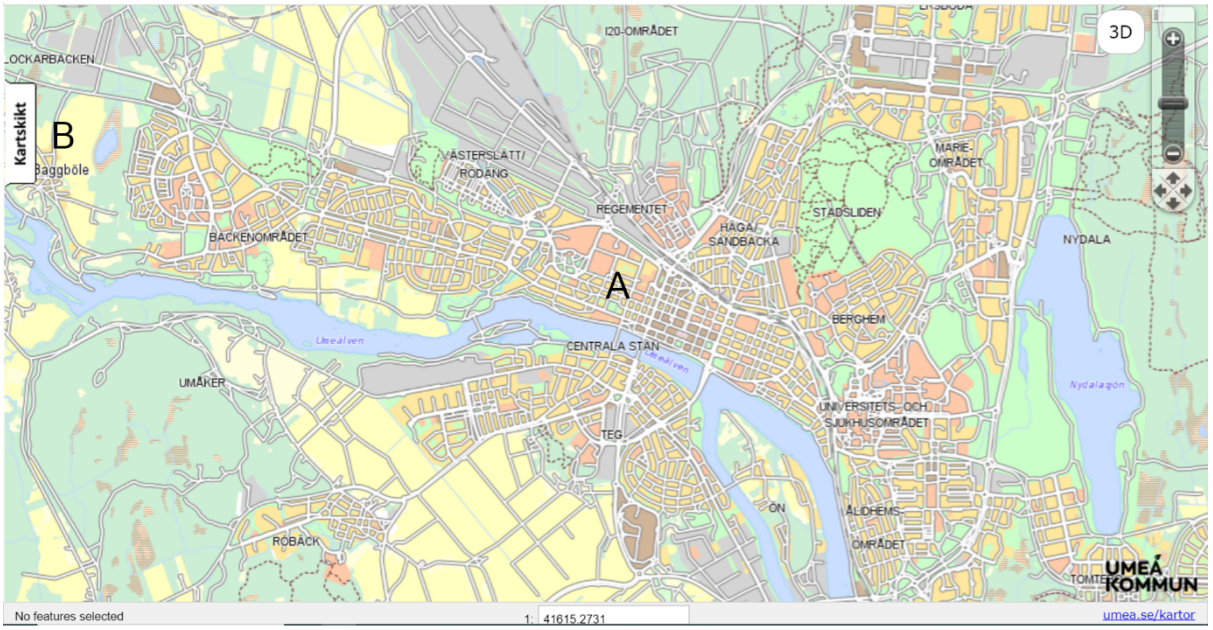
The department of cadastral surveying (lantmäteri-avdelningen)[1] at Umeå municipality has evaluated the usability of their current webGIS. One of the most prominent usability issues found was the design and function of the map layers panel. Map layers are a function for the user to choose in a catalog between the different themes of maps displayed on the screen. When a layer is selected the theme of this layer is presented as graphical elements of the map (Alesheikh et al., 2002). Before moving on to describe this specific study, we will introduce the current map layer panel of Umeå Municipality.

Umeå municipality's current webGIS map layer panel primarily consists of the following functions and elements: A background map, menu button, map layer panel, main and subcategories, map layers, icons, and activating/deactivating map layers. When the user first enters the webGIS they are presented with the background map (see Figure 1). Apart from other options, the user can continue to the menu button which is a button to open the map layer panel. The map layer panel (see Figure 2) is a menu that contains all main and subcategories, which in turn contains map layers related to that category. This gives the user different options of which information to display. A main category is labeled with a broad title or name, for example "kultur och fritid". Each main category can contain subcategories that are related to the main category. For example, the subcategory "fritid" is related to the main category "kultur och fritid". When entering a main or subcategory the user is presented with different map layers. The map layers contain information regarding the chosen category. For example, the map layer of "badplatser" is selected giving the user visual information of where the places for swimming are located on the map. The information is presented on the background map, usually in the form of icons that are semantically related to the information of the map layer. Thus, icons are graphical representations of a map layer. The icon is displayed next to the title of the map layer but also in the background map. To display the information on the background map, the user must first activate the map layer. Activating means that the user clicks in an empty checkbox located next to a map layer. When the checkbox is selected a check mark with a blue background appears in the square. The map layer is now activated, and the icons or graphics of the map layer appears on the background map. If the user no longer wishes to see the information displayed, the user can deactivate the map layer by once again clicking on the activated checkbox leaving the box empty again.

[1] Lantmäteri - Umeå kommun (umea.se)

Figure 1

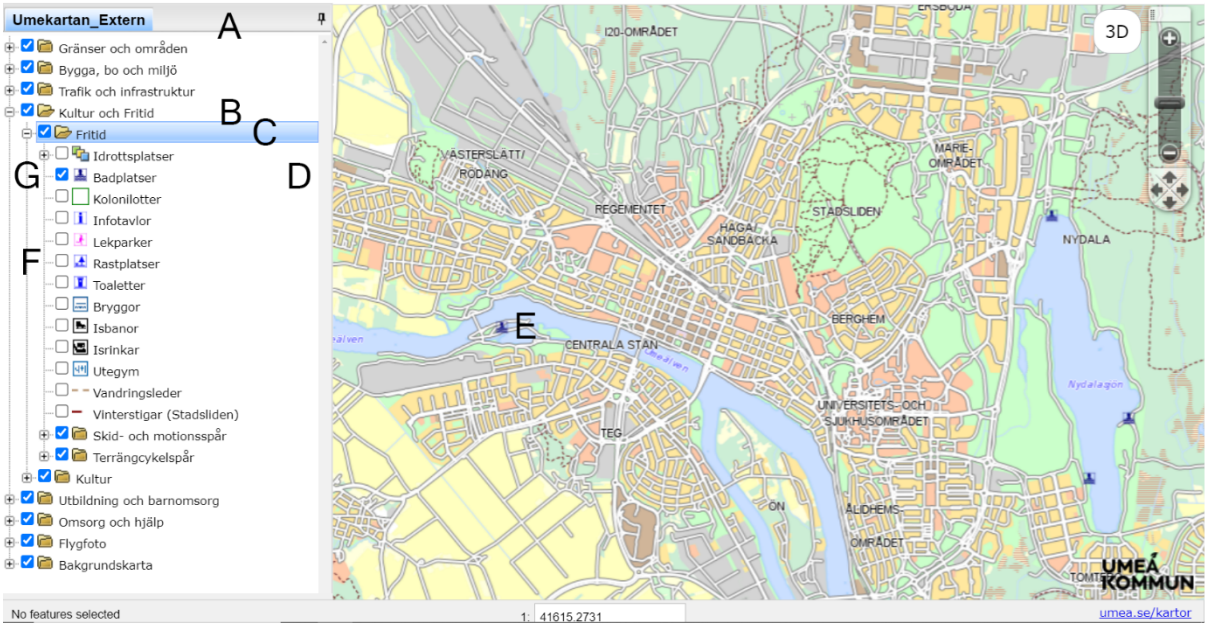
The starting page of Umeå municipality's webGIS



Note: This figure is what a user would see when entering Umeå municipality's webGIS for the first time. A) The background map. B) The menu button. Adapted from https://www.umea.se Copyright Umeå Kommun.

Figure 2

The map layer panel of Umeå municipality's webGIS



Note. This figure shows the map layer panel with a main category and a subcategory opened. A) The map layer panel. B) A main category. C) A subcategory. D) A map layer in the map layer panel. E) The icon of an activated map layer in the background map. F) A deactivated checkbox of a map layer. G) An activated checkbox of a map layer. Adapted from https://www.umea.se Copyright Umeå Kommun.

Introducing the Problem Areas

Umeå municipality compiled and analyzed the results from 28 structured user interviews as well as information gathered through emails or spoken word. From this work, Umeå municipality has identified four main problem areas (PA) concerning the map layer panel in their WebGIS.

PA1: The User is Unable to Access More Information About a Map Layer

A problem of the current webGIS system is that of information presentation. Users expressed that there is a need to be able to get additional information regarding a map layer and the legend. Suggestions from users were also made that the information may be presented by hovering or clicking on a symbol related to the map layers.

The information problem concerns both which information should be presented about a map layer and how this information might be positioned and displayed in the map layer panel. We focus on the latter, mainly on how information might be accessed and displayed in the map layer panel.

PA2: The User is Unable to Export/Import Map Layers

This problem area is mainly a concern for expert users of the current webGIS. There is a need for exporting and importing different map layers into the map, a function that is not yet implemented in the current webGIS. The concerns are mainly about exporting map layers but also being able to export individual information about a map layer. Since there is no current function that

does this, our focus will be on where in the map layers panel such a function might be implemented and how it might be visualized.

PA3: The User is Unsure Which Map Layers are Active

This problem area is experienced by both expert and novice users. The problem occurs when a user activates a map layer and sees no visible change in the map due to the map layers loading slowly, lack of feedback or the user being too far zoomed in. Another instance of this problem area is when the user enters the map layer panel for the first time and is unsure of what layers are active, due to all main categories being checked. This problem area is characterized by the slowness of the web-service and the confusing visual and functional elements of the interface. Since the web-service and deep functionality is out of reach due to the limited time and resources of this study, we will be focusing on how to implement clear visual and functional elements that convey what map layers are active.

PA4: The User is Unsure About How to Activate and Deactivate Map Layers

One issue concerning the current webGIS is that checking the checkbox of a map layer does not always activate it. This is because of the main category not being checked, essentially gating the layers below it. This is a function that is both useful for internal users of the webGIS, and confusing and frustrating to external users. The problem also occurs because of the visual similarity between map layers and categories, making it difficult to know what you are activating. Since the activation and deactivation of map layers is an essential part of webGIS, we will focus on making this function clear for all users.

The rise in popularity and the underlying lack of usability in webGIS makes it important to try to find methods that can be used to create user friendly webGIS. The problems found in the specific webGIS of Umeå municipality corresponds well to previous research (Bunch & Lloyd, 2006; Mwangi et al., 2017; Sharp et al., 2019). The aim of this thesis will be to investigate whether introducing cognitive science theories into the design process of webGIS will help resolve the identified problem areas of Umeå municipality's webGIS. Cognitive science theories will be implemented in the form of principles that highlight human cognitive capabilities and limitations. This study follows the method of User-centered design. Mainly by allowing the user to be involved in the design process (Abras, 2004). The study is qualitative, using interviews and observations to gather data about user opinions and preferences. The data is analyzed using qualitative content analysis (Drisko & Maschi, 2016). However, the specific designs and ideas are all based on the cognitive principles.

Our research question is the following: Does the use of cognitive principles in designing the map layer panel of Umeå municipality's webGIS resolve the usability issues identified in PA1, 2, 3 and 4?

Cognitive Principles and Ideation

Before moving forward, the general structure of the study will be explained. First, we identify cognitive principles that are relevant to this project. Based on this, several lo-fi prototypes are created to test multiple design ideas. Using the findings from the lo-fi testing and the cognitive principles a (final) hi-fi prototype is created. The result from testing the hi-fi prototype determines if the PAs are resolved.

Cognitive Principles

A literature search was made to gather theories that might help resolve the PAs. Theories were chosen based on their relevance for the PAs and their practicality in this study. The chosen theories were formulated into eight principles. The principles were then incorporated in the initial ideation process of the prototypes and as a framework throughout the design process. Following is a list of the principles created.

1. *Structuring/organization of Semantically Related Information* **-** How information is structured will drastically affect how easy it is to find and understand (Sharp et al., 2019). Previous studies have shown several ways in which information can be grouped or structured to improve understandability. These ways of structuring information are called the Gestalt laws. There are also studies showing that framing information with borders is more effective than using a colored background. Gestalt laws include the following laws, among others:
    a. *The law of Similarity* **-** Visually similar items will be perceived as being of the same group.
    b. *The Law of Proximity* **-** If items are near each other they tend to be viewed as a group.
    c. *The Law of Continuity* - Items or groups oriented in the same manner tend to be perceived as a whole if they are aligned with each other. (Todorovic, 2008).
    d. *The Law of Common region* - When objects are located within the same closed region they are perceived as a group (Palmer, 1992).
2. *Feature Integration Theory and Preattentive Cues* **-** Some visual properties are processed earlier in the visual system (Ware, 2021). For example, size, shape, orientation, color and motion are all processed preattentively. Searching for an object based on one of these properties makes the search more efficient. Important visual information or buttons in the prototype should therefore use strong preattentive cues to facilitate visual search tasks.
3. *Working Memory Limitations* - The capacity of working memory has been established to be limited (Baddeley, 1992). People are also in general much better at recognizing things than recalling things (Sharp et al., 2019). To ease the working memory, it is better to always display task relevant information instead of building a system that forces users to remember information. Therefore, information about what map layers are active and visible in the map should always be available.
4. *Using color in interfaces* - When using color for nominal coding of meaning or group affiliation, backgrounds should be low chroma colors while smaller foreground objects or symbols should be of high chroma (Ware, 2021). The Colors used should also be sufficiently distinctive within the interface.
5. *Low-Cost Epistemic Actions* **-** An epistemic action is an action to uncover more information (Ware, 2021). If a situation does not require a specific epistemic action, low-cost actions are preferred. Epistemic actions in an interface are for example eye fixation, hover and click to open/click to close. The webGIS interface should use the lowest cost epistemic actions suitable to each situation.

6. *Familiar Software* **-** People tend to be positive regarding familiar effects and functions (Zajonc, 2001). The layout and functions of the map layer panel should therefore be designed in a way that the user can recognize from their daily use of other technology and interfaces. Familiar objects can utilize already existing neural networks which support interaction with these objects (Ware, 2021). Symbols and visual objects in the webGIS interface should therefore be familiar to the user.
7. *Minimize Cognitive Load* **-** In cognitive load theory, extraneous load is imposed by irrelevant information and hinders learning and completion of tasks (Sorden, 2005). Since using a webGIS involves both visual, motor and higher cognitive resources like problem solving and planning, extraneous load should be minimized. For example, by excluding information that is not relevant to the current task.
8. *Placement of text and images* - Text is more easily recognized when displayed in the right visual field and images are more easily recognized when in the left visual field (Durrani & Durrani, 2009). Text in the webGIS interface should therefore be presented to the right and images to the left.

Ideation

The ideation sessions took place in an online software called Miro. The ideation process followed the cluster method where ideas are generated and grouped into different clusters (Michanek & Breiler, 2007). First, we broke down the problem areas into its smallest parts, resulting in seven different divided PAs, for example, dividing PA2: The user is unable to export/import map layers into two separate problem areas. Moving forward, we generated ideas for every divided PA. Each session was five minutes long. Every idea generated, if possible, was then clustered with one or more of the eight cognitive theories. Exclusion of ideas was made if they could not be linked to a cognitive principle.

Moving forward the ideas for the respective divided PAs were then ranked in a bullseye chart where the best ideas according to us were placed in the middle and bad ideas were placed in the outskirts of the bullseye. The best ideas were then judged by feasibility, how well they could be motivated using the cognitive principles and how well they solved the problems. No ideas linked to the principle of *Placement of text and images* were considered to be relevant enough and the principle was therefore excluded. The selected ideas were implemented in four lo-fi prototypes.

Low Fidelity Prototypes: Methods and Results

Low Fidelity Prototypes

Focusing on one design only can impair the design process and impair group communication. Moreover, creating multiple prototypes helps understanding the fundamental design principles of a design as well as making the designer more open to critique. (Dow et al., 2011). Therefore, the ideas generated in the ideation process were applied in four different lo-fi prototypes. Each prototype was made digitally in the prototyping software Figma. In each prototype the selected ideas were made visual and partly interactive and for every prototype different ideas were used. For instance, the principle *Minimize cognitive load* was the basis for the design choice of making a separate menu bar for the information and export function. This would allow the user to focus on one task at a time and

minimize extraneous load when just activating and deactivating map layers. See Figure 3 to Figure 6 for images of the prototypes with open main categories and activated layers.

Figure 3

Prototype 1

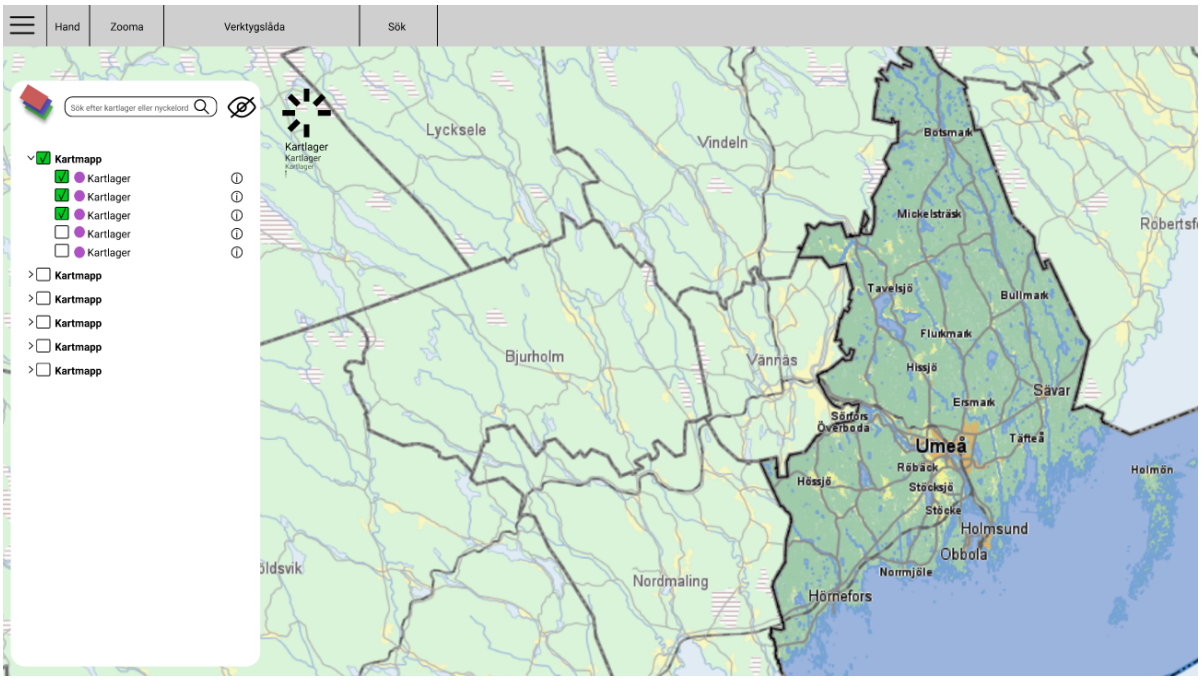


Figure 4

Prototype 2

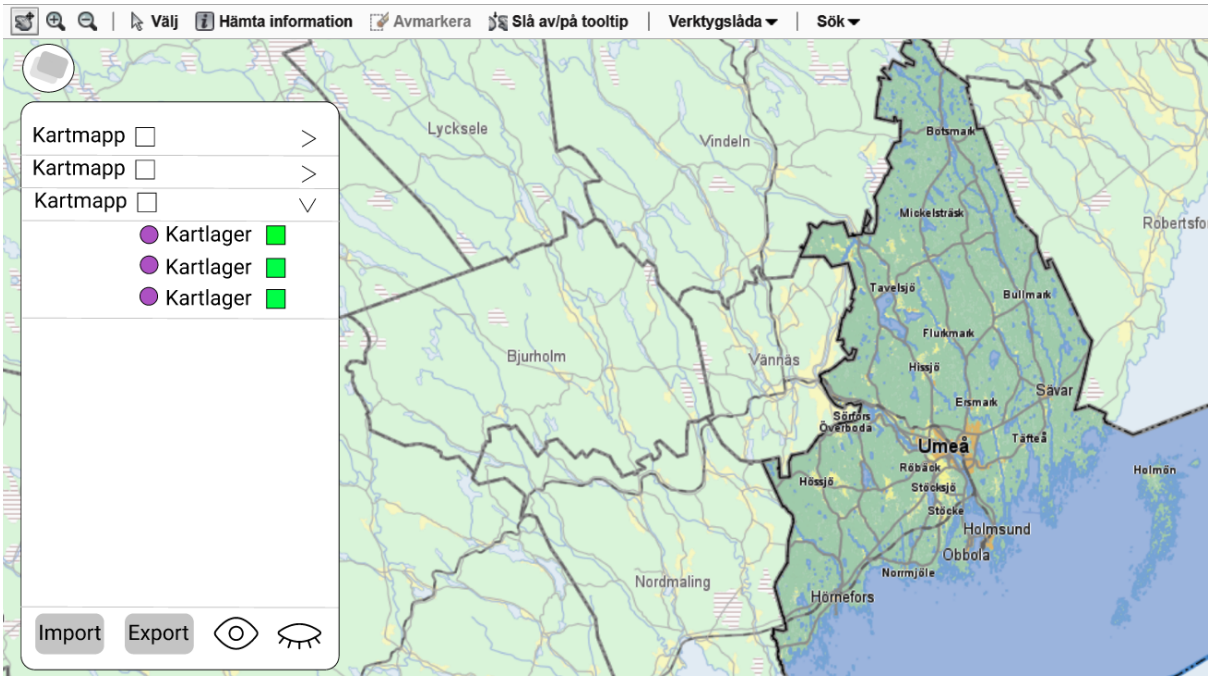


Figure 5

Prototype 3

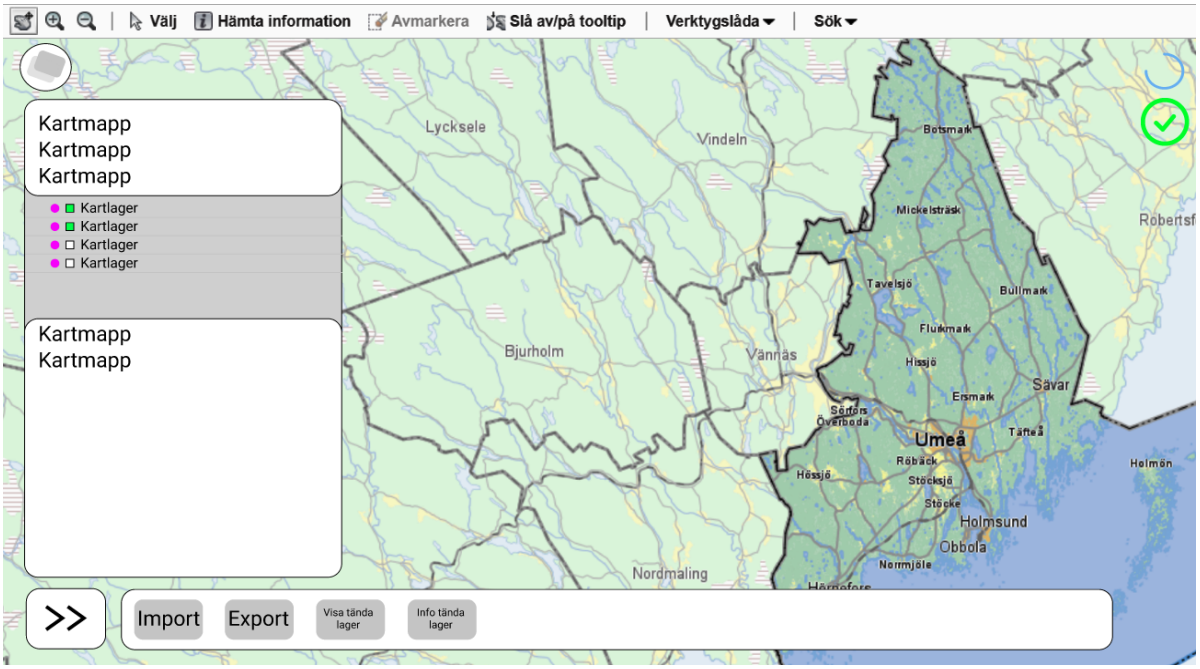
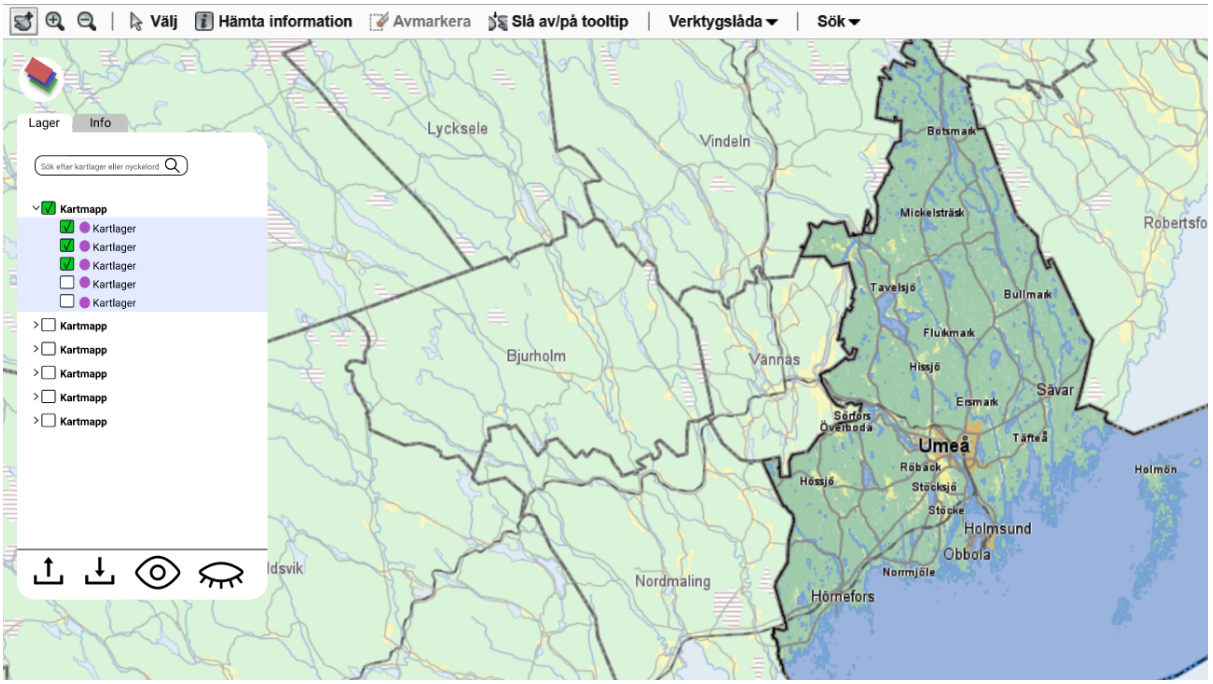


Figure 6

Prototype 4



Testing the Low Fidelity Prototypes

Participants

To test the lo-fi prototypes a total of six participants were recruited, three men and three women. The participants were both expert users of webGIS who work at Umeå municipality, and users considered to be novices at using a webGIS.

Materials

The test was conducted at a distance using the digital meeting platforms Microsoft Teams and Zoom. The participants were recorded using the built-in recording functions of the meeting platforms and informed consent was gained from all the participants before conducting the test. The interactive prototypes were built in Figma and a link to participants were sent out before the test started. Google slides were used to present pictures of the prototype in the semi-structured interview.

Preparation

Participants were first asked to open the link and share their screen. Entering the first page of the prototype participants were given written information about what to expect from a lo-fi prototype and basic information about webGIS as a software. Information about how the test was to be carried out was also made clear. The participants were also reminded of thinking aloud during the testing.

Procedure

The test consisted of five different tasks (see appendix A more information about lo-fi tasks) that each participant was to complete for all four prototypes. All the tasks related to the PAs. During the completion of the tasks the participants were to think aloud. This method was chosen mainly to get as accurate and immediate data of the participants' opinions and experience of the prototype as possible. The think aloud method allows for a direct insight in the participants problem-solving (Van Someren et al., 1994). After the completion of the tasks, a semi-structured interview (See Appendix A for a list of interview questions) was conducted mainly to get the participants' opinion on which of the prototypes they appreciated and which they did not. Questions were also asked about specific functions.

Results: Low Fidelity Prototype

Notes about the participants' experiences of the prototypes were taken throughout the testing. The notes gathered were sorted into four categories, negative, positive, suggestions of improvements, and observations. The notes were then compiled and sorted again according to different tasks, users' level of expertise, and prototypes. The following findings were discovered after analyzing the material.

1. The general opinion of participants was that they preferred the colored menu button as it was visually clear and stood out from the background.
2. The general opinion was that prototype three and four had the best layout for activating a map layer. Most of the participants did not understand the functionality of the icons

resembling open and closed eyes, and thought it was an unnecessary function. There was also the comment that clicking in a checkbox to activate the map layers felt old-fashioned.

3. The general opinion was that prototype one and four were the easiest ones to see which map layers were active. Some participants would investigate every main and subcategory to find out which layers were active, some preferred to rely on the checkbox next to the main category. However, participants were divided on which function the checkboxes of the main categories would carry out. Most of the participants felt that prototype three was the most difficult to see which layers were active.
4. The general finding about getting more information was that participants found that the information button resembling the letter "i" was easy to recognize. The participants liked the hover function but concern was expressed about the risk of not finding the function or that it might become too obvious and annoying. Most of the participants appreciated when information was presented together with the map layer.
5. Most of the participants had trouble finding the export button if it was located in a separate menu. Most participants also thought that using symbols for import and export was confusing. When the export and import buttons were placed in the map layer panel with text, participants had the easiest time finding and decoding the meaning of the function.

High Fidelity Prototype: Methods and Results

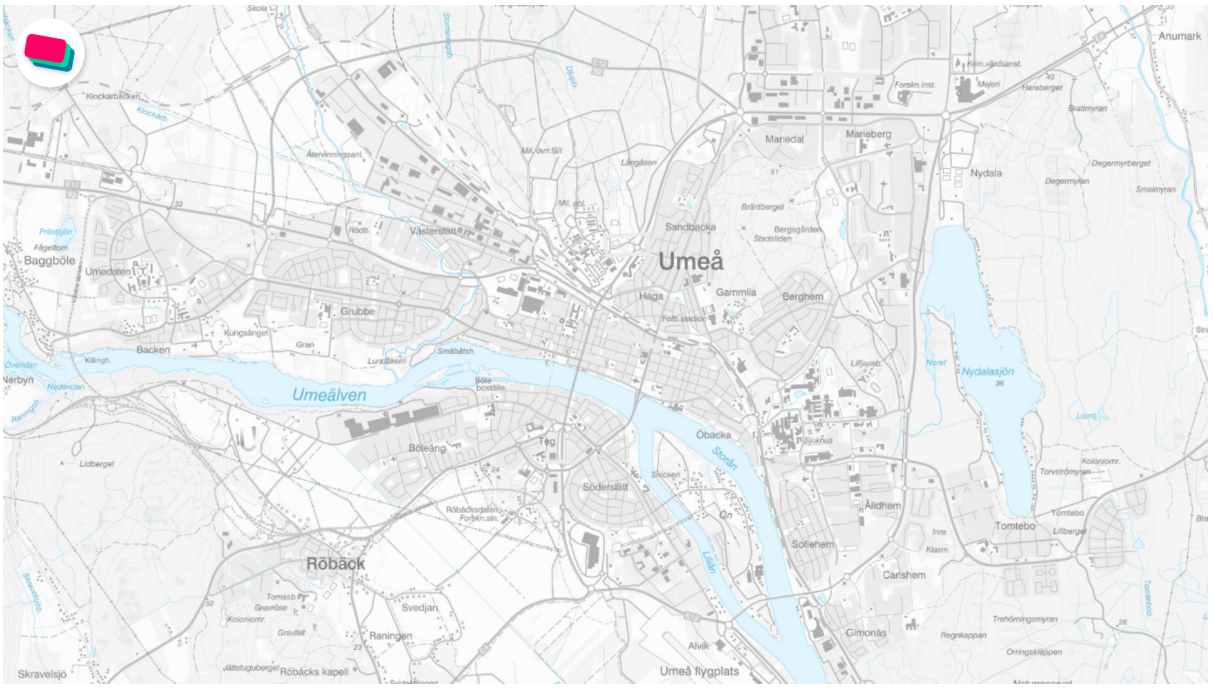
Description of the High Fidelity Prototype

A hi-fi prototype was developed based on the main findings from the lo-fi testing. The design of the hi-fi prototype was largely based on the participants' comments and findings of the lo-fi prototype while still making sure that previously listed cognitive principles were implemented. The following section details the design and use of cognitive theories in the hi-fi prototype.

The menu button (see Figure 7) is designed using the cognitive principles feature/integration theory and preattentive cues and using color in interfaces to stand out against the grey background and be easy to find. According to feature integration theory, color is processed pre-attentively and will speed up visual search (Ware, 2021). The specific colors chosen are of high saturation and chroma, in line with how to use colored symbols in the foreground of interfaces.

Figure 7

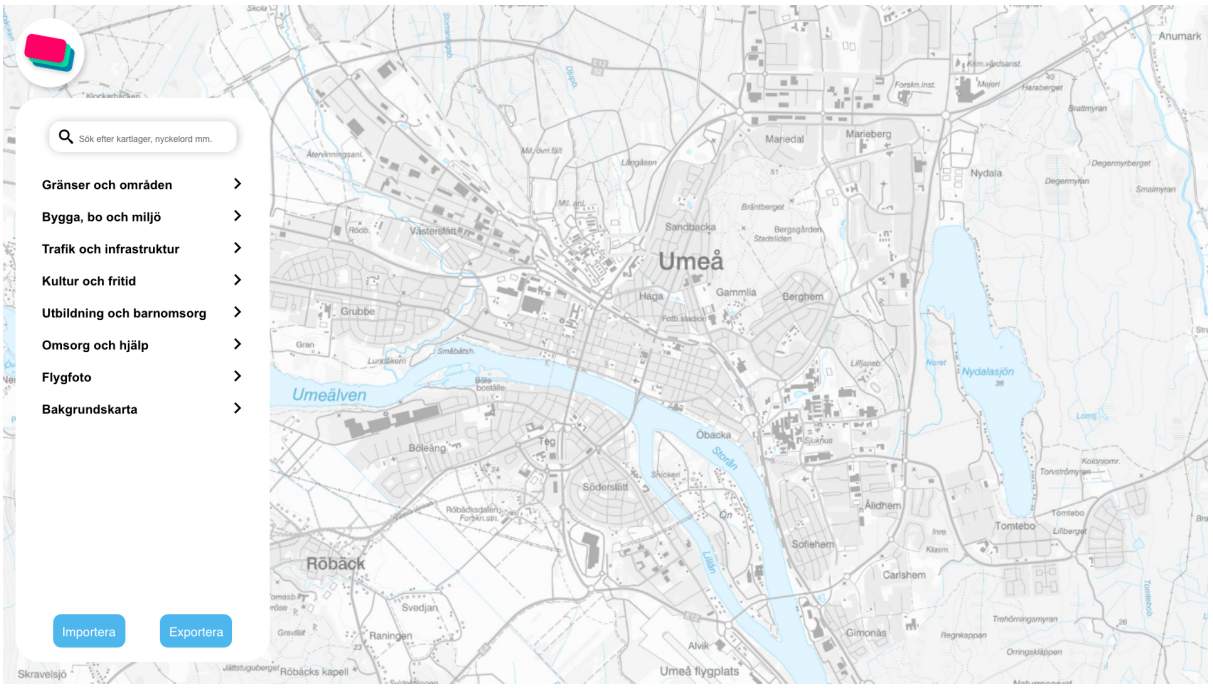
The start page of the hi-fi prototype



The search bar (see Figure 8) was implemented using the cognitive principles *familiar functions* and *minimizing cognitive load*. To ease the cognitive load of completing a task, extraneous load should be minimized, therefore a search function was implemented to allow the user to only show the information needed for the current task. The familiar symbol of a magnifying glass was used to facilitate the recognition of the function.

Figure 8

The open map layer panel of the hi-fi prototype



The visual hierarchy and structure of the main categories and map layers (see Figure 9) was designed using the cognitive principle of *structuring/organization of semantically related information*. The gestalt principles most widely used in this prototype was *proximity*, *similarity*, *continuity* and *common region*. According to the law of similarity, objects that are visually similar are perceived as a group, therefore all main categories look the same and all the map layers of a category look the same. All main categories are set in a white background with bold text and an arrow. The text of all main categories is set to the left and the arrows are set to the right, creating a proximity effect for each element. This indicates to the user that names of categories are to the left while the state of the category is to the right. The fact that the names of categories are aligned with the arrows signifies their relationship, according to the law of continuity.

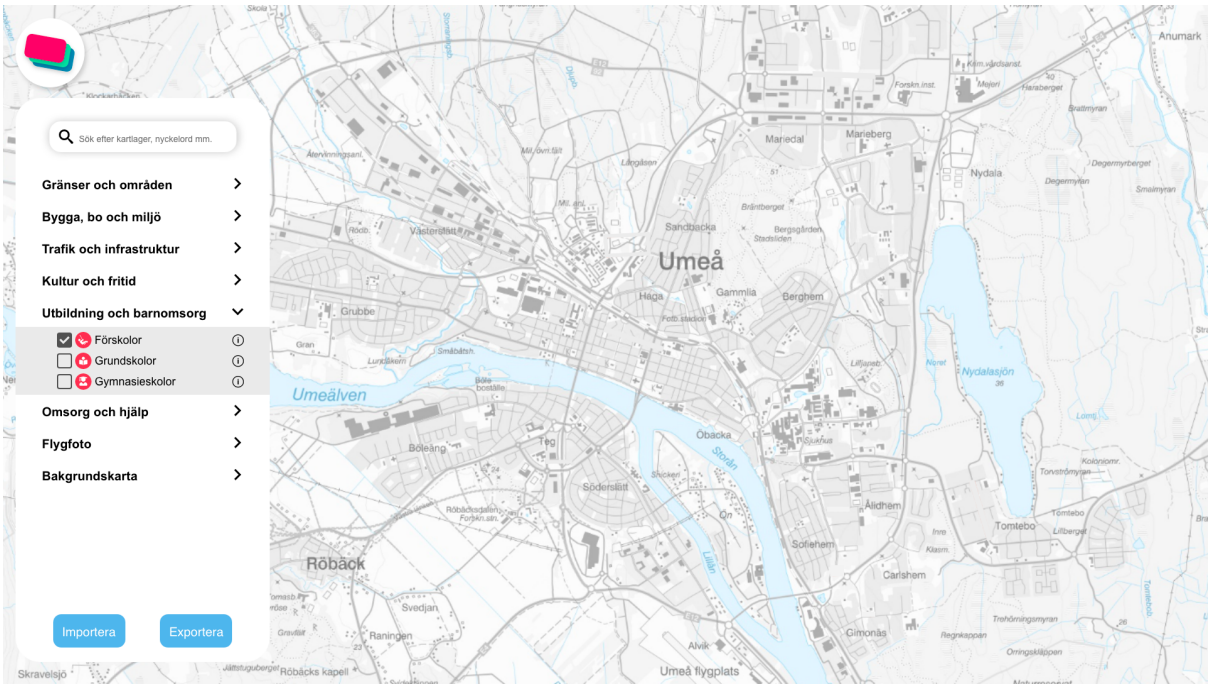
All map layers are set in a grey background with a checkbox, a colored map icon and the name of the map layer to the left, while an information button is located to the far right. This also creates a proximity effect where map layer names are grouped together, and information buttons are grouped together. The fact that the names of map layers are aligned with the information buttons signifies their relationship, according to the law of continuity. The checkbox of each map layer is placed near the name of the map layer that they will activate, to more easily and efficiently indicate to the user what will happen when pressing the checkbox.

The design of individual elements of categories and map layers do not overlap. For example, the categories have no checkbox, icon or information button. The names of categories are bold while the names of map layers are regular. This is so to minimize the similarity between main categories and map layers.

To indicate that individual categories contain different types of information, they are spaced far apart from each other. However, map layers are more closely grouped to signify that they all relate to the same category. This is according to the law of proximity. This also helps distinguish map layers from categories. Using the law of common region all items that are within an expanded main category are contained within a grey background that creates borders when it meets the white background of the main categories.

Figure 9

An opened main category in the map layer panel of the hi-fi prototype

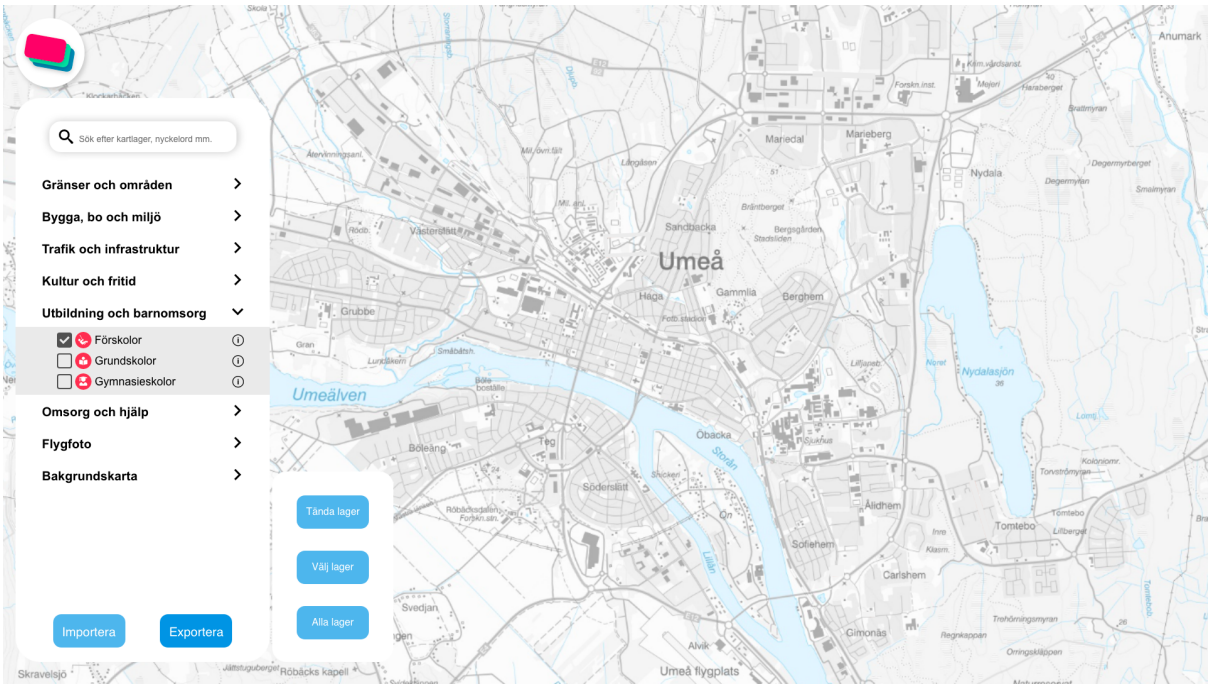


Note. The main category of Utbildning and barnomsorg is open with a map layer activated.

The import and export buttons and related options (see Figure 10) were designed using the cognitive principles *structuring/organization of semantically related information*, *feature integration theory and preattentive ques* and *using color in interfaces*. The buttons are grouped together via proximity to each other, because of their similar meaning and functionality. Once clicked, the export function uses a pop out window to present the different alternatives. This window is in close proximity to the original button to indicate that they belong to that function. The buttons are unique in color and shape in the interface, making them easy to visually search for. High saturation and chroma colors were used to make sure that the buttons stood out against the low saturated background.

Figure 10

The open export function of the hi-fi prototype

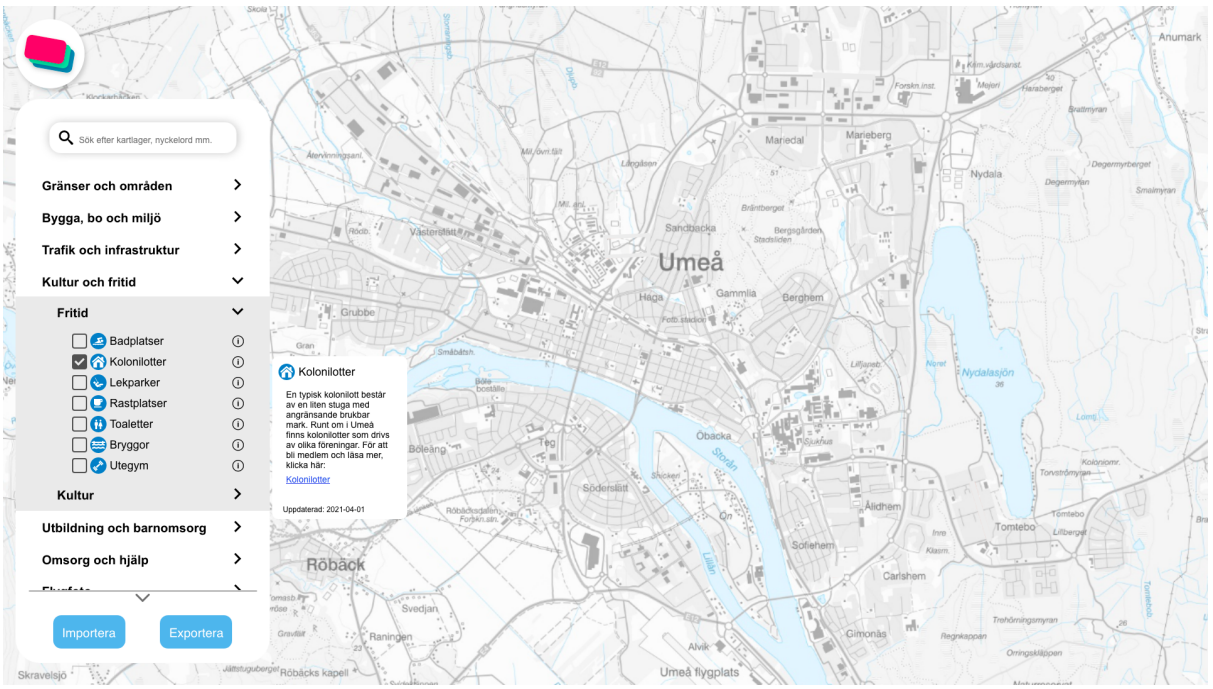


Note. The export function contains additional alternatives such as Tända lager, Välj lager and Alla lager. These alternatives are not interactive but were used to gather information about user preferences when exporting a map layer.

The information function (see Figure 11) was designed using the cognitive principles *low-cost epistemic actions* and *familiar software*. The button for the information function is a familiar and widely used icon, making it easy for users to understand. The information is reached by the epistemic action called click to open, click to close. This specific epistemic action has the lowest cost while still meeting the needs of the user.

Figure 11

The information function of the hi-fi prototype

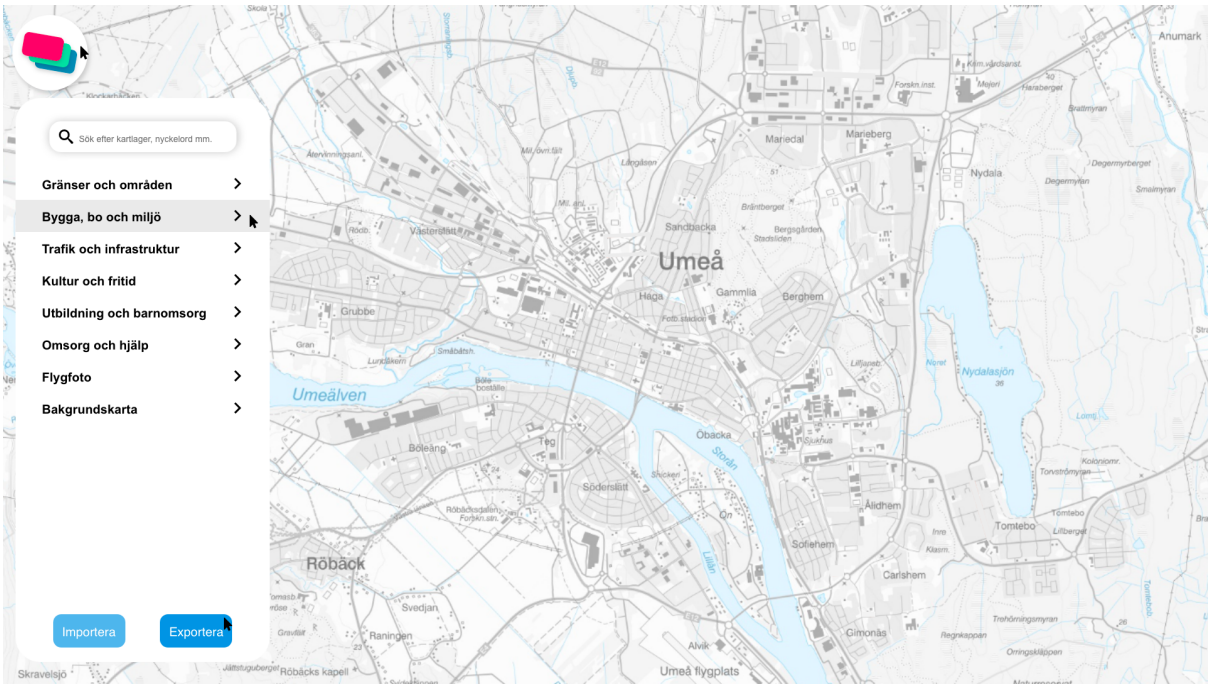


Note. When clicking on the information button a window appears presenting information about the map layer.

Hover interactions were implemented for the menu button, the main categories, the import and the export buttons. They were implemented based on the cognitive principle *familiar software*. Hover interactions are widely used and a familiar indication that an object, surface or piece of text is clickable.

Figure 12

Hover interactions of the hi-fi prototype



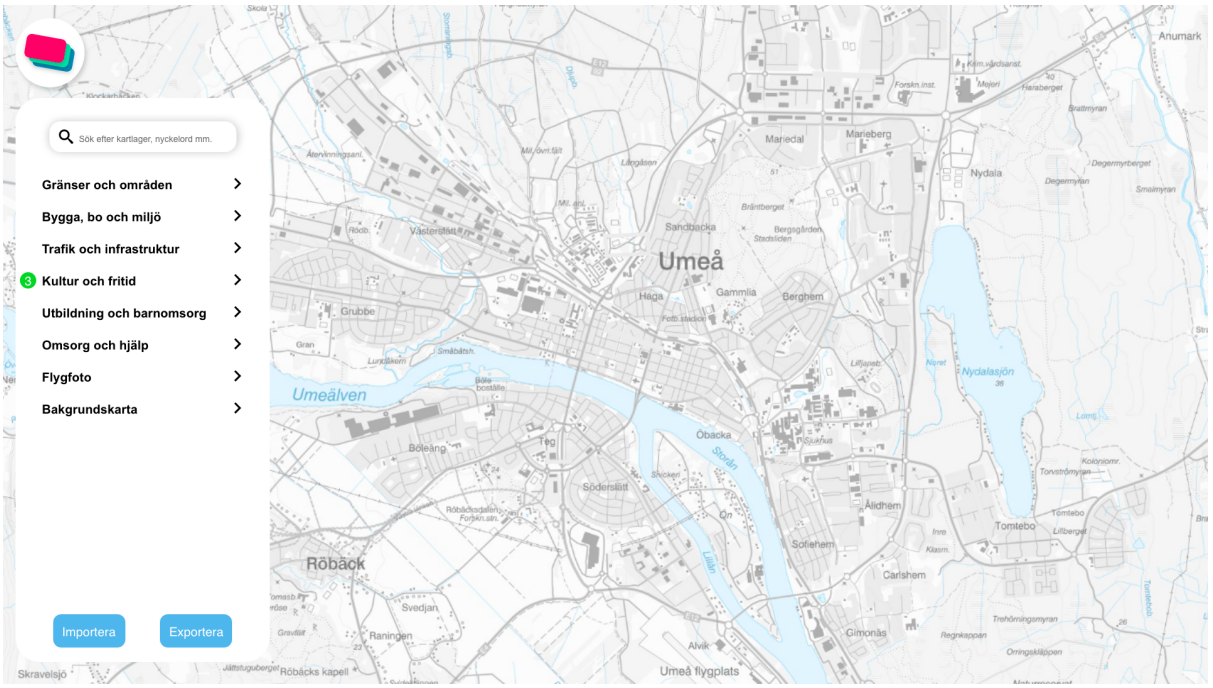
Note. The arrows indicates hover states.

A non-interactive function for showing where active layers are located in the map layer panel (see Figure 13) was implemented using the cognitive principles *structure/organizations of semantically related information*, *working memory limitations* and *using color in interfaces*. The purpose of the function is to relieve working memory from the task of keeping track of where active layers are located, additionally it also gives information about how many layers are active. According to the gestalt law of similarity, the function resembles a map layer icon and will therefore be

semantically related to map layers. The color of the function is highly saturated according to how color should be used in the foreground of an interface.

Figure 13

The function showing active layers in collapsed main categories



Functional Limitations of the High Fidelity Prototype

The hi-fi prototype had limited functionality and not all parts were made interactive for the testing of the prototype. A choice was made to keep the functionality on a level so that it was consistent throughout the prototype and that the functionality that was implemented should be reliable. Also, priority was placed on making the functions related to the PAs interactive so that they could be tested. It was possible to open and close the map layer panel. All main categories were expandable and all checkboxes were made interactive. However, no map icons were displayed on the map when activating a layer. All information buttons were made interactive with a limited amount of text. The export button was made interactive but the alternatives presented were not. A hover interaction was implemented on the menu button, main categories and the import and export buttons. The search function, import function and the background map were not made interactive.

Testing the High fidelity Prototype

Participants

Four men and two women participated in the final testing of the prototype. Three participants were recruited from Umeå municipality and are considered to be expert users of webGIS. Three participants were recruited via social media and were considered to be novice users of webGIS.

Instruments and Materials

The testing was carried out from a distance via the online meeting platforms Microsoft Teams and Zoom. The testing was recorded in audio and video using the built-in recording functions in Microsoft Teams and Zoom. Informed consent was signed by all the participants before conducting the test. The prototype was built in the prototyping tool Adobe Experience Design and an interactive version was sent to participants at the beginning of the test. Microsoft PowerPoint was used to create and display images to the participants.

Procedure

Participants were asked to open the link to the prototype and share their screen. The first page of the prototype consisted of an instructional text that the participants were asked to read. The text contained information about the prototype's purpose and the breadth and depth of functionality. It also contained information about how the testing would be conducted. This information was provided so that issues related to a lack of previous knowledge about webGIS and prototyping would be minimized. Before the test began the participants were reminded to think aloud to the best of their abilities.

Tasks

Participants were given a total of three tasks (see appendix B). The tasks were chosen and designed so that participants would use all the functions and elements that are related to the PA’s. Tasks were given orally one at a time and the participant received oral confirmation by the researchers when a task was completed. A task was interrupted if the participant explicitly expressed that they could not complete the task. If a task was interrupted, the participant was given the next task.

Interview

After completing all tasks, participants were interviewed about their experience of the prototype. The questions (see appendix B for interview questions) were designed to be open and to give the participant a chance to highlight both positive and negative aspects of their experience. The participant was also presented with a picture of the function for showing active map layers (see Figure 13) and asked about their interpretations and opinions of the function. This function was not implemented in the interactive prototype because of limitations in the prototyping software.

Qualitative Content Analysis of High Fidelity Test Data

For analyzing written text to answer a specific research question, qualitative content analysis with a directed approach is suitable. Additionally, this study uses a combined deductive-inductive coding plan for the categorization of collected data. This method allows the use of previous theories or research to guide the categorization process as well as letting new categories and subjects emerge from the data itself (Drisko & Maschi, 2016). The deductively determined categories are sourced from the previously identified problem areas of Umeå municipality webGIS. These categories are broad and serve as a framework for inductively determined categories and subcategories.

The deductively determined categories and meaning units were defined before processing of data began, based on the research question and the previously identified problem areas of Umeå Municipality webGIS:

- Meaning units – All information that relates to the problem areas or to the experience of the prototype.
- Access to information – Meaning units that are related to the access of information and that can help determine whether a problem exists in this area or not.
- Importing and exporting – Meaning units that are related to the act of importing or exporting map layers and that can help determine whether a problem exists in this area or not.
- Active map layers – Meaning units that are related to the user's ability to find, understand and perceive what map layers are active and whether a problem exists in this area or not.
- Activating and deactivating map layers – Meaning units that are related to the act of activating and deactivating map layers and that help determine whether a problem exists in this area or not.

The qualitative content analysis follows four stages. Decontextualization, recontextualization, categorization and compilation (Bengtsson, 2016). The data was collected and analyzed in Swedish, but the results will be presented in English.

Decontextualization

The interviews were divided between researchers and transcribed. Sections of text considered to be meaning units were highlighted. The documents were continually controlled and revised by researchers switching or rotating the documents amongst themselves.

Recontextualization

Text that was not highlighted was re-read and any text that was found and considered meaningful was highlighted and added to the meaning units.

Categorization

First, meaning units were condensed into clearer and easier to handle condensed meaning units. Meaning units were processed using a manifest analysis (Bengtsson, 2016). Meaning that the participants' choice of words was kept to stay as close to the original text as possible. Secondly, the condensed meaning units were categorized according to the deductively determined categories. Thirdly, any leftover meaning units were re-read and categorized inductively, creating new categories based on the data itself. Lastly, the meaning units of each category were re-read and inductively organized into subcategories. In each step, researchers reviewed each other's interpretations and suggestions of categories and subcategories until consensus was found based on objectivity and staying close to the original text. Many meaning units and subcategories were moved between different categories until a satisfactory representation of the original content was achieved. An example of this process is found in Table 1.

Table 1

Example of the categorization process of import and export

Meaning Units	Condensed Meaning Units	Sub-category	Category
import, or maybe export maybe (scans alternatives with mouse, hovers over them). Choose layer (...) (clicks on choose layer button) (...) eeeh I could not click on that but.	Unsure but chooses to export over import, then selects a layer.	Uncertainty about the meaning of the function	Importing and exporting
I expect importing to my computer should as well be what this import button means, and exporting I do not really know what that would actually mean.	Import to own computer, dosent know what export menas	Uncertainty about the meaning of the function	Importing and exporting
(FP5 clicks on import and nothing happens) if it then does something when I click on the import button and it does not, I instinctively click on the export button (FP5 clicks on export and gets the three options) (..) and then I realize that it is actually (..) it is obvious that exporting is what you use instead.	Import is the intuitive choice but I instinctively click on export when nothing happens. Then it feels obvious	Uncertainty about the meaning of the function	Importing and exporting
eeh possibly the third, just because I think the import and export buttons are what to say obtusa, they do not intuitively communicate their functions	Import and export buttons are obtuse, do not intuitively communicate their functions	Uncertainty about the meaning of the function	Importing and exporting
It was well, as I mentioned a while ago that I like to import and export the buttons, they would possibly be there but maybe with a pop-up window that explains what the buttons do when you hold the mouse over them	Export and import should perhaps have an explanatory hover function	Uncertainty about the meaning of the function	Importing and exporting

Note: Selected meaning units were condensed and then labeled with subcategories.

Compilation

The categories that are closely linked to the research question will be presented in a narrative format. Categories that do not contribute to answering the research question will be listed

without further detailing. Reasonable conclusions will be made considering sample size, biases, methods etc. This will take place in the results and discussion sections of this paper.

Results: High Fidelity Prototype

The main categories and subcategories from the hi-fi test analysis will be presented in a narrative format and contain the core information needed to answer the research question. They have been selected by the researchers based on their relevance to the research question. Categories not shown in detail here contain information about future implementations, comments caused by the prototype not being a fully functional webGIS, general comments about the experience of the prototype and information about underlying functions that does not pertain to any specific problem area.

Access to Information

Subcategories

- the information button is intuitive
- understands the meaning of the information button
- hard to find the specific map layer
- would click on map icons for specific information

The information button was received with positive comments from the participants. It was described as intuitive and that the meaning of the button is well known. Some participants expressed that the specific map layer that was to be found in task two was hard to find, making the task of finding information difficult. Some participants also expressed that if the prototype would have shown icons on the map, they would have pressed those for specific information. Here is a comment from a novice user of webGIS “because you had very intuitive information buttons.” This next comment is from an expert talking about how he would use the information function “I’m thinking that if it was a specific allotment that I was interested in, I would probably click it on the map, but I would use this I (hovers over the information button) if I wanted more information about allotments in general.”

Importing and Exporting

Subcategories

- uncertainty about the meaning of the function
- expected other functionalities
- the placement of the function

Almost all participants expressed that they experienced the export function difficult to understand. Some participants attributed this to the words used within the function while others attributed it to the choice of alternatives within the function. There were also comments saying that the button is too large or that it should be in a separate menu. A typical quote of this category is “I think that it is a little confusing with import and export. Maybe you could formulate it like add layer or something, instead of import… Just so it is more self-descriptive what you can do with the different functions.” An expert user of webGIS expressed his thoughts as “I thought that, that thing when you export…that it was a bit unnecessary that I had to choose layers there…” In this category an extreme case was found that differed from all other participants. The participant said “Exporting was very simple, you pressed export and then you could choose, and there were like good alternatives there…”

Active Map Layers

Subcategories

- perceived as a good function
- the function interpreted as showing active map layers
- the function not interpreted as showing active map layers

This is the gathered opinions and intuitive interpretations of the green circle used to present information about where in the map layer panel active map layers exist. Half of the participants Interpreted the function as intended, half of the participants had alternative interpretations. Such as the function indicating new layers that had been added to the map layer panel. When the participants are asked to give their opinion on the intended use of the function, all participants expressed that it was a good idea and would be useful. An expert user of webGIS said “ Sure, it can absolutely be good. I think that sometimes when you are working with this kind of maps it can be like (.) well, you know you have a lot of things up and then, it’s like you would want to remove something and then it would be very simple to see where you have layers activated and where to go in and change. I think so, absolutely.”

Activating and Deactivating Map Layers

Subcategories

- expectation of functionality disturbed the experience
- simple task

All comments and information gathered about activating and deactivating map layers suggest that it was a simple task that did not require much thought. Many comments contained the caveat that the fact that no icons were displayed on the map was confusing or disturbing, making them think that they had not actually activated the map layer. A novice user of webGIS expressed his

thoughts as “If this had worked for real, or if things had shown up on the map. Then it would have been super simple.”

Task Performance

Evaluating the performance of the participants on each task can indicate whether a problem exists in an area or not. Performance is measured based on completion of the task and observations gathered from actions or participants thinking out loud during the task.

Task 1

Find and Activate the Map Layer for High-schools

All participants completed the task. No participant expressed negative comments or confusion while completing the task. One participant expressed the following during the activation of the map layer for high-schools: “...and I’m just going straight for it.” We did observe some confusion after the task was completed, due to the participants expecting the background map to update when the map layer was activated.

Task 2

Find Information About Allotments

All participants but one completed this task. The participant that did not complete the task was a novice user of webGIS and attributed it to not knowing what the meaning of allotment was and could therefore not find the right category. We could also observe this participant try to use the (not functioning) search function to solve this problem. Here is a quote from the participant thinking aloud during the task: “I’m a little unsure of what allotments even are. So I'm thinking that I might search.” Other participants had similar experiences with trying to find the specific map-layer, but all managed to find it. When the map layer was found, no confusion or hesitation was observed concerning where the information was located or how to access it.

Here is a quote from the novice participant explaining what was difficult about the task: “Because I didn't really know what it was, I guess it was harder to know which category to click. So that's what I thought was difficult. But I guess that only has to do with me personally.”

Task 3

Download the Map Layer for Preschools by using the Export Function

All participants but one completed this task. For this participant an observation was made that the meaning of the export function was not conveyed clearly enough, which led to the participant giving up, not knowing what alternative would lead to the map layer being downloaded to his computer. Here he expresses this feeling: “So if I’m supposed to download the preschool layer to my computer I actually feel perplexed at this stage.” All other participants managed to complete the task, but not without issue. Several observations were made of participants being unsure about whether to use the import or the export button to download the map layer. Participants also seemed to be less sure of their decisions and use more trial and error in this task compared to the other tasks. Here is a quote from an expert user of webGIS thinking aloud: “... and then I would either click

export or import. But I would probably click export… A little unclear what import is referring to. But I guess it's if you could add your own layers maybe."

Discussion

This study has focused on using cognitive principles in design, trying to resolve the problem areas found in the map layer panel of Umeå municipality's webGIS. A literature search was made, identifying cognitive findings that served as principles for implementing design choices. Four lo-fi prototypes were created to get participants' opinions and thoughts enabling further development of a hi-fi prototype. The hi-fi prototype was based on the cognitive principles while still making sure to take users' perspectives gathered in the lo-fi testing into consideration. A test of the hi-fi prototype was conducted to gather users' opinions and thoughts. Data from the test were transcribed and categorized using combined deductive and inductive coding. The results of the analysis will be used in the following sections to answer our research question: does the use of cognitive principles in designing the map layer panel of Umeå municipality's webGIS resolve the usability issues identified in PA1, 2, 3 and 4?

PA1: As stated there was no way for users to get access to additional information regarding map layers, more specifically, the problem we focused on was how this information might be displayed and positioned. Trying to resolve these issues we used the cognitive principles of *familiar software* and *low-cost epistemic actions* in the design. The main findings around the access to information was positive. Users thought the function was intuitive and understood the meaning of the information button. Although some issues were found these were mostly related to searching for the given map layer in the task. Therefore, it might be suggested that implementing the cognitive principles resolved the issue of PA1.

PA2: This was a problem concerning the lack of functionality to import and export layers. Our concern focused mainly on the placement of the function and how it was visualized. Trying to resolve the issue, our design was based on the cognitive principles of *structuring/organizing of semantically related information* and *using color in interfaces*. The main findings around import and export suggest that the import and export buttons were confusing. The confusion arose either from the meaning of the words export and import or from the additional functionalities related to the export button. All participants but one completed the task and the majority expressed confusion. Therefore, although the majority of the participants completed the task and found the functions it was clear that the function did not relieve the issue stated in the problem area. It is unclear if this is due to using words that did not convey the intended meaning or due to the general design. However, since all the participants found the import and export button the issue might lie in the semantics of words rather than the use of cognitive principles. To investigate this, further data of user behavior and preferences would need to be gathered and analyzed.

PA3: This issue was characterized by uncertainty about what map layers are active at any given time. Users were confused by slow loading times and checkboxes that looked the same but had different functions. Our main focus was how to implement clear visual and functional elements that convey what map layers are active at any given time. To achieve this, ideas based on the cognitive principles *working memory limitations*, *structuring/organizing of semantically related information* and *using color in interfaces* were implemented. When asked about their initial visual interpretation of the function, only half of the participants interpreted the function as indicating active layers.

However, when the function was explained it was received positively by all participants. As expressed by one of the participants, this could be attributed to the function not being interactive, and that it would be more easily understood in a more natural setting. If we attribute the divide in interpretation to a lack of functionality, we speculate that a full implementation of the solution would resolve PA3. However, based on the data gathered in this study we conclude that PA3 was not fully resolved by using cognitive principles in the design of this prototype.

PA4: Users felt unsure about how to activate and deactivate map layers. This problem comes from users feeling frustrated or confused when trying to activate a map layer. The task can become difficult if the user is required to check several checkboxes to show a single map layer or if the user is unsure if they are activating a main category or a map layer. Our main focus for this problem area was to make this function clear for all users. This was attempted by using the cognitive principles *structuring/organization of semantically related information* to create a coherent visual structure for the interface as well as *Using color in interfaces* to create a visually distinct checkbox. The results show no negative comments or signs of problems in the task of activating a map layer. All observed and expressed confusion was due to the limitations of the prototype's functionality. Since no issues were found, we conclude that the use of cognitive principles did resolve PA4.

Summarizing our findings, we conclude PA1 and PA4 to be resolved as none of the results point to problems linked to the problem area. However, results regarding PA2 and PA3 seem to still have some unresolved issues in relation to the original PAs.

There are some variables that might have influenced the final result. Although the study method was based on qualitative methods and the results are rich on data, more participants would contribute to a more reliable result. We recruited both expert and novice users mainly to get as varied results as possible. However, this could have skewed the results since experts are prone to point out more problems of a design than novice users (Sauer et al., 2010). Although novice users seem to report design problems that are more crucial. Therefore, recruiting participants of only one expertise level might have resulted in a different type of data. Further, we used the think aloud method allowing for users to voice their opinions and thoughts. This method requires a general description, mainly to verbalize every thought that is going through the user's head (Cotton & Gresty, 2006). Given the general description users can find it hard to know which thoughts to verbalize. To make it easier for users, instructions could have been given on which types of thoughts to verbalize on. Finally, making prototypes and collecting data can be difficult since users might be afraid to voice their concerns about a prototype especially if the prototype is in hi-fi state (Rettig, 1994).

Several considerations were made to determine the method of collecting and analyzing data that would allow answering the research question while still minimizing bias. The aim of this study was not to describe how a webGIS interface is experienced by users, but to investigate if the specific problems found in the current webGIS of Umeå municipality would be found in a prototype developed using cognitive principles. The method of qualitative content analysis allows for deductively and inductively determined categories (Drisko & Maschi, 2016) and was therefore chosen for this study. The benefit of using deductively determined categories is that previous knowledge can be used to guide, focus and augment qualitative content analysis (Drisko & Maschi, 2016). The limitations are that new and important viewpoints can be missed and that the data can be skewed. This study used combined deductively and inductively determined categories to focus the content in a way that allows the research question to be answered while still allowing differentiating and interesting viewpoints to emerge.

To ensure the credibility of the analysis, the meaning units and categories created were compared to the original text multiple times and reformed until the categories and subcategories gave a fair representation of the text. Sections of transcribed text were also exchanged between researchers and controlled for any meaningful text that was missed or misrepresented. However, human mistakes are always possible in the analysis (Bengtsson, 2016). These mistakes can be caused by personal bias, error in interpretation and fatigue.

Ethical concerns revolved mostly around participant privacy and the storing of information gathered during the interviews. Before the tests began an informed consent was sent out regarding these concerns. In the informed consent it was stated who we were and what the purpose of the study was, how long the test would take, that we would like to record the test in video and in audio and where the recorded interviews would be stored. It was also stated how and to who the data gathered would be presented. Individual citations could be used in the thesis and presentations; however, these would not be named. Finally, the participants were informed that they could withdraw from the test at any time and without any questions. If the participant did withdraw the data would be deleted. In signing the informed consent, the participants agreed to have taken part of this information. During analysis, steps were taken to ensure that the data gathered was not misconstrued or misrepresented. This thesis was made in cooperation with Lantmäteri (land surveying office) at the municipality of Umeå. However, no monetary or other influence was put on the researchers to produce results that would not be sincere.

The results of this study suggest that cognitive principles can be used to create more usable webGIS, but perhaps not to solve all usability problems. This seems to be in line with previous research that has suggested that implementing cognitive science in interface design is helpful in creating usable interfaces (Patel & Kushniruk, 1998; Slocum et al., 2001). Further research is needed to determine if the methods used in this study could be implemented in the design of other software or products. Additionally, specific research would be required to determine what cognitive principles are applicable to a given design project. This study mainly used principles found from the fields of visual cognition, human-computer-interaction and memory. Cognitive science is a cross-disciplinary field, and several further possible cognitive principles were not explored in this study. For example, principles could be formed from the fields of linguistics or psychology to attempt to address other issues.

Finally, an emphasis will be put on the narrow claim that is being made by the results of this study. Using cognitive principles did resolve some of the problem areas that were found previously in Umeå municipality's webGIS. This does not mean that it is the only way of achieving this result, or that this method can be used to resolve different problems in different interfaces. However, we do believe that the results add webGIS to the list of fields where a cognitive science perspective is beneficial.

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Appendix A

Tasks and Semi-structured Interview Questions of the Low Fidelity Test

A list of the tasks and semi-structured questions given in the lo-fi test. The tasks were given to get a better understanding of what thoughts and opinions the participants had regarding the lo-fi prototype.

Tasks of the Lo-fi Prototype Test

Task 1.1 Open:
Go ahead and open the map layer menu!
Task 1.2 Activate:
Imagine that you want to activate a map layer, how would you have done then?
Task 1.3 Activated right now:
Imagine that you want to find out which layers are activated right now, how would you have done then?
Task 1.4 Information:
Imagine that you want to find out more information about map layers, how would you have done then?
Task 1.5 Export:
Imagine that you want to export (ie download) a map layer, how would you have done then?

Semi-structured Interview Questions

1. Tell us what you thought and if it was something that stood out as good or bad.
2. The menus have slightly different designs, does anyone stand out as good or bad?

3. We intend to give the map a loading function to show when the map layers you clicked on have finished loading. Here you see two different pictures of what the loading could have looked like. What do you think about placement and icon in the left image? What do you think about the location and icon in the right image?
4. If you look at the eyes that are at the bottom corner of the menu, what function do you think they can perform linked to the map layers?
5. We think they should function as a function to turn on and off all layers in the layer panel. What do you think of such a function?
6. The idea with the layers that can be dragged out is that they work as a complement to the layers you have activated. For example, they can be used when you only want to compare two layers and avoid going back in the menu to find them. When you drag out a layer, it gets activated up, when you hover over them, an icon appears to extinguish the layer. To delete the layer, you can drag it into the list again. Performing this is voluntary and can be combined with having other layers activated.
7. If you had clicked in a check box for a map folder, what do you think would have happened to the map layers in the folder?

Appendix B

Tasks and Semi-structured Interview Questions of the High Fidelity Test

A list of the tasks and semi-structured questions given in the hi-fi test. The tasks were given to get a better understanding of what thoughts and opinions the participants had regarding the hi-fi prototype.

Tasks of the Hi-fi Prototype

Task 1: Imagine that you want to see all the high schools in the map area, how would you have done then?
Task 2: You are interested in allotments, how would you have done to find out more about them?
Task 3: Imagine that you want to download the map layer for preschools to your computer, what would you have done then?

Semi-structured Interview Questions

Question 1: Tell us about your general experience of the prototype.
Question 2: Do you think it was problematic to carry out any task, if so why?
Question 3: Do you think it was easy to complete a task, if so why?
Question 4: Did you want something different in the map layer menu?
Question 5: Did you miss something in the map layer menu?
Question 6: What would you like to add to the map layer menu?
Question 7: Imagine that you come back to this map after a year, how do you think it would have been to use it then?

Question 8: How would you interpret the green circle with a number in it?
Question 9: At the bottom of the menu you will see a folder for background maps. What do you expect to be in there? What do you think the background map means?
Question 10: Here you see two map layers that are active at the same time, you would like to change the color of one of the symbols to make the image clearer. How have you done then?