Convey Data in Qlik® Sense from a Universal Design Perspective

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Preface

We would not have been able to do this master's thesis without the help and feedback from these fantastic people.

Karolina Nilsson, Qlik
Thank you for all the help and support during this research. Without all of your great feedback and help to get us on the right track time and again this would not have turned out the way it did.

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Our superhero, thank you for all the help during the development. We could not have made it without you.
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Abstract

"The important criterion for a graph is not simply how fast we can see a result; rather it is whether through the use of the graph we can see something that would have been harder to see otherwise or that could not have been seen at all."

William S. Cleveland

When presenting graphs for people with visual impairments the solutions found on the market today often present pure data values only. Overview is missing and there is no possibility to get any additional information about the visual content of the graph. Should we accept the fact that visually impaired persons are only presented with the data or could they actually benefit from data represented in graphical form?

The aim of this project was to investigate how to provide people with visual impairments the best possible user experience when analyzing data in the business intelligence program Qlik Sense. The research showed that it is possible to convey an overview of the content in graphs with a synthetic speech solution. The synthetic speech presents the purpose of the graph and key values as well as the overall shape of the curve. In a future development it is possible to extend the product to include voice recognition to allow the user to explore the data and make own discoveries.

The project begun with a literature study to find previously conducted work in the same field. To gather proper knowledge about what information users find interesting, what they are looking for and how they can benefit from using charts, a pilot study was initiated. The pilot study was performed by people who have vision classified as normal. Further, persons from the target group, i.e. people with visual impairments, were interviewed to receive an understanding of what is missing from today's low vision aids and solutions. These results were used when creating a Low Fidelity prototype in an attempt to show how to present visual data to a visually impaired user. The prototype was tested on both sighted persons and persons from the target group. Results were then collected and analyzed to create a foundation for the High Fidelity (Hi-Fi) prototype that was developed to realize the design ideas. Finally, the Hi-Fi prototype was evaluated through usability tests that resulted in the above-mentioned conclusion.

Sammanfattning

"Det viktigaste kriteriet för en graf är egentligen inte hur fort vi kan se ett resultat; det är snarare om vi genom användandet av en graf kan se något som hade varit svårare att se annars eller som inte hade alls kunnat ses."

William S. Cleveland
Översättning: Celie Gunnarsson

De lösningar som finns på dagens marknad gällande presentation av grafer för synskadade bygger ofta på ren presentation av enskilda värden. Översikt saknas och det finns ingen möjlighet att få övrig information om det visuella innehållet i grafen. Ska man som synskadad nöja sig med att endast få ta del av datan eller ska man faktiskt kunna ha samma nytta av ett diagram som en seende person?

Syftet med detta projekt var att undersöka hur man kan erbjuda personer med synnedsättning den bästa möjliga användarupplevelsen då de analyserar data i *Business Intelligence*-programmet Qlik Sense. Arbetet visade att det är möjligt att förmedla en överblick av en grafs innehåll med hjälp av syntetiskt tal. Det syntetiska talet kan då presentera grafens syfte, nyckeltal tillika formen på kurvan som bildas. Vid framtida utveckling är det möjligt att utöka produkten så att även röstigenkänning kan inkluderas. Detta skulle ge användaren en möjlighet att på egen hand utforska datan och göra egna upptäckter.

Projektet inleddes med en litteraturstudie för att finna tidigare utfört arbete inom samma område. För att insamla kunskap om vilken information som upplevs som intressant, vad användare tittar efter och hur de kan ha nytta av grafer utfördes även en pilotstudie. Försökspersonerna i denna studie utgjordes av personer med syn klassificerad som normal. Vidare intervjuades personer ur målgruppen, det vill säga personer med olika typer av synnedsättning, för att skapa förståelse för vad som saknas i dagens hjälpmedel och lösningar. Dessa resultat användes för att skapa en Low Fidelityprototyp i ett försök att visa hur man skulle kunna presentera visuell data för en synskadad person. Prototypen testades sedan, både utav seende personer och personer från målgruppen, varefter resultatet sammanställdes och analyserades. Analysen användes för att skapa en grund till den High Fidelityprototyp (Hi Fi-prototyp) som kom att utvecklas ur designidéerna. Slutligen utvärderades Hi Fi-prototypen genom användbarhetstester, vilka resulterade i ovan nämnda slutsats.

Contents

1 Introduction

Accessibility as a field is growing every day and companies all around the world are now beginning to include this important aspect in their products. A company that has worked with accessibility for several years is Qlik. This report presents research performed with the goal to be able to translate Qlik's highly visual product for users whom cannot see. In this first chapter the reader finds the base for the project.

1.1 Aim

The aim of this project was to investigate how to provide people with visual impairments the best possible user experience when analyzing data in the self-service data visualization and discovery application Qlik Sense. We were specifically interested in understanding how people with visual impairment perceive data and what interaction techniques could be used to help them get an overview of large amounts of information that are usually presented visually.

One of the main goals was to make sure that all types of users could benefit from the solution. In other words we wanted to include people and develop a usable solution for every user, instead of proposing an external product suitable only for one group of people with a specific disability. By applying the principles of universal design all users have been considered during the design process.

1.2 Limitations

The project was performed in collaboration with the company Qlik. Since the solution was created for their product Qlik Sense, customers using the product needed to be considered. A requirement was that the customers should not be obliged to buy any additional aids to be able to use the product. This resulted in limiting the project to use of computer or keyboard based interaction techniques. Hence, it was not possible to use tactile feedback as a complement to the solution.

The prototype created was also limited to the presentation of charts and does not include how to navigate and interact with the chart. This decision was made in order to stay within the scope of the project. For the same reason it was also decided to focus on bar charts, otherwise more than one prototype would have been required.

More limitations were discovered during the work process and are discussed in section 5.5.

1.3 Problem Definition

To be able to meet the goal of presenting data to people with a visual impairment in an accessible way the following questions have been fundamental during the research:

- Is there an alternative way to effectively visualize data, which does not demand visual ability?

- What interaction techniques are necessary?

- How can charts be presented for people with visual impairment?

- Is it possible to find a design that is logical and intuitive for all users?

1.4 Target Group

The main target group is people with blindness who possess some computer experience. The end user work at a company using Qlik Sense as business intelligence program and performs independent analysis and collect findings from the data. The user should also be able to have discussions with their coworkers but is not involved in creating apps.

During the research in this project the target group was people with visual impairments, preferably with diverse levels of sight. It was important that they had some experience in computers and it was desirable if some of the users had an interest or extended knowledge in mathematics. Further, it was also beneficial if they understood statistics and were familiar with charts and diagrams. The above-mentioned groups are of main interest, but other users should also find the solution useful.

2 Background

In this chapter the material required to be able to understand the research in a successful way is presented.

2.1 Qlik & Qlik Sense

This project was conducted in cooperation with the company Qlik that creates business intelligence solutions. The company has two successful products, QlikView and Qlik Sense, out of which the latter is in the process of accessibility adaption. The focus in both products is to present findings in the client's data, which he himself did not know was there.

2.1.1 Qlik

It all started with a unique idea to color-code data to distinguish possible choices from invalid ones. Today Qlik is a large international company with a product leading its field.

The company was founded in 1993 by Björn Berg and Staffan Gestrelius in Lund, Sweden. Berg and Gestrelius had a vision to create software, which processes data the same way as the brain does to provide the most intuitive user experience possible. Their work resulted in QuikView, where the name Quik represented Quality, Understanding, Interaction and Knowledge. The product further developed to success, today known as QlikView. The new name stood for the ability to provide the user with "exceptionally-detailed data analysis with a single click". [37]

Today QlikView is the leading business discovery platform and Qlik has about 35.000 customers in over one hundred countries around the world. Furthermore, the company has over 2000 employees worldwide and its headquarters in Radnor, Pennsylvania, The United States. However, most of the development is still situated in Lund.

To keep generating success the company's newest product Qlik Sense is now starting to conquer the market.

2.1.2 Qlik Sense

Qlik Sense is an interactive tool for data discovery and visualization. The application allows individuals, groups and organizations to analyze large amounts of data in a flexible way. Qlik Sense is regarded as simple to use and allows users to customize reports and dashboards regardless of previous level of knowledge. [38]

When opening Qlik Sense the user will firstly arrive at the *Hub* (fig. 1). In the Hub it is possible to get an overview of the *apps* (fig. 2) available to them as well as the opportunity to create new ones. The apps are collections of *sheets*(fig. 3), which in turn contains charts. The charts visualize data in any way the user chooses, e.g. a bar chart, pie chart, pivot table etc. When creating a new chart the user has the possibility to make numerous choices to customize the chart.
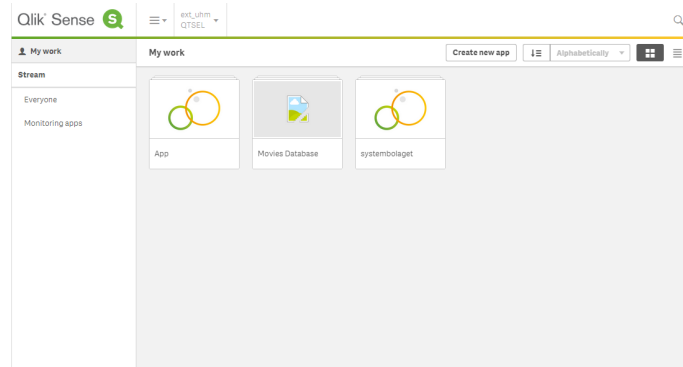
Figure 1: Showing the Hub with three apps in Qlik Sense.[1]
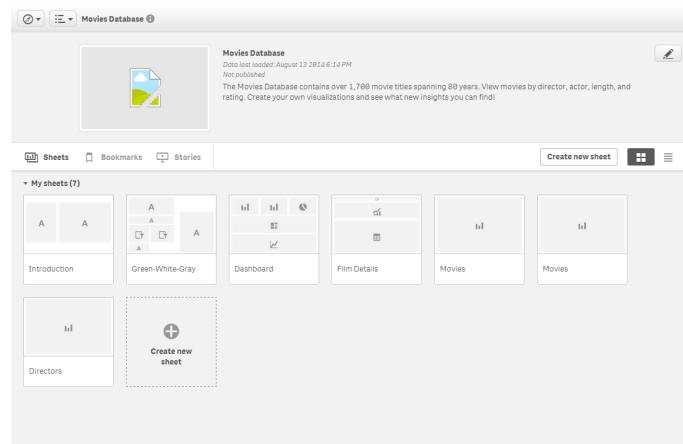
Figure 2: Showing an overview of the content in the app Movie Database [1]

To make Qlik Sense accessible and functional for all users the principles of Universal Design are to be applied. The existing interaction model in Qlik Sense is heavily dependent on the user's visual and motor processing abilities which is not ideal for people with disabilities. This is an important issue that will be addressed in the near future - partly by this project.

2.2   Rules & Guidelines

Creating accessible systems is becoming an important aspect since there are laws requiring these type of solutions. To help people achieve accessible products
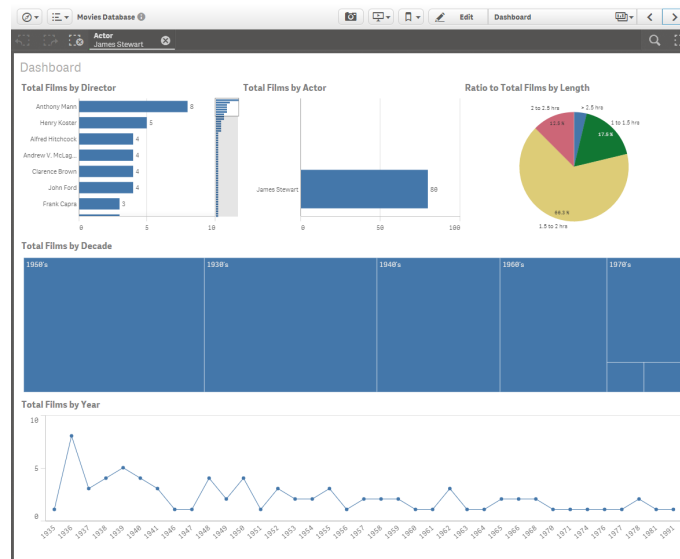
Figure 3: Showing one of the sheets in the app Movie Database[1]

guidelines have been created.

2.2.1 Section 508

In 1998 the Congress improved the United States Rehabilitation Act of 1973 to make sure all electronic and information technology used by federal departments or agencies are accessible to people with disabilities. The section was established to remove barriers, create opportunities and encourage development of information technologies. It should also create the possibility for people with disabilities to reach all information quick and easy. All federal agencies that develop, procure, maintain or use electronic and information technology have to comply. The data and information should be accessible in a comparable way for all employees or persons seeking information from the agency if it does not cause excessive burden.[42][43]

2.2.2 W3C WCAG

The World Wide Web Consortium (W3C) is an international community working to ensure that the web reaches its potential. Full-time staff, member organizations and the public work together to develop web standards, protocols and guidelines that will achieve an improved web.[15] One standard created by W3C Web Accessibility Initiative (WAI) is the Web Content Accessibility Guidelines (WCAG) 2.0. These recommendations are intended to make web content available and usable for people with different disabilities and should be taken into account by developers when in development process.[48]

Different levels of guidance are offered to ensure that the recommendations can be of use to the variety of people using WCAG. As a foundation there are the four overall principles; **perceivable, operable, understandable** and **robust** with the intention of working as pillars to create accessibility of the Web. Under the principles twelve guidelines are providing goals that the developer should aim for. These are testable through success criterias, which creates the possibility for requirement and conformance testing. Each guideline and success criteria is also connected to sufficient and advisory techniques that should be met. Together, all of these levels will support a more accessible Web content and reach a wider range of users.[8]

2.2.3 STEM Description Guidelines

Reading scientific books or papers it is not exceptional to find visual information, such as images or diagrams. However, compared to most pictures they often contain a large amount of information valuable to the reader. An example can be seen in fig.4. In these cases it is crucial that the reader can access the information, regardless if he or she is reading a physical book or an audio book e.g. in DAISY format. The images have to be described in a proper manner for this to be possible. Carl and Ruth Shapiro Family National Center for Accessible Media (NCAM) has developed guidelines for diagram and image descriptions for this purpose called Science, Technology, Engineering and Math (STEM) Description Guidelines. The guidelines are a result from a four year study performed in cooperation with the Nation Science Foundation (NSF).[13]
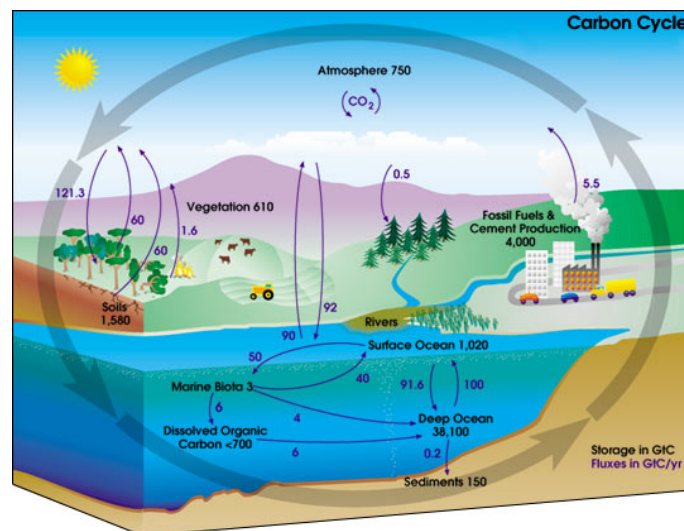
Figure 4: Diagram showing the carbon cycle [2]

The STEM Description Guidelines consists of nine rules: [12]

Brevity
It should not take more time than necessary to listen to and understand the

content of an image. If an image can be understood at a single glance, the description should be as short and concise.

Data
The information should be the main focus.

Clarity
The reader should not be forced to listen to the description multiple times to understand its content.

Drill-Down Organization
A description should start with an overview of the content and then drill down to the details if desired by the reader.

Tables
Tables, bar charts and pie charts should be presented as tables to provide the reader access to its content.

Processes
For example diagrams and flow charts can be presented as nested lists.

Mathematics
Equations should be marked up with MathML, a mark-up language that provides representations of mathematical expressions[14].

Narrative Descriptions
Linear, narrative descriptions can often be used to describe STEM images in a good way.

Navigation Control
Properly written HTML text is simple to navigate and is, in combination with text readers, often preferred compared to recorded audio.

2.2.4 Universal Design

Universal design is a concept founded by Ronald L. Mace [18]. The concept provides a way to solve design problems and achieve solutions that include all possible users, regardless of the context.

A definition for these principals was created by the Center for Universal Design, North Carolina, The United States:

"The design of products and environments to be usable by all people, to the greatest extent possible, without the need for adaptation or specialized design."
[17]

Through this design the human diversity is taken into account and the possibility to develop user-friendly products and environments increase. Regardless if you are designing a website, door handle or building a house, universal design can be applied and many companies strive to accomplish it.

Ronald L. Mace, together with a group of architects, product designers, engineers and environmental designers, coined the Seven Principles of Universal Design:

Equitable Use
The design is useful and marketable to people with diverse abilities.

- It provides the same means of use for all users: identical whenever possible; equivalent when not.
- It avoids segregating or stigmatizing any users.
- Provisions for privacy, security, and safety are equally available to all users.
- The design is appealing to all users.

Sensor doors apply this principle since they open automatically and anyone can pass through. No matter if a person is in a wheelchair, pushing a shopping cart or has their hands full of grocery bags the design is convenient. The doors work exactly the same for all users and no extra effort is needed.

Flexibility in Use
The design accommodates a wide range of individual preferences and abilities.

- It provides choice in methods of use.
- It accommodates right or left handed access and use.
- It facilitates the user's accuracy and precision.
- It provides adaptability to the user's pace.

Card readers on cash machines provide low flexibility compared to RFID readers. There is only one correct way of entering the card into the machine while the card present four possible options. RFID is an example of flexibility in use since the card is read regardless of how it is held against the machine.

Simple and Intuitive Use
Use of the design is easy to understand, regardless of the user's experience, knowledge, language skills, or current concentration level.

- It eliminates unnecessary complexity.
- It is consistent with user expectations and intuition.
- It accommodates a wide range of literacy and language skills.
- It arranges information consistent with its importance.

- It provides effective prompting and feedback during and after task completion.

IKEA's manual for putting together furniture applies this principle since they use pictures to describe the work.

Perceptible Information
The design communicates necessary information effectively to the user, regardless of ambient conditions or the user's sensory abilities.

- It uses different modes (pictorial, verbal, tactile) for redundant presentation of essential information.
- It provides adequate contrast between essential information and its surroundings.
- It maximizes "legibility" of essential information.
- It differentiates elements in ways that can be described (i.e., make it easy to give instructions or directions).
- It provides compatibility with a variety of techniques or devices used by people with sensory limitations.

Most elevators allow the user to employ more than one sense to find the button representing the ground floor since they are elevated and have deviated colors.

Tolerance for Error
The design minimizes hazards and the adverse consequences of accidental or unintended actions.

- It arranges elements to minimize hazards and errors: most used elements, most accessible; hazardous elements eliminated, isolated, or shielded.
- It provides warnings of hazards and errors.
- It provides fail safe features.
- It discourages unconscious action in tasks that require vigilance.

The possibility to correct a mistake on a computer by clicking "undo" is an example when this principle is applied.

Low Physical Effort
The design can be used efficiently and comfortably and with a minimum of fatigue.

- It allows user to maintain a neutral body position

- It uses reasonable operating forces.

- It minimizes repetitive actions.

- It minimizes sustained physical effort.

When opening a wine bottle there is a certain effort needed that might be difficult for people with for example rheumatism. To facilitate this and decreasing the physical effort an electronic vine opener can be used.

Size and Space for Approach and Use
Appropriate size and space is provided for approach, reach, manipulation, and use, regardless of user's body size, posture, or mobility.

- It provides a clear line of sight to important elements for any seated or standing user.

- It makes reaching to all components comfortable for any seated or standing user.

- It accommodates variations in hand and grip size.

- It provides adequate space for the use of assistive devices or personal assistance.

On subway stations wide gates are used to allow all users to pass through without extra effort.

2.3   The Eye & Visual Impairments

Out of all muscles in the human body, the eye muscles are the most active. On average, a person blinks about twelve times a minute with each blink lasting about one tenth of a second. The vision can be regarded the most important sense for perceiving the environment. In fact, the eyes stand for about 80% of the information collection performed by the senses.

The eye is a small and complex organ consisting of the following parts:

The visible areas are namely the sclera, iris and pupil; commonly known as "the white of the eye", the pigmented area and the seemingly black opening in the middle of the eye. The pupil controls how much light reaches the retina; it could be compared to the diaphragm in a camera. Covering the pupil and iris there is a transparent membrane called the cornea, which serves as a protection film to keep the eye free from dust, bacteria and other harmful particles. Deeper into the eye the choroid is found which consists of a network of blood vessels, which provides the retina with oxygen and nutrition.

According to the perspective seen in fig. 5 the retina is located next to the choroid. The retina contains rod and cone cells, which transform the light into images by transmitting it to the brain for interpretation. The ability to see in darkness is achieved by the rod cells, since they are particularly sensitive to light. However, the resolution is poor and colors cannot be perceived. The rod cells are located in the fringe of the central area of the retina, the macula. In the center of the macula the cone cells are found. These cells are responsible for color and sharp-detail vision in well-lit environments.
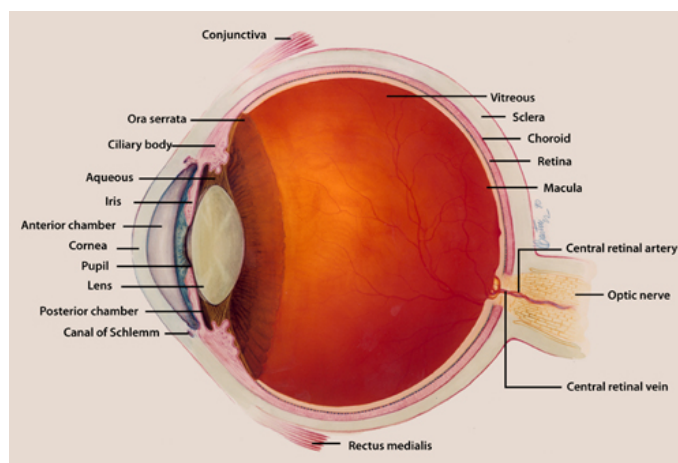
Figure 5: The anatomy of the human eye [3]

When light reaches the eye it is refracted by the lens, a nearly transparent biconvex structure found behind the visible parts [10], to finally concentrate in the macula. If this process is performed correctly it is called emmetropia, to be normal-sighted. However, it is common that the lens refractors the light too narrow or too wide, which hinders the focus point from reaching the macula. In these cases the person suffers from myopia (near-sightedness) and hyperopia (long-sightedness) respectively. Refractive anomalies are common and can, in excess of the two previous mentioned, be caused by astigmatism or presbyopia. Astigmatism is a state in which the eye refracts the light differently depending on the angle of which it hits the eye. Symptoms that can occur are blurred vision, headache and fatigue. When a person grows older the lens becomes less elastic, which is the cause of presbyopia. Presbyopia is characterized by the loss of sharp vision on short distances, which in combination with a possible former refraction anomaly can fuel a need for more than one type of vision correction to cover all distances.

The above mentioned visual weaknesses are all typically categorized as normal vision since it is possible to correct them with aids such as glasses or contact lenses. Apart from the normal vision there are three levels of visual function according to the International Classification of Diseases [34];

- Moderate Visual Impairment
- Severe Visual Impairment

- Blindness

The two first stated can occasionally collocate to the category Low Vision.

According to the World Health Organization (WHO) about 285 million people worldwide are considered visually impaired, out of which 39 million are blind.

A visual impairment can be caused by numerous types of diseases and injuries. Several of the diseases known to cause visual impairments are more likely to strike elderly people. Cataract is one of them. The disease expresses itself by shaping a grey, clouded area behind the iris, which makes the vision hazy and unclear. The complaint can strike either one or both eyes. It is the most common reason for visual impairment for the age group over 55 years old and can often be treated by surgery. In some cases Cataract is triggered by an injury or another disease such as diabetes. There is also a possibility of Congenital Cataract, which means that a person is born with the disease. [41]

Another common eye disorder that is more probable to affect people between the age of 60 – 80 years is Glaucoma. Glaucoma is a group of conditions with the Open-Angle Galucoma as the most occurring. Its symptom is particularly increased vision loss, which often develops gradually and may not be detected before it is too late for treatment. [22] It is typically caused by high pressure in the eyeball and more specifically on the optic nerve. However, science has shown that it is also possible to have Glaucoma with normal and low eye pressure. [40]

One of the most common eye disorders is Age-Related Macular Degeneration (AMD). The illness originates from changes in the macula due to thinning of the tissue and/or depositing of pigment. The symptoms are mainly loss of vision directly ahead and so called blind spots. There are two different diagnoses, wet or dry AMD, out of which dry is the most common with about 85-90 % of the patients. The wet version, however, is more severe. [21]

Losing vision is a major change in life. Still the computer evolution has enabled many people the opportunity to stay at their workplace. Today about 50 % of the visually impaired Swedish persons in working age have an employment [39] and the low vision aid are still being developed to increase the number further.

2.4   Low Vision Aids

To create the possibility for people with visual impairments to use computers, phones and tablets there are low vision aids to create an as equal experience as possible. The following are some examples of these aids.

2.4.1   Synthetic Speech

Synthetic speech is an artificial way of transforming text into human speech. It is a technique of great importance to people with low vision or blindness, but it

can also be a resource for people with reading disabilities [50]. A common use of synthetic speech is screen readers.

Screen readers are a low vision aid that makes sure that persons with visual impairment can access computer programs. The information on the screen is translated into either synthetic speech or braille shown on a braille display, depending on the needs of the user. The functionality can differ when using diverse operating systems. In some cases there is already a screen reader built into the system. Apple's computers and smartphones contain a built in screen reader for different languages called VoiceOver. For other system there are programs to download, out of which a few of the most popular are JAWS and Supernova.

How well screen readers work together with other programs and websites heavily depends on the developer of that specific program or site. For an accessible and well-adapted program it is important to follow WCAG criteria. An example could be to specify alternative texts for images and assign appropriate headings. [46]

All interaction with the synthetic speech program and control of the reading is done by commands on the keyboard. Each system has its own commands consisting of numerous keyboard shortcuts. The amount of shortcuts for the user to learn results in an extensive learning period, often at least six to twelve months. [50]

2.4.2   Magnifying Programs

For people with visual impairments normal sized text and graphics on computer screens can be too small to be readable. A low vision aid that can be of help is magnifying programs. The software increases the dimensions of the screen's content to make it easier to perceive.[49] There are several different products on the market out of which ZoomText is the most common [45]. ZoomText is developed to fit as many users as possible by offering many settings and magnification rates without making the content blurry. As well as in numerous other programs synthetic speech is included in the software and can be used if desired by the user. Another common magnifying program is Dolphin's Supernova. Except the above-mentioned features it also offers Braille support[16].

How the user navigates when using a magnifying program varies depending on the software. A few examples are that the magnifying window follows the mouse movements or that the user positions the mouse and press a key to make the window show the desired part of the screen. A magnifying program is a great aid for persons with low vision, but it has its drawbacks. The lack of overview can be regarded as one of the most important.

2.4.3 Voice Control

Communicating by the use of voice, i.e. to speak, is the most natural way of interaction between humans [23]. As a consequence it has been, and is still, an interesting task to enable the same natural communication between a technical system and its user. The first ideas in this field appear to have been developed as early as during the second half of the 18th century. However, the first important milestone arrives a couple of hundred years later. Developed by Homer Dudley, the Voice Operating Demonstrator (VODER) was presented at the World Fair in 1939. VODER could, with the help of a trained operator, produce speech-like sounds and sentences. From a talking system the development progressed to speech recognition and in the 1950s the Bell Laboratories created the "Audrey" system, which could only understand digits. A decade later the "shoebox" was released by IBM. The shoebox could understand 16 words, which was impressive at the time. In the 1970s the technology took off in a larger scale. A milestone was the development of "Harpy", a system that could understand 1011 words. To make a comparison, that is roughly as many words as a three year old child is able to comprehend [5]. [36]

The systems kept growing and from speech recognition, voice control developed. Voice control is a way to remove the need for buttons, keyboards and other physical input devices by giving vocal commands. The advantages are many and perhaps the most obvious is the fact that the users get their hands free. It can also play an important role for the independence of people with different kinds of disabilities. Today it is a certain part of both computer and cellphone industry, but can also be found in e.g. cars.

2.4.4 Visual Description

In the same way as the voice is the primary method for communication, the vision is our most dependable sense when observing and discovering the world around us. Hence, there is information that is unavailable to the blind and visually impaired. The purpose of visual descriptions is to increase the accessibility of unknown environments, movies, images or a theater shows [32]. This way the visually impaired are able to perceive what is occurring and compensate the inability to see it. A study has shown the importance of the person who does the description. The most preferable is an associated person, e.g. family or a friend, but it can also be a teacher, personal assistant or a professional.[9]

In today's education teachers or personal assistants in addition to audio books perform the visual descriptions in school. As Nyqvist mentioned in [30] the level of education is depending on the teacher, time and the financial situation since there are no standards on how the education is supposed to be provided. In the same way schoolbooks are translated from text to voice, there are also newspapers and magazines that make sure they are accessible to everyone. *Forskning och Framsteg* is an example of a scientific journal that uses visual descriptions to describe pictures and charts in a successful way. In fact, the whole magazine is translated into voice recorded on CD which then is sent to subscribers.

Apart from the visual descriptions made by people translating visual information into audio, there are also partly or completely automated systems that aim for the same goals. Polar Print carried out a project during 2008 where a smartphone was used to take a picture, which then was sent through a special program for interpretation. An interpreter, e.g. a family member, a person close to the user or another volunteer, received the message. Thereafter a description was written and sent back to the user. [35] An iOS application similar to the previously mentioned project is TapTapSee. By using the camera and VoiceOver the application interprets the content of the photograph and reads it aloud to the user [47]. These are examples of two great aids, for the blind and visually impaired, which can lead to a more independent everyday life.

As mentioned before visual descriptions increase the accessibility for shows and movies. If it is a show the interpreter starts by doing an introduction where the audience is informed about what the actors are wearing and what the stage looks like. In movies the environments are usually described. Even though all interpreters write their own scripts they all go by the motto to generate "the greatest benefit to the least possible damage". The interpreters are always well prepared and have watched the play or movie many times in advance to produce a great experience for the audience. If unexpected things happen during a show that results in laughter or outrage the interpreter also comments on these events. This is done to make sure those with visual impairments are included and can participate throughout the whole show. Participation is the big difference with recorded and live visual descriptions. Another important thing, to summarize to the audience, is the events not presented in the dialogue between the actors. If you wish to listen to visual descriptions and experience it you can find some examples on [31]. [33]

2.5 Memory

When people use systems together with today's low vision aids they have to rely a lot on their memory. People with visual impairments do not have the ability to relive their memory by using sight which is important to take into consideration when designing to achieve an accessible result.

2.5.1 Long Term Memory

As the name implies, the long term memory (LTM) stores long lasting information. The capacity of the LTM is seemingly unlimited, which is a major difference from the short term version. In addition to that, studies have also stated the persistence of memories is without limit; the LTM has an infinite duration. However, it is possible to experience difficulties when attempting to remember information from a long time ago. Some scientists claim that this phenomenon is most likely due to increased difficulty to retrieve the information from the LTM, rather than that it has been forgotten. [28] The items in LTM seems to be encoded visually and semantically, i.e. by association or meaning. There is also some evidence that states that it can use acoustic encoding as well,

which means turning the memories into sound. [26]

LTM consists of two main types; declarative and procedural memories. Declarative memory can be explained as "know what", which is the facts a person learns and memories of events. To access the declarative memories it requires a certain effort since they have to be retrieved in a conscious manner. Procedural memories on the other hand, are retrieved unconsciously. This type of memory stores knowledge about how to do things, e.g. to ride a bike or tie a shoelace.[27] The distinction between the two types was made by Cohen and Squire in 1980. Most of the science about the field has originated from studies of amnesia patients. [26]

2.5.2 Short Term Memory

In contrast to the LTM, the information in the short term memory (STM) only lasts for a short period of time. It is occasionally described as the brain's "post-it note" since it stores only temporary facts [29]. The STM has three key properties [25], namely:

- Limited capacity

- Limited duration

- Encoding

In a report called Magic Number 7 (plus or minus 2) from 1956, Miller explains that the STM can hold only between five and nine items at the same time. He describes the concept as memory slots that each can store one piece of information. The number of slots is seven, plus or minus two. Additional studies have been conducted with results supporting Miller's theory. However, more recent research have shown that it can be even less, as low as four pieces of information [REF].

Another limitation is duration. Atkinson and Shiffrin suggested in 1971 that the duration of the STM is no more than 15 to 30 seconds. Information can be lost simply due to time, but also distraction. However, if an effort is made to retain the information it can be moved to long term memory. This can be performed by repeating the information, connect it to previous knowledge or read it out loud. The information in STM is encoded into sounds, which means that even visual impressions are transformed into acoustic form. [25]

2.5.3 Chunks

As previously mentioned the short term memory has much limited capacity. To increase the number of items to store, a technique called chunking can be of use. Together with the magical number, Miller introduced the "chunk" as a way of organizing material into groups. This makes the information manageable and

more items can be stored in the STM. Miller did not specify the amount of information a chunk can contain, but it is clear that meaningful chunks have the possibility of being larger [25] [29].

Hebert A. Simon gave an example where he proved the chunking hypothesis by showing that the meaning of the information to be stored matters. First he read the following words after each other: Lincoln, milky, criminal, differential, address, way, lawyer, calculus, Gettysburg. He had no success in recalling all of them. In the next attempt the words were rearranged as follows:

- Lincoln's Gettysburg Address

- Milky Way

- Criminal lawyer

- Differential calculus

Because of the culture he was raised in these items were familiar to him and therefore memorable [44]. The example shows that when it is possible to associate the information to previous experience the magical number can be exceeded.

2.6 Previous and Related Work

Material from previously done studies within related areas was found and gave inspiration through the project.

2.6.1 Sonified graphs

In the reports *Drawing by ear: interpreting sonified line graphs* and *Browsing Mode for Exploring Sonified Line Graphs* by Brown and Brewster [24], and Brown et al. [11], respectively, have explored the possibility to represent line graphs by non-speech audio. In sonification of graphs every data point is connected to a musical tone. The higher the y-value is the higher becomes the pitch. By doing so a user can tell the behavior of the graph without seeing the visual representation.

In [24], pilot tests with two data series were performed on sighted people. Each graph was represented by a specific musical instrument. The participants listened to examples where graphs were represented by the same instrument as well as different. After listening to the sonified versions they were asked to draw the graphs. The result showed no difference between the two states. However, the accuracy of the graphs was over 80 % on average, which made the tests successful.

The next study, [11], was performed on blind participants. As in the previously described report this study also used two graphs in the same chart, but this

time different browsing modes were explored, serial and parallel. During serial mode the audio representations of the graphs are played after one another, while the parallel mode offers them at the same time, one in each ear. It was clear that the parallel mode was preferred in search for intersections, while there were some indications that serial mode was better when wanting to find maximum and minimum.

Both studies proved it to be possible to interpret multiple graphs in the same chart by the use of non-speech audio.

2.6.2 Combination of sound and tactile feedback

The future new technologies based on audio, haptic and tactile feedback might deliver more affordable accessible graphics. GraVVITAS (for Graphics Viewer using Vibration, Interactive Touch Audio and Speech) is a multi-modal presentation device using touch screens, allowing blind people to explore graphics. Both speech and non-speech audio are used as feedback to hear the graphic while touching it. Haptic feedback is provided by the use of data gloves with vibrator motors attached to the fingers. These indicate when the user is touching an element on the screen. The gloves are optional and the system works properly without them but it removes the tactile ability. [19][20]

2.6.3 Qlik and Visual Impairment

In 2014 a Master's Thesis was conducted in cooperation with Qlik. This researched focused on how people with visual impairment could interact with the program QlikView using a touch screen. A prototype was developed and tested to see how vibration, sound, signals and gestures could be used to preform simple navigation and present graphs.[7]

3 Method

The work progress has been conducted in an iterative manner and a number of steps have been involved to achieve a functional solution. In this chapter all work phases are mentioned and explained to give the reader an informed view of the process.

3.1 Time Schedule

Fig. 6 shows the intended time schedule for the project. The dark areas represent main tasks and the lighter colors are sub-tasks.
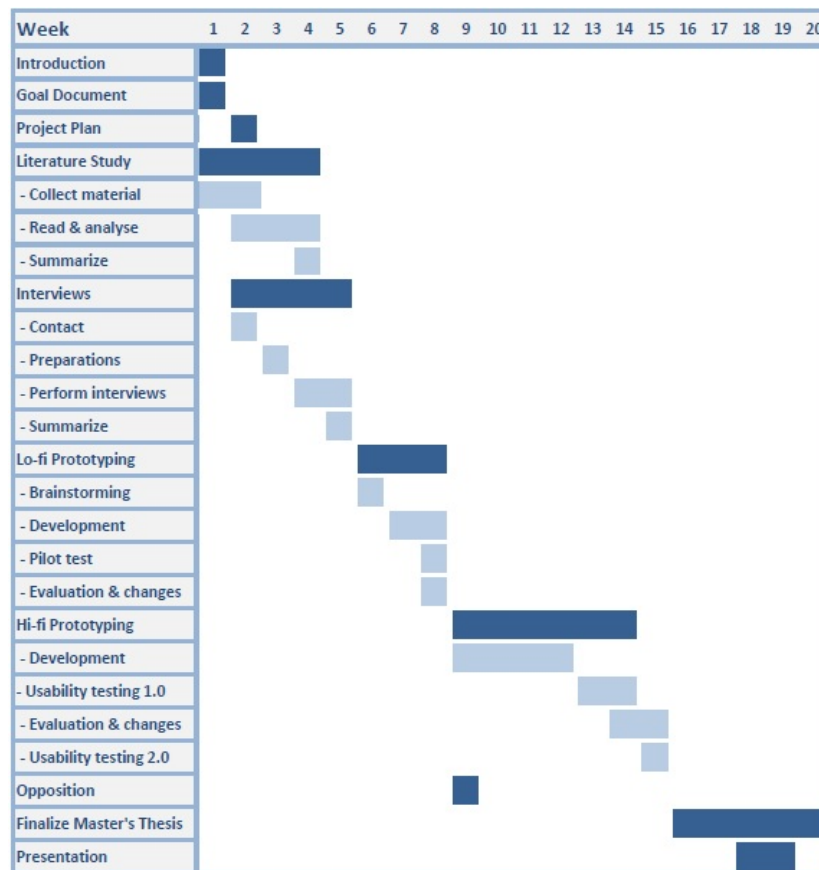

Figure 6: Time Schedule 1.0

In fig. 7 an updated version of the time schedule shows how the work process ended up. Changes were made over time due to unexpected events and increased research. During week three the decision to perform pilot studies was made, which resulted in delays in the work with both Lo-Fi and Hi-Fi prototype. The

pilot study was conducted to give us an insight in what people are looking for in charts and what they find to be valuable information. This study was performed early in the research and became an important part that contributed to guidance throughout the entire project.

As seen in Time Schedule 1.0 (fig. 6) the development of the Hi-Fi prototype was supposed to begin in week eleven. However, there were complications when building the client platform for Qlik Sense, which was an essential step before it was possible to start programming. These issues took two weeks to solve and reoccurred in week fourteen as well. Therefore the prototype was not finished at the previously set date, which resulted in the usability tests being postponed.

Both authors of this report have been contributing to all parts of the work process.

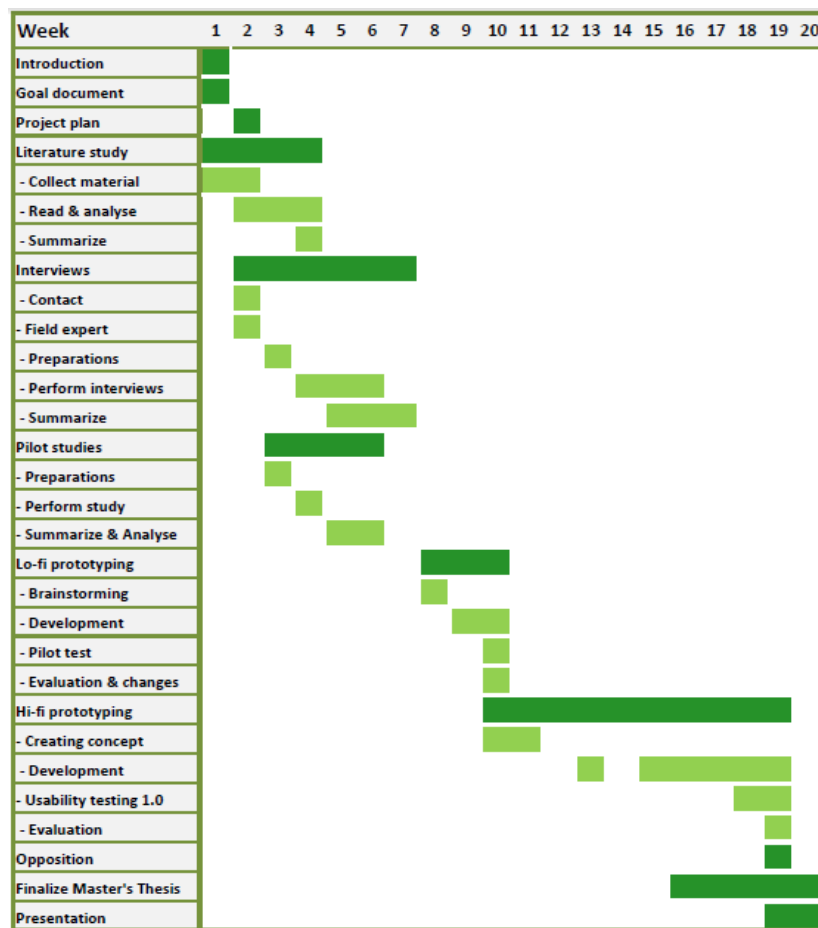| Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Introduction	■																			
Goal document	■																			
Project plan		■																		
Literature study	■	■	■	■																
- Collect material	■	■																		
- Read & analyse		■	■	■																
- Summarize				■																
Interviews		■	■	■	■	■	■													
- Contact		■																		
- Field expert		■																		
- Preparations			■																	
- Perform interviews				■	■															
- Summarize					■	■														
Pilot studies			■	■	■	■														
- Preparations			■																	
- Perform study				■																
- Summarize & Analyse					■															
Lo-fi prototyping								■	■											
- Brainstorming								■												
- Development									■	■										
- Pilot test										■										
- Evaluation & changes										■										
Hi-fi prototyping										■	■	■	■	■	■	■	■	■	■	
- Creating concept										■	■									
- Development													■		■	■	■	■		
- Usability testing 1.0																	■	■		
- Evaluation																		■		
Opposition																		■		
Finalize Master's Thesis															■	■	■	■	■	
Presentation																			■	■

Figure 7: Time Schedule 2.0

3.2 Background Research

A significant part of the time spent on this project was put into the background research. Primarily, literature was read, which formed a base for the following pilot studies. The studies gave valuable insights. Together with the information gathered in the interviews with both target users and experts in the field it created inspiration to develop the concept further.

3.2.1 Literature Studies

To find relevant literature linked to the project, library database searches were performed. The Digital libraries of Lund University, LUBsearch, IEEE Xplore and Springer Link were the main resources. In addition to libraries, other internet resources such as the website for the Swedish Association of the Visually Impaired and the National Agency for Special Needs Education and Schools contributed with valuable information.

3.2.2 Pilot Studies

People with visual impairments have to use other senses than sight when using computer systems. Because of limitations to the project, using sounds became the clear approach early in the work process. From prior research sonified graphs was found as a way to present graphs and a possible direction for this project. One reason why this was not further investigated was because of ambivalent results in other research. It was expressed in [7] that people who are blind was not convinced that this type of solution would be appreciated. It was decided to research a different path where audio with speech was used instead of signals and tones and focus on how to develop descriptions of visual information.

Through discussions around the topic representation of visual information and more specific what kind of advantages a graphical representation can give, a pilot study was initiated. The main idea was to narrow down what kind of data people find valuable when viewing a graph and receive an insight in the importance of overview. Each test was executed by two persons, where one described a graph taken from Qlik Sense demo applications using nothing but sound, e.g. speech. The other person received the portrayal without ability to ask questions or in any way interact with the describer. When the description was completed the test subject tried to draw an equivalent picture of the graph, using nothing but the mental model formed during the test.

One group of seven persons, three men and four women, participated in the study. Their assignment was to describe the graphs. Test leading in addition to memorizing and drawing were roles divided between the authors of this report. The participants were between 23 and 26 years of age and were chosen since they had different educational backgrounds and experiences of graphical representation. Every test consisted of three or four charts. The procedure was recorded and transcribed subsequently to assure no details were lost. See

Appendix A for complete test plan.

The collected material was analyzed through ten predefined questions. The questions can be found in Appendix C.1. The results from the analysis were then written down side by side to be able to show differences between the descriptions. To further structure the work a number of categories were defined, which were each marked with a different color. The categories were:

- Values and numbers

- Axes and scales

- Analysis, descriptions and general information

- Repetition

To separate successful approaches from poor ones the tests were divided into two sections due to the similarity between the depiction and the original graph. Similarities and differences between the descriptions in each section were then defined to find common denominators. An example can be found in Appendix C.2.

3.2.3   Interviews

A number of interviews were performed to receive a more informed image of the differences and requirements from persons with a visual impairment. Contact was made with the Swedish Association of the Visually Impaired, the Association of Swedish Visually Impaired Youth, Skånes Taltidning [1] and various universities in the area to establish a relationship with persons who have the required insights. Several people showed interest in the project, out of which five persons were selected for the interviews.

The five persons selected for the interviews were of diverse age, approximately between 20 and 65 years. There were two men and three women, out of which two were blind and three had low vision. They were all chosen since they had some computer experience and either knowledge in mathematics or were interested in statistics. The sessions were performed during two weeks at sites chosen by the interviewees. Each interview lasted between 30 and 60 minutes.

The interviews were performed in a semi-structured manner with a manuscript of predefined questions found in Appendix E, with the possibility to yield for attendant questions and improvised discussions. This contributed to individualized sessions. However, as a joint fact open questions were used throughout the whole interviews. How the interviews were carried out strongly depended on the type of visual impairment the interviewee had. All sessions were initiated with a short introduction about the project followed by general questions to assure that the interviewee was comfortable. The interview then progressed

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[1]A recorded paper for south of Sweden

to questions based on experiences of visual data and more specifically graphs. Lastly the basics of the project idea were presented and input was received.

3.2.4   Field Experts

To receive an insight in how low vision aids, such as screen readers and magnifying programs work a meeting was booked with Ulf Larsson at Horisont. Horisont is a company specialized in installation, adjustment, support and education for computer users with visual impairments. The employees have experience and knowledge in how a visual impairment might affect a person and the attitude to computer-use. They also possess special competence in certain low vision aids and educate users how to use them.

During the meeting Larsson presented the synthetic speech program JAWS and the magnifying program Magic. The programs are among the most popular to use for people with a visual impairment. Larsson demonstrated different commands used to interact with the systems and described how they teach new users to handle the aids. By paying close attention to the demonstration it was possible to understand what type of interaction was needed. It was clear that practice is crucial to be able to use JAWS in a smooth way.

A phone interview with Björn Nyqvist was also conducted. Nyqvist works at the National Agency for Special Needs Education and Schools (SPSM in Swedish) and is specialized in vision and visual aids. SPMS's purpose is to offer their knowledge and give guidance to Swedish schools. The interview with Nyqvist gave great insight in how visual descriptions are used in today's education. He also informed about what aids are used and how teachers have to work to create pedagogical adaptions to produce an equal education.

3.3   Prototyping

The prototyping phase consisted of a number of brainstorming sessions which resulted in new ideas and suggestions. Together with the previously mentioned test phases, prototypes were developed in both low and high fidelity versions.

3.3.1   Brainstorming

Brainstorming has been an important part of the work process. To achieve new and innovative ideas, brainstorming was used as an iterative method within all design decisions. By letting the imagination run wild a large amount of unique ideas can be produced. A brainstorming session generates many thoughts on different levels and relevance to a project. Quantity usually evolves into quality and a well performed session often results in useful ideas. This method also assists in realizing and solving problems with existing ideas and decisions.

Using a whiteboard made sure that all ideas could be presented. The exposition

of the thoughts allows the ability of association and helps in finding new areas of interest. A better structure among the ideas is also attained. An example of one of the brainstorming sessions for this project can be found in Appendix D.

3.3.2 Lo-Fi

Traditionally, a Low Fidelity (Lo-Fi) prototype is created with pen and paper. It is a visualization of the concept, often merely a sketch, providing a simple and quick way to get a testable prototype. In this project such an approach would be pointless since the target users are unable to perceive visual information. To come around this problem it was necessary to think outside the box. An auditive presentation of the concept became a replacement of the visual Lo-Fi. The result was a number of audio files recorded by VoiceOver for Mac. Since the standard language for VoiceOver is English the synthetic voice Alva was downloaded and used to be able to record a Swedish voice. The choice of language was natural since all participants have Swedish as their native language. The prewritten texts were then converted into synthetic speech files by use of the command "Say" in the command line. Finally, the files were saved as .aiff.

Three audio files with different content were recorded, based on the graphs seen in fig. 8, 9 and 10. To specify what kind of information to convey in the speeches the result from the pilot tests, found in section 4.1, were studied. Two of the three different approaches used techniques that in different ways had shown to be successful. The last one contained methods that did not work properly during the tests. It was used to receive a proper ranking of the alternatives as well as verify the results of the pilot study. The manuscripts used to perform the test can be found in Appendix G.
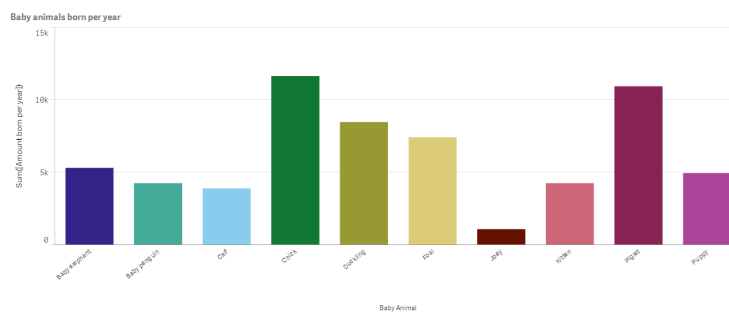

Figure 8: Baby Animals born per year (BA) [1]

24
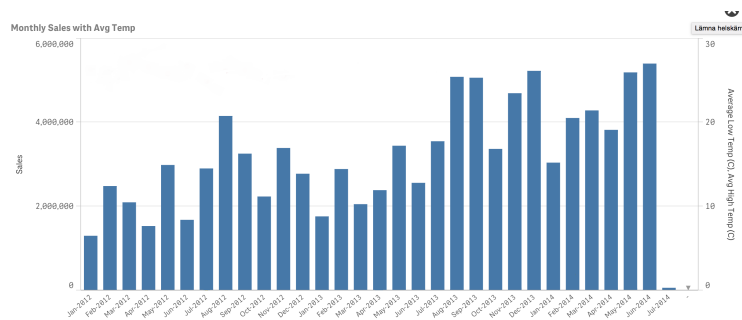
Figure 9: Customer Analysis, monthly sales (CA) [1]
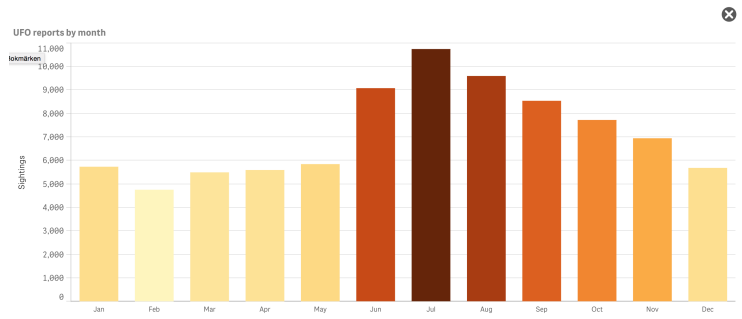
Figure 10: UFO reports per month (UFO) [1]

Five persons out of whom two were previous interviewees tested the Lo-Fi prototypes. The three persons that had not participated in the interviews had vision classified as normal. In these three tests the participants listened to the recorded descriptions one by one and were thereafter asked to draw the graphs. These test sessions were much similar to the ones performed in the pilot studies. However, the interviewees could not test the Lo-Fi prototype in the same manner. Instead they simply listened to the recordings and gave feedback orally. Finally, all five participants were allowed to rank the descriptions in an order they found appropriate with the best description first and the most poor last.

3.3.3 Hi-Fi

A High Fidelity (Hi-Fi) prototype is created to achieve a high tech and realistic representation of the design concept. By implementing the prototype with partially complete functionality the users can interact with the system. This way it is possible to test an almost finalized product.

There are many tools that can be used to create a Hi-Fi prototype. However, for this project it was a natural choice to use the programming language in the existing system, namely JavaScript. The decision allowed the possibility to add the functionality directly into Qlik Sense. The program used for developing the

prototype was WebStorm, a code editor that supports e.g. JavaScript, Node.js, HTML and CSS. This program was a suitable choice since many developers at Qlik use it and Qlik Sense is developed using these languages. Git was also used for the possibility to share the work and changes made over time. Git is a distributed revision control system for software development.

As mentioned before, the design concept focuses on audio since the target group is people with visual impairments and a visual design is not perceivable to them. Therefore an audio solution was the main area of interest. Finding a compatible and functional synthetic speech system has been of high priority since previous research has shown that both performance and voice are of great importance. Google Web Speech API became the choice for this project.

To present a graph to the user the correct data must automatically be collected from the database. The data is then manipulated to find key values which are read out loud to the user. Work has also been put into finding and examining a solution on how to describe the shape of a graph automatically from the collected data. Regression analysis offers a way to describe the shape of a curve and present an equation for it. The formula for the linear regression is calculated as follows:

$$y = a + bx$$

where

$$b = \frac{n \sum xy - \sum x \sum y}{n \sum x^2 - (\sum x)^2}$$

$$a = \frac{\sum y}{n} - b * \frac{\sum x}{n}$$

a and b are the regression coefficients, while x is the variable. By calculating a and b for a number, n, of x and y values it is possible to predict unknown y values. The method can also be used to find a suitable equation for a curve. Fig. 11.
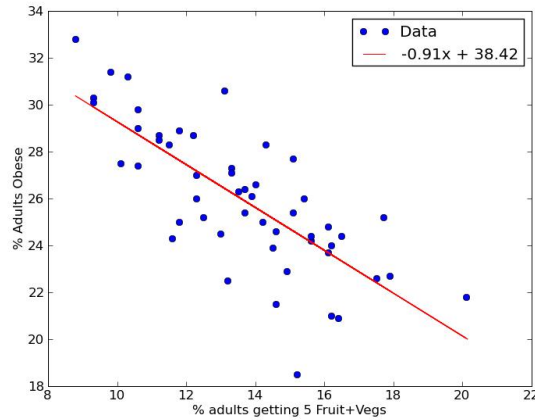
Figure 11: Linear regression [4]

However a linear curve is not always the best fit for the data in a graph. To find out how well the estimated equation fits the data the coefficient of determination, R^2, is calculated.

Total sum of squares:

$$SS_{tot} = \sum (y_i - \bar{y})^2$$

The residual sum of squares:

$$SS_{res} = \sum (y_i - f_i)^2$$

$$R^2 = 1 - \frac{SS_{res}}{SS_{tot}}$$

If the coefficient of determination is higher than the threshold $t =$??? the prediction is considered suitable. On the other hand, if it is lower than the threshold it may be possible to find a better fit with an equation of higher degree. The method used is called polynomial regression and works in the same manner as the linear version, except it provides a curve of a different shape. To calculate the polynomial regression a JavaScript library called *Tom-Alexander/regression-js* [6], containing a number of least square fit-methods, was used. If R^2 become higher than the threshold the equation is used, otherwise the calculations continue with a higher degree. If no equation pass the threshold value the one with the highest R^2 value is chosen.

When a fitting equation is found, it is solved for $y = 0$ to receive the inflection points. The inflection points show where the descending and ascending parts of the curve are located. These parts can be calculated with linear regression to find their individual slope. The number of inflection points as well as the slopes

of the curve gives the user a fairly detailed model of the graph. The model can easily be described in words and give a possibility to analyse the graph and demonstrate trends.

3.4   Usability testing

To complete the project a usability test session was performed according to the test plan found in Appendix G. The goal was to discover if the final prototype met the expectations and added value to potential future users. The sessions were short at a maximum of 30 minutes and consisted of two parts, a listening part and a short debriefing. In the first half of the session the participants listened to three visual descriptions collected from the prototype, fig. 14, 15 and 16. To ease the understanding the descriptions were translated into Swedish. The participants were allowed to listen to the descriptions as many times as they pleased before moving on to the debriefing. The debriefing consisted of the five questions found below.

- Does the description help in creating an overview of the charts' content?

- In your opinion, do the descriptions contain a large, small or appropriate amount of information?

- Is there anything that the descriptions lack?

- Were you able to create a mental image of the charts' content?

- The descriptions are divided into different categories. Were you able to notice a difference between the categories? In that case, what is your opinion of these?

Three participants who were chosen out of the previous interviewees performed the test. Two of the three had also taken part in the Lo-Fi testing.

4   Results

This section presents the results of the project. Through the different stages of the work process the following understandings in how people perceive charts could be recognized. These realizations resulted in a Low Fidelity prototype, which after tests and evaluation evolved into a High Fidelity (Hi-Fi) prototype. Finally, the Hi-Fi prototype was analyzed through usability testing.

4.1   Pilot Studies

Both qualitative and quantitative results were obtained through the pilot studies. The participants presented some successful descriptions while others generated poor results, see Appendix B. Ten out of 22 depictions resembled the original diagrams and gave a proper overview.

When analyzing the test results some similarities could be found in the descriptions that resulted in well depicted charts:

- Description of the shape of the graph

- Repetition of key values and information about the axes

- A low amount of values, four to twelve, mentioned in detail

- Highlighting both maximum and minimum

- Merging of values in the same category, e.g. days of the week, into chunks

In the explanations resulting in depictions less successful the following resemblances were found:

- Highlighting all values, one by one

- Trying to analyze the meaning of values within the diagram

It was clear that the test subject paid attention to different key values depending on the type of graphical representation. To focus on maximum and minimum was common in bar charts. The participants were also tempted to go through all values one by one. In scatter plots maximum and clusters were presented in a distinct way and for line charts the participants concentrated the information around maximum, start and end values.

There was a noticeable difference in the participants approach to the exercise, but it was possible to see similarities between those of equal educational background. The persons having more analytical experience tried to understand the meaning of the graphs and thereby searched for specific values. They also used more technical expressions, while others used everyday language.

The pilot studies resulted in questions and topics in need of more research, which were investigated in the development and testing phases of the Lo-Fi prototype.

Most participants showed a great learning curve since their final descriptions became more successful. While some did not attempt to make any changes which resulted in less resemblance to the original charts.

4.2 Interviews

Interviews with five persons with visual impairments were performed to get an insight in the wishes and needs of the target group. Depending on the severeness of the interviewees' visual impairment as well as what kind of low vision aids they used their feedback were divided into two groups, *Users of Magnifying Programs and Screen Readers* and *Users of Screen Reader*. Since there where clear differences between these groups the division was natural.

4.2.1 Users of Magnifying Programs and Screen Readers

In this group three interviewees participated. Two of the interviewees had received their visual impairment due to aging and previously had full vision. Today Person A only has peripheral vision while person B lack detail vision and merely have mobility sight due to Age-Related Macular Degeneration. The third person, C, has a congenital visual impairment without diagnosis. Their occupations are diverse, but they all have substantial educations. B has previously worked as a mathematics and physics teacher. After several years he changed career to a computer oriented position where he was responsible for all technical aspects in a smaller county. A have also been working with computers, but in his case within the building industry. C is currently a student at Malmö University.

Low vision aids can be of use to overcome some of the difficulties a visual impairment can bring. The interviewees all used synthetic speech when maneuvering the computer. ZoomText, which also functions as an magnifying program, was the program preferred by B and C. Person A used Dolphin's Supernova without enlargement functionality. iPhone was the most popular mobile phone. As a complement, A used the built-in program VoiceOver for screen reading functionality, while C only needed magnification and bold typing to handle the phone. B on the other hand, had not yet embraced the world of smartphones since he was still able to operate a mobile phone with large buttons, e.g. Doro.

Despite the low vision aids some tasks were challenging to handle. Two of the persons experienced difficulties when browsing the web. C mentioned Malmö University's website as especially troublesome, emphasizing the many clicks necessary when navigating for desired information. Lack of contrasts and navigation issues were described as common. These problems even caused person B to avoid non-familiar websites and thereby limit his computer utilization. In addition to websites advertisements were often difficult to interpret. A stated

that leaflets are seldom or never accessibility adapted. The many colors and once again lack of contrasts makes the content unclear. According to person B, the same applied to newspapers especially when containing a great number of graphical components.

Images, graphics and visual information were reappearing subjects when discussing problematic situations, online as well as in real life. An example is the use of ticket vending machines, particularly for train in Skåne. The machines rely fully on touch interaction and demand many clicks per purchase. Person B described the machines as *"completely impossible"*. He added that as a first time user one is always at the mercy of the design. If the designer have not interpreted the user's mental model correctly, complications occur.

Even though there are aspects to improve in many digital systems, they are often more simple to use than the analog equivalent when having a reduced visual ability. B stressed the example of calculators, which were difficult to use with his visual impairment. Thus, he used excel when calculating complex formulas, logarithms and exponential expressions. Unfortunately he looses the capability to get an overview when using the magnifying software.

The lack of overview is a major problem and a subject highlighted several times during the interviews. B compared the use of magnifying programs with that of a loupe. The small area covered by the loupe is very clear, but everything around is blurry. It makes navigation challenging and causes the user to lose the overall context. The same problem applies to the use of the tab button to move around a website or a program. A thought of it as old-fashioned and suggested a synthetic kind of overview that explains the content and automatically lists the user's different options. A also mentioned that it would be nice if the system could communicate feelings related to the information presented, for example A would like to feel the thrill associated with an election showed in graphical form. Both A and C stressed the fact that a visual impairment and the difficulties related to it are individual. C said that *"It is not an easy task to design something to fit everyone, or even as many as possible!"*.

To overcome some of the difficulties A suggested that it should be possible to personally control the information flow. A said that some people want a lot of information, while others do not. C, on the other hand, stated that clarity is crucial and the more descriptions the better. C emphasized that nothing should be taken for granted. However, it is clear that a certain learning time is required for new systems even though they are accessibility adapted. A said that it is all about finding your own way and practice. The threshold can be lower if it is a smart system. B agreed and admitted to have some resistance to new systems and a need to have a motivator to learn new technology. Such a motivator could be that previously used techniques no longer function properly, e.g. due to increased visual impairment.

One of the techniques with a distinct learning threshold was voice control. The technology has been available for years but none of the interviewees used it on a regular basis. However, they all agreed on its advantages and thought that the interaction technique could be valuable in the future. B said that voice

interaction is natural but that it demands some environmental requirements, e.g. fairly quiet surroundings. Furthermore it is important that the technique functions properly to avoid additional steps to control that the voice commands are correctly interpreted. C suggested a solution where the user can choose if they want to use shortcuts or voice control. It should be up to the user to choose the most natural and efficient way to communicate with the software. Although the reactions to voice control were mainly positive, person B added that voice interaction is probably more effective for computer-to-user communication than vice verse.

An alternative to auditive interaction is tactile techniques. A admitted to be fascinated by 3D printers as A has previously worked with modelling and 3D objects. A looked forward to see where the technology is heading. However, A still preferred sound as the interaction technique. The same applied to B. B had limited experiences of tactile information but thought that the use of braille in public environments is great. B hoped that braille and tactile information are going to be available for touchscreens in the near future.

Finally, the project idea was discussed in detail. B gave an example of graph description from the Swedish magazine Forskning & Framsteg where Per Lagergren describes diagrams in a much appreciated manner. B expressed that the analysis of a graph is a matter of judgment that depends on context and previous knowledge. It is a challenge to automatize such an analysis but as he said; *"Nothing in this world is impossible, it is only a question of how do we solve this?"*

4.2.2 Users of Screen Readers

In this group two interviewees participated. They have both been living with a visual impairment since young age. However, none of them were born blind. Person D explained that in the first few years in life, D could see colors, light and shadows but not specific details. D is now a student at Malmö högskola, while person E works with the administration at the Swedish Association of the Visually Impaired. Even though they have different backgrounds both of them considered their basic mathematical education inadequate to some extent. However, later in D's studies D encountered a pedagogically accomplished teacher who used alternative means and aids to clarify some of the abstract and visual parts, e.g. graphs and diagrams. The interviewees agreed on that the teacher's attitude to problem solving is a significant part of learning. E still holds an interest in statistics but admitted not to remember much about the related education.

Computers was explained to be a important part in the interviewee's everyday life. To be able to interact with the computer they used the synthetic speech program JAWS in combination with the computer keyboard where E also used a braille display. The interviewees also had iPhones with VoiceOver. The evolution of smartphones had contributed to a simplified technology use since the phone applications were in general considered better and more compatible with synthetic speech compared to many websites. Consequently, applications were

often preferred. However, there are still errors that often occurred especially when browsing news sites such as Aftonbladet and Expressen with many graphics. Drop-down menus, which are not noticeable together with the synthetic speech programs, are a different issue. If a third party does not alert the user about the menu there is no possibility to be aware of its existence. Furthermore, navigating on websites also created problems, particularly on previously not used sites. Loss of information was a recurring subject, sometimes with serious consequences. One example was bills, which sometimes are attached as PDF-files in e-mails. The picture format cannot be read by the synthetic speech programs thus the content never reaches its receiver.

Supplementary software is needed to interpret pictures. Both the participants had encountered automatic image interpretation in different contexts. On websites it is the web designer's decision whether or not to write explanations. If not, the synthetic speech only recognizes that it is a picture or graphic resulting in lost visual information. Visual descriptions are another way to present visual information like TV-shows and movies. TV in general was said to be difficult information to obtain, even though it is supposed to be available for everyone.

The tactile sense is important and something both of the interviewees depend on in their everyday life. E had for many years read about touchscreens where it is possible to use the tactile sense. This seemed to be an interesting concept but for now she preferred sound interaction since using tactile techniques requires a combination of senses to be efficient. Both participants agreed on the fact that speech is used more than tones. D mentioned an application for work out where tones represent different exercises. However, D seemed to think that it is a good idea to use tones in more advanced situations than it is used today. In addition to the matter, mostly feedback from buttons was discussed.

Voice control was something E had positive attitude towards, even though E had never tried it. It was considered to be a great way to interact with a system if the technique works properly. D had encountered it while ordering mobility service as well as using Siri on the iPhone when calling a friend. The experience was that Siri was too fast between interpretation and action, which could result in unintended choices and phone calls to the wrong person. If voice control worked properly D would prefer to use it in interaction with the computer, despite the opinion that it is not reliable today. The interaction would be simplified if it was possible to ask the computer questions and it responded.

D explained that it is important that the system clearly describes how to interact with it and that it is unambiguous. Since visual design cannot be used, a vocal description is needed. As an example D described an experience where D was not able to execute an exam since there was no description on how to interact with the web-based test. Even when receiving an explanation interaction with the system was not possible since the design was drag-and-drop based and a mouse was required. For a person with blindness computer interaction is performed through the keyboard and keyboard shortcuts. The shortcuts are generally standardized, but using new systems can always be difficult and as E mentioned proper feedback is of importance.
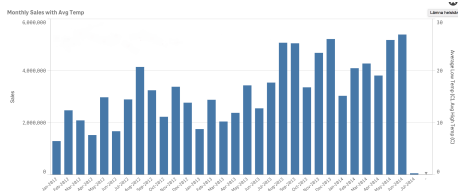
Figure 12: Chart in Qlik Sense [1]   Figure 13: Depicted version
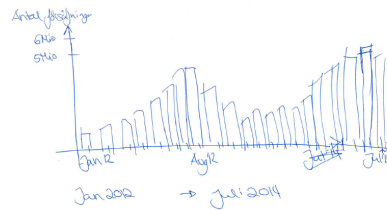
The interviewees both remarked that receiving an overview is not possible when using synthetic speech. In Excel you have to navigate through every column and row to find each value, resulting in loss of context as a whole. Memory strain is also an issue when the tables contain large amount of data. It is essential to regard that there are notable limitations on what can be stored in the short-term memory, although there are differences among users.

As a final remark D said that all users are different and adjusting a system to be compatible to everyone is difficult, but it is still important to reach as many as possible.

4.3 Lo-Fi

Overall the depictions created by the participants had a high level of similarity. However, one test chart was distinguished as resulting in better resemblance to the original chart in all tests, namely CA (fig. 9). When CA was depicted both the values and categories on the axes were correct and the general shape of the bars agreed with the original graph. UFO (fig. 10) was done close to perfect by one test subject, while the others struggled with this chart. In the description of BA (fig. 8) only five x-values were mentioned. The participants recollected three and five of these values respectively. All remembered the maximum and minimum.

When discussing the descriptions after the tests, BA was preferred by two out of the three participants. It was said to have an appropriate amount of information to remember compared to UFO where all values were pointed out one by one. BA was also said to present the basic information, which helped in creating a context. One test subject had the opposite opinion and found it difficult to create a context when some x-values were left out.

In both CA and BA the shape of the bars was described. This received positive feedback from all participants. One of them found the part in BA where four bars were told to be distinguished as higher particularly valuable.

In the second test session the prototype was presented to the interviewees. They did not create any depictions but were positive to the concept and gave the

following comments on the descriptions:

- Which details a user observes is highly individually

- BA contained the appropriate amount of information and was presented in an objective and casual way creating a good overview of the context

- The descriptions allow the user to understand the meaning of the charts

- Pedagogical descriptions resulted in an understanding of the content as a whole

- The description of UFO was found to be more advanced and should perhaps be a choice rather than standard information

- All information in the chart may be of interest and should be accessible depending on the content and situation

- It should be possible to drill down into interesting areas and make individual choices

- CA contained a vast amount of information

- In some cases the developer or creator of a chart might want to point out specific information in the visualization. This should be possible to present to the user.

All participants were also asked to rank the description after the test session. Since the opinions differed and it was difficult to find a clear winner, it was decided to introduce a point system. The winner received two points, number two received one point and number three zero points. By doing so the final ranking became:

First test subject	Interviewees	Ranking in Total
BA 4 p	BA 3 p	BA 7 p
CA 3 p	CA 3 p	CA 6 p
UFO 2 p	UFO 0 p	UFO 2 p

Preferably more participants would have been involved to achieve a more accurate and distinct result. Even so, the assumed description ended up in first place.

4.4 Design Concept

The goal with all research, previously mentioned pilot studies and Lo-Fi tests was to create a concept for accessibility adaption of bar charts in Qlik Sense. This is mainly achieved by the use of speech synthesis to give the user an overview of the chart. Through a visual description the user will receive a review

of what is presumed to be important. When an app is opened in Qlik Sense the description automatically starts describing the content within the chart.

After the visual description is complete the system will ask the user what is of further interest. A voice based question should hopefully attract a voice based respond and make speech communication the most natural interaction. Since the user will interact with the system using voice commands, speech recognition needs to be implemented as well. The possibility to ask the system questions can simplify the usage for someone who cannot see a graphical user interface. After the visual description is performed the user should have the possibility to analyze the data that holds a special interest for that user. Similar to the screen reading program JAWS, a pop-up window should appear but the user primarily interacts with it by using voice commands instead of the keyboard. However, keyboard shortcuts should be accessible to provide multiple interaction methods and to allow the user to find the best fit. The pop-up should contain a list of all the options possible to the user. The options suggested are:

- All x-values

- All y-values combined with their x-value

- All y-values exceeding the average

- All y-values that is close to, below, exceeding or exactly the same as a certain value

- Search for a specific x- or y-value

- Key values like outliers, maximum, minimum, start- and end-values

- Repetition of the visual description

The option of going through all x- and/or y-values should work as a picture slide-show. During the slide-show the user should be able to pause and play the speech synthesis. When it is paused there should be a possibility to save the previously spoken value to allow the user to quickly step between and compare interesting values. When the user wants to continue listening the choices are to either press play or to step through the values one by one, using the arrow keys. Since JAWS uses the up and down arrow key to move sideways a decision to follow the same standard was made.

4.5   Hi-Fi

The Hi-Fi prototype was developed to receive a testable product from the ideas of auditive graph presentation. The remaining parts of the design were left at a conceptual level. When developing the prototype it was realized that there are different cases that need to be considered when creating the visual description. Depending on the shape of the bars and how the chart is sorted different information is important to present to the user. Consequently the bar charts

were divided into three categories; sorted in chronological order, categorized and a combination of categorized while sorted by y-values. For each case different values were collected from the data and versions of the visual descriptions were developed. The manuscripts were used to give the user an overview of the data through the synthetic speech Web Speech API by Google. During the Lo-Fi tests two descriptions were specifically appreciated by the participants, which led to the decision to create a combination of both for the final manuscript. We still kept in mind to achieve a solution with the right amount of values, not to cause memory strain.

Fig. 14 presents a chart where the values on the x-axis are sorted in a chronological order. When describing this chart the shape is found to be important since there is a possibility to detect trends among the data. Therefore the manuscript used for these descriptions focus on shape over a period of time:

This is a bar chart describing <u>Number of films produced per year</u>. The x-axis shows <u>Year</u>, and the y-axis shows <u>Number of Films</u>. There are <u>43 x-values</u>, starting with <u>1931</u>. The final one is <u>1973</u>. You find the highest bar in the <u>first part</u> of the chart, and it is held by <u>1940</u>. The minimum is found in the <u>last part</u>, and is held by <u>1961</u>. The <u>Number of Films</u> varies between <u>13</u>, and <u>60</u>, with an average of <u>32.26</u>. The bars ascend until <u>1939</u> and then descend. After that it rises until <u>1952</u> and drops. Finally it ascends until <u>1967</u>, and then descends.

Figure 14: Chart containing data sorted in chronologic order [1]

The words in the manuscript that have been underlined are the information and values collected from the data in the chart.

In the second case, fig. 15, the data is not sorted in a manner that influences

the appearance of the chart. For that reason each bar is of importance but not the shape of the entire series of bars, hence another manuscript was used. This description focuses on specific values instead:

Figure 15: Chart containing x-values sorted in alphabetical order creating a unregularly shape [1]

This is a bar chart describing <u>Total films by director</u>. The x-axis shows <u>Director</u>, and the y-axis shows <u>Number of Films</u>. There are <u>45</u> x-values, starting with <u>A. Edward Sutherland</u>. The final one is <u>Woody Allen</u>. You find the highest bar in the <u>first part</u> of the chart, and it is <u>held by</u> <u>Alfred Hitchcock</u>. The minimum is found in the <u>first part</u>, and is held by <u>A. Edward Sutherland</u>. The <u>Number of Films</u> varies between <u>8</u>, and <u>51</u>, with an average of <u>14.60</u>. The top three highest bars are <u>Alfred Hitchcock, George Cukor and Ingmar Bergman</u>.

The final chart, fig. 16, present the case where the bars are different categories but sorted depending on the y-values. The visual description for these charts is a combination of the two previous cases since both their shape and their values are descriptive. By the use of linear regression it is possible to distinguish if the chart is sorted in descending or ascending order.

The manuscript used to explain these charts are:

This is a bar chart describing <u>Total films by actor</u>. The x-axis shows <u>Actors</u>, and the y-axis shows <u>Number of films</u>. There are <u>42</u> x-values, starting with <u>Henry Fonda</u>. The final one is <u>Walter Brennan</u>. The <u>Number of films</u> vary between <u>84</u> and <u>21</u>, with an average of <u>42,31</u>. The chart is sorted in <u>descending</u> order.

Figure 16: Chart containing categorized data sorted by y-values [1]

4.6 Usability Testing

Three participants, out of whom two had low vision (person A and B) and one was blind (person C), performed the usability testing. C had a high experience level of synthetic speech, which clearly showed when C only had to listen to the description once. The other two participants had to listen multiple times. It was also observed that C could draw the shape of the graphs in the air as well as give analytic comments about their content after a single listening. A quote can be found below:

"It's not surprising that the movie production decreased during the 1940s because of World War II."

Even though the observations indicated a slightly more positive result for person C, the result of the questions was close to equivalent between all three participants. They said that the descriptions gave a good understanding of the graph and that the amount of information was well balanced. B could easily hear a difference between the three descriptions and appreciated the diverse approaches. A pointed out that the most successful way to describe a chart is highly dependent on the type and purpose of it.

A also claimed it to be difficult to understand the description if the purpose of the graph was not clear, since this could cause the listener to focus on the wrong parts. The same was mentioned by person B, who also added the importance of quickly grasping the key information as well as the purpose.

5 Discussion

In this section the results realized during the project are discussed and analyzed. What could have been done differently and what decisions were especially successful? What remaining problems can be found and how these could be solved in a future solution? Finally we discuss how the work process turned out and how the design decisions influenced the result.

5.1 Problems with today's solutions

A noticeable quote suitable for this research is:

"The important criterion for a graph is not simply how fast we can see a result; rather it is whether through the use of the graph we can see something that would have been harder to see otherwise or that could not have been seen at all."

William S. Cleveland

It explains that a graph is not useful unless it shows something that could not have been clearly presented in any other way. Today the common way of explaining graphs for visual impaired is by recounting all values one by one. These solutions do not offer anything additional compared to that all values were put into a table from Excel and read by synthetic speech. The STEM Description Guidelines defines this to be the best way to create visual descriptions. However, by doing so a graphical representation does not add any information to a person with a visual impairment. The approach also lacks overview, which has been a focal point in this research. Previous work and discussions with the project's target group have indicated that lacking overview is a major disadvantage in today's systems. These discoveries raise a number of questions and thoughts. Primarily; should charts be described in the exact way they are presented visually or is there a better way to do this without announcing all values one by one? As Björn Nyqvist[30] mentioned during the expert interview there are no standards covering how charts are described in school for people with visual impairment. Nevertheless are they generally described using the same concept and expressions as for someone with vision classified as normal. For that reason the decision to describe charts in a classic manner was made. Another reason for this decision was that a user with a visual impairment should have the possibility to discuss the data with other users. If the chart was described differently it could cause communication problems.

The problematics surrounding navigation was also mentioned by Nyqvist and he stated this to be an area in need of improvement. People with visual impairment usually have to put a lot of effort into finding the desired information at, for example, a web page. Consequently, most time is spent on the search for information instead of the processing and interpretation that was the intention of the visit. This was considered an issue and to create a solution that instantaneously presents the data to the user without having to look for it came to be

a priority.

When a user with vision classified as normal analyzes a chart all values are not processed and explored in detail. The user obtains an overview, extracts the values of interest to their analysis and creates a mental model of the chart. If this is the approach for a sighted user why should it be any different for a user with a visual impairment? Creating an equal experience is an essential part of this project and to create a solution, it was important to realize this approach during the pilot studies. The aim was to find the values which were important, how they were explained and whether they were able to create an overview. To be able to answer these questions our participants were people with vision classified as normal. Another reason for this decision was the possibility to get a tangible result because of the participants ability to create depictions of the chart. These depictions led to an understanding in how a visual description should be performed in a successful way.

5.2 Findings

People from different educational background participated in the pilot tests to ensure the possiblility to observe if there were any differences in how they analyzed and explained graphs. We found some noticeable differences and we realized that what is understandable and preferred is highly individual. Widely spread individual opinions are always problematic when trying to realize a solution for a large and diverse group of users. When adapting a system to fit many users compromises are often needed. We found it to be even more so in this project, since the target group is highly heterogeneous; all people are unique and so are their backgrounds and how they experience things in life, including their visual impairments. In an effort to narrow it down, we decided to focus on people with blindness. However, even the needs and wishes of this smaller group of users is difficult to satisfy. A person with blindness can have had their disability since birth or only a year or two. They can have a vast knowledge of the subject in question, in this case graphs, or never learned about it due to inadequate education. Some users prefer tactile feedback, while other have no experience of braille or haptic systems. The interviews made us see the scope of these needs even clearer.

The pilot studies resulted in findings of both successful and unsatisfactory ways of presenting charts. It was clear that repeating values was an effective way for the receiver to retain the information, depict an overview of the graph and remember the important values correctly. However, repetition is not optimal for a voice based system since it increases the time the user have to put into obtaining the information needed. This aspect was pointed out as the first rule in the STEM Guidelines, Brevity. It states that perceiving information by a screen reader is already slow compared to the speed of which a sighted person reads. Hence the time should not be further increased by unnecessarily detailed descriptions. It is also plausible that the user can be annoyed if the computer repeats the same information several times. The possibility to listen to the entire description as well as to look for specific values should be an option,

which allows the user to repeat values if necessary.

A method which showed to be unsuccessful in all of the pilot studies was to announce all y-values within the graph. As soon as the amount of values exceeded approximately five it seemed close to impossible for the receiver to remember them. As a result most values, even the ones regarded as simple, e.g. minimum, maximum and number of bars, were forgotten. This indicates that today's solutions are not optimal. After the first attempt most participants realized that the tactic was not a success and changed their approach. Two participants declared the top three values instead, which resulted in making it easier to create a mental model of the chart and extract the values of importance. Overall it was common to filter the information that seemed unnecessary to create a mental model and thereby be able to depict a usable overview and still point out important values. The approach made the memory load more appropriate, allowing the receiver to recall a more accurate version of the chart.

After having finished the pilot tests we fully realized how important the memory is. It can be considered especially essential for people with a visual impairment since they are unable to unburden their memory by putting information on paper or rely on their vision to repeat it. With this in mind, we started to research the memory. When finding Millers theory about chunks we wanted to try the theory in combination with graphs. How much information from a chart can we actually keep in mind during a short period of time? We calculated how many values were mentioned in the successful descriptions and found that it shifted between four and twelve, which is a low amount compared to the descriptions that did not work. The amount of values in the unsuccessful ones varied between nine and 38, with a majority around 20 values. This demonstrates a clear difference. Because of the findings, we focused on creating manuscripts with an amount of values that did not cause memory strain and did not exceed twelve in numbers. Even though this amount is larger than what Miller announced the magic number to be in his work *Magic Number 7 (plus or minus 2)* some values can be chunked together. For example, if there are dates or years on the x-axis these can be chunked together as a time period between two values instead of the actual 100 dates in the chart.

If we assume that many users with a visual impairment have experience in listening to information as well as practice in remembering the information given, it is possible to add even more values beyond the magic number. During the Lo-Fi tests a distinct improvement was noticed among the participants that had taken part in previous tests. It was clear that their ability to focus on the important parts and organize the information to get the best mental model had improved, which supports the above-mentioned statement. However, this still does not mean that a large amount of values is desirable.

A few of the results from the pilot study were to some extent surprising to us. One of them were the mixed outcome to the approach of analyzing the chart and describing the purpose of it. In some cases the depicting became easier, but to others it had the opposite effect. Our belief was that it would be considerably simpler to create a mental model of the cart if there was a possibility to create an idea about it and find a meaning for the graph. This did not appear to be

the case. However, we found that the everyday language often used together with the analysis was quite successful. It was clear that a bureaucratic language contributed to an increased difficulty in remembering the information given.

When we demonstrated the Lo-Fi prototype to the two persons that had previously been interviewed we saw clear differences between how the participants performed during the test. The person who had been blind the better part of life could create a mental picture of the bars after listening to the recordings one time, while the person who partially lost vision later in life had to listen twice or more times. This further supports our theory that practice makes perfect when it comes to synthetic speech. The fact that the first person preferred CA *(fig. 9)* is not surprising since she was used to screen readers and visual descriptions, while the second person have not had the same amount of practice and preferred the shorter, more straightforward, version *(fig. 8)*.

Finally, they both mentioned the importance of having multiple options since what counts as interesting information is heavily dependant on the data as well as the context. They expressed that a possibility to make options after the overview presentation would be a preferable addition. In some situations it is actually desirable to go through each value, one by one.

5.3   A solution that covers the needs

As previously mentioned an important challenge in this project was to find a solution that allows all users, or at least as many users as possible, to benefit from the product. To achieve this we had the principles of Universal Design in mind during the process. First of all we have *Equitable Use*, which is applied by not changing the look or overall concept of the program. Instead we simply added functionality to the existing product, Qlik Sense. With the addition the program provides *Perceptible Information* by having both visual and auditive functionality. Further, when the speech function is activated the visual descriptions will start automatically every time a user selects a chart. This provides *Low Physical Effort* as well as *Simple and Intuitive Use*. The two principles can also be applied on the voice control from the parts of our design concept that are not yet implemented. Finally we have the slide-show metaphor which we are quite pleased with. The solution is designed to meet the principle *Flexibility in Use* since it is possible to press play and listen to the values as well as step through them at the user's own pace. It is also *Tolerant for Errors* by allowing the user to go back and forth, save and unsave values and compare them to each other, undo and redo.

The target group is non-seeing persons why we early in the process found synthetic speech to be an appropriate base for the solution. We wanted a system that gave the user a natural feeling, hence avoiding the robotic sounding screen readers. After considering several alternatives we decided to use the Google Web Speech API. Reasons for this choice were both the functionality of the API and the simplicity of importing the JavaScript code to our project. The API has several versions of English speech out of which we found the American English voice *Google US English* to function best. Parts that we especially paid

attention to, apart from the pronunciation of words, were how punctuation and the word "and" were used. It was important that these aspects worked as we had imagined for the manuscripts to result in natural sounding descriptions.

The development of the manuscripts started early in the design process. It was clear that we had to filter the information to find an appropriate amount of values to be shared with the user. Some parts of the charts were obvious, while others had to be discussed more thoroughly. An example of the last mentioned type was the scales of the x- and y-axes. We found this information to be interesting only for the visual representation, since the information of real value is rather the maximum and minimum of the bars. Examples of data that we found to be obvious to include were maximum, minimum, the number of values as well as the titles of both the chart as a whole and the axes.

It is not only the information given that affects the receiver; the way information is presented can also alter the way it is interpreted by the user. We found it favorable to give the information in chronological order as far as possible. Some users had difficulties to structure their mental model when the values were given in another manner. The best results were received when starting the description from the left side of the chart and then continue to the right. It was also more natural to present minimum before maximum, since this gave the values in ascending order. We decided to start with the overall information, such as titles and axes, then continue with the key values and finally the shape description. The first two parts give a fairly good view of the graph, while the shape description can correct the possible mistakes in the overall mental model.

Another important issue was how to express the information in words. From the pilot studies we saw that everyday language appeared to be a good approach. This also provided a more relaxed and personal touch to the synthetic speech. As the result shows we came up with three different types of manuscripts (fig. 16, 15 and 14) since it was found impossible to create one description that could fit every kind of chart. The first type is charts sorted by y-values. They can be ascending or descending with different slopes. In these cases it is not necessary to present both maximum, minimum and the first and last values since these are the same. The next type describes a chart with x-values that we decided to call categories, which can be for example names, animals, things. These kinds of charts are assumed to be unsorted, value wise, which makes first and last value uninteresting. For the same reason it is also seldom valuable to present the shape. Instead we decided to present the three highest bars, i.e. the three largest values. The decision was a compromise between what data could be interesting for the user and the amount of information possible to hold in the short term memory. Lastly we have the type of chart that shows a result over time, i.e. where the x-values are dates, time or age. These are often interpreted as line charts, which made us think of the idea to describe them as a continuous line that ascends and/or descends. To apply everyday language we tried to vary the words used to describe the behavior of the line. This made the descriptions more human-like and simpler to relate to.

In addition to above-mentioned aspects, we focused on finding a solution to describe the shape of the graph. The decision was taken because of its good

results in the tests and the fact that a word based description of shape was something that we had not encountered before, despite the thorough background research. We looked at a number of different approaches before deciding to use curve fitting by regression analysis. The linear version of the algorithm worked perfectly, but as soon as we started with polynomial regression it became more complicated. It was difficult to find detailed formulas and descriptions of the mathematics behind the polynomial regression since this level of mathematics often requires calculations by a computer program. To solve the issue within an appropriate time span we decided to use a JavaScript library which performed these calculations for us. This decision saved us time and allowed us to focus on the design and conceptual parts of the project instead.

5.4   How well did the solution work?

The usability testing showed that the prototype worked in the desired manner. However, it was clear that it was a major advantage to have previous training in synthetic speech programs, which could indicate a longer learning period for users without the same experience. Most people with normal vision does not have this experience. Therefore they would need training to use the synthetic speech and be able to benefit from it. However, as an addition to the visual parts of the program it could work in the users advantage, since one more sense is used. It could also benefit those with reading disabilities.

All participants claimed to have understood the overall shape and behaviour of the graphs. They did not wish for more or less information but thought it was well balanced. In addition to that the person with experience of synthetic speech remembered all the important key values, which we believe further confirms that the amount of information was appropriate.

Two persons agreed upon the importance of quickly receiving the key information that can help in creating a mental image of the graph. The order in which the information is presented is highly significant to accomplish this. To develop a suitable order is something that we have put a lot of effort in. We decided to first present the overall purpose of the graph then the key values and finally the shape to connect the values. According to the test results this approach seemed to work like we were hoping. The only exception would be that the purpose of the graph failed to be apprehended in one of the tests. When this happened the whole description was lost, which naturally is concerning and something to take into consideration.

In conclusion we are satisfied with the positive test results. However, we are aware that the number of participants was too low to get an accurate result.

5.5   Remaining limitations

The final prototype contains a number of unsolved issues as well as limitations created by both the product and the human factor.

The main idea with Qlik Sense is the possibility to use large amounts of data to create statistics and charts. We decided that there had to be a limitation to the amount of data in our prototype since the calculations performed would be too demanding for the computer otherwise. Calculations with 500 values have been examined, but more values than that may be difficult and time consuming. In our visual description the calculations are done with all the data loaded, regardless of how many bars are visible on the screen. This can be a quite good solution. When analysing the data you need to have all information and as a visual impaired person it is difficult to scroll among the values. However, when discussing the content of a chart with a seeing person it may be preferable to be informed of the visible values only. In that case there should be an option that does calculations over the entire amount of data as well.

Another limitation in our solution is the complete dependence on how the user decides to structure the data. Primarily it is important that the charts are named properly. If there are no explanatory titles, the visual description will not be comprehend-able, which will create difficulties when analysing the chart. For the same reason, naming both the axes in a logical way is crucial. People who develop apps in Qlik Sense need to keep in mind that persons with visual impairment are possible users of the charts. This should not be a problem since all users benefit from a good structure that simplifies the analysis.

Although we recurrently claim that our target group include all possible user, we have focused on persons with blindness. People with other visual impairments could also benefit from our solution, but to a large extent many of them use magnifying programs rather than screen readers. The ultimate solution for them would be to a combination of these two aids. A possible idea would be to connect a magnifying program with the visual description. While the synthetic speech talk about the graph, the zoom would follow the voice and show the parts discussed in the manuscript. The zoom's movement over the graph would provide an even more complete overview of information.

A combination of aids are in most cases preferable. Many people with visual impairments use their tactile sense to realize how things look like and numerous aids are developed to support this sense. A possibility to use more than one sense is desirable, but at the same time we do not want the Qlik Sense users to need additional products to be able to use the functionality. This was also a request of the company. For above-mentioned reasons we have not considered any kind of tactile solutions during the work process, even though it to some extent conflicts with the second principle of Universal Design; *Flexibility in Use.*

Because of the lack of tactile feedback we had to pay more attention to making the solution clear and descriptive. The shape description was an idea that contributed to that goal. However, in our use of regression analysis, outliers are not taken into account despite their possible importance for the user. In the use case when the x-axis consists of categories, only the top three values are mentioned. If there are outliers among the lower values, they are not acknowledged. A possible solution to point out interesting bars of both high and low values could be to announce the three most extreme values instead. This could also solve the next problem, which could arise in the sorted charts. Here both the

highest and lowest value are mentioned, but only as maximum and minimum respectively. They are not compared to the rest of the bars, which makes it impossible to know whether they could be an outlier or not.

The above-mentioned issues are areas that we for various reasons have not implemented in our prototype. The amount of problems clearly shows that much more work could be put into the solution to achieve a product ready for the market.

5.6   The Process

During the 20 weeks this project has progressed the process, as well as the project itself, has developed and transformed. From time to time the project has grown out of proportion and consequently the scope has had to be narrowed. To keep the research within a reasonable area has been challenging. A possible reason could be the freedom that has characterized the process as well as the lack of previous work in the field, which have also both inspired us to achieve more and take our ideas further. The additional research in the beginning of the project together with the previously mentioned issues with building the client platform made our time schedule fail after only a few weeks. Even though we did benefit greatly from the collected knowledge during the pilot study it would have been good to assure that there was enough time left for the development phase. It is not uncommon that the last weeks becomes hectic and this project was no exception.

As mentioned the pilot study was not included in the original plan and one reason for having to postpone the schedule. Although this study is one of the parts of which we are most content, an issue regarding the pilot studies is the number of participants. It would have been preferred to increase the amount of people participating. Especially regarding the tests, but also in the interviews. A larger number of participants could have decreased the dispersed result caused by the heterogeneous group. Although individual thoughts and opinions were highly appreciated, a statistically valid result could not be obtained. On the other hand, the fact that we to a large extent used the same participants in all studies was something found to be positive. It showed that the learning curve is steep and after only a few tries the accuracy of the sketches increased.

Overall we are pleased with our process, despite above-mentioned details. We have put a significant amount of effort into structuring the work from the start as well as document all decisions, which have shown to be valuable later in the process. If we could change one thing it would have been to use the in-house knowledge and experience at Qlik to a larger extent. At times we have found ourselves to be overwhelmed by the information gained in our tests and interviews. Therefore it was not possible to retain any more information from other resources.

6 Conclusion and Recommendations

To relate back to the problem definition we feel that we have proven that there are ways to offer people with visual impairment an overview of the content in a graph. It is possible to develop usable solutions beyond the idea of stepping through table values.

We also think that one should use the smartness in today's technology and let the system present information that the user most likely is interested in. After an overview is provided the user should be able to explore the data themselves and make their own discoveries.

When it comes to interaction techniques we both hope and think that synthetic speech and voice control will contribute to a natural human–computer interaction. Together with the visual and perhaps even tactical solutions we believe that every user should be able to use the technology.

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A Test Plan Pilot Study 2.0

Syfte
Utvecklingen av en testplan sker för att få en ordentlig struktur på användartestets utformning. Den hjälper till att motverka den mänskliga faktorn, kan påvisa problem med testet innan det utförts och den fungerar även som ett kommunikationsredskap mellan de olika intressenterna.

Problemformuleringar
Hur förmedlar en seende person data representerad i en graf till en annan person? Vilka är nyckeltalen som krävs för att skapa en mental modell av grafen? Är det möjligt att påvisa en skillnad mellan hur personer med stor respektive liten erfarenhet av grafer förmedlar informationen?

Urval
Testet bör utföras på två urvalsgrupper; personer med stor erfarenhet av grafer och personer med liten erfarenhet av grafer. För att specificera de olika grupperna kommer erfarenheten att mätas subjektivt, de är testpersonerna som själva får ange huruvida de har stor eller liten erfarenhet inom området. Hänsyn kommer dock att tas till utbildning och eventuellt arbete som kan vara av betydelse. Könsfördelning ska inte spela någon roll, då detta inte känns relevant för testet.

Sammanlagt antal testpersoner: 10.

Upplägg för genomförande
Testpersonen kommer att få en kort introduktion till det examensarbete som pilottestet kommer ligga till grund för. Därefter kommer uppgiften att förklaras med viss noggrannhet. Syftet med testet kommer ej beskrivas grundligt förrän efter genomförd session.

Inför test:

Hej! Tack för att du vill hjälpa oss genom att delta i detta pilottest. Vi genomför just nu vårt examensarbete på Qlik där vi arbetar med tillgänglighet och visuell data. Vi kommer nu visa dig ett antal bilder på grafer som du i tur och ordning ska beskriva för X (någon av undertecknade) i ord. Det är inte tillåtet att använda gester eller annan visuell information. X har inte sett graferna och ska efter att ha lyssnat på din förklaring av en graf kunna återskapa den på papper. Hon får alltså inte påbörja ritningen förrän du är färdig med din beskrivning. Har du några frågor? Varsågod!

Efter genomfört test:

Bra jobbat! Testet du just utförde ska användas som en utgångspunkt för design av en ljud- och talbaserad beskrivning av grafer för personer med synnedsättningar. Anledningen till att X inte fick påbörja sin ritning förrän förklaringen var genomförd var att försöka återskapa det faktum att en person utan syn inte kan avlasta minnet genom att skapa en visuell figur på papper, istället måste all information lagras i minnet för att kunna skapa en mental modell av grafen.

Genom testet hoppas vi kunna få ut de nyckeltal och den information som anses nödvändig för att förstå grafens innebörd. Tack så mycket för hjälpen! Ha en trevlig dag.

Testuppgift

Testpersonen kommer att bli tilldelad ett antal grafer inom en utav tre givna kategorier. Graferna är hämtade från demo apps på Qliks hemsida och är skapade genom Qlik Sense. Testpersonen ska sedan i ord beskriva var graf för en av testledarna som därefter ska återskapa graferna ur minnet. Gester eller annan visuell information är ej tillåtet. Graferna är numrerade efter den ordning i vilken de ska beskrivas och avbildas.

Tidsåtgången för testuppgiften ska maximalt uppnå 20 minuter.

Testmiljö

Testerna kommer utföras i fält, vistelse i viss avskildhet är önskvärt. Då det inte alltid är möjligt kan man istället fokusera på fler testpersoner för att få tillräckligt med data och därmed undvika ett missvisande resultat.

Testledarens och övrigas rollfördelning

Den ena testledaren kommer beskriva hur testet går tillväga, varför det utförs samt spela in sessionen. Andra testledarens roll är att assistera testpersonen genom att ta emot information och i efterhand återskapa grafen efter bästa förmåga.

Data att insamla

Kvalitativ data kommer att insamlas i form utav;

- Vilken är den första information som testpersonen tar ut?
- Beskrivs graftyp eller endast innehåll?
- Hur beskrivs x- respektive y-axlar?
- Eventuella nyckeltal?
- Beskrivs trender/genomsnittlig kurva?
    - På vilket sätt?
- Beskrivs detaljer?
    - På vilket sätt?
    - På vilken nivå?
- Likhet mellan orginal och återskapad graf.
- Övriga observationer samt analys från ljudinspelning

Hur ska resultaten rapporteras?

Resultatet kommer först att sammanställas och användas i utformning av prototyp samt vidare testning. Det kommer även att presenteras i projektets slutgiltiga rapport.
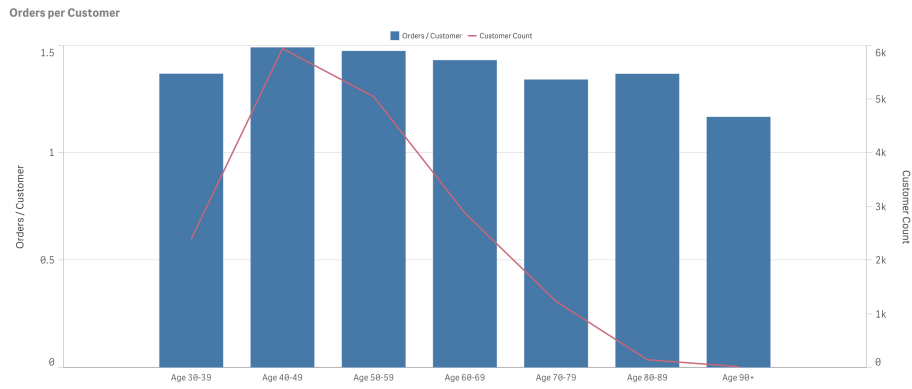
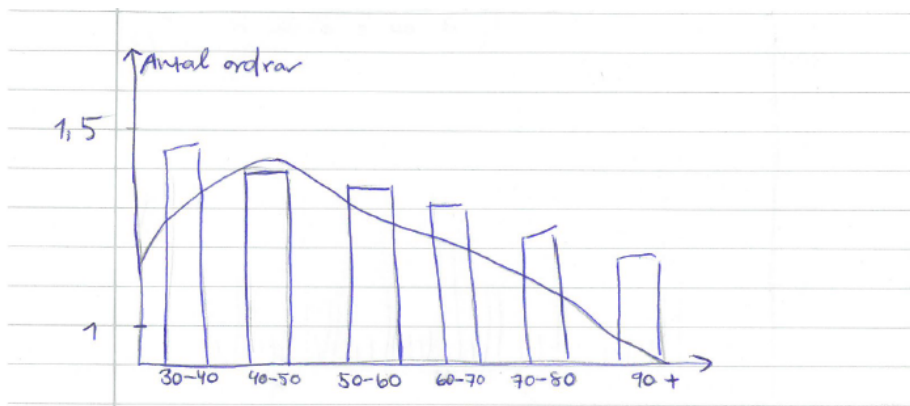# B   Results Pilot Study

Figure 17: Graph in Qlik Sense

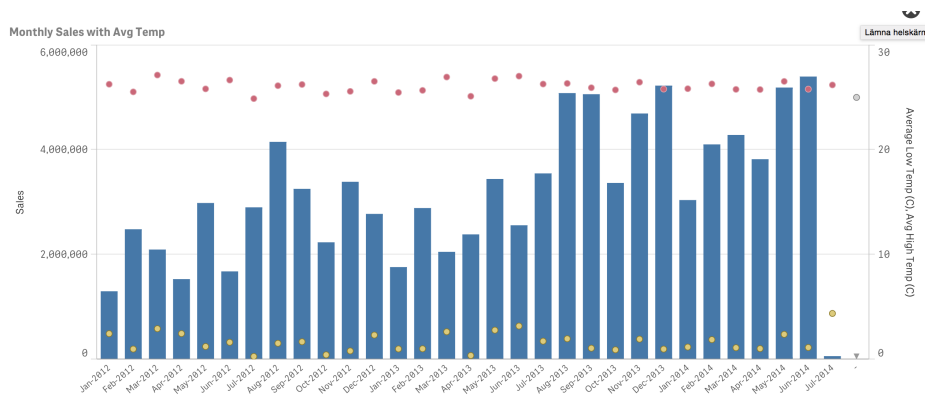Figure 18: A depiction showing good overview

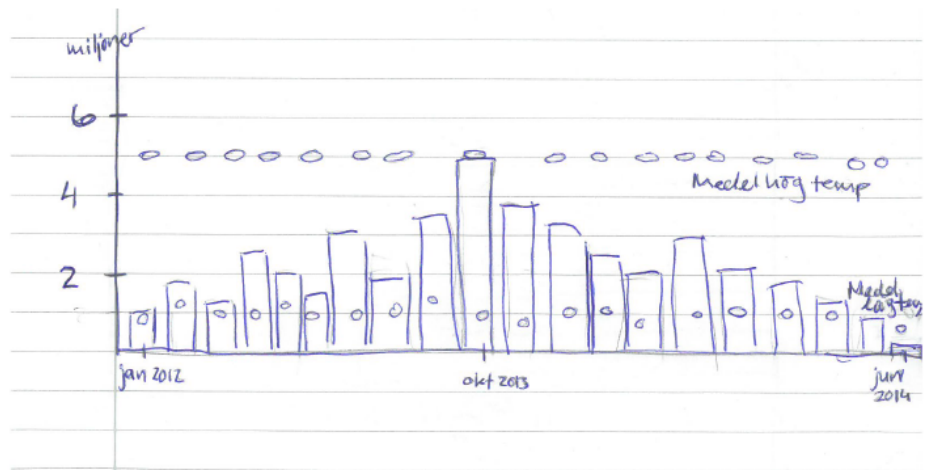Figure 19: Graph in Qlik Sense

Figure 20: A depiction showing poor overview

C Analysis - Pilot Study

C.1 Predefined Questions

1. What is the first information the test subject conveys?

2. Remaining information the test subject conveys?

3. Is the type of graph described or merely the content?

4. How are the x- and y-axes described, respectively?

5. How are possible key values described?

6. Are the shape of the graph described?

    (a) In what way?

7. Are trends and/or the average curve described?

    (a) In what way?

8. Are details described?

    (a) In what way?
    (b) At what level?

9. How similar is the depiction compared to the original?

10. Observations and analysis from recordings.

C.2 Analysis of the descriptions resulting in successful depictions

Sammanställning test - Google Docs

plot - H.2 Beskrivn. x-/y-axel
Typ av graf, beskrivning
Skala x-/y-axel
Medelvärde
Outliers
Kluster

skalor: 4 st
x-värde: 1 st
y-värde: 1 st

Likhet
Formen beskrivs väl
Ger överblick, men inga värden

H. 3, K. 1, K. 4, (O. 3), J. 1, J. 2, J. 3   Upprepning

6

6/18 - (7)/(19)

.3 - vågrät stapel
Beskrivning graf
Typ av graf
Indirekt beskrivning av x-/y-axel
Antal y-värden (länder)
Max/Min
Medelvärde
Topp tre + Sverige — rangordning, ej värden
Använder ibland avrundade tal (heltal istället för en decimal)
Vardagliga termer + lite analys av betydelse
Upprepning
Form beskrivs ej

Antal värden: 3 st
+ 1 (antal y-v.)

4

K.1 - stapel
Typ av graf
Beskrivning, kategorier x-axel
Skala y-axel
Alla värden (7 st)
Beskrivning av graf
Form beskrivs ej
X-axelns värden kan klumpas ihop till en chunk (veckodagarna) - belastar ej minnet.

värden: 7 st
skalor: 2 st
kategorier: 7 st (1 chunk)

16 (10)

K.4 - linje
Typ av graf
Skala x-axel
Beskrivning, skala y-axel
Startvärde, min, vändning, max, slutvärde
Vardagliga termer
Förklarar innebörden innan detaljer anges!
Lagom många y-värden togs ut (5 st)

skalor: 4 st
x-värden: 5 st
y-värden: 2 st

11

J.1 - stapel + linje
Typ av graf
Antal x-värden
Skala y-axel
Beskrivning, skala x-axel

Form 8/10

Staplar: Max/min, variation värden, average
Linje: Startvärde, gissning betydelse, max
Båda graferna beskrivs med en tydlig form
Färg - ej väsentligt
Upprepningar
Ingen förklaring av grafens betydelse - bra överblick, men inget sammanhang.

skalor: 6 st (4+1 dvvli)
y-värden: 2 st
x-värden: 1 st
_____
9 (8)

J.2 - stapel + plot
Skala y-axel
Beskrivning, kategorier, sortering x-axel
Antal x-värden
Färg - ej väsentligt
Staplar: Nyckeltal (3 st inkl max/min), fördelning
Plot: Max/min, variation
Beskriver form på båda grafer.
Upprepningar
Övergripande förklaringar, ej detaljnivå
Visar förståelse för att det inte är möjligt att memorera alla detaljer och att det inte heller är viktigt.
Bra filtrering mellan viktig/oviktig information, ex. jämnt fördelade staplar på olika höjd, sortering
efter bokstavsordning.
Ingen förklaring av grafens betydelse - annars mycket bra mental modell.
Upprepning förenklar för minnet.

skalor: 6 st (3)
         +1 (antal x-v.)
y-värden: 6 st
övrigt: 2 st
_____
15 (12)

J.3 - vågrät stapel (1) + vågrät stapel (2)
Typ av graf, utseende
Antal y-värden
Färg
Kategori, sortering y-värden
Beskrivning, skala, intervall x-axel
1: Max/min
2: "Random"
Formen beskrivs väl   Upprepningar
Förvånande bra resultat!
Association (13 = otursnumret)
Ingen förklaring av grafens betydelse - missade vad de olika grafdelarna stod för.
Något rörig beskrivning av andra delen av grafen, men kan ha underlättat för minnet att beskriva
den som en "randomdel".
Inzoomning svårförklarade - blev bättre när fokus lades på funktion istället för utseende.

skalor: 7 st (3)
        +1 (antal y-v.)
x-värden: 2 st
_____
10 (6)

D Brainstorming Session 1.0

Figure 21: Brainstorming Session 1.0

E   Interview – Perception of Data and Visual Impairments

Intro

- Om oss

- Kort om Qlik

- Om examensarbetet – kort översiktlig beskrivning

- Förklara vad vi ska använda intervjun till

- Får vi spela in?

- Klargöra att det är ok att inte svara på frågor, utan att specificera anledning.

- Frågor? Annars kör vi igång!

Generellt

1. När är du född?

2. Vad är din nuvarande sysselsättning?

3. Vad har du gjort innan dess?

   (a) arbetade (var?)

   (b) studerade (vad?)

   (c) övrigt?

4. Vad har du för typ av synnedsättning? (Namn)

5. Hur länge har du haft denna synnedsättning?

6. medfödd/uppkommit som barn/vuxen?

7. Hur påverkar den din vardag/ditt arbetsliv?

8. Upplever du några svårigheter med din synnedsättning?

   (a) kan du beskriva dem? Specifikt sådana som rör interaktion med datorer, program, telefon etc.

9. Vilka hjälpmedel använder du?

   (a) några favoriter eller riktigt bra hjälpmedel?

   (b) vad är bra med dessa? Mindre bra? Saknas funktioner? Datoranvändning

10. Hur mycket använder du datorn?

(a) hemma?

(b) i arbetet?

(c) övrigt

11. Vilka hjälpmedel har du installerade?

(a) hur hjälper de dig i ditt datoranvändande?

12. Vad är svårt att göra när du använder teknik?

(a) program?

(b) webbsidor?

(c) mail/skriva/övrigt?

13. Är det vanligt att stöta på otillgänglig visuell information?

(a) exempel?

(b) hur löser du det?

Kort intro om vårt arbete. Examensarbete – visualisering av grafer – övergå till allmäna frågor om grafer och dina erfarenheter av det.

14. Vad är din erfarenhet av visuella representationer av data, exempelvis grafer?

(a) matematik?

(b) väderkarta?

(c) valresultat?

(d) förändring över tid?

(e) övrigt?

15. Finns det, vad du vet, något sätt för personer med grav synnedsättning eller blindhet att kunna ta del av innehållet i visualiseringar av data/grafer idag? Ex. Väder?

(a) (Har du hört talas om några system/program/hjälpmedel för att representera data/förklara data? Digitala/Analoga?)

(b) hur?

(c) används det?

(d) har du provat något?

(e) hur fungerade det?

(f) vad var bra? Dåligt?

16. Om blind sedan tidig ålder - Hur fick du lära dig om grafer i skolan?

(a) olika former?

(b) olika typer och deras betydelser?

(c) hur man läser av dem?

17. Finns det något som du känner saknas inom detta område?

18. Om du skulle beskriva data för oss, som vanligtvis visualiseras i form av en graf, hur skulle du då uttrycka dig?

    (a) ex. Beskriv hur glassförsäljningen i närmaste ICA-butik varierade under ett år.

    Interaktionstekniker

19. Vi tänkte nu nämna några interaktionstekniker som vi känner till. Är det någon av dessa som du inte har hört talas om? Eller någon som vi inte nämnt som du vill berätta för oss om?

    (a) touch
    (b) fysiska taktila tekniker – svällpapper, punktskrift, taktil mus mm
    (c) tal (skärmläsare)
    (d) tal (röstinput)
    (e) toner
    (f) musik

20. Vad föredrar du?

    (a) taktilt/ljud
    (b) tal/toner
    (c) röststyrning/kortkommandon via tangentbordet

21. Om du hade fått designa ett system helt själv. Vilka tekniker skulle du ha använt?

    (a) hur skulle du kommunicera med datorn?
    (b) hur skulle datorn kommunicera med dig?
    (c) övrigt?

22. Om tid – Fritt samtal om hur det är att ha en synnedsättning och försöka förstå stora mängder av information? Hur gör de idag? Vad är det för svårigheter? Vad är bra? Vad skulle de vilja ha och vad är intressant för dem att veta?

23. Om tid – Hur skulle du vilja att en lösning ser ut? Hur skulle man förklara visuell information för att du ska förstå? – Vår idé hittills. Kort om överblick och kommunikation.

24. Är det något som du vill tillägga? Något vi har missat?

Annars får vi be att få tacka så hemskt mycket för din tid och att du var villig att svara på våra frågor. Det har varit till mycket stor hjälp! Vi hör av oss framöver med en kopia av intervjun för godkännande. TACK

F Manuscripts Lo-Fi Tests

F.1 Lo-Fi manuscript *Baby animals born per year* (fig. 8):

Det här är ett stapeldiagram som beskriver djurungar födda under 2013. X-axeln beskriver djurarter, y-axeln beskriver antal. Det finns 10 djurarter, antal varierar mellan 2000 och 12000. Maximum innehas av Kyckling, minumum av Känguruunge. Medelvärde ligger på 5000 stycken. Diagrammet är osorterat. Fyra staplar utmärker sig som högre; Kyckling, Anka, Föl och Kulting. Känguru utmärker sig som lägst. Övriga 5 staplar ligger på en jämn nivå.

F.2 Lo-Fi manuscript *Customer Analysis, monthly sales* (fig. 9):

Det här är ett stapeldiagram som visar försäljningsstatistik för ett företag uppdelat per månad under två och ett halvt år. X-axeln visar månad och år, medan y-axeln visar antal försäljningar. Skalan för y-axeln går mellan 0 kronor och 6000000 kronor. På x-axeln finns det 31 x-värden, det börjar med januari 2012 och slutar med juli 2014, varje månad under dessa två och ett halvt år finns representerade. Försäljningen för de här 31 datumen varierar mellan 1000000 kronor och 5000000 kronor. Den högsta försäljningssiffran inträffar i Juni 2014. Och man har sålt minst i Januari 2012. Medelvärdet ligger på 3000000 kronor. Diagrammet är sorterat kronologiskt. Formen på grafen ökar fram till augusti 2012 för att sedan avta. Därefter kommer en ny rejäl ökning under sommarmånaderna året därpå som sedan håller i sig. En dipp inträffar under de första månaderna under 2014.

F.3 Lo-Fi manuscript *UFO reports per month* (fig. 10):

Det här är ett stapeldiagram som visar antal UFO-rapporteringar per månad. X-axeln visar månader, y-axeln visar antal rapporteringar mellan 0 och 11000. I januari var det 5800, februari 4500, mars 5500, april 5500, maj 5900, juni 9000, juli 10700, augusti 9500, september 8500, oktober 7800, november 7000, december 5600.

G   Test Plan Usability Testing

Syfte med testplan

Utvecklingen av en testplan utförs för att få struktur på användartestets utformning. Testplanen hjälper till att motverka den mänskliga faktorn genom att standardisera testen och kan påvisa problem med testet innan det utförts. Den fungerar även som ett kommunikationsredskap mellan de olika intressenterna.

Problemformuleringar

Testet kommer att utföras på en Hi Fi-prototyp och ska undersöka om prototypen kan fungera som ett hjälpmedel då man ska presentera grafer för en person med synnedsättningar.

- Ger denna lösning något mervärde i jämförelse med system som finns att tillgå idag?

- Erhålls en användbar överblick av grafens innehåll?

Urval

Testet kommer utföras på personer som tidigare har deltagit i intervjuer, samt i vissa fall Lo Fi-tester, då de har erfarenheter av projektet samt kunskap inom området. Personerna tillhör även den tänka målgruppen för projektet. Testet kommer att utföras på personer med olika typer och grad av synnedsättning. Könsfördelning tas inte i beaktning, då detta inte känns relevant för testet.

Sammanlagt antal testpersoner: 3.

Upplägg för genomförande

Då testpersonen har deltagit i tidigare moment kommer de enbart få en kort introduktion för att färska upp minnet angående det examensarbete som användartestet kommer ligga till grund för. Därefter kommer uppgiften att förklaras närmre.

Inför test:

Hej! Tack för att du vill hjälpa oss genom att delta i detta användartest. Som vi tidigare har berättar genomför vi just nu vårt examensarbete på Qlik där vi arbetar med att tillgänglighetsanpassa ett program för visualisering av data. Vi kommer nu att spela upp tre ljudklipp för dig. De här ljudklippen tar automatisk ut information ur data representerad i grafer. Mellan varje uppspelning vill vi gärna höra dina spontana tankar angående det du precis lyssnat på. När du har hört samtliga ljudklipp kommer vi ställa några frågor till dig om hur du upplevde beskrivningarna. Har du några frågor? Då kör vi!

Testuppgift

Testpersonen kommer att få lyssna på tre fördefinierade grafbeskrivningar med syntetiskt tal. Graferna är skapade i programmet Qlik Sense och innehåller data hämtad ur en filmdatabas kallad Movies Database. Efter varje beskrivning får testpersonen ge spontana åsikter och funderingar för att efter samtliga

lyssningar få svara på frågor angående hur de upplevde testet och grafbeskrivningarna. Skulle testpersonen vilja lyssna på någon utav beskrivningarna ytterligare en gång är detta tillåtet.

Tidsåtgången för testuppgiften ska maximalt uppnå 30 minuter.

Testmiljö

Testerna kommer utföras i fält på en utav testpersonen vald plats. Detta för att gör testet så bekvämt som möjlig och därmed minimera störningsmoment eller osäkerhet hos testpersonen.

Testledarens och övrigas rollfördelning

Två testledare kommer att finnas till förfogande. Den ena testledaren kommer beskriva hur testet går tillväga, varför det utförs samt ställa frågor då testet har slutförts. Den andra testledarens roll är observera och anteckna under testet gång, samt att spela in sessionen.

Data att insamla

Kvalitativ data kommer att insamlas i form utav svar på följande frågor:

- Tycker du att beskrivningen kan hjälpa dig skapa en överblick över grafens uteseende?

- Anser du att beskrivningen innehöll mycket, lite eller lagom mängd information?

- Är det något du tycker saknas i beskrivningen?

- Kände du att du kunde skapa dig en bild över hur formen på grafen såg ut?

- Beskrivningarna är uppdelade i olika kategorier. Vad tyckte du om dessa? Kunde du märka någon skillnad mellan kategorierna? I så fall, var skillnaden givande?

Kvantitativ data kommer även insamlas i form av:

- Behöver testpersonen lyssna på beskivningen fler än en gång för att förstå innehållet?

Övriga observationer samt analys av svaren från ovan ställda frågor kommer att behandlas efter testsessionens slut.

Hur ska resultaten rapporteras?

Resultatet kommer att sammanställas för att se huruvida projektet har resulterat i ett koncept som kan ge personer med synnedsättningar en överblick över data representerad i grafisk form. Det kommer även att presenteras i projektets slutgiltiga rapport tillsammans med de slutsatser som dragit utifrån testen.