Design and use of 3D typography for indoor Augmented Reality mobile applications

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Abstract

Augmented Reality (AR), a concept where the real world is being enhanced with computer generated objects and text, has evolved and become a popular tool to communicate information through. Research on how the technique can be optimized regarding the technical aspects has been made, but not regarding how typography in three dimensions should be designed and used in AR applications. Therefore this master’s thesis investigates three different design attributes of typography in three dimensions. The three attributes are: typeface style, color, and weight including depth, and how they affect the visibility of the text in an indoor AR environment. A user study was conducted, both with regular users but also with users that were considered experts in the field of typography and design, to investigate differences of the visibility regarding the typography’s design attributes. The result shows noteworthy differences between two pairs of AR simulations containing different typography among the regular users. This along with a slight favoritism of bright colored text against dark colored text, even though no notable different could be seen regarding color alone. Discussions regarding the design attributes of the typography affect the legibility of the text, and what could have been done differently to achieve an even more conclusive result. To summarize this thesis, the objective resulted in design guidelines regarding typography for indoor mobile AR applications.

Skapande och användande av 3D-typografi i mobila Augmented Reality-applikationer för inomhusbruk

Sammanfattning

Augmented Reality (AR), ett koncept där riktiga världen blir förstärkt med datorgenererade objekt och texter, svenska kallat för Förstärkt Verklighet, har under åren blivit en allt mer använd teknik för att kommunicera information med. Tidigare forskning har visat hur den tekniska aspekten kring AR kan optimeras för användandet, men ändå har forskning kring användandet av tredimensionell typografi i AR inte utförts i samma grad. Därför utgör detta examensarbete en studie som analyserar tre olika designattribut som typografi, i tre dimensioner kan tillhandahålla, dessa är: typsnittets stil, färg, och vikt tillsammans med djup, och hur dessa påverkar synligheten av text i AR-applikationer som används inomhus. Analysen görs genom en användarstudie som utförs på både vanliga användare, men även på användare som anses vara expert på området gällande typografi och design, för att ta reda på avgörande faktorer som påverkar synligheten av typografin i AR. Resultatet av användarstudien med de vanliga användarna visade en märkbar skillnad mellan två par av AR simulationer, tillsammans med en lätt favorisering av ljus text istället för mörk text. Detta även fast ingen signifikant skillnad kunde påvisas mellan endast färgattributet. Diskussioner kring hur de olika designattributen påverkar synligheten av texten görs, tillsammans med diskussioner kring hur metoden har fungerat och vilka faktorer som spelat in på det resultatet. Som avslut tas designriktlinjer fram för hur typografi bör användas och designas i AR-applikationer för inomhusbruk.
Acknowledgements

First of all, I would like to thank Humbly for their involvement in this master’s thesis, their enthusiasm and genuine interest in the thesis has helped bring the result and conclusion it got, and made me enjoy my stay there. A special thanks to my supervisor at Humbly Magnus Bäcklund, CCO Giuliano Garonzi, and Isak Larsson for guiding me through the prototyping process.

I would also like to thanks my supervisor Shafiq Ur Réhman at Umeå University, for helping me through the whole process of this thesis, along with my peer-review group Jonas Halvarsson and Mattias Johansson.

Lastly, I thank all the participants of the user studies, the experts from Humbly, and Niclas Drugge, who did his thesis work at Humbly at the same time, for discussing ideas with me throughout the process, along with family and friends.
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A User study - Regular users

B User study - Expert users
1 Introduction

Innovation in the field of computers has lead to smaller and more powerful devices, which has lead to new smartphone, wearable and pervasive computer applications that are becoming more popular [1]. With this, people have come to expect the ability to access information anywhere, anytime. Therefore, new technologies have been developed to display information that is easily accessed for the user and one of those are called Augmented Reality (AR). With this technology, usable information can be displayed as a layer over the real world. Augmented Reality supplements reality with virtual objects while the user is simultaneously able to see the real world around them. This is different from the concept of Virtual Reality (VR) that displays a complete virtual environment for the user to explore.

AR is a relatively new technology for developers to implement in our everyday smartphones. However, already in the late 1960’s, Ivan Sutherland created the first Augmented Reality system that was called The Sword Of Damocles. The system used a see-through head-mounted display and was one of the first systems that used six degrees-of-freedom tracking [2]. A few years later, in the middle of 1990’s, Milgram with the help of three other people [3], defined Augmented Reality as part of Mixed Reality (MR) in the Reality-Virtuality Continuum, see Figure 1, where MR is a way of displaying an environment that is a combination of Virtual Reality and a real environment.

The Augmented Reality technology has already been applied in various situations with great success for applications like Pokémon GO\textsuperscript{1}, Snapchat\textsuperscript{2}, and IKEA Place\textsuperscript{3}. But AR could essentially be applied anywhere, for example, by letting firefighters communicate better and see a building’s blueprint in their helmets, letting tourists navigate in a new city, or letting costumers consume advertisement about a company’s newest car model and its features in a new innovative way.

As Augmented Reality is getting more available and developed with for smartphones, there has not been a lot of studies done on the applications’ user interface (UI) and the user experience (UX). This is especially the case when talking about how text should be displayed in a mobile AR application. The way of displaying the text is namely about how the typography should be designed, where typography could be defined as the art of arranging characters [4]. The design of the typography includes what typeface, color, size, style effects, etc that should be used. The UX-design of AR applications are as important as in our daily web based applications, and should still be a part of the design process.

\textsuperscript{1}Pokémon GO: https://www.pokemongo.com
\textsuperscript{2}Snapchat: https://www.snapchat.com
\textsuperscript{3}IKEA Place: http://www.ikea.com/au/en/apps/IKEAPlace.html
1.1 Objective

The objective of this study will be to investigate how the design of typography affect the legibility of text that are being displayed in mobile Augmented Reality for indoor use. This encounter investigating design guidelines regarding UI/UX-designing for Augmented Reality applications on handheld smartphones, with a focus on typography in specific. The evaluation of how typography could be used in mobile AR, will result in design guidelines for 3D typography. The objective will be fulfilled by accomplishing several goals listed below.

- Investigate design guidelines for typography and explore how they can be applied to display text in a mobile AR indoor environment.
- Explore how different colored typographies display enough contrast against objects in the real world around it.
- Explore if the weight of a typeface affects the legibility of a displayed text in mobile AR.
- Evaluate and create guidelines for designing 3D typography for a mobile indoor AR application.

1.2 Humbly

This thesis has been written in collaboration with a company named Humbly\(^4\) in Umeå, Sweden. Humbly AB was founded in 1994 under the name Plakat, and has grown to be a company with 20 employees and a large knowledge base. The company has the knowledge to handle everything their clients need, from an idea or concept to a campaign and functional website. Humbly has recently been interested in broadening their knowledge with new techniques to let their clients have options when they want to communicate with their potential costumers. Therefore, a growing interest in mobile Augmented Reality technologies, and a need to investigate how typography could and should be designed and used in such applications, began.

\(^4\)Humbly: [http://www.humbly.se](http://www.humbly.se)
1.3 Limitations

The biggest restriction this master’s thesis have, is the timetable with limited 20 weeks of work. The study only contains the work of designing already existing typography that later is being used in an indoor mobile Augmented Reality environment. The design process has been limited to investigating color, weights, and the difference between serif and sans-serif typefaces, in AR.

1.4 Thesis outline

Apart from the introduction, this thesis has been divided into five chapters and have been summarized for a overview of the work that has been done here:

Theoretical framework - This chapter provides relevant previously done research about the field of Augmented Reality, the relation to Virtual Reality, display techniques, how typography is being used nowadays, and how typography can be used in a 3D environment.

Method - This chapter describes the method and how the work has been conducted to fulfill the given result, which includes research, prototyping, user testing, and evaluation of the result with the statistical method Kruskal-Wallis.

Result - This chapter displays the result of the user study, done with regular and expert users, with the different 3D typography in a simulated mobile Augmented Reality application in a indoor environment.

Discussion - This chapter discuss the outcome of the result in the aspect of which design of the typography that could be considered more legible than others, and compare the results from the user studies different groups to see if they correlate or not.

Conclusion - This chapter displays design guidelines, for how to design and use 3D typography in a mobile Augmented Reality application for indoor purposes, from the conclusions that could be drawn from the user study, together with future work.
2 Theoretical framework

This chapter contains the background and theoretical framework relevant to this study to give an understanding of the field of Augmented Reality, and the use of typography displayed in such environments. In more detail, the subjects that will be described in this chapter is different types of AR techniques, different AR displays, guidelines when designing user interfaces for AR, and typography guidelines that are used for traditional web design nowadays.

2.1 Augmented Reality, Augmented Virtuality, Virtual Reality

As described in the introduction, Milgram together with three others, defined Augmented Reality as part of Mixed Reality in the Reality-Virtually Continuum [3], but MR also contains a concept called Augmented Virtuality (AV). The differences between AR and AV can be defined as, AR taking place in the real world but containing virtual objects in that environment, while AV is a virtual rendered world containing objects that are close to virtual, meaning that the object is virtual but have some physical behavioural characteristics [5].

These two concepts, AR and AV, should not be confused with the concept of Virtual Reality. The concept of VR can be described as a virtual world with virtual computer generated object with no physical behavioural characteristics within that environment [5]. VR has already been implemented in various successful applications. For example, games on our smartphones implemented with VR technique have become more popular through the years, but also the ability to experience real music or sport events afterwards from the couch at home has become a implemented feature for mobile VR. Example of games, together with music and movie applications that are available for smartphones and takes advantage of VR technology are YouTube\textsuperscript{1}, WITHIN\textsuperscript{2}, and NYT VR\textsuperscript{3}.

2.2 Different types of Augmented Reality

Augmented Reality is a big field with many possibilities when it comes to implementing it. The technique can for example, be used with head-mounted displays like helmets or glasses, wearable devices that display objects onto the real environment, or smartphones that nowadays contain the necessary sensors for AR technology. Augmented Reality can be categorized into different types based on the techniques

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\textsuperscript{1}YouTube: https://www.youtube.com
\textsuperscript{2}WITHIN: https://www.with.in
\textsuperscript{3}New York Times VR: http://www.nytimes.com/marketing/nytvr/
they use. The different categorizations of AR is applications that uses Computer vision, which contains four different types, and AR applications that use Location based techniques.

2.2.1 Augmented Reality with Computer Vision

There are four types of AR that use Computer Vision to analyze the environment and display computer generated objects into that environment. This section contains information about recognition based, projection based, superimposition based, and outlining Augmented Reality. These kinds of AR is being described to enhance the knowledge about different AR solutions.

2.2.1.1 Recognition based Augmented Reality

Recognition based AR, is used in every type of Augmented Reality, except Location based AR, to detect an object that should be augmented with additional information. When talking about recognition based AR it usually refers to the ability of recognizing specific object, images, and so called AR-markers, which generally is an image constructed of black and white squares in a pattern. When recognizing these kind of objects, additional information replaces the object and supplements the recognized object [6]. For example, recognition based AR could be an application that recognizes a toy box and shows the user how it looks when it is built together, or a printout fan-card of a celebrity that the application recognizes and displays a 3D rendering of that person on top of the card.

2.2.1.2 Projection based Augmented Reality

Applications with projection based AR use projection technologies to augment and enhance real world environments and objects with computer generated images and 3D renderings [7]. These objects do not necessarily have to be interactive for the user. For example, projection based AR could be projecting interior decorations in the kitchen to see if they fit, projecting a keyboard to the desktop to write on, or projecting movie characters to the bench below the TV for entertainment.

2.2.1.3 Superimposition based Augmented Reality

Superimposition based AR, is a type of recognition based AR that displays the recognized object in a different way. This is done by either replacing the entire object or just part of it with supplemental augmented information that is relevant to the recognized object [6]. Different from regular recognition based AR that can recognize simple objects and images, superimposition based AR can, for example, recognize a patients arm and display its x-ray images on top of it, which would supplement the doctors visualization of what could be wrong with the patient.
2.2.1.4 Outlining Augmented Reality

Augmented Reality that use outlining as a technique, also use recognition based AR, to recognize objects that the human eye have a hard time seeing [6]. For this technique, a special camera is used to determine the outlines of, for example, a road to enhance the drivers vision in dark conditions, by visualizing the edges.

2.2.2 Location based Augmented Reality

A location based type of a mobile AR application takes advantage of the smartphone's built-in sensors to determine where the person is located and in which direction they point their mobile device. A location based AR application uses the GPS, digital compass, and accelerometer to determine where the user is looking and displays the additional information into the camera view on the device [6]. A good example of this type of AR, is an application that displays points of interest on the user screen, so that people visiting new cities easily can find close by restaurants, museums, or shopping malls based on their exact location.

2.3 Display technologies for Augmented Reality

Since there are many different techniques on how Augmented Reality can be accomplished and developed with, there are also different ways to display and interact with an AR application system.

How an AR application is displayed to the user, can be done in several different ways. It is important to consider how the user should interact with the created system and adapt the way of displaying the content of the application, to enhance the user’s experience. Mainly, there are three different ways of implementing display technologies for AR. These different ways are mobile, video spatial, and wearable displays [8].

The mobile displaying technology can easily be described as a modern smartphone with an AR application, by holding the smartphone up to the environment, different types of AR can display computer generated objects overlaid the real environment in real-time [8]. The modern smartphones, of the 2010's, have the required sensors, software, and hardware to run AR applications for everyday use, including having enlarged screens that could enhance the users’ experience. Tablets with their big screen capacity also have the capabilities of running AR software, which could enhance the legibility of, for example, typography. A mobile display does not necessarily have to be a smartphone or tablet with AR capabilities, it could also be a specially designed handheld device that is movable and implemented with the resources to run an AR application [8]. This type of display technique is the one in focus for this thesis work, and the development of designing and displaying typography in an AR environment.

A video spatial display is a technique that uses a camera, for example, a webcam that is looking to scan an AR marker and displays a computer generated object on top of the real object on the screen [8]. Instead of displaying the computer generated
object on a stationary screen, the object can be projected onto a surface in the real world. The technique is then called spatial AR, and could be beneficial for displaying content to a large number of people at the same time.

Wearable displays are devices with display techniques that a user can wear on their body. The most commonly used wearable displays are called head-mounted displays. These displays have see-through glass that overlays information on the glass that connects to real object in the environment [9]. The head-mounted display is beneficial for the user experience because of its large field of view and because it allows for natural movements for the user. This is so that the user can move around an environment freely and enjoy Augmented Reality applications.

2.4 Typography

Typography has become one of many important tools a designer has to master for effective visual communication [10]. Nowadays, there are many different channels to communicate information through, from traditional posters, to web pages on desktop and mobile devices, but also applications with various new techniques like Augmented Reality. All of these different ways of displaying content has resulted in several guidelines on how typography should be designed and used in different media.

Following sections contain a brief history of typography, and guidelines that are used when displaying text in the more traditional media like printed posters and web pages. The purpose of these sections is to give an understanding of guidelines that could be interesting to investigate further in a mobile AR application.

2.4.1 Brief history of typography

The written word has been with us for many centuries, it began with pictograms and ideographs, and continued with hieroglyphics and Greek lettering, and then the Romans developed their alphabet based on the Greeks [10]. The development of the written words had its breakthrough in the 1400’s, when a man called Johannes Gutenberg invented the letter press. The letter press made it both easier and cheaper to spread the written word. He also created one of the first typefaces called Black letter, that is known to be used when printing the 42-line Bible [11]. Black letter was really dark and intense, and not particularly legible. Superseded to Black letter, roman typefaces began spreading, which was considered far more legible by the people. Between the years of 1470-1815, the creation of the roman type developed. It resulted in italic typefaces that would save money on printing since there could fit more words on a single paper. It also resulted in what we today call old style typefaces that features straight serifs and a little difference between the thin and bold letter strokes. After the old style typefaces, the Roman style type that we today call transitional type came with sharper serifs and a drastic contrast between the thin and bold lines. Then the modern Roman typefaces was created that had even more extreme contrast between the thin and bold letter strokes [10]. And at last, what we nowadays call the Slab Serif, or Egyptian, typefaces was created and had squared serifs.
The evolution of typography did not stop there, and typefaces without serifs got created, that are called sans-serif typefaces, that literally means "without" serif. In 1816, William Caslon IV created the first sans-serif typeface of any kind [12]. An illustration of the differences between serif and sans-serif typefaces can be seen in Figure 2.

![Comparison of serif and sans-serif fonts](image)

(a) Visualization of a serif font, where the so-called serifs are the "feet" to the letter.  
(b) Visualization of a sans-serif font.

**Figure 2:** Here shows a visualization between how a serif and sans-serif typeface can look like.

### 2.4.2 Typography guidelines for traditional media

The ways of designing typography are many, but in order to optimize the use of typography, a set of guidelines has been created. Following paragraphs contains guidelines regarding color contrast, font weight and size, and line length, that are used for traditional media like posters and websites in the 2010’s. The word legibility has been used frequently in the following paragraphs. A simple definition of the word in a design aspect has been done by Jakob Nielsen, as whether people are able to actually see and recognize the words and characters in the displayed text [13].

#### 2.4.2.1 Color contrast

Color contrast has been a part of the design process for a long time, and is important to evaluate when designing a new user interface for an application. A clear contrast in colors between the text and the background creates better legibility as the text visually pops out from the background, which could lead to faster reading and comprehension of the read text [14, 15]. World Wide Web Consortium\(^4\) (W3C) is an international community that works to develop standards on web design. They have set a color contrast minimum between the text on a website and its background color. That contrast minimum is set to a ratio of at least 4.5:1 for normal presentation of text and images of text, and 3:1 for large scale text. Large scale text is considered 14pt in bold and 18pt regular, and anything bigger than that [16]. The W3C community also has color contrast ratios that are described as enhanced contrast, which is set to a ratio of 7:1 for regular text and images of text, and 4.5:1 for

\(^4\)World Wide Web Consortium: [https://www.w3.org/](https://www.w3.org/)
larger texts [17]. See Figure 3 for a visualization of color contrast ratios that, does not meet W3C’s guidelines, meet the minimum, and meet the enhanced guidelines.

W3C’s guidelines were developed for web design, but how will the consideration of color contrast ratios of a text against a real environment that is not in one set color, like in an AR application, be done? The so called billboard text drawing style is a common method when displaying text overlaid onto photos or videos to enhance text visibility [18], and has been spotted in various AR applications where typography has been used in the design. Billboard text is text that has been placed on top of a white surface with or without opacity, which is the most commonly used background color for graphical user interfaces and printed materials. How could 3D typography, i.e., typography that has a depth to it, be placed and designed to avoid the background surface of an Augmented Reality application, and still contain the legibility of the text being displayed? These questions will be answered later on in this thesis with a couple of guidelines when designing typography to be used in an AR environment.

(a) **Does not** meet W3C’s guideline of color contrast, and has a ratio of 2:1.

(b) **Meets the W3C’s minimum** color contrast guideline, and has a ratio of 4.5:1.

(c) **Meets the W3C’s enhanced** color contrast guideline, and has a ratio of 7:1.

**Figure 3:** Color contrast visualization of W3C’s guidelines [16, 17]. The text used is Arial 12pt with regular weight, and represents the ratios which, does not meet the criteria of contrast, meets the minimum, and meets the enhanced criteria guidelines.
2.4.2.2 Weight, size, and line length

Typeface style has a significant influence on a text’s legibility. The different styles, sizes, weights, widths, colors, and cases, all have to be cautiously considered when implementing them in a design [19], and then tested on users to understand from a user perspective if the typeface was the right choice.

Studies have shown that typefaces with lighter weights tend to enhance the legibility of a text, this compared to heavier weights on the typeface [20]. Interestingly, there have not been a lot of studies done on how different typefaces work in an AR setting. In AR, when the real world competes with the computer generated objects for the eyes’ attention, an interesting question that this thesis is going to answer, is if a heavier font-weight is beneficial and enhances the legibility, compared to a lighter font-weight that is beneficial in traditional media? Figure 4a shows how the typeface Roboto changes depending on the set weight in a font size of 18pt.

Depending on the typography, used on a desktop or mobile device, it is important to test if the chosen typeface can still be read if the size of it changes. A visualization of five different typefaces in three different sizes can be seen in Figure 4b, that shows how the legibility of some typefaces disappears in smaller sizes.

![Typefaces](image)

(a) Different weights of Roboto in 18pt.  
(b) Arial, Perpetua, Vivaldi Italic, Informal Roman, and Copperplate Gothic Light in 18pt, 12pt, and 10pt.

**Figure 4:** Showing how one typeface looks like in a range of five different weight and how five different typefaces look in three different sizes.

When deciding what size of the typeface that should be used in a design, it is important to consider how the text will be displayed in that design. To have the right amount of characters on every line is a key aspect of the legibility of a text. Therefore the length of the lines depend on the font-size. The optimal line length differs depending of which device the text should be displayed on, which has resulted in the development of guidelines regarding this. Baymard Institute has come to the conclusion that the optimal line length is 50-60 characters including spacing. Although, they refer to another source that suggests that up to 75 characters is still acceptable when the text is displayed on a digital medium like computers [21]. When displaying text on a mobile device the character amount per line should be 30-40 in order to optimize the legibility [15]. In Figure 5 it is being shown how long a line gets depending on the number of characters.
Too long lines could essentially make it harder for the eye to concentrate on reading a whole line when it is not clear where the line starts and ends [21]. The long lines of text, could make it more difficult for the reader to continue on the right line of a long text. With too short lines on the other hand, the reading rhythm gets interrupted by having to move the eye back and forth too often. To have the right amount of characters per of a text can be difficult to achieve, but could help enhance the legibility of the text. It is therefore an essential part of implementing typography in the design [21].

2.5 Design guidelines for mobile Augmented Reality

Research in the field of Augmented Reality have become of interest for many companies, mostly within the technical side of the field but even more research have come up regarding the design and user experience of AR. As this thesis will not implement a user interface for a mobile AR application, the guidelines that have been created for those kinds of applications will not be displayed here. Instead guidelines regarding text and typography for use in an AR environment can be read here.

Displaying information with text has to be done clearly. This includes what typeface that is used, in what size, and how the text is visualized on top of the background/real world. The visualization depends on the color and the contrast between the text and background. Therefore, it is important that the same text can be visible against different backgrounds, since the background of an AR application is continuously changing when the user moves around [22]. If a text drawing style, such as outlining or shadow, is used, it is important to also consider the contrast ratios between them and the background [23].
3 Method

This section presents the method that has been used to determine the creation of guidelines while designing typography to fit in an indoor environment within a mobile Augmented Reality application. The method started with information gathering, and continues with the development of a simulated AR application that has been user tested, to conclude guidelines.

3.1 Literature study

A literature study has been made to investigate different AR technologies to build a knowledge base around the concept of AR, how to design for an AR application, typography and how typography could be used in such an environment. With the literature study, research about user experience and how to test and evaluate a system with users have been assessed and applied on the user study with the created typography and simulated AR prototype. The literature that has been reviewed for this study has been collected from Umeå Universitetsbibliotek\(^1\), Google Scholar\(^2\), and other related and relevant articles and sites from the web.

3.1.1 Typography research

The research about different types of typography and how they have been used in earlier technologies, and different guidelines regarding line length, color contrast, and typeface style has been collected through various website articles, and scientific research from Google Scholar. The guidelines for usage of typography has primarily been for printing and 2D graphical interfaces like desktop and mobile devices, and have been implemented on the typography that could be used for a mobile AR application. Some guidelines of use of typography in an AR environment have been collected as well.

3.2 Simulated Augmented Reality application prototype

The simulated Augmented Reality experiences has been created in the program Adobe After Effects. The program allows camera tracking of an input video to trace different text or objects to a specific point in the video, which makes it easy to simulate an AR experience. With the program the design of the typography was applied on the text test words. These are explained in the following sections with

\(^1\)Umeå Universitetsbibliotek: http://www.ub.umu.se/

\(^2\)Google Scholar: https://scholar.google.se/
the applied types, colors, and weights. The simulated AR application prototype, is essentially made to be eight different simulations, each containing a short videos with the attached designed typographies.

The indoor environment used for this study was a shopping mall in Umeå, that was selected because of its openness, lighting and good structure to include computer generated typography into the surroundings. The video was filmed with a HTC One m9 smartphone, with no added filter or materials. The only thing that was included in the rendered videos was the designed typography that was user tested.

3.2.1 Typography design

The typography that has been used in the eight simulated Augmented Reality applications, has been designed using guidelines regarding serif and sans-serif typefaces, light and bold font weights, and color aspects. The eight different combinations of type, color, and weights can be seen in Figure 6. The text that was placed in the simulated AR also had a depth to it that had different thickness depending on the weight, but was also displayed in different sizes.

![Figure 6: Visualization of the designed typography used in the simulated AR experience.](image)

### 3.2.1.1 Serif and sans-serif typeface

The fonts that have been selected, Helvetica and the Google font Frank Ruhl Libre, were selected because they are sans-serif and serif, respectively. This was done to be able to test them against each other. An old usability guideline for typography used on screens was clear on using sans-serif typefaces because of the low rendering capacity of old computer screens. Nowadays a new guideline is set for using typography on screens, that the legibility of either serif or sans-serif typefaces shows to be the same and the use of the different types has to be chosen by the designer [24]. In research that has been conducted on computer screens and the use of four different fonts’ legibility were user tested, and resulted in a preference of sans-serif fonts although the serif font tended to support faster reading of a text [25, 26]. Therefore one serif and one sans-serif typeface were chosen from the criteria of being highly used and both had rendering with different weights. The different typefaces that
were selected for this study can be seen in Figure 6, as a representation of a serif and sans-serif type.

### 3.2.1.2 Bright and dark colors

The two colors that have been selected for this study were one bright color and one dark color. This was done because different colors have a way of affecting physical and emotional reactions in different people. Objects and spaces that are in white or bright colors are considered "cool", and have a tendency to be considered larger than those that are colored black together with colors that are considered "warm". This means that dark and "warm" colors have a slimming effect to them [27]. Therefore, one bright color with hex code #DEDEDE, and one dark color with hex code #2C2C2C, were chosen. This was done to investigate color differences of typography for indoor AR environment. The different colors for the text can be seen in Figure 6. The words were displayed in 8-24 pixels, but have been scaled up in the prototype to fit the size of the video, and therefore they were considered as large texts.

With the website Contrast Checker\(^3\), the colors of the text have been checked against 2-3 nearby points, that were taken as general color around the text, for contrast. This website use the color contrast ratio guidelines from W3C. In an AR environment, the colors in the environment are constantly changing while the camera is moving around. Out of the point that were checked, both the bright and dark color passed the W3Cs minimum contrast requirements. Therefore, the colors that were picked were not solid white and black.

### 3.2.1.3 Light and bold weights

Since studies have shown that lighter typefaces tend to increase the legibility of text [20], while really bold typefaces have a negative effect on reading speed [28], the typefaces in the AR simulations were displayed in both light and bold weights. The regular weight was not compared to either the light or bold weights because of the information collected from studies about legibility dependent on font weight. The different weight renderings of the typefaces can be seen in Figure 6.

### 3.2.1.4 Test words

The test words that were used for this study comes from a sentence that contains all the letters in the English alphabet for testing typography and goes as follows: *The quick brown fox jumps over the lazy dog*. The words that were used in this thesis were quick, brown, fox, jumps, and lazy. This sentence and the words were selected to not affect the user thought the actual meaning of the words. In one simulated AR video one font, color, and weight were applied on all the words, and the words were displayed in different sizes. The words were displayed at the same location in every video, this was done to have a consistency in how the different designs were tested. Using the same words could cause inaccurate result because the user was already

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\(^3\)Contrast Checker: [https://contrastchecker.com](https://contrastchecker.com)
familiar with the words and where they were located by the end of the test. But as memory of the words was not the factor that was tested, only the visibility of the word, this should not have been a crucial decision of the purpose of this thesis.

3.3 Experiment - User study

The user study was tested on 33 people that were divided into two groups. One group with 3 people considered to be experts in the field of typography that worked at Humbly. The other group of 30 people were considered to be regular users. The regular users are considered to be general users of an Augmented Reality application’s target group, with little to none prior experience of design and use of typography. The two groups were instructed to look at the created simulated Augmented Reality application prototypes that contained eight different 16 seconds long videos. Then they had to answer some questions about the different videos. The two groups were tested differently because of the expertise in the field of typography and design the company had to offer, and the time restriction of this thesis. More specifics on how the different groups tested the prototype to investigate 3D typography in indoor AR are described in different sections below.

3.3.1 Regular users

The regular users were tested by sending them a survey that contained five different sections, Introduction, Contact, General information, Videos, and Finishing questions. The survey questions were asked in Swedish in order to decrease the possibility of misunderstanding. They were asked in Swedish because the users that the survey was sent to, through various social media channels, lived in Sweden at that time being and generally considered to have a larger knowledge in Swedish than any other language. In Appendix A the Google Form survey that was sent out to the users is presented. Following paragraphs explain the survey and why certain questions were asked.

The first section began by introducing Augmented Reality briefly, to give general information, so the users understood the concept of AR. Following that, the introduction contained information about this thesis and that the survey they answered was completely anonymous. Along with that, the answers to the questions of the survey would not be saved for any other purpose than to answer this thesis objective questions. After that, information about how the users should perform the test, by instructing them to do the test from their smartphones. This information was included to optimize the result, since the thesis investigate mobile AR. After all the information was given, a question about if the user understood the instructions had to be answered to go forward with the survey. This was to create a level of certainty that the users had read the given information and understood how the test should be performed. If the user did not understand the introduction phase they were sent to the second section of the survey that contained contact information that the user could use to ask questions about the survey. If the user understood the introduction, they were sent to the third section of the survey.

The third section of the survey contained questions about the users themselves. The
questions were asked in such a way that the participants kept their anonymity.

The fourth section was the one containing the simulated AR prototypes, with several questions about what the user did or did not see in them. More about how the prototypes were constructed can be read under Section 3.2 and its several subsections. The question that followed every video was about how visible the user thought that the texts were on a scale of 1-7. The exact scale was chosen because a smaller or larger scale would give the user too few or too many options, and would then not give a conclusive result. Lastly, there where questions about if the user did or did not see the text at first glance, and if they did not, the user had the opportunity to explain why.

The last section of the survey contained a question about when the user thought the text was the most visible, depending on, for example: placement, color, weight, and contrast, and why they thought that. To end the survey, the users could also write additional comments about if there were anything they would like to add. At the end, the users were thanked for their contribution to the results for this thesis.

3.3.2 Expert users

The expert users were tested in a similar way to the one described in Section 3.3.1 for the regular users. The difference was that the expert users were tested in person. This to have more of a dialog with the users to get more thoughts from an experienced designer’s perspective. All the experts were tested on the same device, a HTC One m9, with the brightest screen capacity to ensure that the lightning of the screen would not change during the different tests or videos.

The test was divided into three different sections, *Introduction/General questions*, *Videos*, and *Finishing questions*. The material that was used in the test can be seen in Appendix B and are displayed in Swedish. This was done because all the expert participants have Swedish as their native language.

The first section began by giving the expert user some general information about the test, this ensured that they were familiar with the concept of AR. Then, the user was able to write down general information about themselves, regarding age, color vision, their role at Humbly, and how often they use YouTube to look at videos on their smartphone. The purpose of them writing this by themselves was done for the user’s privacy.

After that, the second section of the test contained the eight different simulated AR prototypes, which can be read more about in Section 3.2. After every video were watched by the user, questions about how visible the texts were, were asked to the user and a dialog opened up about why the user thought so.

After every prototype was watched, finishing questions about what made the visible text actually visible were asked and followup questions continued the conversation. The test ended with three fast questions about if the expert user had to design a typography for indoor AR, how would it look? This was conducted to get fast relevant information about typography from an experienced typographer and designer, for evaluation of the visibility of the text in the prototypes.
3.4 Evaluation of the user study

The evaluation of the results gathered from the user study was analyzed for significant differences on how well the participants thought that the text was visible between the different simulated AR applications. With the program Minitab\(^4\), which is a program for analyzing data statistically, a Kruskal-Wallis test was conducted to investigate if there was any noteworthy difference between two or more AR simulations, from the result of the regular users. To analyze the expert users’ test results the Kruskal-Wallis test was also conducted. With the test, differences between factors can be shown. The expert users’ results have been used as a support to analyze the regular users’ results to see if they correlate or not.

3.4.1 Regular users

For the group of regular users, the Kruskal-Wallis test was conducted because the measured variable of text visibility was on an ordinal scale \([29]\), from not at all visible \((1)\), to very visible \((7)\). This statistical analysis was chosen because of the ordinal data and the result of a normality test that showed that the data was not normally distributed. The test was conducted with a 95 percent significance, therefore an \(\alpha = 0.05\). Before the calculations of significant differences, the mean values were calculated to investigate which tests were going to be done. The calculations for significant differences were calculated on all of the attributes of the typography in the videos, i.e., serif or sans-serif, color, and weight. Other tests for significant differences were calculated between the videos where only one or two attributes were involved. What that means is calculations, for example, between the four videos that had serif typeface against the four that had sans-serif typeface, or between videos that had serif and bright text against text of sans-serif and dark color, were done. All the tests that were calculated can be seen in Table 1.

Table 1 Showing what factors that were tested against each other with a Kruskal-Wallis test, and the number represent the order in which they were represented in the survey.

<table>
<thead>
<tr>
<th>Nr.</th>
<th>Factor 1</th>
<th>Nr.</th>
<th>Factor 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>Serif - Bright - Bold</td>
<td>6</td>
<td>Sans-serif - Bright - Light</td>
</tr>
<tr>
<td>4</td>
<td>Serif - Bright - Bold</td>
<td>3</td>
<td>Sans-serif - Dark - Bold</td>
</tr>
<tr>
<td>4</td>
<td>Serif - Bright - Bold</td>
<td>2</td>
<td>Serif - Bright - Light</td>
</tr>
<tr>
<td>7</td>
<td>Sans-serif - Bright - Bold</td>
<td>6</td>
<td>Sans-serif - Bright - Light</td>
</tr>
<tr>
<td>1, 2, 4, 5</td>
<td>Serifs</td>
<td>3, 6, 7, 8</td>
<td>Sans-serifs</td>
</tr>
<tr>
<td>2, 4, 6, 7</td>
<td>Bright colored</td>
<td>1, 3, 5, 8</td>
<td>Dark colored</td>
</tr>
<tr>
<td>2, 5, 6, 8</td>
<td>Bold weighted</td>
<td>1, 3, 4, 7</td>
<td>Light weighted</td>
</tr>
<tr>
<td>2, 4</td>
<td>Serif - Bright</td>
<td>3, 8</td>
<td>Sans-serif - Dark</td>
</tr>
<tr>
<td>1, 4</td>
<td>Serif - Bold</td>
<td>6, 8</td>
<td>Sans-serif - Light</td>
</tr>
<tr>
<td>4, 7</td>
<td>Bright - Bold</td>
<td>5, 8</td>
<td>Dark - Light</td>
</tr>
</tbody>
</table>

\(^4\)Minitab: http://www.minitab.com
3.4.2 Expert users

For the expert users a Kruskal-Wallis test was conducted to test for significant differences of the text visibility between the videos. This test was selected because the result of an normality test showed the user study answers were not normally distributed and the measured data of text visibility was conducted on an ordinal scale. The data from the expert users included three independent test answers, which could lead to an incorrect P-Value since the Kruskal-Wallis test performs best with at least five observations [30].

Therefore, before the Kruskal-Wallis test was done, the calculations of the mean values of the results of visibility from the scale of 1-7 were done to be analyzed and used as a support while discussing the results of the user study that was done on the regular users. All the tests that were done, based in their mean values, can be seen in Table 2.

Table 2 Showing what factors that were tested against each other with a Kruskal-Wallis test, and the number represent the order in which they were represented in the survey.

<table>
<thead>
<tr>
<th>Nr.</th>
<th>Factor 1</th>
<th>Nr.</th>
<th>Factor 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>Serif - Bright - Bold</td>
<td>8</td>
<td>Sans-serif - Dark - Light</td>
</tr>
<tr>
<td>7</td>
<td>Sans-serif - Bright - Bold</td>
<td>8</td>
<td>Sans-serif - Dark - Light</td>
</tr>
<tr>
<td>2</td>
<td>Serif - Bright - Light</td>
<td>8</td>
<td>Sans-serif - Dark - Light</td>
</tr>
<tr>
<td>4</td>
<td>Serif - Bright - Bold</td>
<td>3</td>
<td>Sans-serif - Dark - Bold</td>
</tr>
<tr>
<td>1, 2, 4, 5</td>
<td>Serifs</td>
<td>3, 6, 7, 8</td>
<td>Sans-serifs</td>
</tr>
<tr>
<td>2, 4, 6, 7</td>
<td>Bright colored</td>
<td>1, 3, 5, 8</td>
<td>Dark colored</td>
</tr>
<tr>
<td>2, 5, 6, 8</td>
<td>Bold weighted</td>
<td>1, 3, 4, 7</td>
<td>Light weighted</td>
</tr>
<tr>
<td>2, 4</td>
<td>Serif - Bright</td>
<td>3, 8</td>
<td>Sans-serif - Dark</td>
</tr>
<tr>
<td>1, 4</td>
<td>Serif - Bold</td>
<td>6, 8</td>
<td>Sans-serif - Light</td>
</tr>
<tr>
<td>4, 7</td>
<td>Bright - Bold</td>
<td>5, 8</td>
<td>Dark - Light</td>
</tr>
</tbody>
</table>
4 Result

This chapter presents the results of the conducted user study that was explained in Section 3.3 and its following subsections. The result has been evaluated and analyzed as the method of Section 3.4 explains. Furthermore, the results are being discussed regarding the analyze of the results from the tests with the expert users, and conclusions are drawn in Chapter 5 and 6, respectively.

4.1 Result from user study

The user study resulted in 33 answers. Out of those, there were 17 men and 13 women in the group of regular users, and in the group of experts, all three of them were men. The age range between the regular users was between 21 and 63, and no one considered themselves of having any problem seeing colors. In the group of experts, the age distribution was between 32 and 37, and no one considered themselves of having any problem seeing colors.

Out of the two groups, there was not a conclusive result about how often the user watched videos distributed from YouTube. The whole range, of watching no video at all, to watching more than twelve videos in the users’ past week were answered, but with a majority in the interval of 1-3 videos and 7-9 videos.

In the following sections, the results from the user testing is presented for each of the two groups of regular and expert users.

4.1.1 Regular users

The mean values were calculated regarding the visibility of the text the regular user selected from a scale of 1-7 in the survey, and the results are presented in Table 3.

When calculating significant differences of the distributions with a Kruskal-Wallis test, the hypothesis and significance level were set to:

Null hypothesis, $H_0$ : All distributions are equal.

Alternative hypothesis, $H_1$ : Not all distributions are equal.

Significance level : $\alpha = 0.05$.

The calculations started with the videos that had the highest and lowest mean values, i.e., video number 4 and 6. A Kruskal-Wallis test with those two factors, resulted in a P-Value of 0.028, adjusted for ties. With a P-Value that is lower than the set $\alpha = 0.05$ means that the $H_0$ can be rejected, which means that there is a
Table 3 Mean values, from the regular users’ test, presented regarding the visibility of the text in the different simulated AR videos, ordered from highest to lowest. The numbers in the first column represent the number in the order they were placed in the survey.

<table>
<thead>
<tr>
<th>Nr.</th>
<th>Typography design</th>
<th>Mean value</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>Serif - Bright - Bold</td>
<td>5.967</td>
</tr>
<tr>
<td>7</td>
<td>Sans-serif - Bright - Bold</td>
<td>5.800</td>
</tr>
<tr>
<td>5</td>
<td>Serif - Dark - Light</td>
<td>5.767</td>
</tr>
<tr>
<td>8</td>
<td>Sans-serif - Dark - Light</td>
<td>5.667</td>
</tr>
<tr>
<td>1</td>
<td>Serif - Dark - Bold</td>
<td>5.500</td>
</tr>
<tr>
<td>2</td>
<td>Serif - Bright - Light</td>
<td>5.300</td>
</tr>
<tr>
<td>3</td>
<td>Sans-serif - Dark - Bold</td>
<td>5.267</td>
</tr>
<tr>
<td>6</td>
<td>Sans-serif - Bright - Light</td>
<td>5.200</td>
</tr>
</tbody>
</table>

noteworthy difference on the text visibility between video number 4 and 6. In Table 4 the test result of the Kruskal-Wallis test is displayed for the different P-Values.

Table 4 Displaying the P-Values that the Kruskal-Wallis test, from Minitab, resulted in for video with the highest and lowest mean values, i.e., video number 4 and 6, from the regular users.

<table>
<thead>
<tr>
<th>Method</th>
<th>DF</th>
<th>H-Value</th>
<th>P-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Not adjusted for ties</td>
<td>1</td>
<td>4.50</td>
<td>0.034</td>
</tr>
<tr>
<td>Adjusted for ties</td>
<td>1</td>
<td>4.84</td>
<td>0.028</td>
</tr>
</tbody>
</table>

The same assumptions and test were done with the video that had the highest and second lowest mean values, i.e., video number 4 and 3, and resulted in a P-Value of 0.049, adjusted for ties. As the P-Value is lower than the set α, the $H_0$ can be rejected, which means that there is a noteworthy difference between video number 4 and 3. The results of the different P-Values from the Kruskal-Wallis test can be seen in Table 5.

Table 5 Displaying the P-Values that the Kruskal-Wallis test, from Minitab, resulted in for the video with the highest and second lowest mean values, i.e., video number 4 and 3, from the regular users.

<table>
<thead>
<tr>
<th>Method</th>
<th>DF</th>
<th>H-Value</th>
<th>P-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Not adjusted for ties</td>
<td>1</td>
<td>3.50</td>
<td>0.056</td>
</tr>
<tr>
<td>Adjusted for ties</td>
<td>1</td>
<td>3.75</td>
<td>0.049</td>
</tr>
</tbody>
</table>

Further calculations with the Kruskal-Wallis test were done for the different videos with one, two or, three attributes and resulted in a P-Value higher than the set α of 0.05 for both adjusted or not adjusted for ties. With this result, the $H_0$ can not be rejected, which means that no conclusions regarding notable differences of text visibility can be drawn for the rest of the different designed typography. All the Kruskal-Wallis tests that were conducted can be read in Section 3.4, Table 1.

The survey also asked questions about if the user at first glance saw what all the words said and if they thought that anything that unclear, they could leave a com-
ment about that. The video with the highest mean value, video 4, only had one
user that answered that they did not see the words at first glance, and the video
had three comments regarding unclear typography. The comments for video 4 were
one about the thickness of the font, i.e., the depth of the typography, and two about
that the typography color blended with the background’s colors. The video with the
second lowest mean value, video 3, had four users that did not see the words at first
glance, and the comments were four regarding the thickness of the characters and
three about the dark color. Video number 6, the video with the lowest mean value,
also had four users that did not see the text at first glance and the comments were
six about the bright color that they thought did not have enough contrast against
the background, and two about thinness of the characters.

4.1.2 Expert users

The mean values for the text visibility of every video, from the results of the user
study with the expert users, were calculated and can be seen in Table 6.

<table>
<thead>
<tr>
<th>Nr.</th>
<th>Typography design</th>
<th>Mean value</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>Serif - Bright - Bold</td>
<td>6.667</td>
</tr>
<tr>
<td>2, 7</td>
<td>Serif - Bright - Light, Sans-serif - Bright - Bold</td>
<td>6.333</td>
</tr>
<tr>
<td>6</td>
<td>Sans-serif - Bright - Light</td>
<td>5.667</td>
</tr>
<tr>
<td>1</td>
<td>Serif - Dark - Bold</td>
<td>5.333</td>
</tr>
<tr>
<td>3, 5</td>
<td>Sans-serif - Dark - Bold, Serif - Dark - Light</td>
<td>4.667</td>
</tr>
<tr>
<td>8</td>
<td>Sans-serif - Dark - Light</td>
<td>4.333</td>
</tr>
</tbody>
</table>

When calculating significant differences of the distributions with a Kruskal-Wallis
test, the hypothesis and significance level were set to:

Null hypothesis, \( H_0 \): All distributions are equal.

Alternative hypothesis, \( H_1 \): At least one distributions is different.

Significance level : \( \alpha = 0.05 \).

A Kruskal-Wallis test between the video with the highest mean value, 4, and the
video with the lowers mean value, 8, resulted in a P-Value that was 0.043 adjusted
for ties. With this result, the \( H_0 \) can be rejected since the P-Value is lower than the
set \( \alpha \), and the results of the P-Values can be seen in Table 7.
Table 7 Displaying the P-Values that the Kruskal-Wallis test from Minitab resulted in for video with the highest and lowest mean values, i.e., video number 4 and 8, from the expert users.

<table>
<thead>
<tr>
<th>Method</th>
<th>DF</th>
<th>H-Value</th>
<th>P-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Not adjusted for ties</td>
<td>1</td>
<td>3.86</td>
<td>0.050</td>
</tr>
<tr>
<td>Adjusted for ties</td>
<td>1</td>
<td>4.09</td>
<td>0.043</td>
</tr>
</tbody>
</table>

The Kruskal-Wallis test also showed noteworthy differences between the videos with the second highest mean values, video number 7 and 2, and the video with the lowest mean value, video number 8. This can be said because the P-Values from those tests were lower than the set \( \alpha \). The results of the P-Values were the same between video 7 against 8, and between video 2 against 8, and the results of those can be seen in Table 8.

Table 8 Displaying the P-Values that the Kruskal-Wallis test from Minitab resulted in for the videos with the second highest and lowest mean values, i.e., video number 7 and 2, and 8, from the expert users.

<table>
<thead>
<tr>
<th>Method</th>
<th>DF</th>
<th>H-Value</th>
<th>P-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Not adjusted for ties</td>
<td>1</td>
<td>3.86</td>
<td>0.050</td>
</tr>
<tr>
<td>Adjusted for ties</td>
<td>1</td>
<td>4.09</td>
<td>0.043</td>
</tr>
</tbody>
</table>

Further calculations with the Kruskal-Wallis test resulted in P-Values higher than the set \( \alpha = 0.05 \). With this result the \( H_0 \) can not be rejected, which means that no conclusions regarding notable differences between any other AR videos with one, two, or three typography attributes, can be drawn. All the tests that were made, to analyze the results from the user study with the expert users, can be seen in Section 3.4.2, Table 2.

When asked which typography design the expert users preferred, all three experts answers a bright colored text with a bold weight. A difference of opinion between the experts was if a serif or sans-serif typeface should be used in an indoor AR environment. Two of the experts chose sans-serif, and one serif typeface. When asked why, it was mostly about personal preferences, but a comment saying that a cleaner looking typeface like sans-serif would be beneficial in an information crowded environment like AR can be, was made.
5 Discussion

This chapter will discuss the results that the user study gave and were presented in the last chapter. The results will be discussed regarding the legibility of the texts that were presented to both the regular and expert users, and have been used as a support for the conducted typography guidelines together with the findings from the literature study. The conducted design guidelines for typography for indoor mobile Augmented Reality is presented in Chapter 6, Section 6.1. The method used to get the given results will also be discussed in this chapter, and what factors that could have impacted the given result the most.

5.1 Results of the text legibility in the AR simulations

From analyzing the results from both the regular and expert users, some statistical noteworthy differences could be seen between the typography designs. These differences could be seen when analyzing the legibility of the typography’s three attributes of typeface, color, and weight, at the same time. The discussion will investigate how and why the different attributes affected the legibility of the text for both groups of users, and how they correlate.

Overall, the result showed that the regular users thought that the fourth video, containing the typography design of serif typeface with bright color and bold weight, were the most visible. This were based on the mean values of the text visibility scale the users had to answer in the survey. This result can be confirmed by the expert users, who also thought that this typeface design was the most visible of all of the different typography designs that the AR simulations prototype could have. The expert users were all convinced that this design of the typeface was the most legible of them all, and would best fit in the purpose that the AR simulations had, indoor and in a shopping mall. The result of the visibility did not only depend on the bright color. According to the expert users, the weight and depth of the typography combined with the size, helped to bring contrast between the text and the background.

As can be read in the result, Chapter 4, testing for significant differences of the visibility of the typography resulted in a noteworthy difference between video number 4 and 6, and between video number 4 and 3. The differences in the design of the typography between video number 4 and 6 were the difference of typeface and weight. And between video number 4 and 3, a smaller differences could be seen. The design differences of the typography were the typeface and color. From this we can not draw any concrete conclusions beyond the fact that the noteworthy differences that could be seen from the expert users’ tests, showing that a changing factor of color between the texts improved the legibility of the text if it was brightly colored.
5.1.1 Color

The different colors of the text, bright and dark, have an important role to the visibility of the text. This can be said because the expert users favored all the bright colored texts for the purpose of this AR simulation, but it will have to be investigated if this could be the case in other environments too. The experts also said that the contrast between the text and the background depended on where the text were placed but with the help of the text’s bright color and bold weight, the text popped out of the background and caught the eyes’ attention anyway.

Not any notable differences could be found among the different colors when looking at that attribute alone, i.e., the videos containing bright colored text tested against the dark colored text. As the expert users all said that the color was a deciding factor for higher legibility of the text, we have to take this in to consideration as they are experts in typography and design. Of course, even different shades of the chosen colors could give a completely different result. But as research in the field of typography in AR has given us, the most frequently used color in AR applications are in fact bright colors that are close to white. And the results of this study show that it may be used for a reason.

5.1.2 Weight

Differences in legibility depending on the weight of the typography design have been difficult to investigate since there could not been found any notable differences could be seen when analyzing the weight attribute alone, i.e., videos containing light weight text against bold weight text. As the top two typography designs, according to the regular users, are both bold weighted, and the expert all preferred the bold type, it has to be discussed if a bold typeface is a better fit for AR applications. This instead of a thinner typeface that earlier has been described as the clear choice for legible typography in the traditional media.

5.1.3 Typeface

As the statistical analyzes show no significant differences between a serif or sans-serif typeface, when analyzing the typeface attribute alone, drawing any conclusions about the two are difficult. What could be said about the two typefaces are that both the regular and expert users preferred a typography design that contained a serif typeface, when looking at them in the simulated AR prototype, analyzed from the mean values. No direct comments about the typefaces were made by the regular users, but the expert users all said, when asked about their favorite design, were the sans-serif typeface. However, since the experts ranked the serif typeface higher when visualized in the AR simulations, the question about which one they preferred, along with how they would have designed typography for an AR application themselves, could have been forcing the expert users to just answer the questions without further thoughts about what they really preferred.
5.2 Method evaluation

The methods to investigate the legibility of typography in Augmented Reality applications that have been explained in Chapter 3 are being evaluated, along with how the methods could have impacted the given result in any way.

5.2.1 Literature study

The literature study of gathering relevant information and basing the design of the typography through, could have resulted in another look of the different typography options. This because some of the relevant information did not come from peer-reviewed material, instead from various websites. But since those sources where thoroughly investigated, the information from the sources should still be trustworthy and the design of the typography should not undergo major changes if different sources where collected.

5.2.2 Simulated Augmented Reality application prototype

When discussing the simulated Augmented Reality applications, it can not be avoided discussing the matter of the application in fact being a simulation of an AR experience. Since the method of showing several simulated AR applications to the users were done because the time of the thesis had required, the outcome of the result may have differed if another method would have been chosen. One method of displaying the different designed typography to the user could have been made though an actual application that used recognition based AR, and that could have been interacted with. This method to develop the prototype for the user tests would have taken longer than the chosen method, and would have affected the other work done in this study. However, in the scope of this thesis the chosen method of an AR simulation gathered information from the users in both a quantitative and qualitative way rather quick. This improved the way that the expert users could be tested, since more time could be spent on the way they were tested.

Within the AR simulations five different words were spread out throughout the environment. The placement of those, together with the fact that the same words were used in all of the video simulation, may have given a more conclusive result. However, the fact that the same words were used should not have any impact since the users were told that the actual words were not tested, just the design of the typography they were representing. Regarding the placements of the words, the design of the typography could have been displayed with another contrast to a different background, and therefore be more legible. This could be the case even though the contrast between the words and the background at where they were placed was checked and approved by W3Cs contrast guidelines. Since the contrasts were checked and approved the result can still be considered valid.
5.2.3 Experiment - User study

The regular users were tested, through a survey, in order to gather as much information possible from as many users as possible within a set time frame, which may have impacted the results. Even though, the result from the regular users are still relevant, and the information collected from the survey have been analyzed and investigated regarding the results from the expert users and should therefore be considered valid. One aspect that could have been done better in the phase of collecting data, would have been that the data could be considered continuous, instead of in a scale of seven set numbers. This would have made the evaluation of the results more powerful [29, 31].

5.2.4 Evaluation of the user study

As said in 5.2.3, if the collected data would have been collected a continuous variable, instead of a set of numbers on a scale, the statistical method One-Way ANOVA could have been used instead of the Kruskal-Wallis method. A One-Way ANOVA test has more power than a Kruskal-Wallis and if the data were continuous, the fact that the data were not normally distributed would not have mattered. The One-Way ANOVA could have been conducted since the sizes of the groups met the requirements of 2-9 groups with at least 15 samples in each [31].

The fact that the sample size of the expert users were only three, the Kruskal-Wallis test could give an inconclusive P-Value since it is optimal for sample sizes of at least five. Therefore, the result when analyzing the result of the expert users may be affected by this, the result also analyzed the mean values of the text visibility to assure a the conclusions made.
6 Conclusion

The conclusions described in this chapter have been presented in the form of design guidelines when using typography in Augmented Reality applications for indoor purposes. This chapter also covers potential work in the future that could be done to investigate different design options further.

6.1 Typography guidelines for indoor mobile Augmented Reality

From the results of the user study, with both the regular and expert user, the objective of this master’s thesis presents five guidelines regarding how to design and use 3D typography for indoor mobile Augmented Reality applications.

6.1.1 Guideline 1: Font weight and depth to improve legibility

When using three-dimensional typography in Augmented Reality applications, it is important to consider how deep the characters should be. In AR applications, it could be possible to see the typography from all 360°, therefore, it is crucial to investigate how the different angels affect the legibility of the text. Regarding the weight of the typography, the environment where the AR application is being used, should be investigated and the purpose of the text should be considered. This is further explained with an example of an environment that includes a lot of details and information, the purpose of the augmented text might wanting it to be eye catching. Then the text should brake out of that detailed pattern and stand out, which could lead to a bolder looking text being selected for the beneficial legibility reasons.

6.1.2 Guideline 2: Colors and Contrast

To decide what colors that should be used on the typography in an Augmented Reality application, investigations regarding color contrast have to be made around the selected environment, just like when selecting colors for the typography used in a web interfaces. However, since the background to a text in an AR application is constantly changing, further contrast checks should to be made. When the text that are being displayed have a depth to it, color contrast checks should also be considered on the shadow colors of the depth against the background. A brightly colored text should be considered when the environment the application should be used in, is indoors.
6.1.3 Guideline 3: Placement

As the font weight and color have a great impact on the legibility of the text, the consideration of where to place the text in the environment plays a role to the legibility too. First, consider the purpose of the text. Then investigate where the text should be placed to complement the purpose to enhance the text’s legibility.

6.1.4 Guideline 4: Impact of the typeface

When using three-dimensional typography in Augmented Reality applications, the use of a serif or sans-serif typeface does not necessarily impact the texts legibility, rather than the feeling of the text. Consider to use a sans-serif typeface, because it has clean and straight forms, when placing text in an AR environment that is rich in detail and the text need to stand out. If the background of the environment does not affect the texts legibility, it may be better to follow the companies graphical profile instead, since the typeface dose not play a big part to the legibility as font weight, color and contrast, and placements of the text.

6.1.5 Guideline 5: Careful planing

To ensure legibility on the placed text in a mobile AR application, the planing and prototyping phase should have the same resources as any other part of the process. The important part of getting the text legible, the focus should be on making sure attributes like color, weight and typeface are tested in the environment, which could mean that the design profile have to be overlooked sometimes.

6.2 Future work

To further investigate how the design of typography affects the legibility of a text in mobile Augmented Reality, more testing have to be done. This includes investigating other color options and different font weights, together with other style options like shadows and text outlining. When testing other design options for AR typography, it would be beneficial to do this in a real AR application that uses a technique to augment computer generated object. This could be done do enhance the realistic feeling for the users when testing the application, and ensure that the test result mirror an everyday use of the AR application that is being created. To further enhance the design guidelines, the importance of testing in a real AR application would make it easier to test in different environments and from there create specific guidelines that would help designers create typography for their AR application.
References


A User study - Regular users

Typografi i simulerad Augmented Reality
Augmented Reality, eller Förstärkt Verklighet som det brukar bli kallat på svenska, och förkortas till AR, är ett sätt att förbättra/förstärka en verklig miljö med digitalt skapade objekt eller text. Exempel på appar som idag använder sig av Augmented Reality är Pokémon GO, Snapchat, och IKEA Place. Men hur man ska designa och använda typografi, det vill säga text, i en AR miljö har inte blivit undersökt allt för mycket bland forskare, speciellt inte när det gäller 3D-typografi.

Därför undersöker jag i mitt examensarbete, i samarbete med företaget Humbly i Umeå, hur typografi ska se ut och vara designad, för att passa in i en AR applikation för inomhusbruk. Undersökningen är komplett anonym och inga specifika svar kommer sparas på något annat sätt än i syfte att svara på examensarbetets frågeställningar.

För att optimera testresultaten vill jag uppmana dig att utföra testet på din MOBILTELEFON. Testet innehåller åtta olika videoklipp med tillhörande tre frågor. Varje videoklipp är 16 sekunder långt och hela testet beräknas ta max 8 minuter. Försök komma ihåg vilken video du anser att texten är mest synlig.

Tack på forhand!

*Obligatorisk

1. Jag har läst igenom hela beskrivningen ovan och förstått hur jag ska utföra testet. *
   Markera endast en oval.
   - Ja Fortsätt till frågan 2.
   - Nej Fortsätt till Har du frågor?

Har du frågor?
Om du inte har förstått beskrivningen är det bara att höra av dig till mig via keig_qatm@hotmail.com så förklarar jag gärna vidare om oklarheter uppstått.

Sluta fylla i det här formuläret.

Generell information
Alla frågor är komplett anonyma och svaren kommer inte sparas i något annat syfte än att svara på examensarbetets frågeställningar.

2. Hur gammal är du? *

3. Välj ditt kön *
   Markera endast en oval.
   - Kvinna
   - Man
   - Övrigt:

4. Upplever du att du har problem med att se vissa färger? *
   Markera endast en oval.
   - Ja
   - Nej
5. Hur ofta, under den senaste veckan, har du använt mobiltelefonen för att titta på videoklipp via YouTubes mobilapplikation, eller via en extern sida som använder sig av YouTubes videospelare? * 
Det vill säga, sett videoklipp på mobiltelefonen, ej Chromecast eller liknande.
Markera endast en oval.

- Ingen gång
- 1 - 3 gånger
- 4 - 6 gånger
- 7 - 9 gånger
- 10 - 12 gånger
- Fler än 12 gånger

Videoklipp
Här följer 8 videoklipp på 16 sekunder vardera, med följande 3 frågor tillhörande videon du just tittat på.

Videoklipp 1 av 8

[Video clip]

http://youtube.com/watch?v=bqwE2ljjx9E

6. På en skala mellan 1-7, hur synlig tyckte du att texten i denna video var? * 
Markera endast en oval.

<table>
<thead>
<tr>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inte alls synlig</td>
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<td></td>
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<td>Mycket synlig</td>
</tr>
</tbody>
</table>

7. Vid första anblick, anser du att du såg vad det stod för ord på alla ställen i videoklippen? * 
Markera endast en oval.

- Ja
- Nej

8. Om det fanns något eller några ord du tyckte var otydliga, vad anser du att det berodde på? 
Om möjligt, försök gärna förklara på vilken plats ordet eller orden som du tyckte var otydliga var placerade, eller vad det stod för ord.
Videoklipp 2 av 8

[På en skala mellan 1-7, hur synlig tyckte du att texten i denna video var?]

Markera endast en oval.

1  2  3  4  5  6  7

Inte alls synlig  Mycket synlig

[Vid första anblick, anser du att du såg vad det stod för ord på alla ställen i videoklippet?]

Markera endast en oval.

Ja  Nej

[Om det fanns något eller några ord du tyckte var otydliga, vad anser du att det berodde på?]

Om möjligt, försök gärna förklara på vilken plats ordet eller orden som du tyckte var otydliga var placerade, eller vad det stod för ord.

Videoklipp 3 av 8

[Om en skala mellan 1-7, hur synlig tyckte du att texten i denna video var?]

Markera endast en oval.

1  2  3  4  5  6  7

Inte alls synlig  Mycket synlig
13. Vid första anblick, anser du att du såg vad det stod för ord på alla ställen i videoklippet? *
   Markera endast en oval.
   ☐ Ja
   ☐ Nej

14. Om det fanns något eller några ord du tyckte var otydliga, vad anser du att det berodde på?
   Om möjligt, försök gärna förklara på vilken plats ordet eller orden som du tyckte var otydliga var placerade, eller vad det stod för ord.

15. På en skala mellan 1-7, hur synlig tyckte du att texten i denna video var? *
   Markera endast en oval.
   1 2 3 4 5 6 7
   Inte alls synlig ☐ ☐ ☐ ☐ ☐ ☐ ☐ Mycket synlig

16. Vid första anblick, anser du att du såg vad det stod för ord på alla ställen i videoklippet? *
   Markera endast en oval.
   ☐ Ja
   ☐ Nej

17. Om det fanns något eller några ord du tyckte var otydliga, vad anser du att det berodde på?
   Om möjligt, försök gärna förklara på vilken plats ordet eller orden som du tyckte var otydliga var placerade, eller vad det stod för ord.

http://youtube.com/watch?v=5rW5sNG5S3c
Videoklipp 5 av 8

18. På en skala mellan 1-7, hur synlig tyckte du att texten i denna video var? *
Markera endast en oval.

1 2 3 4 5 6 7

Inte alls synlig Mycket synlig

19. Vid första anblick, anser du att du såg vad det stod för ord på alla ställen i videoklippet? *
Markera endast en oval.

Ja Nej

20. Om det fanns något eller några ord du tyckte var otydliga, vad anser du att det berodde på?
Om möjligt, försök gärna förklara på vilken plats ordet eller orden som du tyckte var otydliga var placerade, eller vad det stod för ord.


Videoklipp 6 av 8

21. På en skala mellan 1-7, hur synlig tyckte du att texten i denna video var? *
Markera endast en oval.

1 2 3 4 5 6 7

Inte alls synlig Mycket synlig

http://youtube.com/watch?v=CLWjYJbo2yQ
http://youtube.com/watch?v=6te2zXMRVJg
22. Vid första anblick, anser du att du såg vad det stod för ord på alla ställen i videoklippet? 

Markera endast en oval.
- Ja
- Nej

23. Om det fanns något eller några ord du tyckte var otydliga, vad anser du att det berodde på?

Om möjligt, försök gärna förklara på vilken plats ordet eller orden som du tyckte var otydliga var placerade, eller vad det stod för ord.

24. På en skala mellan 1-7, hur synlig tyckte du att texten i denna video var? 

Markera endast en oval.

<table>
<thead>
<tr>
<th>1</th>
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<td>Inte alls synlig</td>
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<td>Mycket synlig</td>
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</tbody>
</table>

25. Vid första anblick, anser du att du såg vad det stod för ord på alla ställen i videoklippet? 

Markera endast en oval.
- Ja
- Nej

26. Om det fanns något eller några ord du tyckte var otydliga, vad anser du att det berodde på?

Om möjligt, försök gärna förklara på vilken plats ordet eller orden som du tyckte var otydliga var placerade, eller vad det stod för ord.

Videoklipp 7 av 8

http://youtube.com/watch?v=cu6_VWzgrGY
Videoklipp 8 av 8

http://youtube.com/watch?v=YwWPRyG2KC0

27. På en skala mellan 1-7, hur synlig tyckte du att texten i denna video var? *
   Markera endast en oval.

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<thead>
<tr>
<th></th>
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<td>Mycket synlig</td>
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</tbody>
</table>

28. Vid första anblick, anser du att du såg vad det stod för ord på alla ställen i videoklippet? *
   Markera endast en oval.

☐ Ja  ☐ Nej

29. Om det fanns något eller några ord du tyckte var otydliga, vad anser du att det berodde på?
   Om möjligt, försök gärna förklara på vilken plats ordet eller orden som du tyckte var otydliga var
   placerade, eller vad det stod för ord.

   ___________________________________________

   ___________________________________________

   ___________________________________________

   ___________________________________________

Avslutande fråga

30. I det eller de videoklipp du ansåg att texterna var som synligast, vad anser du att det
    berodde på? *

   ___________________________________________

   ___________________________________________

   ___________________________________________

   ___________________________________________
31. Finns det något övrigt du skulle vilja tillägga är du välkommen att lägga en kommentar här.
Typografi i simulerad Augmented Reality

Augmented Reality, eller Förstärkt Verklighet som det brukar bli kallat på svenska, och förkortas till AR, är ett sätt att förbättra/förstärka en verklig miljö med digitalt skapade objekt eller text. Exempel på appar som idag använder sig av Augmented Reality är Pokémon GO, Snapchat, och IKEA Place.

Denna undersökning är komplett anonym och inga specifika svar kommer sparas på något annat sätt än i syfte att svara på examensarbetets frågeställningar. Testet innehåller åtta stycken 16 sekunders långa videoklipp med tillhörande tre frågor, tillsammans med några avslutande frågor.

Vad är din roll på Humbly?

Hur gammal är du?

Upplever du något problem med att se vissa färger?

Hur ofta, under den senaste veckan, har du använt mobiltelefonen för att titta på videoklipp via YouTubes mobilapplikation, eller via en extern sida som använder sig av YouTubes videospelare.

<table>
<thead>
<tr>
<th>Ingen gång</th>
<th>1 - 3 gånger</th>
<th>4 - 6 gånger</th>
<th>7 - 9 gånger</th>
<th>10 - 12 gånger</th>
<th>Fler än 12 gånger</th>
</tr>
</thead>
</table>
**Videoklipp 1 av 8**

På en skala mellan 1-7 hur synlig anser du att texten i videoklippet var?

![Synlighetsindikator]

Bra / Dåligt - Varför?
Om något kändes otydligt, vad anser du att det berodde på?
Vid första anblick såg du vad det stod?

---

**Videoklipp 2 av 8**

På en skala mellan 1-7 hur synlig anser du att texten i videoklippet var?

![Synlighetsindikator]

Bra / Dåligt - Varför?
Om något kändes otydligt, vad anser du att det berodde på?
Vid första anblick såg du vad det stod?

---

**Videoklipp 3 av 8**

På en skala mellan 1-7 hur synlig anser du att texten i videoklippet var?

![Synlighetsindikator]

Bra / Dåligt - Varför?
Om något kändes otydligt, vad anser du att det berodde på?
Vid första anblick såg du vad det stod?

**Videoklipp 4 av 8**
På en skala mellan 1-7 hur synlig anser du att texten i videoklippet var?

<table>
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<tr>
<th>1</th>
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Bra / Dåligt - Varför?
Om något kändes otydligt, vad anser du att det berodde på?

---

Vid första anblick såg du vad det stod?

**Videoklipp 5 av 8**
På en skala mellan 1-7 hur synlig anser du att texten i videoklippet var?

<table>
<thead>
<tr>
<th>1</th>
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</table>

Bra / Dåligt - Varför?
Om något kändes otydligt, vad anser du att det berodde på?

---

Vid första anblick såg du vad det stod?

**Videoklipp 6 av 8**
På en skala mellan 1-7 hur synlig anser du att texten i videoklippet var?

<table>
<thead>
<tr>
<th>1</th>
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</tbody>
</table>

Bra / Dåligt - Varför?
Om något kändes otydligt, vad anser du att det berodde på?
Vid första anblick såg du vad det stod?

**Videoklipp 7 av 8**

På en skala mellan 1-7 hur synlig anser du att texten i videoklippet var?

![Videoklipp 7 av 8](image)

Bra / Dåligt - Varför?
Om något kändes otydligt, vad anser du att det berodde på?

Vid första anblick såg du vad det stod?

**Videoklipp 8 av 8**

På en skala mellan 1-7 hur synlig anser du att texten i videoklippet var?

![Videoklipp 8 av 8](image)

Bra / Dåligt - Varför?
Om något kändes otydligt, vad anser du att det berodde på?

Vid första anblick såg du vad det stod?

**Avslutande frågor**

Vilken design av typografin ansåg du passa bäst in i en AR miljö? Varför?

Om du skulle använda typografi i AR.
Tre snabba, typografi i AR miljö.

Serif / Sans-serif  Ljus / Mörk färg  Light / Bold vikt