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Master Thesis

Space as a medium. On designing a GUI for HoloLens

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Przestrzeń jako medium: O projektowaniu GUI dla HoloLens

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The purpose of the following thesis is to analyse various aspects of spatial design and define practical principles for creating an effective Mixed Reality application. The research question undertaken in the thesis is the following: How to design an ergonomic user interface for a Mixed Reality application for HoloLens so as to enable a satisfying user-experience? The answer to this question is undertaken within the thesis and the findings served as a basis for the practical diploma piece. Firstly, technical capacities and limits of the HoloLens device will be described with the aim of setting up a clear, knowledge-based background for design choices. Then, a historical background of Augmented Reality will be outlined in order to identify dominant design solutions. To discern a user's influence and expectations, the next section of the thesis will analyse the characteristics of holograms' visual style presented in cinematography. In the subsequent section, an assessment of existing design rules will be given. Next, psychological findings relevant to spatial design as well as rules of ergonomic design will be discussed. Finally, an evaluation of the Spacey application will be presented.

Keywords: cognitive ergonomics, HoloLens, GUI (Graphical User Interface), Mixed Reality, meditation, multimodal perception

Celem niniejszej pracy jest analiza różnych aspektów projektowania przestrzennego na potrzeby określenia praktycznych zasad tworzenia efektywnych aplikacji Mixed Reality. Pytanie badawcze niniejszej pracy jest następujące: Jak zaprojektować ergonomiczny interfejs użytkownika dla aplikacji typu Mixed Reality dla HoloLens aby zapewnić satysfakcjonujące doświadczenie użytkownika? Do odpowiedzi na to pytanie wykorzystane zostaną przykłady dwóch procesów: badawczego i projektowego, a ich wyniki zostaną wykorzystane do ewaluacji praktycznej części projektu. Po pierwsze, aby uzyskać jasny i oparty na wiedzy o wyborach projektowych obraz tematu, przedstawione zostaną możliwości techniczne oraz ograniczenia urządzenia HoloLens. Następnie zrekonstruowane zostanie tło historyczne powstawania Augmented Reality, dzięki czemu czytelnik uzyska obraz obowiązujących rozwiązań projektowych. Ponadto, aby nakreślić zagadnienia wpływu i oczekiwań użytkowników, zbadane zostaną cechy hologramów obecnych w kinematografii. Następna część poświęcona będzie ewaluacji istniejących już zasad projektowania. W dalszym ciągu przybliżone zostaną zagadnienia z obszaru psychologii i ergonomii poznawczej relewantne w kontekście projektowania przestrzennego. W finalnej części pracy rozważone zostaną aspekty projektowe oraz opis samego procesu projektowania aplikacji Spacey.

Słowa kluczowe: ergonomia poznawcza, Mixed Reality, HoloLens, graficzny interfejs użytkownika (GUI), medytacja, percepcja multimodalna

Table of Contents

1. Introduction

The last decade witnessed the deployment of a number of futuristic inventions implemented into daily lives. Several science fiction scenarios have become the reality and Human-Computer Interaction acquired a new, deeper meaning. We have just started recognising the ubiquity of technology and have realised that blending both worlds, that of what is real and that of the virtual, is closer at hand than we could have imagined.

My field of interest is strictly associated with one of the current releases of Mixed Reality (MR). In contrast to Virtual Reality, here the user is not completely immersed in the created world, as the real world is intertwined with virtual components. This parallels a different form of VR, namely Augmented Reality (AR). However, whilst Augmented Reality presents elements without in-depth analysis of space, Mixed Reality uses spatial mapping and adapts to the arrangement of the mixed environment[1].

The most popular device for Mixed Reality is the HoloLens device manufactured by Microsoft Corporation. HoloLens is a head-mounted display which allows the user to interact with the artificially created world by means of natural gestures. There are three ways to interact with this hardware: through gaze, gesture and voice commands. These are accompanied by an additional tool: a clicker designed to be used by the user’s hand. Equipped with multiple sensors, HoloLens is sensitive to body movement and can analyse the surrounding space with spatial mapping as well as create spatial music experiences.

Elements of the holographic display can be pinned to specific locations or connected with the position of the user. However, the device has been projected according to some rules, and it has internal limitations, which the designer needs to analyse and anticipate. Narrow Field of View (FoV), colour separations and shivering images – these are just a few examples of HoloLens bugs.

The introduction of HoloLens has given rise to favourable circumstances in the exploration of new approaches to display design in a context that has never been tested before. These possibilities have led designers to create situations that can cross the boundaries and push the limits of possible experience. Moreover, mixing realities creates questions and places the designer in a new, unexplored position. As technology improves, users come to expect more from it. Especially when the virtual components are not encapsulated in the virtual world but need to fit into the human natural environment.

[1] Yuichi Ohta, Hideyuki Tamura, *Mixed reality: merging real and virtual worlds* (Dordrecht: Springer Publishing Company, 2014); Steve Benford, Gabriella Giannachi, *Performing mixed reality* (Cambridge, MA: The MIT Press, 2011).

This technology has had an enormous impact on several industries over a relatively brief time. For instance, planned market investments of Virtual Reality are estimated to reach about 200 billion dollars by 2025[2] and the phenomenon of its market expansion is being compared to the release of mobile phones[3]. This estimate reflects an ever-expanding presence of technology in the near future for users, but it also underlines the idea that virtual displays have a tremendous value for investors and leading companies.

Already today, numerous companies and individual designers are developing new methods of enriching the experience of 3D users. Introducing the technology into everyday use imposes and requires conscious and responsible decisions on the part of the designers. It is indisputable that technologies have exerted influence on the nature of man. Technology has become an integral part of a culture that shapes and reflects the values of the current social system[4].Creators are facing a new dimension of experience, in which the user's senses are engaged in a new way which has not been tried before and interacting in their natural environment not just with the real but with entirely virtual components[5].

Creating a convenient and ergonomic application requires a comprehensive approach to designing as well as knowledge of the ways, in which senses participate in the Human-Computer Interaction (HCI). In this new context the HCI should be analysed and redefined if needed. A comprehensive approach must be adopted in order to achieve the goal of creating an effective design system. Firstly, the design's form should follow and fulfil its function, then, through visual appearance, it ought to please the user and enhance the experience. A consistent structure of the visual language should imperceptibly sensitise one to aesthetic and formal aspects.

In this state of affairs, we need to ensure that users follow their natural reflexes while using the application, all the while also resorting to their habits, and so we need to reflect as well upon their expectations from the past, when they were using previously available technologies. As the challenge of creating this kind of experience appears to be very complex, designers need to have comprehensive, science-based guidelines which they can use during the designing process. One could say that this kind of solution can multiply the effectiveness of people's work and also could prevent design and

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[2] "Global Virtual Retinal Display Market - Growth, Trends and Forecast (2018 - 2023)", Mordor Intelligence, accessed July 10, 2018, https://www.mordorintelligence.com/industry-reports/virtual-retinal-display-market.

[3] "What Comes After Smartphones? The Next Mobile Computing Platform Is Already Emerging", CB Insights, accessed August 10, 2018, https://www.cbinsights.com/research/mobile-computing-platform-future.

[4] James Rutherford, Andrew Ahlgren, "Science for All Americans: A Project 2061 (American Association for the Advancement of Science, 1990)", 67.

[5] Wiliam R. Sherman, Allan B. Craig, *Understanding Virtual Reality: Interface, Application, and Design* (Burlington: Morgan Kaufman Publishers, 2002), 21.

interaction mistakes, for which there obviously is no place in a 3D-environment experience. Any errors occurring during the use of an application can frighten, frustrate and as a result discourage a person from future usage.

According to the fact that the body of knowledge about HCI has been growing tremendously since the 1990s, by studying spatial interactions we have obtained a source of knowledge, to which we can refer[6]. Consequently, the improvement of design principles should become the object of a thorough study that takes into account both design concepts as well as a wide range of issues connected to the field of perception.

The shift from traditional to spatial design opens up a discussion about the sustainability of already existing principles. The guidelines that have been established for VR and AR cannot be mereley be reapplied to HCI without proper analysis, as both technologies pose a different set of questions and challenges. HoloLens has its own manual, but it has to be remarked that Microsoft focused on developing applications more than on design principles. Individual developers and designers are working on exploring good and bad practices and spread their knowledge through thematic portals and forums. However, their discoveries are often presented in a simplified way and outside of a broader context.

As we are no longer dealing with just a screen or a sheet of paper, but instead with a three-dimensional space, then consequently the designer is positioned in a whole new set of circumstances, one could go as far as to speak of a previously unknown working environment. Extending the boundaries of experience has increased the range of skills required from the designer. There is no place for mistakes when designing holographic applications. It is not only the requirements that change but also the process of creation itself; when the graphic design is part of a complex project, there is not much room for intuitive solutions. Every change and every mistake may cost the project considerable amounts of time and money. Obviously, there is space for testing in terms of the project's proper behaviour and implementing adequately grounded alterations, but undeniably this environment allows for significantly fewer changes than when one designs for computers. A sustainable system based on a set of tested and researched principles could facilitate the process of creation, and this could in turn minimise the possibility of failure.

The distinctive nature of HoloLens requires a sensitive approach in design and exhaustive research-based displays. The designer, as a person who shapes and creates this experience, must first of all be aware of the explicit regulations which govern cognitive processes. It is a consequence of the multidimensional involvement of the user while using the application. Connections between the

[6] David Kirsh, "Embodied cognition and the magical future of interaction design", *ACM Transactions on Computer-Human Interaction (TOCHI)* 20, no.1 (2013): 3-30.

human user and the environment, as well as a hybrid of the real and the virtual worlds come to light. Consequently, the designer needs to be aware of the consequences of the intricate web of mutual relations between man and their surroundings.

A designer must take under consideration the limitations of human nature, impulses and behavioural patterns shaped over the last decades of interacting with different types of devices. At a time when people are living immersed in all-embracing technology, its impact and its effects on their behaviour and their psyche remain undeniable. This should draw our attention to making design responsibly.

The whole body of the user is engaged in this experience[7]. Arranging design elements inappropriately can easily cause exhaustion of the user and even cause pain and muscle soreness. Three-dimensional Human-Computer Interaction requires comprehensive studying, whereas research must take into consideration major mechanisms such as human information processing or perceptual-motor behaviour. This is due to the complexity of the design process, which in this case has tremendous importance in creating a user-friendly environment. Further research on scientific field is needed to improve Graphical User Interface.

[7] James Hollan, Edwin Hutchins, David Kirsh, "Distributed cognition: toward a new foundation for human-computer interaction research", *ACM Transactions on Computer-Human Interaction (TOCHI)* 7, no. 2 (2000).

Chapter 1: Background to the theory of Mixed Reality

The first part of this chapter will present the Virtual Reality Continuum and the concept of Mixed Reality in the context of the taxonomy of the former. The history of AR will be presented with the aim of exposing dynamic development of this branch over the last 50 years due to its direct interconnections between Augmented and Mixed Reality[8].

The most important examples of the interfaces created will be analysed in terms of use and development of visual style, composition and typography. Furthermore, the construction of the HoloLens device will be described with the intention of better understanding its specificity and its mode of operation. That part will show the limitations and possibilities of HoloLens. This will provide background for and help understand the proposed rules of design.

We cannot underestimate just how much pop culture has influenced users' expectations of holographic applications. Three dimensional, interactive optical representation displayed in space has been stimulating and captivating everybody's imagination since the early 1970s. This gave rise to somewhat peculiar expectations. A brief history of Mixed Reality depictions in a movie industry will be presented in order to analyse the leading trends of visual representation of it and present the background and the significance of the use of holograms. This part shows graphical expression not limited by technical restrictions, and will attempt to verify whether the solution can be implemented using HoloLens.

Virtual Reality Continuum

The Virtual Reality Continuum (VRC) diagram was presented by Paul Milgram and Fumio Kishino in 1994. VRC visualises the systematics of worlds stretching between the world of the virtual and the real one. The more immersive the system is, the less of elements of the real world are to be found in it. Scientists included four stages in the diagram: Real Environment, Augmented Reality, Augmented Virtuality and Virtual Environment. With the development of technology, the number of stages which could intersect in this diagram increased by mid-sections and hybrids of the above-mentioned worlds[9].

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[9] Paul Milgram, Fumio Kishino, "A Taxonomy of Mixed Reality Visual Displays", *IEICE Transactions on Information and Systems*

E77-D, no. 12 (1994), accessed September 20, 2018, http://www.alice.id.tue.nl/references/milgram-kishino-1994.pdf.

A different approach to perceiving realities is presented by B. Joseph Pine II and Kim C. Korn in *Infinite Possibility: Creating Customer Value on the Digital Frontier.* To describe these realities they use three variables: Time, Space and Matter. They base their idea on a concept from the field of physical cosmology – the Multiverse. Originally, this idea included the conviction about the existence of many worlds which contain in themselves all the things that man has defined and which can be described through the laws of physics and constants. Many of these worlds exist at once in a parallel relationship. In their concept, they assumed that the VR, AR and the real world differ in the relationship between Matter, Time and Space. Augmented Reality functions in Time and Space, but is devoid of living or tangible matter. Virtual objects are not considered as part of the Matter domain.

Mixed Reality

In the article published in 1994 by the Institute of Electronics, Information and Communication, engineers, Kishino and Milgram described a creation between the virtual and the "real" reality as a hybrid of these two environments. Previous technological discoveries differed significantly from the tools at our disposal today, but their taxonomy, despite the passage of time, is still of great value. With the hope of better understanding their classification, I shall lay out their basic definitions.
"Real objects are any objects that have an actual objective existence.
Virtual objects are objects that exist in essence or effect, but not formally or actually." (Paul Milgram 1994)[10]
These statements mean that an action needs to be performed to make a *virtual object* visible, the realness of *real object* always being an incontestable fact. Microsoft divided and placed HoloLens experiences on the spectrum between Digital Reality and Physical Reality. Their position between them relies on the level of digitalisation and usage of virtual elements in the context of an application. Microsoft recommends getting acquainted with the possibilities offered by them at the initial stage of application design in order to fully exploit their potential.
The main goal of MR developers is to create such a system that will enable the user to receive virtual applications in an individual, unrestricted manner.

HoloLens technical limitations and possibilities

HoloLens is the first tetherless holographic computer which allows to perceive reality extended to virtual objects. It is a high-end device that enables human-computer interaction in an innovative way.

[10] Ibid.

Its hardware component and technical details of holographic projection display will be described in this chapter in order to illustrate the possibilities and support future design decisions.

Sensor bar

This device is able to scan the environment and map the surfaces. This is achieved through several sensors mounted at the front. It has four environment-understanding, greyscale cameras which create a map of the room. One depth IR camera which allows the device to react in live time, which is based on the Time-Of-Fly technology. This camera is also responsible for recognising surfaces, understanding hands tracking and reading object positions. An additional HD Video camera is placed in the centre of the device, which allows user to take photos and shoot videos while using HoloLens, as well as recording the surrounding space with holograms. The resulting video is not limited by Field of View frames. There are also four microphones.

Optics

Optics of HoloLens rely on the mechanism of waveguides. Diffractive waveguides are superimposed on one another, with every one of them being dedicated to present a different RGB colour. They can produce bright, good quality images without the ghosting effect.
In the front, there is a system of IMU which contains Gyroscope, Magnetometer and Accelometer which provide fast position updates. Optics mechanism relies on two see-through holographic lenses and two light engines placed between the lenses. It has two High Definition light engines in proportions of 16:9 located at the top of the screen connecting element. They retrieve visual information that passes through a part called the combiner to process this and as a result create a space containing real and virtual images. These engines are responsible for projecting images onto the lenses with holographic density of around 2.5K radiant. It also has automatic pupillary distance calibration.

Internal hardware

As a high-end device, HoloLens has 64GB of Flash memory, an Intel Atom Processor and a custom-built Microsoft Holographic Processing Unit HPU 1.0 and a GPU Intel 8086h, Dedicated Video Memory of 114MB and Shared System Memory.
HoloLens is equipped with see-through lens with a length at the widest point of 21 cm with a curve of about 30 degrees and 5 cm at the thickest point.

Spatial Sound

HoloLens provides a unique 3D audio experience, which was based on a researched scientific model of how the ear receives sounds from a defined location, and Microsoft exploits the results of these findings to provide a dynamic sound system. The audio behaves differently depending on its position.

Spatial Mapping

Spatial mapping is a kind of analysis of the environment around the user that the HoloLens performs and transfers to internal memory. Thanks to this, it is possible to interact with the user's environment in a natural way.

The main function that uses spatial mapping is Placement, thanks to which we can place virtual elements on appropriate surfaces, such as tables, floors, walls or even ceilings.

What makes it possible to obtain the impression of a natural presence of an object in a real environment is called occlusion. It's a technique that visually subtracts a piece of virtual element to give the user the impression that this element is actually hiding behind the real object.

Types of the HoloLens applications

The different types of applications possible to experience with the HoloLens have been divided by Microsoft into three groups: enhanced, blended and immersive environment.

The first one makes use of the user's natural environment and enriches it with information relevant to the context of the application and updated on an ongoing basis. They are designed with the purpose of naturally enhancing the user’s surroundings and letting them freely switch between regular tasks and digital ones. Examples of this kind of applications are: cooking assistants, communicators such as Skype, TV apps, applications dedicated for industrial workers[11].

Blended environment applications use Spatial Mapping in a similar way as the before mentioned one but with the knowledge of accessible surface they decide about the optimal placement to achieve the best possible performance. This type of application can even turn a real element into a completely different one, while preserving its physical values by means of overlapping layer. Examples of this include home decor apps, applications which show the underlying virtual world.

The last type of application is the immersive one. This feature makes the HoloLens an extraordinary tetherless device that allows its users to experience both VR and AR. This kind of app completely changes the user’s surrounding into a virtual interactive projection.

[11] “Types of Mixed Reality Apps”, Microsoft Docs, accessed December 10, 2018, https://docs.microsoft.com/en-us/windows/mixed-reality/types-of-mixed-reality-apps.

The creative possibilities offered by the HoloLens are really wide. Each application can combine and mix many types of applications, the only barrier is the designer's imagination and the developer's skills. However, when switching the user between complex scenes, it is worth informing them about the upcoming experience or to do it naturally and create an intuitive platform based on behavioural patterns.

Hologram

The term hologram comes from the Greek expressions ὅλος (*holos),* which explicitelly means "whole", and γραφή (*graphē*), referring graphic, image or writing. Nowadays, the hologram can be described as a 3D projection of an object that can be observed from every angle. It can be created by the interference of light beams from a light source. In the HoloLens, the hardware lenses are in fact holograms that come from the technique of display, although the projection itself is called a hologram to unify and simplify the used nomenclature[12].

It is important to underline the fact that not every hologram will be classified as being an element of a Mixed Reality world. Classic holographic displays, independent from any performed action in the real world, wouldn't be counted as such. The outstanding feature of the Mixed Reality is the ability of holograms to interact with real objects and respect grounds, ceilings, surfaces of furniture and elements of the interior. Talking about the perceived experience of this technology, contrary to Virtual Reality, users are not scared and overwhelmed by the experience as they feel safe and confident in their usual environment. From an economic point of view, it is worth mentioning the estimations of analysts from Juniper Research and Goldman Sachs who expect the AR market to grow about 20-100 times in the coming 5 years. At the moment, investments in the AR market significantly exceed those in the VR market, and this difference is expected to grow even further. The unbeatable rise and increasing popularity of Augmented Reality make it one of the most exciting new technologies in the world.

Culture has a certain impact on the users' expectation of the appearance and experience of Mixed Reality. This topic has been mentioned for around 50 years in Science Fiction films, from mainstream productions to alternative TV shows, holograms were portrayed with the generous visual outcome what trained users to expect powerful effects[13]. Nowadays, despite the character of application, the main dissatisfaction comes from the narrow Field of View (FoV)[14].

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[12] *Cambridge Dictionary*, "hologram", accessed November 11, 2018, https://dictionary.cambridge.org/dictionary/english/hologram.

[13] F. J. Rutherford, A. Ahlgren, op.cit.

[14] Kharis O'Connell, *Designing for Mixed Reality. Blending Data, AR, and the Physical World* (Sebastopol: O'Reilly Media, 2016).

Augmented Reality (AR)

This reality can be described as a state where computer generated components displayed on a device such as graphics, audio or other sense enhancements are superimposed on physical environment. Ronald Azuma presented the definition of AR as the system combining the real and virtual world, which enable the user to interact with components in real time in a 3D space[15].

These elements can interact with the user in real time while the physicality of the real world does not affect their appearance. Virtual elements only overlap with the real world. Augmented Reality can be triggered and induced only by an external device. The most popular ones called "see through" are smartphones and tablets. Another way to experience AR is to use specially dedicated head-mounted hardware like Google Glass or Meta 2.

Typography in Augmented Reality is the main medium of providing information. The user follows by written messages and get leads and suggestions of possible use over the whole application. As the audio information may also be used, the visual language is more universal.

AR has already crossed the border of entering the market and has become widely used for entertainment and advertising. Regardless of the purpose of usage, the technology and graphic design have been rapidly evolving from 1995, while the patterns in typography are easily recognisable.

Differences between Mixed and Augmented Reality

In both Realities, Augmented and Mixed, the real world is intertwined with virtual components. However, whilst Augmented Reality presents elements without in-depth analysis of space, Mixed Reality uses spatial mapping and adapts to the arrangement of the environment. In 2018, more advanced AR technologies entered the market, mainly dedicated to shopping and furnishing apartments. IKEA's applications, Shopify and ARKit, are using tracking to detect user's environment and place objects in a more realistic way. Despite this similarity to Mixed Reality, where Spatial Mapping is able to scan the whole environment, the before mentioned AR applications allow virtual things to obtain real but not complicated surfaces, only flat and horizontal ones. Therefore, one could say that MR elements of Holographic applications can interact with the discovered space more realistically.

Taking into account the visual style and the number of existing applications (and the fact that AR's artistic manifesto has been consistently developed thanks to a common access to software as well as the ease of creating of such works) Mixed Reality applications are more and more enthralling and allow for a greater interaction with and the perception of Mixed World.

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[15] Eugene Ch'ng, Albert "Skip" Rizzo, and Roy Ruddle, *Presence: Teleoperators and Virtual Environments* 6, no. 4 (1997), 355-385.

Trend Analysis

In order to research the new technology and anticipate its directions, it is worth analysing the assumptions that prevailed in the field and how they developed. Historical analysis is an indispensable part of trend analysis. Thanks to such estimates it is possible to draw conclusions and determine the strength and direction of interactions between trends. Although the HoloLens is the first MR device, it has its roots in the history of the AR, which is why it will be analysed below. It still remains, however, a very expensive device, which makes it difficult to access, and its development complicated.

History of Augmented Reality (AR)

Augmented Reality was first announced in 1968, when professor Ivan Sutherland with his students from Harvard University and the University of Utah presented their invention – a head-mounted device called "The Sword of Damocles"[16]. Name was inspired by a Greek tale. The expression itself means that *"something big is hanging over you/your head"* by which scientists referred to the device's tremendous size because of which it needed to be hung from the ceiling.

This see-through head-mounted system presented simple computer-generated wireframe drawings. An example of it is presented above on a screenshot from a documentary about the experiment. The scope of this project was to support pilots during night landings[17]. Data was designed to be displayed in front of the user's eyes, which could prevent pilots from being distracted by changing of viewpoint and present important data without diverting attention from a control panel.

Sutherland's invention pushed forward the development of interactive environment technology. In 1974 Myron Krueger built Videoplace, which can be qualified as an Artificial Reality device. He established a laboratory of interactive and immersive space which gave feedback on the movement of users. The experience was not restricted by any external device, movement controllers transmitting information about position and motion. The installation created a visual response in real time. Videoplace was the first art installation which allowed users to interact with computer-generated components in real time. This invention pushed the borders of a typical interaction with computers to the active experience in a never before seen environment. Even despite the limitations of technology, Krueger built a successful, novelty and visually pleasing experience[18].

[16] Rick Van Krevelen, (2007). Augmented Reality: Technologies, Applications, and Limitations. 10.13140/RG.2.1.1874.7929.

[17] Ivan E. Sutherland, "The Ultimate Display", *IFIP* 65 (1965): 506-508.

[18] Douglas Dixon, "Augmented Reality Goes Mobile", Manifest Tech, accessed June 20, 2018, https://www.manifest-tech.com/society/augmented_reality.htm.

In 1980, professor Steve Mann, named “The Father of Wearable Computing”, invented the first head-mounted, tetherless computer which reminds actual devices the most. His thorough research was dedicated to exploring the possibilities of computerised eye-glasses. In his visions Mann predicted a future, where people freely wear computer systems to enhance their usual possibilities. His works were limited by technological restrictions, nevertheless, he succeeded in developing the EyeTap. This device after conducting analyses of the environment gives feedback with information to the user. EyeTap displays graphics and is equipped with a tracking technology allowing the computer to modify the generated scene in real time. Possible uses of this device included the stock market, sports and entertainment. Therefore, EyeTap was the first AR device dedicated not for army training or medical purpose but for personal use.

In 1990, Tom Caudell first coined the term “Augmented Reality” with display of representative media mixed with reality[19]. At that time, Tom Caudell was working at the Boeing Computer Services in Seattle. This department was working on a system which would help workers in the building process information with an AR device which displayed overlapping graphical instructions. In 2018, with the spread of technology and its development, it becomes common to use AR to improve efficiency in large companies. However, the idea and general concept remain the same.

In 1992, Louis Rosenberg presented the first working AR system for training pilots in the US AirForce[20].

The invented system of overlapping information increased people’s effectiveness at work by a system of assistance performed in real time. The system was constructed with an external armour and binoculars.

In 1993, Steven Feiner, Blair MacIntyre and Doree Seligmann introduced a system called KARMA: Knowledge-based Augmented Reality for Maintenance Assistance. They were the first group of designers who emphasised the role of proper visual communication in AR. In their paper about the IBIS system (Interactive Intent-Based Illustration: A Visual Language for 3D Worlds), they considered and then rejected multiple ways of visual communication, and referred to the meaning of visual styles to underline their approach: design should be functional and effective. What is worth mentioning is their approach to the effect of each graphic element that can autonomously create disturbances but also act as a part of a system that can create *constraints*[21]. They have underlined that in a properly designed experience, what the user sees and perceives is a whole image without much

[19] Donna R.Berryman, "Augmented reality: a review.”, *Medical Reference Services Quarterly* 31, no. 2 (2012): 212-218.

[20] Tony Sperry, *Beyond 3D TV 2010* (Sperry Publishing, 2010).

[21] Steven Feiner, Blair Macintyre, Dorée Seligmann. “Knowledge-based augmented reality.” in: *Communications of the ACM - Special issue on computer augmented environments: back to the real world,* (CACM Homepage archive, 1993), Volume 36 Issue 7, 53-62.

separation. To sum up, what we can learn from this design group is that ultimately the user will perceive the graphic elements and their environment as a complete system. From this point, we can conclude that when designing for these hybrid environments, we should try to create an effective system in every possible environment.

Medical applications were developed and carried out in 1994 at the University of North Carolina at Chapel Hill, which allowed doctors to see foetuses through the abdomen skin of a pregnant woman. It was one of the first applications of this type to start further work on medical programs, showing the great potential of this technology. (picture: View of the inside of the womb of an expecting mother. Courtesy of Andrei State, UNC Chapel Hill.)

In 1994, Julie Martel presented his first theatre performance using AR. The actors played together with virtual objects, performing complex stunts around computer-created elements. With their movement and behaviour, the acrobats kept the specific space of the installation.

In 1995, the first handheld Augmented Reality system was developed. With this invention, the name of Augmented Interaction appeared for the first time. The AR computer was meant to be a user's assistant. The hardware was a small palmtop with a see-through system, in which the interface displayed computer-generated information triggered by a particular image. Authors Jun Rekimoto and Katashi Nagao were predicting that their device, after upgrading it with the special detector, will outrun the Personal Computers (PC) in becoming the daily use device[22]. NaviCam presented information after detecting the previously programmed visual code. This was the first software which contained a graphical structure which could be described as a simple Graphical User Interface. Typography was the main transmitter of information. The only additional graphic elements were navigational arrows also accompanied by text information. NaviCam had two applications, one dedicated to displaying additional information about still objects such as paintings or bookshelves, and the second which showed the way and displayed leads in real time on the screen. Both of them worked according to the same mechanisms – the device recognises the code, displays data and produces sound communication about the performed action.

In 1996, Studierstude system was released. This AR application was dedicated to teaching mathematics and geometry to secondary school students. Many people at the same time were able to observe the three-dimensional elements in the classroom and contemplate them from different angles. The objects kept correct proportions regardless of the point of view. It was a first shared AR application. Studiestrude researchers have identified four features of cooperation in AR: Virtuality,

[22] Jun Rekimoto, Katashi Nagao, "The World through the Computer: Computer Augmented Interaction with Real World Environments", in: *User Interface Software and Technology* ed. G.G. Robertson (Pittsburgh: ACM Press, 1995), 29-36.

Augumentation, Cooperation, Independence. The most interesting of which is the latter, which states that each of the users has their own point of view under control.
Between 1997-2001, Mixed Reality research company was established in Japan, funded by the Japanese government. The most notable invention at that time was the COASTAR, the first video see-through head-mounted device[23]. In 1999, they developed a Mixed Reality multiplayer game called RV-Border Guards which allowed users to intuitively use natural gestures to control the action[24]. The plot was based on virtual creatures attacking real players. That description might somewhat resemble the game called RoboRaid released by Microsoft Corporation in 2016. In short, the vision of a fight against extra-terrestrial creatures attacking people has been with people since time immemorial. However, it is only this technology that makes it possible to experience it in controlled conditions.
What is worth mentioning is that Japanese scientists, designers and developers carried out a lot of scientific research that can be of great value today. Unlike today, they had the time and the money to look at Mixed Reality in a very broad sense. They were also present and active at the beginning of the century when our everyday technological world was at the threshold of undergoing immense changes, which makes their perspective all the more interesting. Their work is in fact rich in details that we do not notice today because technology is a daily experience for an average person and we are, so to speak, desensitised to many of its aspects surrounding us.
After this project another one was created, which continued its assumptions, called MiRai-01. Its main goal was to promote this promising technology all over the world. The research was conducted to expand future knowledge and prepare the 21st century for responsible work with this technology[25].
In 1997, the first mobile AR system was released. It was called a Touring Machine and was created to show directions and explore environments. Creators of this system wanted to bring the idea of AR assistance to life and to be helpful in a regular day. They pulled the AR out of the rooms to the open space.
The system was hidden in a big backpack and was equipped with see-though head-mounted device. In a backpack operating system with wireless Wi-Fi and a GPS was hidden. The application overlaid the view with information about buildings or locations after receiving coordinates. The trial Map-in-the-Hat was released just one year later, which was also an outdoor navigation assistant.

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[23] Dieter Schmalstieg, Tobias Höllerer, *Augmented Reality Principles and Practice* (Boston: Addison-Wesley Professional, 2016).

[24] Toshikazu Ohshima et al., "RV-Border Guards : A Multi-player Mixed Reality Entertainment", *TVRSJ* 4, no. 4 (1999).

[25] Hideyuki Tamura, *Overview and Final Results of the MR Projects,* Reality Media Lab., accessed July 05, 2018, http://www.rm.is.ritsumei.ac.jp/~tamura/paper/tamura2_clc.pdf.

In 1998, Spatial Augmented Reality introduced at University of North Carolina at Chapel Hill by three scientists: Raskar, Welch, Fuchs. They created visually attractive virtual elements which coexisted with a real environment. It was unusual because they projected renders of the objects onto the natural space of man. They achieved unrestricted FoV by the projection displayed straightforward onto the real objects, although interaction with the synthesized image occurred only to a small extent[26].

In 1999 at HITLab, Hirokazu Kato created ARToolKit. This was an open-source collection of features that allowed to create AR applications. It used such options as camera calibration, optical stereo calibration, square marker generation, and natural feature marker generation utilities in the aim of creating a good AR experience[27]. Within 20 years, this library has grown and has become a fundamental element in the creation of AR experiences.

ARQuake was released in 2000 and is said to be the first AR outdoor game. It was a modified version of the iD Software's game Quake. They provided an original plot for the game but transferred it into the real world. The gaming world begins the expansion and development of Augmented Reality technology commensurate with people's increased interest in virtual games. In this system they used an upgraded version of the GPS, a head-mounted device, a mobile computer and a head tracker[28].

The first commercial use of AR took place in 2008. BMW used it in as a printed advertisement showed in three automotive magazines. Users needed to hold the advertisement up to the web camera and as a result, a 3D model of the MINI appeared. The model was sensitive to movement of the magazine and changed position and rotated with it[29].

In 2009, SixthSense from MIT presented gesture-based wearable AR. Prototypes of this device had been created with Steve Mann since 1994, but only in 2009 did the group of MIT developers achieve a satisfactory level of interaction and usability. Mann described the device as *Synthetic Synesthesia of the Sixth Sense.* He meant that this technology could constitute an enhancement of human possibilities and that it could play the role of an additional sense[30].

A French start-up called LASTER Technologies from the University of Paris developed the first AR ski goggles in 2011.

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[26] Ramesh Raskar, Greg Welch, Henry Fuchs, "Spatially Augmented Reality", in: *First International Workshop on Augmented Reality* (San Francisco, 1998).

[27] "ARToolKit", Wikiwand, accessed December 20, 2018, http://www.wikiwand.com/en/ARToolKit.

[28] "ARQuake: Interactive Outdoor Augmented Reality Collaboration System", Wearable Computer Lab, accessed November 25, 2018, https://wearables.unisa.edu.au/projects/arquake/#videos.

[29] Paul Strauss, "Mini Augmented Reality Ads Hit Newstands", accessed January 3, 2019, https://technabob.com/blog/2008/12/17/mini-augmented-reality-ads-hit-newstands/#

[30] "Synthetic Synesthesia of the Sixth Sense", Wearcam, accessed January 3, 2019, http://wearcam.org/6ense.htm.

AR was mostly popularised by the game Pokemon GO released to the mainstream market in 2016 by Nantic. In the period of two years it was downloaded 800 million times. The success of the game was the reason of an increase in the development of AR design.
From 2016 to 2018, Microsoft UX designer Dong Yoon Park was working on Typography Insight for Mixed Reality, which is an extension and continuation of his previous typography projects. He designed and developed an MR application which allows the user to play and work with typography in a 3D space. Using this application, the designer created a typographic sculpture at the Bellevue Arts Museum. As part of the interface, the program he has created allows designers to work with typography and actively explore its details in Mixed Reality.

Pattern recognition

To sum up, the future of Augmented technology aims to be in the shape of glasses. Regardless of the technological place of origin, where they are created, they are intended to improve human capabilities, develop abilities, entertain and generally make life easier. In terms of visual style, each manufacturer so far has emphasised the features of their company in the newly created devices. Microsoft simply refers to the appearance of Windows 10, Magic Leap wants to make its applications look hyper-natural. The solutions proposed by the above-mentioned companies for developers are tested and in most cases fulfill their role, but they are still strictly limited by technology. Some predict that when Apple releases its device, it will present a design that will capture the aesthetic predispositions of the majority of users as they are known for redefining existing technologies in their own unique way. Leaving aside the subjective assessment of visual style in general, it is worth focusing on design principles that will enable the user to use the AR application in changing conditions. In the future, further technological solutions will lead to greater capabilities of each of these devices, but basic problems such as too little or too much contrast between a virtual object and the real world will most likely continue to cause difficulties.
Due to the development of technology and more and more advanced AR and MR applications, the amount of information presented is growing. At the same time, there is a growing demand for ways of presenting this information properly while maintaining the highest quality of use.
The pattern that can be seen among the interfaces presented is the background under a displayed text. Such a solution improves the readability of the text if the contrast between the text and the background is sufficiently high. Nowadays, the HoloLens has a very good level of text display, so that its edges are crisp and the whole text is very legible. However, in the past they struggled with low readability even on screens, so you can guess how difficult it was to achieve proper readability in AR. They managed this in the above-mentioned way, with a coloured background under the text and a thin border around the text, which is a technique also known for displaying subtitles in a movie The use

of a contrasting background is currently the solution to the problem of a legibility of text resulting from an unpredictable background of the environment, recommended by Gabbard and Fiorentino in numerous tests on legibility of text in the AR environment[31].

Holographic imaginary in pop culture

Pop culture arousse curiosity and expectations of the holographic experience but has also affected the tech industry. With the development of technology, the complexity of presented concept rose, but overall some styles have maintained their characteristics. Holograms in films are used for various purposes, which we can group into the following categories: as a form of remote communication, to entertain, to improve human abilities or to present extra-terrestrial situations that break the laws of physics.

The first visual representation of holographic display was presented in a Sci-Fi animation *The Jetsons*, where a family had a holographic projector hanging straight from the ceiling. It was a part of their daily lives, comparable to nowadays usage of the TV set in typical middle-class household. Quality or colours of the presented scene did not differ from their own reality. Moreover, concerning animated series, in the TV show *Jem and the Holograms* the plot was based on the transformation of the main character with the use of a holographic computer named *Synergy*. The hologram was used to present *a better version* of the main character. The holograms allowed characters to perform superhuman capabilities. In 1974's Star Trek, we can find the *HoloDeck* (*Holographic Environment Simulator)*, a room equipped with technology allowing holographic display of the virtual world based on previously added data. The displayed image was not much different from the real world. In the film, it was created with the aim of presenting existential considerations and entertaining crew members during space travel. In 1977 *Star Wars: Episode IV – A New Hope*, Princess Leila Organa was projected by the R2D2 robot. In this case, the characters used holograms to communicate remotely with each other. Her silhouette was semi-transparent, a very bright and vivid shade of blue. This representation of a hologram enhanced people's imagination and inspired the development of 3D volumetric displays. It also created taste and expectations of the visual form of holograms in the broad range of what is easy to observe, especially on the internet. Lively debates about holograms are held on numerous forums and discussion groups. More and more fans declare that they are still waiting for the device which will display image in the same way as the one of Princess Leila was.

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[31] Michele Gattullo et al., "Effect of Text Outline and Contrast Polarity on AR Text Readability in Industrial Lighting", in: *IEEE Transactions on Visualization and Computer Graphics* 21, no. 5: 638-651.

In *Batman* (1989), a hologram concealed the entrance to the batcave. A glimps from the future was presented in *Back to the Future Part II*. In the film, taking part around 1989, a clip of a 3D holographic film from 2018 was presented, but even the main character undermined the visual style of the 3D element. This case is very interesting, because the creators of this film accurately predicted the trends that were to come to life in the future. The current virtual objects available in Microsoft's library, for example, are visually very similar.

The first wearable holo-device was presented in the 1990 film *Total Recall* as a wrist-held small projector which enabled the user to make their holographic double. After the destruction of the displayed human image, the visuals start to glitch and the "natural" linearity of a display was depicted. Additionally, a holographic display was used by one of the characters as a training partner for tennis. In *Vanilla Sky*, we can find the projection of a jazz musician displayed from the device put on the floor. This display did not look like a real person, but the computer essence of it was easy to recognise. Science Fiction culture quickly adapted the concept of holographic displays, with the development of technology they were presented in a more and more sophisticated way.

The breakthrough moment can be traced back to the year 2000, when tools and applications enabling interaction and creation of AR applications were launched on the market. The general technological progress and the decrease in prices of computers not only improved people's abilities, but also the aesthetics of the image. Films began to use visual metaphors based not only on imagination but also on the interpretation of actual possibilities.

In 2002 Steven Spielberg’s *Minority Report*, a holographic UI is shown to be controlled by hand gestures. This invention did not remain just in the domain of film fiction. John Underkoffler, who worked as a science advisor for this film, made available the device on which he worked. G speak is a technology that allows real-world entities to control the computer by hand gestures. The device is able to recognise data arising from active movement. This spatial interaction was groundbreaking, but the feedback returns to the user nowadays only as non-spatial information. The graphics were based on bright, small elements, mainly graphic and text information. The interface was arranged spatially, usually semi-circularly around a person and its reception was not limited. Such a solution fulfilled the expectations in the dark rooms, where the action of the film took place.

Most similar to nowadays interfaces was the one presented in the film *The First $20 Million Is Always the Hardest* in 2002. The plot was based on the adventures of releasing a holographic computer. The presented holographic projections concern personal computers. Colours are vivid, semi-transparent objects known from current devices. Many animations appear in front of the user, interaction with the interface is possible by physically touching the hologram. Such a system is currently the goal pursued by the largest technology companies.

In the 2004 film *Sky Captain and the World of Tomorrow* holograms were used as a medium to express a quite specific idea. Through the hologram a posthumous character was presented called *Dr. Totenkopft*, also posthumously portrayed by the actor Sir Laurence Olive, who had been dead at that time for 15 years and the scenes were created based on archive footage. Again, the hologram was used to present the persona from another space. Doctor Totenkopft was displayed as a glowing, light blue head projected from two lookalike Tesla coils.

Paycheck in 2005 presented another gesture-controlled computer display. We can notice the following pattern of bright elements floating above the desk. Also in 2005, the film *The Island* conveyed the idea of a holographically created reality imitating the real world. Many times holograms were used in creations such as *Voyager, Star Trek: The Next Generations, Stargate* as very complex visualisations of people or situations.

In *Prometheus* the presented holograms had a very complex and interesting form. In fact, the HoloLens is able to display graphics in a similar way, although the limitation created by the narrow Field of View are depreciating this kind of experience. In the before mentioned film, holograms were interactive and displayed without any additional wearable devices, they came from a stationary computer. Their colours were bright, semi-transparent and with a visible grid.

In 2012's *Total Recall*, which take place on a dystopian Earth, there are complicated usages of holograms in the plot. The presented interfaces are based on textual information.

Comparison of visual styles

Holograms in films showed projections of remote communication, in which we can see the body of the interlocutor, and used them to show things impossible and extra-terrestrial, or to create a projection imitating the real world. Based on the interfaces presented in the Sci-Fi movies, we can determine the advantages and disadvantages of the presented solutions in the context of currently available applications. Their spatial appearance in some way shapes the ideas and expectations of users. A dream interface would surround the user's space, would be interactive with natural gestures, it would even be possible to physically move the projection. Huge amounts of information, despite the consistent appearance and low contrast between them, would be easy to read and to extract information from. At the beginning of showing holographic projections in films, they were used to create an image that represented reality as accurately as possible. Slowly a style entered, in which the hologram usually was of blue coulor, there were visible minor disturbances or stripes regularly passing through the projections, most likely to visually reassure the user about the essence of the holographic projection. The blue colour commonly used to represent the holograms can most probably be explained by the fact that its creators wanted to refer in some way to scientific solutions. Namely, blue light has the shortest wavelength, so it has the potential to be displayed best, it's projection visually seems to be much sharper than that of red or green light.

Light blue is also seen as an extra-terrestrial colour, used in culture and art to represent ghosts, phenomena or ectoplasms. Holograms in films were also used to depict things that do not have a rational argument to be real earthly objects. The visual style of presenting phenomena was giving the outer world a magic-like impression. Projections were much brighter than their surroundings, presented with outer aura created by saturation of light.

In summary, with the developing technology, the way of presenting holograms turned into more visually sophisticated. Mutual influence of on the other cannot go unnoticed. Both the technology and the film industry interact with each other and with the mass of viewers, shaping their expectations and feelings about the future. In the beginning, the hologram was presented as a double of the real vision and with time it turned into complicated spatial interfaces full of elements. Some visualisations were directly interactive and the holograms were displayed independently, the user was not limited by wearing additional equipment.

In visual style, bright, slightly glowing, vivid colours rule, at least in the biggest budget productions. Nowadays, expectations regarding holograms can be divided into two groups. In other words, users expect blend the two worlds of the real and the virtual or enhancing their environment in a distinguished way. In one group, we can place holograms that look very real, perfectly imitating the real world and its objects. The technical challenge of this solution lays in the system of displaying images in the HoloLens – it's not able yet to perform this quality of an image and make elements not even semi-transparent. Another disadvantage mentioned by Kharis O'Connell "can appear when humans will perceive *virtual objects* as *real objects*"[32.] As a result, dangerous situations can occur, not only in physical life like accidents but also dangerous changes to the human mind. However, the many functions the HoloLens has in mapping space and adapting interactive elements to the real world suggest that Mixed Reality seems to want to blend in with the natural world.

The opposite approach is more about stunning graphical visualisations. Bright colours with an outer glow, neon-like, lively animations and extra-terrestrial style make an impression and meet the expectations of users. The HoloLens operates on an additive system of displaying colours which enables creating attractive and distinct tinges that can enrich the overall looks of the application.

Microsoft used the typical appearance of Windows 10 as the interface for the HoloLens. This solution makes it clear what is an interface and what is an application, but it does not bring the maximum possible joy and does not take advantage of the opportunities this device brings. The predominant visual style of 3D games can be seen in already released applications. Skeumorphism is already broadly recommended by the Microsoft. What's more, the many features of the HoloLens, such as mapping space and adapting interactive elements to the real world, suggest that Mixed Reality wants to blend in with the natural world.

[32] Kharis O'Connell, op.cit., 12.

Skeumorphism is a way of designing a virtual object while maintaining its real visual properties such as texture. This technique is used with the aim of making the interface more familiar and more enjoyable for the user to easier implement the new technology. The appearance that is known from previous experience will make the user know what to do with the item and what to expect. However, it should be noted that a limited amount of information from the real world can be translated into the virtual world. Thanks to spatial mapping and interaction with the environment, the HoloLens is able to reproduce, for example, the weight of an object that falls, but is not able to translate all the properties of the object. Further complications may occur, users may not be familiar with the object whose interface style has been inspired, which makes the aforementioned goal unattainable. Therefore, it is important to use this solution carefully in order to preserve the aesthetics of the design. Magic Leap creators claimed that their aim was to create elements which will be *hyperreal* and to make them not easy to differentiate from the real-world elements.[33]

Enhancing the real world by the very realistic holograms is said to be even dangerous. It is known that during the use of AR applications, users focus more on the contents of the app than on the real world. People can lose the ability to distinguish between real and virtual elements, and take the created world too seriously. At this stage, when this technology is relatively new and has not entered the mainstream market completely, we cannot measure its impact on the human's mind. Inquiries have begun, but we will know the results perhaps too late to protect the future human beings from the not unlikely unwholesome impact. Head-mounted devices, independent of any external computers are designed to be more and more easy to use during normal day. They perfectly fit into the current mania of enhanced human's abilities and effectiveness. Everyday usage of Mixed Reality applications can bring with it multiple risks. Awareness of that should influence designers with the need of making responsible design decisions.

[33] Ibid., 11.

Chapter 2: Design

Firstly, this chapter will describe the specific aspects of designing for the HoloLens and propose the solutions based on the literature research and on my experience as a designer.
Secondly, the present chapter will provide an explanation of the idea of ergonomic design and user experience in Mixed Reality. It will also bring up topics from fields such as cognitive science, mechanisms of perception and Gestalt psychology, to create a comprehensive overview of the processes taking place during spatial interaction. A designer needs to understand human psychology, especially in order to create an efficient design system for the complex stimulating experience that is MR. These principles will prove helpful in establishing an environment that provides image and a high-quality experience consistent with the assumptions and the intended use of various types of applications.

Colour display

Holograms in the HoloLens are displayed by adding light to the other light, a solution which is called the additive display system. In this case, bright colours will appear more vivid and pure black will be transparent. As they are projected in a real-world environment, the presented image can differ each time depending on existing environmental conditions. The HoloLens uses a similar colour gamut to RGB, which by nature is much more visually powerful than the CMYK colour gamut. In addition, the HoloLens gamut is much larger than those available on screens.
The colour in Mixed Reality, as in any other case study, should be chosen consciously, taking into account its psychological impact, its meaning among religions and cultures. There is a wide colour gamut similar to already known from computer displays, RGB.
Due to problems with colour glowing, it is not recommended to design large bright areas, the preferred background colour is dark. Also using very saturated colours will bring many unpleasant feelings to the user. There is also a problem with the use of high contrast gradients, not every shade is visible due to the insufficient number of bits of information to present them. This is called banding or false contours and as a result the gradient is visible as separate bars.
This can be prevented by using dithering, i.e. creating soft tonal transitions between each colour. The most recommended colour for creating gradients is blue.

Colour accessibility

Creating an application accessible to as many users as possible is as important as it is difficult. It is necessary to take into account the real problems they face and create working solutions. Being aware of the importance of adapting the interface, I would like to emphasise here that appropriate solutions should be supported by appropriate research. For the purpose of designing for the HoloLens, I am able to implement only obvious solutions. It is also to them only that I wish to point in the following part of the paper.

Taking colours into account when designing is one of the easiest ways to customise an application for as many people as possible.

Adequate contrast in the design of this type of interface is essential to achieve adequate legibility. It can enhance the amount of information retained by the user and helps cognitive processes.[34] According to the W3C Web Content Accessibility Guidelines (WCAG), the appropriate level of contrast between lowercase letters and background is 4.5:1, and between uppercase letters and background at least 3:1. It is assumed that the best-perceived contrast between colours is between black and white. Due to the additive colour display by the HoloLens, black with an RGB value of #000000 is transparent. The black equivalent recommended by Microsoft can be found under 16, 16, 16 and recommended white values are 235, 235, 235. Contrast between these values is around 7. Although WCAG2 is intentionally targeted at web designers and developers, the values it provides are also ideal for the MR world. In addition to the above-mentioned portal, pages such as WebAIM Color Contrast Checker or Color Safe can help you choose the right one. It should also be remembered that the contrasting element attracts attention, so it is worth directing it to the right place intentionally.

It is important to ensure that the information provided visually and by colour is also written down in text. This will make it easier for the user to read the designer's intentions, not only when considering a type of disability, but also when the information system itself is designed unreadable or too abstractly.

The human eye can distinguish lighter colours more easily than dark ones. There is also a relationship between colour intensity and letter thickness. A thin font will look better in light or bright colours, because it will optically enlarge its field.

Difficulties with colour

The most common problems with the HoloLens' colour display are colour separation and colour glowing. The first one consists in the visible division of colours into basic RGB with simultaneous intentional movement. This problem is caused by the curvature of the optical lenses present in every

[34] Jean-Éric Pelet, *Mobile Platforms, Design, and Apps for Social Commerce* (Pennsylvania: IGI Global, 2017), 291.

AR/MR device, which cause disturbances such as pincushion and barrel distortion. It becomes impossible to achieve the sharpness of all colours at the same spot. Blue and red light have different refractive indices, lenses produce chromatic aberration that affects the appearance of particularly small holographic elements. This defect originates directly from the device and cannot be prevented at the design level yet.

The problem with colour glowing is that when we use an intense background with a light, uniform colour it will be very unpleasant, blotchy with a strong glow of colours and can cause pain through its shine. The disadvantage of colour irradiation prevents the use of white background in interfaces, to which users have been adapted through years of using websites, where such tone is considered to be the most popular. Negative polarity is recommended when designing MR interfaces, despite research carried out by Richard Hall and Patric Hanna in 2002, which proved that "the black background of a website arouses negative emotions in users and encourages them to leave it faster and abandon their online activities"[35]. It should be noted that these conclusions were based on the great discomfort due to strain and eye fatigue with the black screen, thus a technical fixed screen. In an interface designed for the HoloLens, these sensations should be reversed, so it should be stressed that not all guidelines for screen design translate into the design of Mixed Reality.

Vergence accommodation conflict

Vergence-Accommodation Conflict (VAC) is a factor that disturbs the reception and enjoyment of the application. This problem occurs in 3D environments, it is the problem of catching the focus and reading the true depth of space[36]. The eye captures a virtual object that is semi-transparent at a different distance from the real world. Microsoft, with aim of minimising VAC, recommends not to place virtual elements closer than 2 meters from the user. To maintain maximum user comfort, they recommend a space of between 1.25 and 5 meters away. They also recommend not to place the user at a distance of about one meter in total for longer than 25 percent of the duration of the entire application run time. Only after this time will there be an increased chance that the user will feel unpleasant effects and mainly remember these feelings in the context of using the application.

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[35] Richard H. Hall, Patric Hanna, "The impact of web page text-background colour combinations on readability, retention, aesthetics and behavioural intention", *Behavior & Information Technology* 23*,* no. 3 (2004):183–195, accessed September 05, 2018, DOI: 10.1080/01449290410001669932.

[36] Gregory Kramida, Amitabh Varshney, "Resolving the Vergence-Accommodation Conflict in Head Mounted Displays A review of problem assessments, potential solutions, and evaluation methods", UMD Department of Computer Science, accessed January 3, 2019, https://www.cs.umd.edu/sites/default/files/scholarly_papers/Kramidarev.pdf.

David M. Hoffman in a paper titled "*Vergence–accommodation conflicts hinder visual performance and cause visual fatigue*" proposed several solutions which can help to prevent this fatigue and improve Spatial UX. Let me mention a couple of his practical guidelines and leave them for free interpretation as their usage could be universal:

- "Use long viewing distances when possible because focus cues have less and less influence as the distance to the display increases; there should be little influence beyond 1 m.

- Minimize the conflict between the vergence and the focal distances because conflicts cause inappropriate disparity scaling and failures of binocular fusion. One can minimize the vergence–focal conflict by matching the simulated distance in the display and focal distance as well as possible.

- Maximize the reliability of other depth cues in the stimulus because the influence of focus cues should decrease as its relative reliability decreases.

- Minimize the vergence–focal conflict by setting the physical distance to the display as close as possible to the disparity-specified distance of the important parts of the virtual scene. If the physical distance cannot be changed, ophthalmic lenses can be used to make the focal distance compatible with the vergence distance. Of course, one cannot in general set the vergence–focal difference to zero in conventional displays because the virtual scene will contain a variety of disparities, so the vergence stimulus will vary as the viewer fixates different parts of the scene.

- When reasonable, minimize the consequences of vergence–focal conflicts by making an existing conflict less salient. This can be accomplished by increasing the distance to the display and to the virtual scene. It can also be accomplished by attenuating high-spatial frequency content from the images, but this is generally undesirable for other reasons."[37]

[37] David M. Hoffman et al., "Vergence–accommodation conflicts hinder visual performance and cause visual fatigue", *Journal of Vision* 8 no. 33 (2008), accessed December 12, 2018, https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2879326/, DOI:10.1167/8.3.33.

Field of View

The HoloLens belongs to the optical see-through devices, which thanks to the use of silver-plated mirrors have half-transmissive properties, which allows combining the vision of the real world and the virtual world. As a displaying system, it uses waveguides, which despite rich projection also put enormous limitations on the perceived experience. The disadvantage of such a system is the narrow Field of View, which is currently less than 40 degrees, however, Microsoft promises that with the release of the next edition of the HoloLens they will enlarge them by the next 10 degrees.

An average person uses a field of vision equal to about 120 degrees on a daily basis when looking at a straight line of sight, and an additional field of vision extended to 200-270 degrees is achieved by means of eyeballs movement. In the HoloLens, the visible field of view is reduced as it is 34°stated by Bimber and Bruns[38]. This makes the experience not immersive and creates mental barriers. From my observations it appears that users are dissatisfied with this particular feature and perceive the use itself as a curiosity rather than experience. As a result, they are less emotionally involved and less inclined to move in space.

As a result, visible virtual elements appear only in the area of a small rectangle in front of the user's eyes. This is due to the way the waveguides described above would need a much larger computer to provide the expected FoV. The limited FoV is the reason for the highest number of complaints about the HoloLens, but it is an element that will be improved over time. The larger the viewing area, the more immersive and engaging the experience is.

The biggest disadvantage of FoV is that it can prevent the user from seeing all the elements of the application and as a result, it can omit something. To prevent this, it is worth using Directional Indicators and sound signals coming from the element, which thanks to Spatial Sound will enable spatial orientation.

The next difficulty comes when designing the interface. In order to avoid the effect of "cutting" its elements through a narrow FoV, it is necessary to adjust its multiplicity and distance from the user to fit within this frame.

However, this may have advantages when designing the next steps of the application. The navigation and settings interface can be "hidden" away from the visible area in order not to distract the user while using the application and at the same time it can be accessed again after pointing the user's head into this direction. In this case, consistency of placement this navigation bar should be preserved.

[38] Oliver Bimber, Erich Bruns, "PhoneGuide: Adaptive Image Classification for Mobile Museum Guidance", 2*011 International Symposium on Ubiquitous Virtual Reality* (2011) Accessed December 12, 2018. DOI: 10.1109/ISUVR.2011.12.

The solution proposed by a group of scientists from the School of Computing and Digital Technologies Staffordshire University is a spatial interface. They created it to find a way to overcome the limitations of the device by means of an appropriate design.

Information Filtering

The problem of mixing virtual and real visual information and its excess is one of the most difficult to deal with. Current technology allows for a relatively opaque background, but if the visual style of the interface does not provide for such colour intensity, the problem still exists. This makes the information unreadable and unstructured. In 2002 in response to this problem, Simon Julier proposed a solution that was to revolutionise the way of display in AR. His program takes the user's location, his assumptions, as well as objects that correspond to these assumptions and on the basis of this data, the program selects objects that will be shown to the user at that time[39]. This solution has not yet been developed to meet the requirements of the HoloLens, but this theory is worthy of further exploration. For now, increasing legibility can be achieved by the use of darker background which masks the background full of different objects[40].

Size and position

In Mixed Reality there are 3 options of setting elements of GUI: pin it to a place, pin it to the user's body position and pin it in a billboard style. The last two options give designers control over the distance between user and text so he or she can design experience in a proper way and set appropriate text size. In the situation when text is pinned to a particular place, it is not possible to predict the user's position and angle of view so maximum legibility in every context is highly important.
To ensure proper readability, the recommended text size is between 19px and 22px at a distance of 1.5 meters from the user in a straight line.

Typography

Text in Mixed Reality is one of the most important elements of providing information to the user. Although voice commands are the easiest and natural to process by humans, not everybody is capable of hearing properly or might just be distracted and thus the audio information will not be retained in

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[39] Simon Julier et al., "Information filtering for mobile augmented reality. Computer Graphics and Applications", *Proceedings IEEE and ACM International Symposium on Augmented Reality (ISAR 2000)* (2000), DOI: 10.1109/ISAR.2000.880917.

IEEE. 22. 12-15.

[40] Joseph L. Gabbard et al., "Legibility in Industrial AR: Text Style, Color Coding, and Illuminance", *IEEE Computer Graphics and Applications* 35, no. 2 (2015): 59.

a user's memory for a sufficient amount of time. The specificity of the displaying system brings much constraints unpredictable environment, in which the text is displayed, and the unforeseeable axis of perceiving text creates many new design challenges. Due to the development of technology and the increasingly complex use of MR applications, the amount of text displayed has increased significantly.

With the development of screens, a branch of typography designed for screens has developed and MR is for now still a rather new environment so that the number of fonts dedicated to displaying in space is very small. The correct use of screen fonts in augmented reality is commensurate with the use of book fonts in web design.

The number of new problems that the designer has to face in connection with the selection and design of such text information is very large.

The biggest problems with the text in MR are optical refractions which makes clogging of the stylistic differences and anatomical typographic features. Another disadvantage of narrow FoV today is that the text must be designed to fit into a small area.

Anatomy of the letter

In order to make the text as readable as possible, attention should be paid mainly to the universal factor among all fonts. These principles are universal regardless of the device, because they have their origin in the way of the reading act. Knowing these rules and having the theoretical foundations to construct a readable text, it is necessary to take into account the new factors created by Mixed Reality. Firstly, I will describe the component which is known for making font more legible: the large x height. In research conducted from the 18th century onwards, the relation between height x heightand perception of the height was noticed.[41] In their article, Bigelow and Holmes bring up the words of Stanley Morison from 1937 that, "The history of type design involved the reduction of the real size of letters while maintaining their apparent size."[42] When type designers of that time focused not only on legibility but also on economic aspects of using typefaces, in Mixed Reality there is no such variable. The following question arises, though, s*hould we still be bothered by reducing size with the impression of a bigger letter?*

The answer lies in the possibilities of presenting typography in MR. In fact, the elements of GUI behave as a 3D object not as a flat representation displayed on the screen or printed on paper. In this environment also extraordinary situation takes place – a flat letter can be displayed in a three-

[41] Yannis Haralambous, *Fonts & Encodings* (Sebastopol: O'Reilly Media, 2007), 385.

[42] Charles Bigelow, Kris Holmes, "How and Why We Designed Lucida", Bigelow & Holmes, accessed November 12, 2018, https://bigelowandholmes.typepad.com/bigelow-holmes/how-and-why-lucida.

dimensional space. In this case, the letter works in the y and x axes, but the value of the axis z is nearly 0.

Part of the research, which affects the legibility of the text, i.e. research into how we read a text, concluded that it consists in distinguishing and classifying the shape of the whole word. Others prove that we read letter by letter. To sum up, in both approaches the easy-to-read text is based on letters whose shape we can quickly be distinguished from one another. Letters with high x-height are more readable to the eye even in small sizes, the whole proportion of the letter changes with the increase in x size[43].

However, too high x-height may affect the legibility of the letter, because it will be more difficult to distinguish its shape. In order to prevent this, care should be taken to ensure that the ascenders and descenders are strongly marked.

Medium contrast in the letter is recommended. High contrast in letters can make thinner elements optically disappear, making it very difficult to read. It is also recommended that text should have large counters, because from a long distance small counters optically merge. A similar situation occurs in the case of dots and accents, it is recommended that they should be significantly away from the letter base, and preferably in a round shape.

Iconography

Basing on my observations and test, in order to maintain the best legibility, the minimum icon size should be a minimum of 37px by 37px observed from a distance of 2 meters. The negative space should be a minimum of 4 px to maintain its significant distance and not to make it visually fade[44].

In addition, it is important to remember about the role and significance of each shape.

When deciding on the shape of an icon, focus on communication, make their goal recognisable quickly and clearly.

Alignment and icons

As the typography in MR is usually used to transmit short and accurate commands and information, it is worth raising the issue of the arrangement of this information in relation to the icon. The appropriateness of using icons correlated with text information is discussed broadly in the basics of Graphic Design and will not be described more in this part.

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[43] Allan Halley, "X-Height", Cdncms Fonts, accessed September 30, 2018, https://cdncms.fonts.net/documents/45a5dcc927619212/Fontology_x-height.pdf.

[44] "Iconography", Magic Leap, accessed November 03, 2018, https://creator.magicleap.com/learn/guides/design-iconography.

Due to limited FoV and limitations resulting from the inability to predict all angles in which the user receives the graphic item, it is recommended that the icon should be placed above the text information and centred. Such a solution will enable condensation of information on a relatively small area.

Organizing Content in Mixed Reality

"Writing systems vary, but a good page is not hard to recognize, whether it comes from Tang Dynasty China, the Egyptian New Kingdom or Renaissance Italy. The principles that unite these different schools of design are based on the structure and scale of the human body—the eye, the hand, and the forearm in particular—and on the invisible but no less real, no less demanding and no less sensuous anatomy of the human mind.”[45]
Robert Bringhurst

From the early beginning of human development, the fundamentals of artwork were based on mathematical rules[46]. From the architects and sculptors in ancient times to new media designers today, every epoch takes advantage of the calculations. Mathematics organise and clarify the structure. The grid history of typography begins with column grids used by the authors of the Dead Sea Scrolls, dated around 150 BCE-70 CE. In Fine Arts, the Elgin Marbles sculptures in Pantheon are said to be one of the first to be designed on the bases of the Golden Ratio[47]. For centuries, the aesthetic taste of people has been shaped by the same principles and proportions.
Since then, dynamic development and progress in developing the rules of organising content have continued. Later on, around 1920s designers inspired by the power of clarity were looking for solutions to create designs that show the power of harmony. Movements such as Die Stijl, Bauhaus, Swiss Style were deepening the concepts of balance, compositions and visually effective solutions. And so, designers by using the discoveries of the biggest names in art history have been inquiring and working on different approaches to problems of composition.

Factors affecting the effective compositions are independent of the medium. Possessing a historical background and access to scientific research makes it possible to present a comprehensive overview of the existing solutions and test them in Mixed Reality. It should be stressed that despite the many advantages of using such methods, they should not be used too hastily. Excessive use of such methods does not of itself add any value to the project and can be considered as a sign of lack of knowledge and amateurism. Appropriate contextual interaction can help minimise user steps in spatial content

[45] Robert Bringhurst, *The Elements of Typographic Style* (Vancouver: Hartley & Marks, 2008), 10.

[46] Kim Williams, Michael J. Ostwald, *Architecture and Mathematics from Antiquity to the Future: Volume I: Antiquity to the 1500s,*(Basel: Birkhäuser, 2015), 735.

[47] *The Golden Number*, accessed December 7, 2018, https://www.goldennumber.net/golden-ratio-history.

management. This requires designers to better understand the technical framework in order to use the most appropriate feature sets.

White Space

In the design, the essence of white space has always been emphasised. Despite the lack of elements, it can play a key role, which sometimes might even surprise. The definition of the word evokes the notion of something negative, the space created between graphic elements. In Mixed Reality the same white space exists between two elements from one set, such as the space between two letters but also this one between the GUI element and the 3D model. In summary, macro- and micro-white spaces play an equally important role in design.

Properly balanced white space is unnoticeable to the viewer, which makes it fulfil its function. Without a suitable white space, the project is unstructured and chaotic. In Mixed Reality, white space is not so easy to plan or to predict its behavior, but at the same time its role is all the more important. It can be said that the challenge of MR design forces a redefinition of the concept of white space. While in the GUI elements themselves it should be treated in a “traditional” way, in the spatial design itself, we can use principles borrowed from the principles of Gestalt psychology or cognitive perception of space and memory load, as well as limitations of the amount of impressions assimilated. In general, designing elements of inadequate size or placing too many of them drastically affects the quality of application reception. When designing an application dedicated to the mainstream market, remember that we design additional elements that will be displayed in various places and that solutions that meet their purpose in the designer's environment may not be appropriate in the user's environment.

Designing for an unspecified space, we can go beyond the chaos of emptiness of the project in the initial phase and predefine some constants. These assumptions will never be completely true, there may be instances and spaces unforeseen, but it can be assumed that most of the space will have some common features. The first constant we can specify is the floor platform. Its distance can be estimated, from the height of the HoloLens it will be about 1.5 meters down, one meter forwards and one meter backward

White space in the HoloLens should be used consciously. When the user of the application does not see any of the virtual elements in the predicted time or space, they can get lost and thus the level of joy can decrease. The user can also be less immersed in the experience when looking for any more attraction or interaction, and in the worst scenario also can close the application. The narrow Field of View is not helpful in this situation because the user needs to make more action to see and scan the whole environment. To avoid this, it is crucial to use the direction indicators which guide the user

through the created space. Additionally, it is important to introduce the guiding element in the begging of the experience.
When designing elements that are meant to work with a specific room, it is necessary to take into account the intensity and colour of light at selected times of the day in order to adjust the colour and brightness of the application to it. Important are the spatial lines which, despite their transparent nature, govern the spatial perception of humankind. It is recommended to create a grid of spatial lines of such a room, so as to be able to design applications and experience in an appropriate way. It is particularly important to be aware of such lines when designing an interface based on polygonal elements such as rectangles, squares or even the circles. Each of them is described by mathematical functions which can find common denominators with a different mathematical variable or constant. The geometric essence of these elements allows for a more structured work with a spatial grid. Their guides may coincide with the guides of space, but also having knowledge about space layout, you can consciously break it to get the intended effect. When designing according to the lines of space, it is worth remembering about the principles of optical alignment. Even designing abstract forms is easier to manage on a grid.

Gamification

The main factor that prompts people to enter the world of technology is to achieve a state of pleasure. In a study conducted at Stanford University by Alan Reiss, it has been shown that a simple video game activates many areas in the brain, not only the obvious ones such as those related to visual processing, visuospatial attention, motor function, and sensorimotor integration, but also those related to experiencing pleasure. Such an experience, which is generally unnatural to man, has strongly activated these areas of the brain: the nucleus accumbens, the amygdala, and the orbitofrontal cortex, which proves that the reward centre has been activated and dopamine levels have increased.
According to Freud's thought, the unconscious seeks pleasure and strives to avoid pain. We can translate this statement simply into the user's interaction with the device, if it is not pleasant for them, it will not be used anymore. The same thing will occur, when the user feels any physical discomfort. In article an titled “Pleasure systems in the brain” written by Kent C. Berridge and Morten L. Kringelbach about the research they conducted on the topic of neuroscience of pleasure they mentioned that “In a sense, pleasure can be thought of as evolution’s boldest trick, serving to motivate an individual to pursue rewards necessary for fitness, yet in modern environments of abundance also inducing maladaptive pursuits such as addictions.”[48] This observation is important in the creation of

[48] Kent C. Berridge, Morten L. Kringelbach, “Pleasure Systems in the Brain”, *Neuron* 86, no. 3 (2015), accessed November 20, 2018, DOI:https://doi.org/10.1016/j.neuron.2015.02.018.

computer games, it can even be considered that it is nowadays the basis for the design of addictive games. Designing an application system should not stand on the verge of ethics and be based only on primitive human instincts, but their proper interpretation may be correct and noticeably improve the user's feelings.

Gamification in an application uses the above-mentioned dependencies to create an engaging application. It uses mechanisms known from computer games in a non-game context. It also makes it easier to achieve goals and rewards for it. Stronger user involvement results in a better chance of achieving the user's goals, such as reaching the next stage in the application, or long-distance goals such as developing one's skills.

Pleasure

Good design is based on the fact that it creates positive emotions in the recipient. Man strives in life to feel pleasure, which is recognised as a feeling of enjoyment. It is a very individual feeling, complex and appearing on many levels of life. In terms of the relationship between man and products, Patric Jordan distinguished three different product benefits: emotional, hedonistic and practical. Pleasure results from complex interactions at many sensory levels; it is not just a product feature that can be universalized[49].

In addition to game-inspired application development systems, it is worth noting that the pleasure of experiencing Mixed Reality consists of many factors. To organise them I will use the four pleasure framework created by professor Lionel Tiger from the University of Rutgers University in New Yersey.

He divided the pleasure of communing with the product into four categories: physio-pleasure, psycho-pleasure, socio-pleasure and ideo-pleasure, to encourage a holistic approach in product design[50]. Physio-pleasure is based on the purely physical achievement of pleasure through direct contact with the product and through the sensors of organs. This can be, for example, a pleasant paper texture. In the case of Mixed Reality achieved with the HoloLens, this pleasure from the beginning of the entire interaction process can be achieved already due to the texture of the material of its casing. High-quality finish is aesthetically pleasing. The small buttons that allow you to control the volume or brightness of the application are designed so that their small squeeze harmonises with the protrusions of your finger. You can hear a silent sound when you press the button to indicate a status change. As virtual objects do not have physical features that could affect other senses than sight, consideration of the physical pleasure of the application elements themselves must be postponed for the future.

[49] Patrick Jordan, *Designing Pleasurable Products* (Taylor & Francis Ltd, 2002), 12.

[50] Lionel Tiger, *The Pursuit of Pleasure* (Transaction Publishers, 2000), 10.

Psycho-pleasure includes pleasure derived from emotions and cognitive reactions evoked by the use of the application. In this case, the above-mentioned gamification of the application may cause this kind of pleasure, associated with satisfaction. It is important to fulfil the tasks for which the application is designed as well as its smooth operation. If the application is consistent and the user quickly learns how to move around it, he or she is satisfied. To ensure this kind of pleasure, it is also necessary to provide addictive storytelling. It should be remembered that experiencing this is conditioned by many factors, it can be said to be almost individual in nature. In some user groups, it is possible to draw some common features and requirements among them, and it seems all the more worthwhile to conduct surveys concerning this target group.

Ideo-pleasures are connected to human ideals and values. Products that are aesthetically pleasing fall into this category because they affect people's perception of beauty. This kind of pleasure is also felt when philosophical, religious, political or environmental responsibility issues are raised.

Socio-pleasure, as the name suggests, is closely linked to the sense of positive connection with the society. Relations with people, social interactions, identification in society are all topics which, if positively developed, provide this kind of pleasure. As a case of using technology to extend social interactions, we can mention the use of social communicators such as Skype or Facebook. In addition to their basic communication function, they enable contacts with people who are physically distant from us, they also foster a sense of social commitment and even the growth of new environments. The HoloLens enables you to communicate via social media and instant messaging, and its unique feature is the ability to share your MR experience with people in the same room as well as remotely. Sharing this extraordinary experience strengthens the relationships and creates shared memories. Thanks to the ability to recognise faces, the HoloLens also gives the impression of a relationship between the machine and the person[51].

The feeling of belonging to a group, the need for harmony and for knowledge appear in the Maslow pyramid as some of the most basic needs. Recognising the common features between the guidelines for the sources of pleasure and the basic needs of the human being leads to the thesis that their provision should be crucial for the designer.

Human Factors in Mixed Reality

Ergonomic design is defined by International Ergonomics Association as “the scientific discipline concerned with the understanding of interactions among humans and other elements of a system, and the profession that applies theory, principles, data and methods to design in order to optimize human

[51] Ibid., 14.

well-being and overall system performance.”[52] It focuses on system-oriented design and shares awareness about a holistic approach to design. The general concept of Ergonomic design consists of physical, cognitive and organisational aspects. I will exclude from the following considerations the issue of Ergonomic organisation, as its scope is not related to the subject of the present work.

Abiding by rules of ergonomics during the design process will enhance the possibility of designing a system which allows to achieve optimal human performance. As the Mixed Reality app forces the user to behave in particular way to achieve goals, it is a designer’s duty to provide the most ergonomic experience possible. Think about it as space, in which to interact with, not just an app to use. The possibility of designing an interface in a three-dimensional space is almost unlimited, however, one should remember about physical and mental limitations of the human being. These guidelines and limitations indicate to us the direction in which we should head in order to optimise the use of the application. Even the best designed interface will not perform its function if its reception will cause discomfort to the user.

Mental ergonomics

The cognitive load is the sum of the amount of physical effort that the user has to perform during the task, from its beginning to the achievement of the goal. Compared to interacting with a typical personal computer, the HoloLens requires much more effort. In order to minimise it, it is necessary to make sure that the number of steps required to achieve the goal is as small as possible.

The HoloLens is a head-mounted wearable device. It weighs 579 grams, the weight of a pair of glasses being approximately 30 grams. The weight of the device allows the user to adapt to carry an additional element, but nevertheless, it influences the user's well-being and behaviour. The HoloLens equipped with appropriate handles rests on the natural construction of the human face and is equipped with an individually adjustable belt keeping the device stable on the head. It is possible to adjust the device individually with additional handles and controllers built-in the hardware. The device adheres closely to the face to allow the user the best possible visual experience, while the use of the HoloLens by people with visual impairment, however, encounters many adversities. An adjustable holder allows you to have glasses between the HoloLens screens and human face, but this is associated with high discomfort of the user. Having contact lenses while using the HoloLens is not associated with additional discomfort. Any visual problems can be very unpleasant when using the device, and therefore it is recommended to consult your health problems before using the application for the first time.

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[52] „Definition and Domains of Ergonomics”, International Ergonomics Association, accessed November 28, 2018, https://www.iea.cc/whats/index.html.

Vision

The most significant way of human perception is through the sense of sight. In Mixed Reality, communication between the user and the device depends on the direction of the gaze. Like in the real world, the HoloLens requires from the user that they look in the direction they want to interact with. This kind of interaction was named g*aze-and-commit* by the HoloLens creators.

The HoloLens does not use EyeTracking, it is equipped with motion capturing sensors. These cameras read only the movements of the user's head and positions and are programmed to read specific gestures such as Bloom and AirTap.

Interaction with the device is possible by making predetermined gestures, but more conditions must be met in order for the interaction to fully take place. The HoloLens lets the user interact with an object only if its targeted. Object selection is one of the fundamental tasks in 3D user interfaces.[53] Targeting of an intractable object occurs when the position of the user's head is pointing towards the object. Only one object can be targeted at a time.

The user's head must be pointing in the direction of the object with which the user wants to interact, and the performing hand should be placed in a proper position. Such a solution requires the user to actively move their head while using the application. This can cause pain and fatigue in the cervical region of the spine. This risk can be reduced by designing applications that limit the unnatural movement of the user's head.

Microsoft provided two innovative solutions in presenting the 3D user interface: Tag Along and Billboarding. The use of the Billboarding function allows locking the interface element opposite the user in a specific position. This option allows the designer to determine the distance of the displayed text and provide full control over its display, so that the text and interface designed can be better and more readable. When setting up the Billboarding, one should remember about the minimum distance at which theboard can be set, namely the distance should be at least one meter to prevent nausea.

The Tag Along is an additional option which could be added to any holographic object, especially to a user interface element. Therefore, an element with Tag-Along follows the position of the user and comes into the user's view. The Tag Along, usually used to present the user menu, is a panel that follows the movement of the head and is centred in relation to the centre of the length axis. The designer determines the distance between the presented item and themselves. It is very important that the object with the Tag Along marked should not be placed too close as this will block further use of the application. The HoloLens will not capture the object as an active object and no interaction will be possible. Too close arrangement of the element may cause discomfort and dizziness

[53] Doug Bowman et al., *3D User Interfaces: Theory and Practice* (Boston: Addison Wesley, 2004), 35.

In the type of Mixed Reality application called the heads-up-display, it is recommended to block the content to the body and not to the head position.
The HoloLens creators recommend that virtual elements should be placed in specific areas to reduce discomfort around the neck and head in the following words,: "avoid gaze angles more than 10 degrees above the horizon, no more than 60 degrees below the horizon and to prevent neck rotation more than 45 degrees from the central position."[54]

Gesture

Gesture interaction besides voice recognition is the most important way to commission tasks to the HoloLens and obtain the intended feedback. The user must easily learn and then recognise how to perform an action. More gestures increase amount of troubles with memorising. The HoloLens recognises five gestures: Bloom, Ready, Tap, Hold and Drag. We can highlight two the most frequently used : AirTap is a gesture with the output comparable to a mouse click, and Bloom opens the main menu of the HoloLens's operation system. The main issue regarding 3D UIs is the necessary transition from a 2D WIMP system to 3D menus and interactions without a customary mouse[55]. The AirTap has been recognised as a gesture beyond accepted anthropometric and biomechanical standards and tolerances[56]. It is also possible to add supplementary gesture events specified by the HoloLens creators allowing scaling, drawing and moving elements. Research works on extending usability by unrestricted gesture input are being carried out by researchers from Microsoft.[57] It is, however, possible to extend the HoloLens system with external motion sensors like the one used in the Kinect device or 3D camera.
In the case of engaging the user's body, using a computer mouse involves small muscles with quick reaction, while gestures recognised by the HoloLens involve larger muscles and cause a larger range

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[54] Robin Held et al., "Comfort", Mixed Reality, accessed December 11, 2018 https://docs.microsoft.com/en-us/windows/mixed-reality/comfort.

[55] Gabriel Evans et al., "Evaluating the Microsoft HoloLens through an augmented reality assembly application", *Digital Engineering Conference Presentations, Papers and Proceedings* 5 (2017), Acessed November, 7, 2018, https://lib.dr.iastate.edu/cgi/viewcontent.cgi?article=1178&context=me_conf.

[56] Jed Looker, "Reaching for Holograms: Assessing the Ergonomics of the Microsoft™ HoloLens™ 3D Gesture Known as the Air Tap", Research Gate, accessed November 13, 2018, https://www.researchgate.net/publication/284283876_Reaching_for_Holograms_Assessing_the_Ergonomics_of_the_Microsoft_HoloLens_3D_Gesture_Known_as_the_Air_Tap.

[57] Robert Xiao, et al., "MRTouch: Adding Touch Input to Head-Mounted Mixed Reality", *IEEE Transactions on Visualization and Computer Graphics* 24 no. 4 (2018), accessed September 24, 2018, https://ieeexplore.ieee.org/document/8263123/references#references.

of movement.[58] Although AirTap itself does not require overcoming physical resistance, limb fatigue does occur. Such movement is also unnatural for the average person. The user subconsciously uses only one leading hand. Such a situation causes specific pains and cramps of the abused limb. In a book titled *A Survey of 3D Object Selection Techniques for Virtual Environments* this state of affairs is summed up with the following words "*3D interaction is more physically-demanding and might hinder user tasks by increasing the required dexterity*."[59]

It must be underlined that the HoloLens read gestures only in its Field of View and the movement is read by a short-range depth camera, recognising the shape of the hand. The area in which this gesture works best is opposite the user at the height of their head. This limitation of the space, in which the hand can be moved, creates more problems in trying to make this interaction as easy as possible.

AirTap was recognised as a gesture that goes beyond natural human movements and causes because it contributes to the occurrence of muscle pain. There are two types of muscle stress: static and dynamic. The first one is caused by the effort that a person has to put into maintaining a particular position for a specified period of time. The second one is caused by the movement that the body must perform in order to achieve a specific pose[60].

In summary, if the device itself fails at the level of ergonomics, the only thing that can be done to prevent the failure of the entire application system is to adapt the design to minimise the negative consequences. In order to reduce the distress associated with this movement, interaction of the whole application should not be based only on AirTap. Tasks can be divided between voice commands and AirTap at intervals. The user should also be made aware of the fact that he or she can change the position of his or her hand at will.

Height

Ramy Hammady and Minhua Ma in a study dedicated to spatial UI design during the evaluation of tests with users noticed a certain phenomenon in cases where the interface was designed based on fixed height figures. When designing an interface for a person of 170 centimetres height, users with of lower height lifted their heads up in order to better see the elements. Such unnatural gestures can

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[58] Ferran Argelaguet Sanz, Carlos Andujar, "A Survey of 3D Object Selection Techniques for Virtual Environments", *Computers and Graphics* 37, no. 3 (2013):121-136.

[59] Werner A. König et al. "Adaptive Pointing - Design and Evaluation of a Precision Enhancing Technique for Absolute Pointing Devices", *Human-Computer Interaction - INTERACT 2009* 5726 (2009): 658–671.

61 J. Looker, op.cit.

cause fatigue and pain. To avoid this, researchers suggested that distances should automatically be scaled individually for each user [61].

Cognitive ergonomics

Cognitive ergonomics in the context of design can be considered as the one that optimises the visual system to maximise efficiency and minimise fatigue and overload.

Cognitive load is the amount of work the brain has to do in order to achieve the desired goal. Compared to the textual information presented, the more visually presented information requires much less mental activity. This leads to the reduction of visual noise and displaying only necessary information, all the while organising information logically and supporting the user in memory intensive tasks[62].With the improvement of HCI system to optimise the cognitive load, the use of application will be more efficient and joyful. Associating positive emotions with the product increases the user's involvement and, as a result, increases profits[63].

In *The Essential Guide to User Interface Design An Introduction to GUI Design Principles* and Techniques, the author distinguishes nine factors that are characteristic of human behaviour.

As those that play the greatest role in the interaction of the human with a computer are mentioned: perception, memory, visual acuity, foveal and peripheral vision, sensory storage, information processing, learning, skill, and individual differences. For the purpose of this work I will present some of them in the context of the HoloLens design.

Perception

In order to design a system that will be easy for the user to understand and experience, it is advisable to also rely on theoretical knowledge of how perception operates.

Perception in the Oxford Dictionary is described as "a way of regarding, understanding, or interpreting something; a mental impression."[64] This phenomenon occurs through the experience and

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[61] Ramy Hammady, Minhua Ma, "Designing Spatial UI as a Solution of the Narrow FOV of Microsoft HoloLens: Prototype of Virtual Museum Guide*",* Staffordshire Online Repository, accessed November 30, 2018, http://eprints.staffs.ac.uk/4799/1/Designing%20Spatial%20UI%20as%20a%20Solution%20of%20the%20Narrow%20FOV%20of%20Microsoft%20HoloLens-%20Prototype%20of%20Virtual%20Museum%20Guide%20%28002%29.pdf.

[62] Wilbert O. Galitz, *The Essential Guide to User Interface Design An Introduction to GUI Design*, *Principles and Techniques* (Hoboken, NJ: John Wiley & Sons, 2007), 85.

[63] Naveen Kumar, Jyoti Kumar, "Measurement of Cognitive Load in HCI Systems Using EEG Power Spectrum: An Experimental Study*", Procedia Computer Science* 84 (2016): 70 – 78, accessed January 10, 2019, https://www.sciencedirect.com/science/article/pii/S1877050916300825.

[64]*Oxford Dictionary,* s.v. "Perception", accessed July 11, 2018. https://en.oxforddictionaries.com/definition/perception.

understanding stimuli coming to a person from their environment through all senses. Perception depends on the individual background of each person. People classify the stimuli received through the prism of previous experiences, compare them to experienced events, compare the new images to those previously seen.

In terms of interface design, it is important to mention a few Gestalt principles of visual perception, thanks to which the project will be coherent and the information received by it easier to process. It is particularly important in the case of new technology to assimilate the user in a non-invasive way.

Proximity, also known as grouping. This feature says that elements arranged in close proximity to each other, especially logically segregated ones, are perceived as one. This happens regardless of whether the elements have a similar shape. Useful for organising content in User Interface, related objects should be placed nearby.

Similarity. If objects share some visual property, the mind sees them as a pattern. Such a common feature may be texture, colour, or size When we use similarity, along with distinguishing one element we can create an effect called anomaly. Such use allows you to draw attention to the selected item's *focal point,* by creating contrast and as a result helping in navigation.

Emergence. The outlined, semi-abstract figures bring more attention to themselves. The human mind recognises a basic, well-defined object more quickly than a very detailed object.

Invariance, the brain recognises objects from various perspectives, regardless of rotation or scale and in spite of their different appearance.

Closure, the human brain ignores breaks and fills the gaps with information which through previous experiences is able to match analogically and create a seamless whole. This allows us to reduce visual noise by minimising the amount of information elements needed to communicate. We can make it stronger while using simpler elements, making the project more engaging and interesting.

Symmetry. Objects arranged symmetrically are perceived as belonging to each other independently of the distance, which gives people a sense of order. Symmetry evokes positive feelings in a human being, referring to the eternal search for harmony and its recognition as one of the basic elements of beauty. Such an arrangement can be visually tiresome at the same time. By entering an anomalous element, we can direct the user's attention to the appropriate element and it is easier to create a Call to Action.[65]

With the knowledge of perceptual possibilities, we can create a structured system, with the appropriate hierarchy to convey information through visual images as easily as possible.

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[65] Kinda Cherry, "Gestalt Laws of Perceptual Organization", Very Well Mind, accessed January 11, 2019, https://www.verywellmind.com/gestalt-laws-of-perceptual-organiation-2795835.

Memory

Human memory works with the aim of achieving possibly high effectiveness at the cost of the amount of memory load burdened over the short period of the time. A person passing one place several times will not perceive it in the same way as they do for the first time. To save energy, the brain creates mental maps.

At the moment, the memory system is divided into two areas: short-term memory and long-term memory. Short-term memory is said to be more easily overloaded than the long-term one.

In order to improve interaction and facilitate the achievement of a certain goal, the user's memory load should be reduced. Recognised ways to achieve this are the following:

- "Structured and simple organisation of information
- Giving the user control over the time of information received
- Arranging the information needed to perform the task in a short distance from each other
- The information is arranged according to its level of importance (information at the middle or end of the list is less well remembered).
- Visual differentiation of elements by means of which they are to be better memorised or have the greatest importance in terms of usability[66]

During complex tasks, working memory is increased by activating the two senses, most often the sense of vision and hearing. Multiple tasks performed at the same time adversely affect the user's performance.[67] It is estimated that the average number of objects that a person can store in the working memory is 7 plus or minus two[68]. This is called Miller's law and it also says that the objects can be, for example, seven groups of elements.

Long term memory is a memory that stores knowledge. During the learning process, a part of the information from the short-term memory is transferred and then coded. It is a complex process, requiring time and energy. It is believed that long-term memory does not have a defined limit and it is not easy to reload it.

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[66] Wilbert O. Galitz, *The Essential Guide to User Interface Design An Introduction to GUI Design*, *Principles and Techniques* (Hoboken, NJ: John Wiley & Sons, 2007), 85.

[67] Alan Baddeley, “Working Memory”, *Science* 255, no. 5044 (1992): 556-559, DOI: 10.1126/science.1736359.

[68] George A. Miller, “The magical number seven, plus or minus two: Some limits on our capacity for processing information”, *Psychological Review* (1956), 63.

In the context of interfaces, long-term memory plays an important role in recognising or restoring data. It is worth presenting lists of alternative choices they have in order to refer to previous experiences or to activate deeper memory resources[69].

Affordance

Term of affordance was popularised in 1977 by James J. Gibson as a general identification of ability to take an action with an object[70]. Later on Daniel Norman has enriched this definition with a second meaning. In his book *The Design of Everything Things*, he elucidates that the affordance takes place when the subject is aware of the possibility to take an action that is contingent on the subject's experiences and their background

A Mixed Reality designer needs to be aware that their users in the early stages of development of this branch, will bring expectations and habituations from using devices like tablets or smartphones. Their instincts are based on prior experience with previous products.

The icon of a letter will remind them about e-mail, and the user recognises the metaphor that he or she is able to check the email, and accordingly does not predict traditional snail mail view. With more complicated elements, like the 3D keyboard, the situation changes. This kind of element was usually used by the user in a different way, with haptic input and immediate output. In the HoloLens, Microsoft proposed virtual keyboard, with which the user would not to be able to use hands to write in an expected way, but would be forced instead to complete their plan in a laborious, uncomfortable way by gazing at a letter and confirming the chosen element by an AirTap. Actions which are unnecessary and unfit for the technology can cause discomfort to the user and ruin the overall experience. To avoid this, designers should be aware of the disadvantages which come with some solutions and avoid them, replacing them with the more appropriate arrangement.

Additionally, especially when designers work with a new technology, they should work to provide a consistent interface. It should be built in a way that the user will be able to unconsciously achieve their goals and find the elements they were searching for. This would help the user to build a stable connection with the application.[71]

More extensive research and reflection is needed, the objective of this work is also to draw attention to the complexity and variety of issues that should be taken into account when designing the Mixed Reality experience. Human-Computer Interaction is a very complex issue, but an attempt to reinterpret it is required in order to create applications that are enjoyable to use. It has been proven

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[69] W. O. Galitz, op.cit., 79.

[70] James J. Gibson, "*The theory of affordances" in Perceiving, Acting, and Knowing. Towards an Ecological Psychology* (Hoboken, NJ: John Wiley & Sons, 1977), 67-77.

[71] Robert L. Myers, *Display Interfaces: Fundamentals and Standards* (Hoboken, NJ: John Wiley & Sons, 2003), 112.

above that the pleasure of using technology is the key to the success in creating a connection with the product.

Chapter 3: Case study

The above-mentioned aspects of designing for the HoloLens are indicators of the design of techno-spiritual application. The decisions that I made while creating the interface of this application, taken on the results of the analysis carried out in this work and on the basis of my own experience as a designer will be described.

Origin of the idea

Today's society is confronted with many chronic stress-related diseases. Mental pressure exerts an impact on the mood, mental and physical health, daily wellbeing, as well as the quality of sleep of people. Long-term stress is associated with very serious consequences, disturbs a person's homeostasis, which in consequence may shorten their life.

In the world of ubiquitous technology, it is increasingly difficult to find moments of rest. The pressure of society, constant access to information leads to deterioration of people's mental state and disrupts their lives. Technological progress makes it more and more often accompany us in our everyday activities, it has even become a part of our personal attire. Excessive use of technology has also a negative impact on people, their bodies and minds. Destructive activities such as Internet addiction disorder and other forms of behavioural addiction have been identified.

On the other hand, technology allows the human race to significantly develop mental and physical capabilities. It has been noted that certain behaviours and activities can reduce stress levels. One of them is meditation, which began to be practiced in Antiquity in the Hindu tradition. It was usually practiced by Taoists and Buddhists, and since the 19th century it has been accepted by other cultures as a way of improving well-being, with increasing globalisation as its backdrop.

Meditation

Meditation is also referred to as a spiritual exercises.[72] In different beliefs it takes a slightly different form, with the same goals such as attention, concentration and awareness.

Meditation in European countries strongly refers to its Eastern roots, referring to known and respected gurus and cultivated practices. The growing interest in spiritualism may be linked to the collapse of the Christian Church as an unquestionable entity, while maintaining the need for ethical support.[73]

Research is being carried out on the influence of meditation on human neuroscientific wiring, and it

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[72] Sam Harris, *Waking Up: A Guide to Spirituality Without Religion,* (Simon & Schuster, 2014).

[73] William Little, "Introduction to Sociology", OpenStax College, accessed January 23, 2018, https://opentextbc.ca/introductiontosociology2ndedition/chapter/chapter-15-religion.

has been suggested that different forms of these practices correspond to different parts of the brain.[74] Hundreds of research channels have been carried out since the 1950s, but this is a difficult subject to measure accurately, due to the different forms of meditation and very individualised responsiveness. However, the fact that meditation practices have a positive effect on man, their body and mind, is not denied in the general assessment.

The link between meditation practice and employee's effectiveness, resulting from cognitive and social effects as well as from stress reduction, is increased[75]. This has been used by large companies such as Google, Aetna, General Mills Inc. These companies introduced mindfulness courses for employees, the effects of which they expected to obtain[76].

Techno-spirituality

In recent years, research has been launched into the possibility of combining mindfulness and technology. The biggest challenge is to create a system that does not distract the user and does not focus their attention on technology, but uses it only to deepen their experience. Focusing on technology can ground the user and not allow them to break away from everyday life and the real world.

Research is being carried out on how we can achieve a feeling of transcendence and conscious thinking through technology. There is a demand from people for such solutions, e.g. considering the popularity of meditation applications or the number of video impressions on YouTube about self-help audio, theta waves, yoga classes devoted to awareness raising. There are millions of applications, portals, videos and online guides for supporting spiritual experiences and practices from the basic level as well as for advanced and immersed people. There are also devices that measure heartbeat rhythm and respiratory rate to intervene in a recognised crisis situation. More and more technologies and ideas are being developed which aim at helping to understand and improve the state of mind.

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[74] Antoine Lutz et al., “Attention regulation and monitoring in meditation”, *Trends in cognitive sciences* 12, no. 4 (2008), accessed January 23, 2018, https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2693206/?_escaped_fragment_=po=3.57143.;
Julie A. Brefczynski-Lewis et al., “Neural correlates of attentional expertise in long-term meditation practitioners”, *Proceedings of the national Academy of Sciences* 104, no.27 (2007): 11483-11488.; Richard J. Davidson, Daniel J. Goleman, Gary E. Schwartz, “Attentional and affective concomitants of meditation: a cross-sectional study”, *Journal of Abnormal Psychology* 85 no. 2 (1976): 235.

[75] Koichiro Shiba et al. “The Association between Meditation Practice and Job Performance: A Cross-Sectional Study”, *PLOS One* 10, no. 12 (2015).

[76] Kimberly Schaufenbuel, “Why Google, Target, and General Mills Are Investing in Mindfulness”, Harvard Business Review, accessed January 11, 2019, https://hbr.org/2015/12/why-google-target-and-general-mills-are-investing-in-mindfulness.

This subject is controversial, however, various circles express their concerns about the correctness of the methods used, distinguishing among others: financial intentions used by application developers, the suppression of the autonomy that technology promotes, distinguishing some methods from their truly-spiritual basis to create an illusion of understanding spiritual matters.

Mixed Reality Application

Bearing in mind the advantages and disadvantages of using technology for meditation and spiritual purposes, I have created an application whose aim is to help in the practice of mindfulness. The application is designed to arouse interests, reduce stress, help in the performance of spiritual practices. Not wanting, however, to deprive a person of the autonomy of engaging themselves in this process, the application contains only such functionalities that are not available to a person on a daily basis. It is important to emphasise that this application is only a proposal and an incentive for further consideration and research, because the creation of such a system should be supported by further invesigations into the field of psychology, computer science and spirituality.

The application is dedicated for the HoloLens device, because it allows the user to immerse in the extensive experience without interfering too much with their environment and allowing them to move freely, without forcing them to stare at the screen. The research on a proposal of practices in designing this device was carried out in order to create an optimal application for the user. In particular, relaxation and meditation activities should be carried out in a comfortable and ergonomic manner.

I will divide the description of the application into two parts: the first one will concern the merits of selected elements to help in the practice mindfulness and the second one will summarise the technical aspects of the application and indicate the application of conclusions drawn from the research.

Application content

The application is an interactive space in which the user can freely experience the selected type of meditation. The HoloLens device should be kept on the head at all times, selected physical activities are chosen so that an additional device on the head does not hinder the use of the application. There are three types of meditation to choose from, visual, active and sound.

In order to give a brief description of the elements used to help in relaxation, I will briefly summarise the selected components of this system and introduce the subject of application architecture.

The first of them, *sound* uses music with frequencies responsible for relaxation. Selected sounds in the real world are emitted by the koshi bells, tingshe, ocean drum, spring drum and monokurants. Each of these instruments has been used for relaxation or therapeutic purposes for centuries.

The sound spreads in the application after interacting with virtual objects that float in the space around the user. This interaction is also followed by the movement of objects, motion and the creation of geometric shapes. Objects distributed around the user can be divided into seven groups, each of which differs in shape, colour and sound. The appearance refers to the concept of chakras and the visual properties attributed to them. Each sound is also assigned according to the frequency corresponding to the appropriate colour. This stage is aimed at relaxation through the reception of music and the pleasure of fast feedback from performed action. Visually, the objects have also been designed to be aesthetically pleasing. Explanations of the chakras, music properties and the visual part are available in the information section of the application.

The second part concerns active meditation. It contains in-depth yoga pose instruction of standing asana sequences from dynamic yoga. This type of sequence has been chosen so that the device on the head does not interfere with the exercise. In front of the user there is a humanoid, who performs asanas one by one, accompanied by a word description. The humanoid and their mat are spatially aware.

The third part of the application is devoted to visual meditation. A looped animation is displayed, accompanied by music. Fractals are computer-generated visualizations of mathematical formulas. Their nature is infinite and undefined, and the spiral character of animation helps focusing concentration and is comparable to the effect of hypnosis.

The music chosen for this stage is composed by Steven Halpern, recognized as one of the fathers of New Age music. The chosen track is called "Deep Theta Brainwave Entrainment Track 9". The artist himself describes it as "The acoustic brainwave entrainment of the tambura, the drone instrument central to traditional Indian raga music. The combination of the hypnotic tambura and Aural-Sync tm entrainment make this a very potent soundscape for brainwave balancing in the deep theta zone."[77]

There is a thesis that theta waves interact with brain waves and through their interference, the current state of the brain and its active areas changes. As a result of interfering with theta waves, the brain is activated in the frontal and middle parts[78].

Prototype of Virtual Human

In order to smoothly introduce the user to the use of the application I decided to use the concept of Virtual Human, which imitates their features and behaviour.[79] The application has a head model, adopted from Internet resources and adapted for the needs of the application. It presents itself as a Spiritual Guide and declares its role as an application helper. The user can interact with it with specified voice commands. Creating such a form, giving it a name and imitation of a natural interaction such as verbal response to verbal stimuli affects the positive reception of the whole application. Using a humanoid unit creates a sense of attachment, care provided by the assistant,

[77] Steven Halpern, "Deep Theta Brainwave Entrainment Track 9", Youtube, accessed July 30, 2018, https://www.youtube.com/watch?v=ZaNJeGUZynw.

[78] Lagopoulos et al., "Increased Theta and Alpha EEG Activity During Nondirective Meditation", *The Journal of Alternative and Complementary Medicine* 15 no. 11 (2009): 15.

[79] Daniel Thalmann, "The Role of Virtual Humans in Virtual Environment Technology and Interfaces", Computer & Information, Scence & Engineering, accessed January 15, 2019, https://www.cise.ufl.edu/research/lok/teaching/dcvef05/papers/EU.NSF.PDF.

which makes the user feel safer. This character does not take control over the application, does not lead through subsequent stages, all decisions depend on the user.

System architecture

My process of designing “techno-spirituality” applications will be presented in four stages in order to explain my methodology in a clear and understandable way.

Stage one: Acquaintance with new technology
The application design process started with the research on the appropriateness of applying the currently known design principles in the context of the HoloLens and consideration of mental and physical processes taking place during such interactions. Starting to learn how to design and develop Mixed Reality applications based on books, videos and recourses released by Microsoft Corporation.

Stage two: Overview of past practices
After gaining technical knowledge and determining the possibilities, I decided to review past projects in order to determine the expectations of users and to check which project solutions worked and which ones did not. Historical analysis was carried out in order to know what stage technology is now and what the past has, which influenced its development. The features of the designed interfaces were also taken into account if archival materials were made available. Later on, I have made analysis of trends shown in Science Fiction films in order to define the probable expectations of the audience regarding holograms. Fonts were selected which according to the general rules meet the guidelines for legibility of the text, after which the group was tested in the HoloLens and narrowed down to 3 fonts. Subsequent considerations regarding the selection of text focused mainly on the characteristics of the HoloLens projects.

Stage three: Multimedia library
The third phase was aimed at selecting appropriate interactive and multimedia elements. The purpose of the selection was to select suitable elements for relaxation. As a result, a database of videos, music and guidance texts was created. Additionally, the icon system was created based on the knowledge of how the HoloLens can display the image. With complete group of assets and detailed architecture system, the Unity project was created. Later on, working app-prototype was developed with working

Spatial Mapping. With the aim of creating application dedicated to the real demand, user experience test was held. After the test, errors were listed and corrected.

Stage Four: Final implementation

With a tested prototype, the final design was created. The main stages of this process are: implementation of a time-correlative narrative sound system as well as implementation of elements into scenes, correction of positions based on ergonomic and physiological guidelines for vision. At the end, self-evaluation of design-test was made with last modifications of noticed errors being applied. Finally, an informal test with users was carried out and as a result a list of proposals for the future development of the application was created.

Placement

The layout and position of interface elements is a very important variable in the design of spatial experiences. I decided on using a semi-circular form, slightly surrounding the user as a base for the 2d elements and textual elements of the interface. Looking at an interface that is not curved carries a risk of unnatural body movements for the user who might not be able to see all elements at an angle. Main interface 3D elements, the buttons to each scene were set directly in front of the user based on the user's height data, measured by the program as the ratio of the HoloLens distance from the floor. This procedure individualises the experience and prevents problems of maladjustment of the application for people with non-standard height.

Working with such a device as the HoloLens, which has many of its limitations, such as limited field of vision, encourages the designer to use of its flaws creatively. With the aim of providing stronger immersion, the elements were set up and adjusted in such a way that no important information is visually "cut off" by a narrow field of view by fitting them in the limited, calculated space. If any of the interface elements were originally placed outside the field of view, Directional Indicator was added to indicate its position.

Besides the main scene, the navigation menu is hidden outside the Field of View at each stage of the application. At each stage, the coordinates are the same. This procedure has been applied in order not to interfere visually with the experience and at the same time to make navigation to the main menu simple. Small interface elements such as the play button are placed next to the directly related interactive elements.

Colour

The colour of the main interactive elements of the application is blue. Physical properties of blue light waves enable the best quality of the HoloLens display and in video analysis this colour appeared most often. As far as the social and psychological significance of this colour is concerned, it is appropriate for the assigned function. Dark grey, opaque with properties similar to those suggested by Microsoft, has been chosen as the interface colour. This colour is mainly dedicated for backgrounds for typographic elements, to minimize the visual noise (problem broader described in the sections of Chapter 2: Difficulties with colour and Information Filtering). Another main colour is the unsaturated light orange for displaying text due to its high legibility and being less striking and tiring for the eyes.

Icons

Icons that were designed for the main stage which enables the transition to the other scenes dedicated to entertainment and meditation were designed to convey visually a metaphor for the transition to the next space. In their appearance I wanted to take advantage of the possibilities offered by spatial design without overwhelming the user with complicated elements. I used the way the HoloLens displays colours and the dependence that in the additive system the HoloLens displays black as transparent. So I created a black box in the middle of which I placed one element that has a significance and additional graphic elements that emphasise the space of this mini scene. The box has a circular cut-out which is located opposite the user, the circular form resembles icons that people already know, appearing in the screen interfaces. This makes it possible to quickly and easily recognise the essence of the icon in this creation.

Typography

The choice of Larsseit font was made due to the high level of readability and small field of occupied text. The latter feature is particularly important for two reasons: limited FoV and the area which is the optimal for man to receive and process information quickly is 100 square cm. It is easy to read thanks to the large lights in the letter structure, visible ascenders and descenders and the high x-height. Its humanistic features harmonise with the application's purpose and style.

Ergonomics

In order to create the most ergonomic application, after a thorough analysis of the research carried out on this subject and from my own experience with this device, I have implemented several solutions in this product.

In order to prevent hand and back pain from performing AirTap, I have adjusted the solution based on the providing an appropriate interval between performing actions required to achieve a specific goal. Every interaction is also possible to be acted by the voice commands. Additionally, small number of actions that need to be carried out in order to achieve the goal. There is no imposed time to read any information, the user has control over the time needed to perform the task.

The elements are set at least 1.6 metres away from the user to prevent eye strains, and none of the screens is attached to the FoV in order not to arouse unnecessary unpleasant sensations. To sum up, the Billboarding and the Tag-along functions have not been used to intensify the feeling of Mixed Reality.

I have decided to use the concept of gamification to encourage the user to use the application regularly as the repetitively acted relaxation practices are more efficient.

Conclusion

At the beginning of my thesis, I stressed the importance of a holistic approach to design in this new environment as the key to creating an effective application. In the holistic approach to design, mental and physical ergonomics, technical parameters of the device, psychological issues were listed as important aspects. I would like to emphasise that the proposed areas of knowledge are not the only ones to focus on, but rather my personal vision focused on my previous experience as a designer and content research carried out for the benefit of this work. It was not just knowledge containe in books that was studied, but also forums for designers and developers so that my knowledge has been enriched with true, raw information of the actual state of things.

In the first chapter I focused on explaining the history of Augmented Reality, both theoretically and practically. Mainly as a designer I emphasised the visual ways of presenting information. I recognised that typography is the main element for communicating information between a human being and a computer in this environment, which is also appropriate for Mixed Reality.

I also analysed the history of cinematography in the context of visualisation of holograms, assuming that this area shaped the expectations of users. It seemed significant that in a large number of films the main colour of the holograms was blue. It had its own scientific explanation which is the physical nature of blue light and its short wavelength which is very well projected by the HoloLens creators. This prompted me to choose this colour as the main colour of the interactive elements.

Then, getting acquainted with the technological possibilities and limitations of the device, I proposed design solutions that can improve the overall quality of the project by adjusting the typography, using colour and location of the interface elements. Some of the conclusions were based on theories of screen design or book design, if their assumptions were made on general perception rules. Other insights come from my own observations and experiences with this device or from sources dedicated to Mixed Reality design.

I followed the recommendations proposed by the company that created the HoloLens, i.e. Microsoft Corporation, tested them in a real environment and identified the shortcomings in the proposed instructions.

Then I moved on to areas related to ergonomics and psychology. The knowledge from these areas helped to determine the distribution of the ways of interaction into two groups: gesture and speech interaction, and also helped to determine where the arrangement of the interface elements would have the best effect.

I used the acquired knowledge while creating the practical part of my master's thesis. The design process is described in the last chapter. During its creation I had the opportunity to test the conclusions in a real environment. Knowing the possibilities and limitations of the HoloLens, I decided to use things that would seem to be its drawbacks and translated them into positive elements that helped me achieve the intended design effect. Designing a spatial application brings with it many areas that are worth considering, the environment brings with it many opportunities but also many adversities that can completely squander the user's enjoyment of using the application. The in-depth and detailed study of many areas of knowledge that I touched upon in this work has enabled me to create innovative solutions. I consider creating spatial icons using the features of additive colour display as the first one of them, and the use of narrow FoV to hide the navigation menu so as not to interfere with the interaction with the relaxation components as the second one.

As a research project for the future, I plan to test them in a controlled environment and to draw up a formal design guide for the HoloLens and Mixed Reality on this basis.

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