AUGMENTED SPACES: THE EFFECTS OF NAVIGATIONAL AUGMENTED REALITY APPS ON THEIR USERS' PERCEPTION OF SPACE

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Abstract

Navigational Augmented Reality (AR) apps for smartphones approach the presentation of location information in a way that entails much potential to change how space is experienced and navigated through. The purpose of this thesis is to determine the effects of navigational Augmented Reality apps on the users' perception of their surroundings (operationally defined by "awareness" and "familiarity"), as well as to analyze in which ways these effects are related to the performance of AR apps on currently available devices. To answer these questions, an exploratory experiment, with extensive pre- and post-test surveys combined with interviews with AR app developers has been employed. It was determined that AR users are actually less aware of and familiar with their surroundings than non-AR app users. This is mainly due to the comparatively worse performance of AR apps on currently available smartphones, as the overall quality regularly suffers from a cluttered and confusing presentation, erratic result behavior, and some severe compass and GPS problems. These issues make the retrieved information unreliable and decrease the user's overall levels of trust into the technology. Furthermore, some initially unexpected issues related to the social acceptability of AR app usage in certain public situations were encountered during the experiment and contributed to aforementioned issues. Nevertheless, Augmented Reality was found to have a number of distinct advantages over other navigational apps, namely the ability to influence users' understanding of proximity, directions and spatial relations, as they present locational information unlike other navigational apps. AR was furthermore found to be a more enjoyable and engaging way of interacting with location information.

Key Words: *Augmented Reality, AR, Apps, Performance, Perception, Familiarity, Space*

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1. Introduction

Augmented Reality has been in development for decades, yet the general public is still largely unfamiliar with the term and its underlying concepts. Although the technical development of Augmented Reality has been the subject of much academic research (e.g. (Azuma et al., 2001), the effects of Augmented Reality on users have been largely ignored up to this point. Researches within computer science are dealing extensively with developing technical possibilities to improve the overall functionality of Augmented Reality (e.g. Bergig et al., 2010, Langlotz et al., 2011, Verbelen et al., 2011) and while this effort is worthwhile and of great importance, analyzing the potential (social) impacts of an increasingly “augmented” world is an effort relatively rarely undertaken at this point in time.

The concept of Augmented Reality, which is the combination of virtual objects and information with real-world images, has great potential for assisting users in day-to-day activities. The aforementioned academic vacuum is therefore in need of filling, with the research at hand attempting to do so.

At first though, a working definition of the term "Augmented Reality" is needed. Augmented Reality (AR) can be defined in the following way: **“**An [Augmented Reality] system supplements the real world with virtual (computer-generated) objects that appear to coexist in the same space as the real world” (Azuma et al., 2001, p.34). It furthermore has the following properties: “[AR] combines real and virtual objects in a real environment; runs interactively, and in real-time; and registers (aligns) real and virtual objects with each other” (Azuma et al., 2001, p.34). Putting it simply, Augmented Reality superimposes text, pictures or virtual objects onto live camera-images, in context of where the user is and which direction he or she faces.

Augmented Reality is used in a number of fields and can be produced by a number of devices (see Chapter 4.2), however for the purpose of this research the focus rests on navigational “point-of-interest” (POI) Augmented Reality apps, meaning programs that run on smartphones, and help their users to learn about and navigate through their respective environments.

Fig. 1 – Augmented Reality App *junaio* (Image stitched together from four individual pictures made within the app)

A typical navigational Augmented Reality app determines the user's location, accesses online databases to find out which places are close, and then presents these as floating textboxes, which are aligned according to which direction the user is facing, and superimposes them onto the device's camera feed. Fig. 1 is a visual example of how results are presented in an Augmented Reality app.

As seen in Fig. 1; the map and location information are presented in an entirely new way. Since in the case of navigational Augmented Reality apps the two-dimensional, top-down map-view of more traditional systems is being replaced with a constantly contextualized first-person perspective, the unification of the observer with the observed becomes possible. The Augmented Reality User is located "within" the map itself. Users are learning about and experiencing space with no disconnect from their actual surroundings, and from their natural perspective. They are also presented with locational information in linear distances, as opposed to the distance of the way they would have to actually traverse to get to any given location (as employed by most other navigational devices, such as SatNavs). AR apps furthermore display results in constant directional relation to the user, which eliminates the element of abstraction that is present when correlating map-information with one's actual position and viewpoint. Since media has the undoubted potential to affect our overall perception of the world, Augmented Reality clearly has the potential to challenge and change users' existing perceptions of space.

Fig. 2 – Wearable Computing Solution from the early 1990s

Fig. 3 – *Wikitude* Augmented Reality App on an iPhone 3GS

For a long time Augmented Reality has exclusively been in the hands of engineers and scientists, who for decades have been experimenting with superimposing and reliably aligning virtual objects with live-images of the real world. This research resulted in the creation of sophisticated Heads-Up Displays, as well as Wearable Computing solutions (see Fig. 2), which, while powerful, were never intended to be used by the public at large. Besides being extremely expensive and requiring expert knowledge to properly operate, these systems were simply not practical for "casual" usage.

The growing proliferation of smartphones in recent years changed this though. While initially smartphones were simply internet-capable mobile phones, subsequent hardware generations introduced special sensors to the hardware, like compasses and accelerometers, that enabled a plethora of new usage options for these devices. One of these new possibilities was Augmented Reality, as the combination of several of these subsystems enabled to functionally emulate what was reserved for hardware specifically dedicated to Augmented Reality before. Furthermore and perhaps most importantly, Augmented Reality became usable without first having to "gear up" (see Fig.3). To understand the emerging importance of this form of reality mediation, it is helpful to locate this process within the evolution of digital spheres, or more precisely; the internet.

In 2009, Tim O'Reilly, founder of the omnipresent term "Web 2.0", and influential figure for the popular technology discourse, updated his manifest on "Design Patterns and Business Models for the Next Generation of Software" (O'Reilly, 2005), introducing the phrase "Web Squared". In this document, co-written by fellow web-alumni John Battelle, a large part of his focus lies on the "smartphone revolution", and how collective intelligence applications are increasingly driven by sensors, instead of humans with keyboards. By way of these sensor-based smartphone applications, the web is more closely integrated with the real world, which O'Reilly describes as "qualitative change", and as the "web [meeting] the world" (O'Reilly, 2009).

O'Reilly's focus on sensory input measures as new ways of interacting with synthesized data underlines the potential relevance of Augmented Reality: what was still considered as high tech, avant-garde experiments a couple of years ago, might soon very well be as prevalent as keyboards, acting as more natural input methods, and potentially eliminating other, more cumbersome input methods altogether.

This idea of a more intelligent web, and more intelligent programs, especially applies to sensor-based applications (including Augmented Reality apps). It must be noted of course that all benefits of sensor-aided programs only apply to smartphone owners, thereby only a portion of the population. This of course raises concern about the harmful effects of a digital divide, meaning the disparities between those in possession of technology, and those who are not.

However, the portion of the population in possession of modern smartphones has been exponentially growing, especially in the last two years. The internet marketing research company comScore released their annual study on mobile phone ownership and usage in February of 2012 (Radwanick & Aquino, 2012), compiling the following insights:

In 2011, smartphones "gained rapid adoption among mainstream consumers", with ownership shares of 44 % in the US and 42 % in Europe, with a "strong growth in the usage of apps, reaching parity with the mobile browser audience by year's end".

Mobile media usage increased heavily as well, with the main reasons cited being "[…] the popularity of smartphones, the growing availability of WiFi paired with the proliferation of 3G and 4G wireless networks, and a continuing shift towards a constantly connected consumer lifestyle." (Radwanick & Aquino, 2012, p. 6)

Combining Augmented Reality's multifaceted potential for day-to-day activities with the exponential and ongoing proliferation of AR-capable smartphones across all markets, the possible relevance of this research is clearly evident: suddenly the number of people able to experience Augmented Reality is exponentially increased. The emergence of simple-to-use apps on App Stores opened Augmented Reality to a much wider public. Technological determinism, as exemplified above by Tim O'Reilly, would lead to the conclusion that this new technology will undoubtedly change the way space is perceived. There are however also differing viewpoints on this topic: the "social shaping of technology" perspective proclaims that the development of new technology is not the single determining factor regarding technology's role in society, but that there is "a mutual influence of technology and society on technology development" (Jørgensen, Jørgensen, & Clausen, 2009, p.80). Taking this into account it is reasonable to assume that Augmented Reality has reached a pivotal point in its life-cycle. Now that it is employable by large amounts of the population, its benefits and overall position in day-to-day life are in actual negotiation.

According to a large amount of technology-websites and blogs, Augmented Reality is the next big tech trend and will play a huge part in the future: "[…]'AR' will clearly soon be talked about by everyone the way they used to talk about 'social media' and 'Web 2.0' before that" (Perez, 2009). The annual Horizon Report, which attempts to produce educated predictions about the future of technologies, stated in 2010 that AR "has become simple, and is now poised to enter the mainstream in the consumer sector", with a projected mass market adoption time of "two to three years" (Johnson, Levine, Smith & Stone, 2010, p.21).

Combining the underlying potential of navigational Augmented Reality apps, as explained above, with this newfound and massive potential user base explains the motive of the research at hand, and supports its relevance: a significantly new and distinctive approach to convey geographical and locational information, which is theoretically employable by an already huge and constantly growing group of people across the world, has the potential to change how we, as users, perceive, learn about and experience space, proximity, and locations, and thereby our world.

Since Augmented Reality builds upon the foundation of digital maps, it is of great interest for this study to analyze theories dealing with the effects of the wide dissemination of annotated, highly contextualized maps. The umbrella term for these theories is "Net Locality", a perspective able to inform much of the research at hand. Augmented Reality furthermore has the theoretical potential to compress space, as it condenses a multitude of locations onto the screen. It potentially also compresses time, as getting a plethora of information about one's surroundings is done in the time it takes to load up an app, as opposed to the time it takes to physically explore any given area. Theories relating to Time-Space compression are therefore also of great relevance to this study. Besides a general theoretical framework, built with the intention to produce educated expectations about the possible effects of regular navigational AR usage, the aforementioned approaches will help to approach the subject matter from a number of viewpoints.

Since it is this research's objective to explore the effects of a regular usage of navigational, "point-of-interest" Augmented Reality apps on their users understanding of space, the central thesis question is:

What are the effects of Augmented Reality Apps on the users' perception of space?

However, while researching these effects, another aspect needs to be kept in mind: currently available smartphones initially were not designed as devices with the purpose of displaying Augmented Reality. Quite contrary, Augmented Reality became possible on these devices almost by accident. The technical sophistication of Augmented Reality apps on smartphones is therefore an important factor for this exploratory research, as determining how well AR works on smartphones is an important step for the evaluation of the user experience. Determining the current state of Augmented Reality apps in the field of "point-of-interest" navigation is therefore needed to contextualize all findings and represents the second main research objective:

In which way are the effects of AR apps on their users' perceptions of space related to the performance of AR apps on currently available devices?

The combination of these two fundamental questions is the ultimate purpose of this research. In order to answer the research questions as adequately as possible, the following research design was developed: an exploratory experiment, with extensive pre- and post-test surveys combined with interviews with experts (Augmented Reality app developers).

The remainder of the thesis develops as follows. At first, background information is provided to deepen the understanding of the concept of Augmented Reality. Specifically, the exact definition of the term is given, its history and development, as well as its fields of application and underlying functionality are covered. After this, the precise research focus guiding the research at hand is explained. At this point the foundation for dealing with the chosen topic is established. The ensuing chapter builds a Theoretical Framework in order to incorporate previous research into related topics, including the Geospatial Web, Web Mapping Practices, Net Locality and Time-Space Compression.

The subsequent chapter details the methodology chosen for answering the research questions, including research method, sampling process, allocation of participants, focus of pretest Interviews, chosen apps and focus of posttest interviews. Afterwards, the findings that emerged from questionnaires, posttest interviews with users and the interviews with developers are presented in detail, divided into thematic sub-sections. These findings are then further contextualized in the discussion chapter. Finally, the implications of the findings are summarized, the limitations of the study are discussed and recommendations for future researchers are given in the conclusion. By doing so, the thesis thoroughly evaluates the current state of navigational POI Augmented Reality apps, and their potential effects on the user's perception and understanding of space.

2. Augmented Reality – Background

2.1. Definition

In order to adequately deal with the topic at hand, at first a definition of "Augmented Reality", a clear demarcation of what is included within this term, and what is not, is needed. Within popular terminology, Augmented Reality refers to the technology that "offers a real-time view of one's immediate surroundings altered or enhanced by computer generated information. When users examine their environment through AR devices, they see information superimposed on the objects around them." (Financial Times Lexicon, 2012)

This definition includes AR's biggest differentiation from other forms of reality, such as virtual and mixed reality, as well as augmented "Virtuality". Augmented "Virtuality" means that what "is being augmented is not some direct representation of a real scene, but rather a virtual world, one that is generated primarily by a computer" (Milgram, 1994). Today, mixed reality is often seen as encompassing Augmented Reality and Augmented Virtuality, though it factually only refers to an "environment in which real world and virtual world objects are presented together within a single display" (Kher, 2002). Locating these concepts within the "Reality-Virtuality (RV) continuum" (Milgram, 1999) provides additional information about their respective proximity to real and virtual environments (see Fig. 4).

While virtual reality can be defined as "an artificial environment […] provided by a computer and in which one's actions partially determine what happens in the environment" (Merriam-Webster, 2012), with this definition clearly underlining the separation between the natural and the digital, augmented reality is a term describing the relationship between those two, the different amounts of "on- and offline" (Rey, 2011), the mixture ratio of real and digital, between atoms and bits (Negroponte, 1995).

Fig. 4 Reality – Virtuality continuum (Freeman, 2007)

AR therefore refers to the augmentation or enhancement of the real or physical world with electronically synthesized data (Milgram, 1999), by way of any kind of display that allows its user to “observe a direct ‘see-through’ view of the real world […] upon computer generated graphics are superimposed” (Kher, 2002). These demarcations make clear that the Augmented Reality applications currently available in App Stores in fact do fulfill the theoretical and technological requirements needed to be considered as true Augmented Reality.

2.2 The History and Development of Augmented Reality

To deepen the understanding of how Augmented Reality differs itself from other forms of computer-guided mediation, it is of benefit to take a closer look at the history of AR development. The first device capable of displaying what today would be regarded as Augmented Reality was developed in 1966, by Ivan Sutherland, and called the "Head-Mounted Three-Dimensional Display" (Sutherland, 1968). What today is known as AR's basic functionality was already present in this early prototype:

> "The fundamental idea behind the three-dimensional display is to present the user with a perspective image which changes as he moves. […] The image presented by the three-dimensional display must change in exactly the way that the image of the real world would change for similar motions of the user's head." (Sutherland, 1968, p. 5)

In 1975, the American computer artist Myron Krueger developed "Videoplace" at the University of Connecticut, pioneering the concept of Virtual Reality. In this laboratory, users were able to create and control virtual objects through their own movements, which were captured through video and projected onto screens around them (Krueger, 1988). This interaction with virtual objects through real-life movements later became one of the foundational concepts of Augmented Reality, though it was not before another form of mediated reality gained a lot of traction at the end of the 1980s, and through much of the 1990s, that American computer scientist Jaron Lanier coined the widely known term of "Virtual Reality" (Lewis, 1994).

Lanier founded VPL Research in 1983, and was responsible for its main focus on Virtual Reality (VR) soft- and hardware, as well as the first commercialization of interface gloves (needed for the interaction in virtual 3D spaces) and head mounted displays (Burkemann, 2001).

After having gained huge popularity and enthusiasm in the mid-90s, public interest in VR waned quickly soon thereafter, which is today largely attributed to a plethora of factors: technical improvements were slow, and had very little support from established companies. Furthermore, the potential and benefits of VR were oversold and largely exaggerated, with the technology itself being comparatively very expensive (V–Rtifacts, 2010).

Though mass-market adoption never happened on the scale it was expected to be, the potential of VR was exploited in other areas, notably by Tom Caudell. Tom Caudell graduated with a Ph.D. in astrophysics from the University of Arizona and developed “virtual reality systems in manufacturing and engineering processes” (Goodale, 2003) while working for Boeing. In 1990, while trying to develop systems that were able to help engineers assemble the complex wiring for modern airplanes, Caudell came up with the term and concept for Augmented Reality:

> “He applied the term to a head-mounted digital display that guided workers through assembling electrical wires in aircrafts. The early definition of augmented reality, then, was an intersection between virtual and physical reality, where digital visuals are blended in to the real world to enhance our perceptions.” (Chen, 2009)

This idea was further developed at the University of Columbia into KARMA; an AR system in which users had to wear a display over one eye, which gave an overlay effect when the real world was viewed with both eyes open (Feiner, Macintyre, Seligmann, 1993). Its use was similar to that of Caudell’s AR system, in that KARMA could produce additional schematic information helping its users in complex maintenance operations.

While such initial applications for Augmented Reality were largely restricted to engineering support, AR quickly found its use in other domains as well. Between 1992 and 1993 experiments in live combat training included the use of AR, specifically to allow “vehicle crews to see virtual vehicles and weapon effects” (Barilleaux, 1999, p. 1).

Other uses included culture production, such as the “Dancing in Cyberspace” theater production (Simon Fraser News, 1999), and workplace improvement, such as the “The Office of the Future” program, conducted at the University of North Carolina, which was similar to Krueger’s Videoplace in the respect that it produced “spatially immersive” Augmented Reality by projecting interactive images on surfaces surrounding the user (Raskar, Welch, Cutts, & Lake, 1998).

While all the aforementioned projects were built with a controlled environment and indoor use in mind, Bruce H. Thomas made significant strides in the outdoor and mobile functionality of Augmented Reality when he developed AR Quake, an Augmented Reality game based on the popular first-person shooter Quake by the game development company id Software (Thomas, Close, & Donoghue, 2000). While the game itself entailed not much more than classic first-person shooter mechanics, meaning players firing virtual weapons at virtual enemies to progress, the input method was revolutionary, and laid much of the foundation for today's implementation of AR in common mobile phones. Although the implementation was not perfect, many interesting results were found, especially in relation to "user interface issues [and] an architecture for low cost, moderately accurate indoor/outdoor […] tracking" (Thomas et al., 2000, p.8). The significance of this project for future generations of AR applications lay in exactly this low cost combination of optical tracking and GPS/compass tracking, which served as "proof that augmented reality is readily achievable with inexpensive, off-the-shelf software" (Thomas et al., 2000, p.8).

Although the technology was already inexpensively available in 2000, it took another eight years for the underlying technology to become so widely distributed that the first AR app was designed for the average consumer. Now, one did not need to buy any additional special equipment, but was able to experience Augmented Reality with one's mobile phone, meaning hardware that was already present in the household. The biggest obstacle for Augmented Reality; having to buy expensive equipment dedicated to the sole use of producing AR experiences, was surmounted. This change of user base for AR happened when the Austrian company Wikitude GmbH released the Wikitude Travel Guide for the G1 Android phone in late 2008 (Perry, 2008).

The app produced digital overlays onto the camera image of the user's mobile phone, providing additional information about point-of-interests in the direction the user is facing. It was the first of its kind, and acted as blueprint for many of the apps that followed, and many of the apps of which effects are the focus of this research.

While select Android phones were capable of running such apps as early as in 2008, it took another two years for Apple to provide developers with an open API (application programming interface) to access live video from the phone's camera (Chen, 2009). After AR enthusiasts pleaded for access to this API with an Open Letter to Apple (Inbar, 2009), this feature was finally implemented with the operating system software update iOS 3.1, which was released in February of 2010 (iPhone Wiki, 2012). Due to the immense popularity of the iPhone, and its pioneering role on the smartphone sector, this change in Apple's policy became one of the biggest factors enabling the proliferation of navigational Augmented Reality apps in recent years.

This new access to previously locked APIs was subsequently used by developers to program and release a plethora of Augmented Reality apps on the iPhone, all the while development on AR apps for new Android models continued, resulting in today's situation, in which a multitude of apps with different purposes is available for free and for small amounts of money on different operating systems and phone models.

2.3 Fields of Application

Besides the aforementioned functions, namely navigation and point-of-interest search, Augmented Reality is used and experimented with in a number of fields. One of AR's main purposes as of now is in the field of advertising. A number of companies used webcam based AR to promote their products by producing 3D models of their products, models that the user then can interact with in front of their computer (Savov, 2009). As mentioned in the previous chapter, AR helps engineers with complex maintenance tasks (Chen, 2009), is of assistance in military and emergency services (Barilleaux, 1999), and is used in interactive digital games: outdoor games such as the aforementioned AR Quake (Thomas et al., 2000), as well as indoor games on the Nintendo 3DS, PlayStation Vita and PlayStation home consoles (AR Play, 2012) use Augmented Reality to make gaming more engaging.

It is furthermore experimented with in the realm of medicine, to guide surgeons during complicated operations., where AR is employed with the purpose of displaying "a merged real and synthetic image in the surgeon's video-see-through head-mounted display" (Fuchs, Livingston, Raskar, & Colucci, 1998, p.1). AR is furthermore used in clinical psychology, for instance to help persons with intense phobias of cockroaches, by enabling them to interact with virtual cockroaches on their real hands, therefore allowing them to lower their anxiety levels in a safe environment (Botella et al., 2011). Another noteworthy field of AR is for the purpose of instantly translating foreign languages, as demonstrated for example by the iPhone app "Word Lens", which is able to translate words and short sentences from the live-camera feed in real time (Tsotsis, 2010).

While most of these purposes serve very specific, single needs, the navigational point-of-interest search purpose of Augmented Reality is potentially able to be of benefit in a plethora of situations. It is furthermore not only the most likely contact point of the average consumer with the concept of AR (since as of now it is the most accessible and broadly employable form of Augmented Reality), it also has the biggest potential to change the way we perceive the world. Due to this potentially very significant influence on our perceptions of space, the purpose of this thesis restricts itself to the examination of the effects and intricacies of Augmented Reality point-of-interest navigation.

2.4 Point-Of-Interest Navigation Functionality

In order to situate the findings regarding the performance of Augmented Reality, it is important to first establish a general understanding of how Augmented Reality works on currently available smartphones. First of all, it is important to note that all Augmented Reality apps on current smartphones operate by gathering data from multiple sources present within the device, and then present the results based on the combination of data resulting from those systems. Layar, a perfect example for a typical navigational/POI AR app produces its results in the following way:

> "Layar works by using a combination of the mobile phone's camera, GPS, compass, accelerometer and a mobile Internet connection. The camera captures the world as seen through its lens and shows it on the screen. The GPS determines the exact location and the compass and accelerometer the field of view. Based on these sensors and the selected layer, digital information is retrieved over a mobile Internet connection and augmented on top of the camera view." (Layar, 2010)

To emphasize the complexity of this system: for the AR app to display any result, it first needs to combine the data out of five different sub-systems. While the camera and accelerometer (a device that measures acceleration, thereby able to determine the phone's alignment) are largely independent systems, the GPS, compass and mobile Internet connection are subject to environmental circumstances. The GPS accuracy depends on factors outside of the user's control, "including atmospheric effects and receiver quality" (Official U.S. Government information about the Global Positioning System, 2012), and the proximity to structures affecting signal strength, such as buildings. The accuracy of the phone's compass "can be affected by magnetic or other environmental interference", with "some areas [having] more magnetic interference than others" (Apple, 2012). Lastly, the mobile Internet connection largely depends on the coverage provided for any given area by the individual telecommunications companies, which depending on the situation typically ranges between no, slow (2G) and fast (3G) connection, heavily influencing at which speed the results of AR apps can be found and displayed. In conclusion, Augmented Reality only works on modern smartphones by combining several sophisticated systems, many of which are not failure-proof and heavily dependent on external factors. It is important to keep in mind how complex and potentially fragile this system is when evaluating the actual experience of users, which will be addressed in the findings.

3. Research Focus

Augmented Reality is not only a new type of app for gathering geographically contextualized, navigational information; it also produces an entirely new perspective for "experiencing" map information. The observer is placed squarely within the scene, by producing information directly connected to the user's location and especially viewpoint. Without turning around, the user is unable to actually see what the app locates behind him. This approach for orienting oneself radically differs from previously employed "top-down", isometric map views. Since perspective plays a major role in how we perceive reality, this raises the question to what extent Augmented Reality has the potential to change the way its users perceive their surroundings.

On the other hand, Augmented Reality is a technology that, even though in development for decades, still needs to be seen as in its infancy; especially in connection to the sort of device it is currently accessible for the majority of consumers; the smartphone. The purpose of this research is to bring those two aspects together. The objective is to evaluate the effects of navigational, point-of-interest based Augmented Reality on its user's perception of space, in context of the performance of currently available apps and devices. The following research questions were designed based on the aforementioned research interest. Sub-questions are explained in more detail to give a better understanding of their intent.

> **RQ 1:** ***What are the effects of Augmented Reality apps on the user's perception of space?***

This question is operationally further divided into three sub-questions.

The traditional information gathering process in regards to potential points-of-interest is very specific and linear: an individual develops a specific need, gathers specific information related to the fulfillment of this need, and then fulfills the need. This is done for instance by entering specific search criteria into an online search engine, like Google. Augmented Reality apps on the other hand, while also allowing its users to conduct specific searches based on their needs, generally produce very inclusive results. Its purpose is less to show where one specific place is located, but more to inform its users about all kinds of places in his or her vicinity.

Thus, it can be argued that prolonged and regular usage of Augmented Reality possibly increases its user's awareness of all the options available to him/her. This subsequently might fundamentally alter his/her way of thinking about and perceiving the variety of options and the plethora of reachable locations in his/her respective surroundings. Single instances where realizations regarding the previously unknown quantity of options are made, might lead to a general re-evaluation of the perceived familiarity with places. Awareness in this regard is also to be understood as the amount of attention that is being paid to locational information. Determining whether these processes of thought actually take place or increase is the motivation behind the first sub-question.

> RQ 1.1: *Are users of Augmented Reality apps more aware of their surroundings than non-Augmented Reality app users?*

It is within human's nature to establish a rough understanding of the geography of places in order to orient oneself within them. Everyone has different levels of familiarity with places, depending on how often they are travelling within them, how expansive these travels are, and how many of the available activities in any given place have been taken advantage of before, or are known. One of the biggest benefits of Augmented Reality might be to inform users more about options available in an area that the user has not visited before, has not experienced first-hand, or wasn't even aware of at all.

The increase of (for the user relevant) information is one of the basic goals of AR apps. What however needs to be evaluated is if this amount of additional information is then able to actually produce an increased familiarity with a place. Familiarity in this respect is to be understood as the amount of accurate and relevant information one has about any given area. Do users feel more familiar with an area simply because they know what other activities are available in the area? Evaluating changes that occur after the regular and intense usage of Augmented Reality apps is the purpose of the following sub-question.

> RQ 1.2: *Is the regular usage of Augmented Reality apps positively influencing user's familiarity with their respective surroundings?*

Up to this point, navigational information was retrieved by looking at on- or offline maps, from a bird's eye, meaning isometric and remote from what the map is actually trying to represent. Augmented Reality is the first type of map-application that allows its user to view the map from his/her actual perspective; standing on the ground, looking in one specific direction. The fact that any and all results are directly superimposed on the picture of a live video feed of what is directly in front of the user might lead to an entirely new way of perceiving those results. One might assume that AR users are potentially able to fully immerse themselves in the experience, experiencing space based on their physical movement, thereby implementing previously unused senses in the interaction with maps, allowing them to physically "dive into" the digital representation of reality. Whether these feelings of immersion actually occur during prolonged and regular sessions of Augmented Reality usage is the focus of the next sub-question.

> RQ 1.3: *Does Augmented Reality enable its users to immerse themselves in the digital representation of space?*

The second research interest, focused on the usability and performance of currently available Augmented Reality apps is expressed in the second Research Question:

> **RQ 2: *What is the current state of Augmented Reality Apps in the field of navigation and "point-of-interest" search?***

This question is operationally divided into the following three, more specific, sub-questions:

> RQ 2.1: *How do Augmented Reality apps perform on currently available smartphones?*
>
> *RQ 2.2: How much does this performance affect the overall user-experience?*

These sub-questions result out of the need to determine the significance of this research for navigational Augmented Reality as a concept. The validity of the answers to all previous research questions heavily depends on the performance of the employed apps. Testing for effects with potentially non-functioning instruments (meaning not or badly working apps) needs to be avoided. Therefore evaluating the extent and limits of the functionality of AR apps on currently available devices is not only a definite necessity for this research; it also becomes its secondary focus.

After having determined the performance of aforementioned apps, it is of relevance to illuminate the underlying reasons for the determined performance. This not only allows for a thorough evaluation of the status-quo, and the underlying reasons for this status-quo, it also enables a look at the future of the technology. Therefore, the following, last sub-question needs to be answered by experts:

> RQ 2.3: *What are the main technical possibilities and limitations that are responsible for the performance of Augmented Reality apps in their current form?*

The final research question is the following:

> **RQ 3:** ***Does the information obtained through regular use of POI Augmented Reality apps influence the user's actual actions?***

This final question is focused not on potential changes in user's perception of space, but on the potential of Augmented Reality apps to directly influence the actions and day-to-day routines of its users. Does AR mainly serve as an additional source for information, with no direct impact on the information's recipient, or is its regular use directly affecting actual behavior, thereby drastically increasing the levels of potential effects as surveyed by this research?

To adequately approach answering these research questions, at first a theoretical framework must be employed to deal with the different aspects and intricacies involved in Augmented Reality in its current state. The following section, dealing with theoretical approaches connected directly, as well as indirectly, to Augmented Reality, attempts to do so.

4. Theory

Due to the only recent emergence of Augmented Reality apps available to the average consumer, not much research has been completed into the effects these comparatively new applications have on their users. To establish a working framework usable for the purposes of this research, a variety of theoretical approaches and angles are introduced and applied to the concept of navigational AR apps on mobile phones at the beginning of this chapter. Afterwards a linear narrative is established, which at first focuses on the emergence of digital maps, which are the foundation of all currently available AR apps. Attention is then shifted towards the effects that developed out of the merging of digital, contextualized maps with portable computing devices (e.g. smartphones), capable of displaying these maps "on the go". The underlying logic behind the aforementioned narrative can be summarized as follows.

Without the emergence of online maps, Augmented Reality, as it is realized today on smartphones and tablets, would not have been possible. After the introduction of the theoretical framework it is therefore of great relevance to take a close look at how the rise of the Internet influenced mapping practices. These phenomena have been approached from a multitude of angles. The most relevant for the research at hand are the "Geospatial Web" (Scharl & Tochtermann, 2007), as well as the practices of "Web Mapping 2.0" (Haklay, Singleton, & Parker, 2008). To evaluate how these relatively new methods of mapping and orientation affect the social spheres and the way we are experiencing space, the focus of this chapter will then shift towards an analysis of "Net Locality" (Gordon & de Souza e Silva, 2011). Since this new fluidity of geography is able to contribute to the shrinking of the perceived world, the chapter will close with a final review of relevant theories relating to "Time-Space-Compression".

4.1 A Theoretical Framework for Augmented Reality Apps

First of all, the effects of being located in an environment relative to what else is in this environment need to be evaluated. This new way of experiencing space, for example by way of mediation through AR, is believed to change the perception of what seems near and what is actually near (Couldry & Markham, 2008).

Being placed into a map, in constant relationship to other landmarks (or points-of-interest), has two potential effects, which are not necessarily to be seen as mutually exclusive. On the one side it creates a sense of unspecific "distancelessness", since one is surrounded by a plethora of options, leading one to believe that access to everything is practically possible, while on the other side it also produces a sense of "nearness", since the actual, physical distance is also determined and easily observable.

To make this point clearer, it is of benefit to further illuminate the concept of "distancelessness", a concept that was first established in the early seventies by German philosopher Heidegger, who applied the concept to (back then) modern broadcasting:

> "Yet the frantic abolition of all distances brings no nearness; for nearness does not consist in shortness of distance. What is least remote from us in point of distance, by virtue of its picture on film or its sound on the radio, can remain far from us, […] everything gets lumped together into uniform distancelessness. (Heidegger, 1971, p. 165)

This aspect of course stands in stark contrast to the latter possible effect mentioned, the "feeling of nearness". This aspect arises due to the raw locative data, which is readily visible in most Augmented Reality apps. Seeing how far away places actually are in the physical world has the clear potential to create what has often been referred to as media's power to produce "meaningful nearness to things and people" (Scannell, 1996).

Besides this evaluation of "nearness" vs. "distancelessness", the intricacies and effects of "Immersion" (as expressed in RQ 1.3) is another important aspect to tackle. Immersion can be defined as a "sense of being there" (Smith et al., 1998). While apps such as Google's Street View have incorporated this sense of being there into their design of a map application as early as 2007, Augmented Reality has the clear potential of expediting this process, and is seen as further proof that the link between digital information and physical location is only growing stronger:

> "It reduces the perceived distance between located data and the user experiencing the data, and it is likely that future mapping applications will build on this feeling of immersion in order to more strongly map information available on the web to local physical spaces." (Gordon & de Souza e Silva, 2011, p. 32)

It should not go unmentioned at this point that previous studies into this topic have come to the conclusion that textual interfaces might actually prove to be more powerful when it comes to immersing their users into the application, especially compared to computer-generated images (Murray, 1998). Augmented Reality however is not easily put into any of those two categories, as it produces textual information superimposed onto real-time pictures of reality, thereby falling squarely in between those ends of the spectrum.

Another theoretical concept that potentially can be connected to the experience of using Augmented Reality in places full of "points-of-interest", is what German sociologist Georg Simmel called the "blasé attitude" (Simmel, 1971). According to Simmel, the blasé attitude occurs especially in dense metropolitan areas, due to an overflow of equally relevant information: "[It] results first from the rapidly changing and closely compressed contrasting stimulations of the nerves." (Simmel, 1971, p. 5) The blasé attitude is to be understood as a mechanism to filter all the information present at any given moment down to what is truly relevant to the individual in his or her respective situations.

> "It needs merely to be pointed out that the metropolis is the genuine arena of this culture which outgrows all personal life. Here […] is offered such an overwhelming fullness of crystallized and impersonalized spirit that the personality, so to speak, cannot maintain itself under its impact" (Simmel, 1971, p. 13)

The blasé attitude therefore acts as "a coping device that people adopted to deal with the realities of urban life" (Gordon & de Souza e Silva, 2011, p.87). In this context it is of great interest to this research to determine whether Augmented Reality is able to aid in this filtering process, or if it adds to the (possibly already overwhelming) amount of information.

Another aspect worth including in this theoretical framework are the effects of "hybrid spaces". Hybrid spaces are "mobile spaces, created by the constant movement of users who carry portable devices continuously connected to the Internet, and to other users" (de Souza e Silva, 2006, p. 265). The basic idea of this concept is that mobile devices contribute to "the blurring of borders between physical and digital spaces" (de Souza e Silva, 2006, p. 272), essentially causing the mobile device user to be situated in two separate spaces at once, the digital and the real, with the resulting creation of aforementioned "hybrid spaces".

This development has been viewed as critical by some, who argue that the use of digital networked connection in urban spaces effectively remove the user from their actual surrounding, thereby diminishing the value of real places, in favor of already familiar digital surroundings (Hampton & Livio & Goulet, 2010).

These concerns about how technology can distort our perception of distances were not only brought up since the emerging popularity of smartphones. Even such early technologies as the microscope, or the telescope, were criticized for changing something that was "instinctive or unconscious into something more sure but fragmented. […] What was distant before now comes closer, at a cost of greater distance to what was previously closer" (Zeuner, 2003, p. 81, as cited in Gordon & de Souza e Silva, 2011, p.87).

This focus on remote places over what is in immediate proximity, instantaneously reachable, is a large factor of the basic concept of Augmented Reality: AR thrives on its users urge to not only know what is directly in front of them, directly observable with their own eyes, but also what hides behind the buildings, architecture and other view-obstructing geometry. Augmented Reality however is by far not the only type of application enabling the possibility to be present at multiple places at the same time: "It is progressively more common to navigate two spaces simultaneously, to see digital devices and telephones as extensions of our mobile selves." (Varnelis & Friedberg, 2008).

This act of temporarily escaping the physical reality of any given situation is however, again, no new phenomenon that only occurred since the invention of smartphones. It has been analyzed as early as in 1963, long before the advent of any portable media device:

> "While outwardly participating in an activity within a social situation, an individual can allow his attention to turn from what he and everyone else considers the real or serious world, and give himself up for a time to a playlike world in which he alone participates. This kind of inward emigration from the gathering may be called 'away'." (Goffman, 1963, p. 69)

This “going away” from what is actually in one’s immediate surroundings certainly detracts from one’s mental presence in any given location in the case of for example” checking social networks”. “Going away” to focus one’s attention on digitally mediated location information however might not be really considered as “going away”. Augmented Reality therefore may have the potential to keep its users present, and potentially actually “more there” than any other kind of attention alternative. When turning one’s attention away from “real” reality to “augmented” reality, one might actually achieve the direct opposite of “going away”: “Going away reinforces the dominant involvement with the local” (Gordon & de Souza e Silva, 2011, p.96). This however has not been proven up until this point in time. “Is the fact that technology has become more aware of locations actually responsible for its user to become more aware of their locations as well?” is a question that has not been thoroughly evaluated by empirical research yet. Therefore measuring the actual “awareness” Augmented Reality users have in regards to their surroundings (as addressed in research question 1.1) is another subject for the research at hand.

The final aspect worth including in this theoretical framework is concerned with the Social Shaping of Technology (SST). Central to SST theories is the concept of choices, “inherent in both the design of individual artefacts and systems, and in the direction or *trajectory* of innovation programmes” (Williams & Edge, 1996, p. 866). According to SST, technological innovation is inherently fluid, not static, and initially in constant negotiation. Although the SST perspective includes the notion of irreversibility, meaning the extent in which branching paths may be shut down, and closure, meaning “the ways in which innovation may become stabilized” (Williams & Edge, 1996, p. 867), it generally focuses on the implicit dialogue between technology creators and technology users, which becomes indicatory for the future development of said technologies. In relation to Augmented Reality apps on mobile phones, it is therefore of interest for the study at hand to determine in which ways AR apps are employed by users, and how much this usage corresponds to the original intention of the AR app developers.

Further expectations regarding the effects of navigational AR apps on users can be drawn from theories concerned with new, digital mapping practices, and the consequences these practices have for our perception of time, space, and our surroundings. The following sub-chapters deal with these relevant topics.

4.2 Geospatial Web

Until a certain point in time, the internet was thought of and treated as a way of collecting, compiling and categorizing massive amounts of information, often with little direct connection to what it sought to represent. The internet existed as an almost completely separate entity of reality. The (at that time) "available methods for finding and using information on the web [were] often insufficient" (Egenhofer, 2002, p. 5). Information was not contextualized, the web was "blind" (O'Reilly, 2009). This changed with the advent of the semantic, geospatial web, "by incorporating the data's semantics and exploiting the semantics during the search process" (Egenhofer, 2002, p. 5). Location became crucial in the effort to present users with data more relevant to their respective situations. This effort was mainly motivated by the desire to reduce any annoyances during web searches to a minimum, for example by "weeding out irrelevant hits" (Egenhofer, 2002, p. 7). Fortunately, the technology needed to achieve this goal was readily available, and served an entirely different need as well: "[…] GPS, radio frequency identification (RFID), Wi-Fi triangulation, and other situating technologies have been adopted for web information storage and retrieval because of the social desire to locate ourselves in relation to information. (Gordon & de Souza e Silva, 2011, p. 3)

The ability to connect the previous "wasteland of unfiltered data" (Stoll, 1995) to actual locations on a map, thereby instantly and exponentially increasing the respective relevance of search results, is what makes the geospatial web powerful, and ultimately popular. Geospatial web services have changed the way in which "spatial information systems and applications are designed, developed and deployed" (Zhao & Yu, 2007, p.1)

In order to create an online sphere that accurately represents geographic realities a lot of effort was put into "geotagging" huge amounts of real world information to digital maps in recent years (Scharl, 2007). Geotagging refers to the process of "assigning geospatial context information ranging from specific point locations to arbitrarily shaped regions" (Scharl, 2007, p. 5). While this development started around the middle of the last decade, it is a time-consuming and still ongoing process. The most optimistic views on this development can be summarized in the following way:

> “Once geospatial context information becomes widely available, any point in space will be linked to a universe of commentary on its environmental, historical and cultural context, to related community events and activities and to personal stories and preferences.” (Scharl, 2007, p. 6)

This constantly growing web of interconnected locations, with “annotating the Planet” (Udell, 2005) as the targeted outcome, is believed to ultimately be able to create a highly accurate map of physically contextualized information.

Accessing the web with the intent to obtain information about locations and navigation is no recent phenomenon though. As early as 1998 these activities were amongst the most popular ones on the internet (Peterson, 1999). What can potentially be seen as increasing though is the desire of many people to actively help the process along, to offer “volunteered geographical information” (Goodchild, 2007, as cited in Gordon & de Souza e Silva, 2011, p. 27).

The practices of editing, annotating and contextualizing digital maps shall be looked at more closely in the next section.

4.3 Web Mapping 2.0

Web Mapping describes the "process of designing, implementing, generating and delivering maps on the World Wide Web" (Neumann, 2008, p. 1261). Web Mapping 2.0 therefore implements the underlying structure of Web 2.0, meaning "the transformation of the original Web of static documents into a collection of pages that still look like documents, but are actually interfaces to full-fledged computing platforms" (Roush, 2005, p.4), to the practice of enriching maps with information. Through this new form of "mapping", the act of annotating geography with contextualized information became a participatory process. All of a sudden, one did not need to study cartography anymore to be able to edit maps read by thousands of people.

Many different techniques and concepts have emerged since the beginning of this trend, such as (but not limited to) location aware search engines, geotagging (as explained earlier), geoblogging (adding locative references to personal blogs), and mashups (combining existing databases with existing maps) (Gartner, 2009). Without going into too much detail regarding these specific forms of applying tools on different platforms, the definition of "neogeography" provides a relevant overview about the benefits and motivations connected to these new forms of user-created content on the web:

> "Neogeography means 'new geography' and consists of a set of techniques and tools that fall outside the realm of traditional GIS, Geographic Information Systems. […] Essentially, Neogeography is about sharing location information with friends and visitors, helping shape context and conveying understanding through knowledge of place" (Turner, 2006, p.2)

How quickly this new form of web participation grew in popularity can be easily deducted by looking at the following numbers: by 2007, Google Maps had 71.5 million active users, and over 50.000 websites had adopted Google Maps as a way of providing navigational information (Haklay & Singleton, 2008). Soon thereafter, location-based services furthermore became the fastest growing sector of web businesses, with a forecasted profit growth of 515 million dollars in 2007 to 13.3 billion dollars in 2013 (ABI Research, 2009).

This rapid adoption by a broad user base, who makes use of available technology to suit their individual needs, demonstrates the argument that employing digital, interactive mapping systems is not purely the result of technology, as technologically deterministic perspectives might proclaim, but instead is "emerging out of a cultural need to contextualize ourselves within a growing network of information" (Gordon & de Souza e Silva, 2011, p. 13).

This fundamental change in how Geographic Information Systems (GIS) are mapped and organized, who contributes and is given access to them, has already been seen as having significant implications for society: "The value of geographic information (like all forms of digital information) and the power of GIS applications to solve problems are proportional to their accessibility" (Harder, 1998, p. 1). Today's ubiquitous nature of the web underlines the immense accessibility, and thereby immense value, of geographic information. Since the effects of a massively adopted technology are usually not unilateral, this newfound relevance of geographic information in turn of course also affects social practices and local cultures.

It should be noted at this point that while many GIS services are in the public domains (see; http://opensourcegis.org/), some of the most popular (as well as most sophisticated and convenient) ones (Google Maps, Bing Maps, etc.) are owned by private corporations. While at the time of writing none of the big GIS owning corporations have made attempts to close off or monetize the user directly (although money is already being made by selling context-sensitive ads to private companies), this might change in the future, and would have a drastic effect on the participatory and inclusive nature of current Geographic Information Systems.

To turn the attention more onto the effects of aforementioned processes, in order to understand how communication and the experience of spaces are altered, it is of great benefit to attend to the concept of "Net Locality".

4.4 Net Locality

All concepts presented up to this point describe more or less the same phenomenon. They however focus less on a very important factor, as it is succinctly summarized by the following quote:

> "[…] these terms are employed typically to describe the technologies or the unique goals of using them, and not the social and phenomenal processes of interacting with networked spaces. […] What has not been properly addressed, however, is how this new context for geographical knowledge production through web mapping is doing more than transforming mapping practices; it is transforming communication more broadly." (Gordon & de Souza e Silva, 2011, p. 20)

Similar to this approach, the research at hand tries to go beyond a descriptive analysis of the functionalities and practices of the new and emerging way of navigation, and aims to reflect on the possible effects these developments will have on individuals' perception and understanding of space. In doing so the notion of Net Locality, which "implies a different way of knowing and experiencing space, not just a different tool for visualization" (Gordon & de Souza e Silva, 2011, p. 20) is an important addition to the theoretical framework of this study.

The web is no longer a realm accessed from singular places, since the emergence of smartphones the web is carried around, and since the emergence of neogeography the web is furthermore all encompassing: it is around its users. Geography has become the web's fundamental logic, and this importance is felt by its users. The once clear demarcation line between "atoms and bits" (Negroponte, 1995) is increasingly eroding. The new freedom in web interaction enabled by internet-capable phones, which locate themselves in the physical world, and subsequently filter results based on physical location, created a new mentality regarding the separation between what is virtual, and what is physical (Sheller & Urry, 2006).

Geography grew less static, and became something much more fluid. Although location has always been an important factor, "the increasing popularity of mapping tools and location-aware mobile technologies are transforming the ways we experience locations, either remotely or proximately." (Gordon & de Souza e Silva, 2011, p. 79) Especially the concept of experiencing locations "proximately" is of relevance for the research at hand, since producing information about the type, location and respective direction of places is navigational Augmented Reality's main purpose. If places really can be experienced proximately though is a question that remains to be answered at this point. The effects of social spaces being augmented with digital information and accessed from a distance is therefore at the core of this research.

It is important to note that all the aforementioned effects are in no way believed to be the direct, singular result of location-aware technology, participatory mapping practices, and the mobile internet. These technologies and developments rather sped up and intensified an already long existing social need; the desire to locate oneself within the world, within social networks, and within networks of information, to develop "connections based on who and what's nearby" (Gordon & de Souza e Silva, 2011, p.173).

What all this makes undoubtedly clear, is that locality is and has always been of utmost relevance. Even in a time of the World Wide Web, in which the "Global Village" (McLuhan, 1964, p.6) should theoretically grow smaller and smaller, the meaning produced by what is local is as important as ever. This reduction of perceived space is at the heart of Time-Space-Compression concepts, which therefore is the last logical step of this theoretical narrative to understand the potential effects of navigational Augmented Reality apps.

4.5 Time-Space Compression

Time-space compression has historically speaking been in effect for a long time by now. Far before digital communication was able to be established, time and space shrunk, due to the invention of roads. Even "technologies" such as writing have had a considerable impact on how societies perceive space and time, in a similar fashion as today's "hyperspace" (Deibert, 1997). Researchers dealing with this subject have described the symptoms of this phenomenon with the metaphor of a "shrinking world" (Kirsch, 1995). Especially the speed of increasingly sophisticated methods of transportation has drastically reduced the time it takes to cover distances, for people as well as information.

Therefore, the meaning of distance has reduced drastically as well. This can be easily demonstrated by comparing the speed of modern transportation means in 1970 (by way of airplane) with the speed of modern transportation means in 1500 (by way of medieval ships), resulting in the insight that regarding the time of travel, "the world became 60 times smaller" (Warf, 2011). However, this "shrinking" is not to be regarded as a simple "compression" of the world as we know it:

> "By accelerating the velocities of people, goods and information, the world is made to feel smaller even as social interactions are stretched over larger physical distances. The word 'compression' is, therefore, misleading: time-space compression in fact is an *expansion* in the spatial extent and range of social activities." (Warf, 2011, p. 145)

Historically, two periods are considered to be heavily affected by such a "time-space compression". Firstly, the mid-19th century up to the beginning of the First World War, due to the invention of technology such as the telephone, and significantly improved methods of transportations, such as the airplane, and secondly; the end of the 20th century, largely due to the emergence of mobile telecommunications technology, enabling broadcasting technology used for radio or television, and the internet. These periods are today often characterized by a "significant acceleration in the pace of life concomitant with a dissolution or collapse of traditional spatial co-ordinates" (May, 2001, p. 7).

Another conceptual term for this development is "time-space convergence", though this concept refers more "to the increased velocity of circulation of goods, people and information, and the consequent reduction in relative distances between places" (Stein, 2001, p. 106). More relevant for the research at hand are the effects of such developments, described within time-space compression theories as "the sense of shock and disorientation such experiences produce (Harvey, 1990, as cited in Stein, 2001, p. 106). Space-time compression therefore refers to

> "processes that so revolutionise the objective qualities of space and time that we are forced to alter, sometimes in quite radical ways, how we represent the world to ourselves. I use the word 'compression' because a strong case can be made that the history of capitalism has been characterized by speed-up in the pace of life, while so overcoming spatial barriers that the world sometimes seems to collapse inwards upon us" (Harvey, 1989, p. 240)

Space-time compression is believed to be the result of various factors, which are often interconnected: free market-based capitalism and technological change (including new communication technologies) shape contemporary economic, social and political processes, while at the same time enabling the increasing globalization of economies (Stein, 2001).

Augmented Reality, without a doubt, shows all the signs of a "world-shrinking" technology. It allows for information to travel faster than before. The results shown in AR apps are able to produce knowledge more quickly compared to previous methods of obtaining exactly this information; by either walking around the area, asking locals, or conducting several specific web searches. Theoretically there is no quicker way to obtain an overview about what points of interest are in the vicinity of any given area than by employing a navigational Augmented Reality app.

Saving time in the information gathering process, and then being presented with all available options, displayed as big, hovering letters on top of images of the actual surroundings, including direction and distance information, certainly has the potential to "collapse worlds inwards upon us" (Harvey, 1989, p. 240). Therefore, in theory, Augmented Reality concerned with navigation and point-of-interest presentation might be one of those technological developments that both reduces time requirements and changes the perception of space.

It is, however, worth noting that such changes possibly should not be seen as instantaneous events, but potentially slow, yet steady developments. This can be extrapolated when taking a critical look at previous stages of time-space compression, such as the one taking place in the nineteenth century. It has been argued in recent years, that it is false to assume that any one period saw a revolution in the experience of space and time. A more realistic approach would be to assume that "technological improvements and reductions in travel times between places were cumulative and gradual (Stein, 2001, p. 119), thereby evolutionary, and not revolutionary. The character of these processes needs to be kept in mind while evaluating the time-space compression power of current Augmented Reality apps.

Maps have always played a big part in the evolution of time-space compression, as they are able to produce representational insights into how spaces are structured, thereby creating a drastically scaled-down image of any given area. This further justifies the relevance of previously analyzed mapping practices in today's digitally mediated world. A subset of time-space compression theories however are concerned with the (supposedly largely overlooked) role of time for geography. This set of theories is aptly named "time-geography", and includes a very relevant aspect for the research at hand: "the consequence of a corporal ontology" (Gren, 2001, p. 210).

What is being conveyed by this is that the reality of moving through space in a singular body, which is constantly restricted to one location and one perspective at one point in time, has not been adequately incorporated into the academic understanding of geography. To produce truly representational data, one needs to find a way to represent the "place- and time-dependent context", or as Gren summarizes:

> "The development of a method for representation which would make it possible to put together (and hold on to) observations in such a way that data was not pulled out from its place- and time-dependent context has been central from the outset in the time-geography project" (Hägerstrand, 1974, p. 88, as translated and cited in Gren, 2001, p. 210).

Gren formulates four general requirements needed for such an accurate representation: it needs to be easy to realize what the representation corresponds to in reality, the representation ought to have a wide scope of applicability, it should generate questions that were not able to be posed without it, and it needs to be reliable without the need for additional verification (Hägerstrand, 1974).

Therefore, Hägerstrand's, and subsequently Gren's, challenge is to not only represent space in an easily approachable, widely applicable, curiosity-producing and reliable way, but also to "overcome the shortcomings of the map's ability to represent space 'as time goes by'" (Gren, 2001, p. 210), while somehow incorporating the reality of being situated in the map itself, of having to align two different perspectives with reality.

By this point the potential benefits of Augmented Reality for exactly these purposes should be clear. Not only does navigational AR produce a representation of space out of a perspective situated within the space it is representing, it also gathers its data out of live data-bases. These data-bases are supposedly regularly updated, with entries appearing and disappearing as time goes by, based on what is happening in reality. What this illustrates is that Augmented Reality in theory has the potential to present maps, as well as compress time and space unlike any other technological approach representing geographic information before.

This chapter started by gathering a number of theoretical approaches and combining them into a framework built to produce informed expectations about the possible effects of regular navigational POI AR app usage. It then shifted its focus on the production and dissemination of digital, annotatable maps, which are the apps' technological foundation, and afterwards analyzed the effects of such highly contextualized information systems on social spheres. It ended by linking the insights gathered from these theories to an evaluation of how navigational Augmented Reality is able to contribute to the compression of time and space. In order to answer the research questions posed at the onset of this study, the following chapter will explain the applied methodology in detail.

5. Methodology

5.1 Research Method

This chapter is dedicated to explaining the method that was chosen to produce answers to the questions that were posed at the outset of this research. At first the main research method, an experiment, is explained, after which more focus is spent on detailing the motivation behind and setup of the individual elements.

A controlled experiment was employed as the main research method, due to its applicability to conduct an exploratory study, and its “focus on determining causation” (Babbie, 2008, p. 246). The experiment, comprising three different groups of participants, was accompanied with two rounds of interviews, one before, and one after the time period of the experiment. Additional data was gathered through questionnaires, which were filled out multiple times by each of the participants during the experiment. This approach allowed gathering information, perspectives and experiences from the user’s perspective, while at the same time monitoring the effect of the experiment itself. The following segment will go into more detail regarding the experiment setup, and why the chosen method is suitable for answering the research questions.

> “Essentially, an experiment examines the effect of an independent variable on a dependent variable, typically the independent variable takes the form of an experimental stimulus, which is either present or absent.” (Babbie, 2008, p. 247)

In the case at hand, the independent variable is “Augmented Reality”, which is operationally defined by separating its individual aspects into clearly distinguished elements, which then are evaluated by asking questions in the second interview, as well as by analyzing the questionnaires. The experiment itself is an empirically based one, and aims to “demonstrate the effect in a controlled setting from which we can generalize to ‘real-life’ conditions” (Neuman, 2011, p. 281).

One way to explore the effects of Augmented Reality is by employing pre- and post-testing, which in this case are represented by two rounds of interviews, conducted before and after a period of regular Augmented Reality app usage. During the pre-test phase participants were evaluated in regards of dependable variables: *mobile phone usage, information gathering methods,* and *methods of navigating through familiar and unfamiliar spaces.*

After being exposed to the stimulus (i.e. using AR apps on a regular basis) for seven to ten days, the posttest allowed to re-evaluate the aforementioned variables (Babbie, 2008), as well as to gather information on the participants' *perception (meaning awareness and familiarity) of space, quality, usefulness and reliability of Augmented Reality apps.* These dependent variables and possible outcomes of the experimental research are the "physical conditions, social behaviors, attitudes, feelings, or beliefs of participants that change in response to a treatment" (Neuman, 2011, p. 285).

To control the effects of the experiment itself participants were divided into three groups, two were assigned to use navigational POI AR apps, while the third group acted as a control group, by using non-AR navigation and POI apps, which provide the same information without displaying it in the Augmented Reality perspective.

5.2 Sampling Process

To recruit participants for the experiment, a snowball method of sampling was employed, with an expressed interest to gather a group of people with vastly differing characteristics. The overall goal was to construct a diverse group of 15 participants, differing in the following characteristics: *gender, age, educational background, familiarity with the used technologies, predispositions towards technological innovation, travelling habits* and *hardware ownership.* These different categories are important in order to create as much exploratory value as possible. Employing a diverse group of participants is beneficial for such an endeavor, as it ensures that any results obtained through the study are more generalizable compared to a rather homogeneous group of participants (e.g. students, etc.). Fig.5 demonstrates the high level of fragmentation of the aspects that were just described by listing the participants with their accompanying attributes as they were obtained during the pretest interviews.

Participants / Attributes	Gender	Age	Edu. Background	Familiarity with Tech.	Predisp. towards tech. Innov.	Travelling habits	Hardware Ownership
A	Male	27	Medium	High	Open	Occasionally travelling	Advanced
B	Female	24	Medium	High	Open	Occasionally travelling	Advanced
C	Female	53	High	Medium	Open	Occasionally travelling	State of the art
D	Male	51	High	High	Enthusiastic	Peripatetic	Advanced
E	Male	24	High	Medium	Enthusiastic	Occasionally travelling	State of the art
F	Female	42	Medium	Medium	Skeptical	Sedentary	Advanced
G	Female	50	Medium	Low	Dismissive	Occasionally travelling	Average
H	Male	35	Low	Low	Dismissive	Sedentary	Average
I	Male	48	Low	Medium	Open	Occasionally travelling	Advanced
J	Male	46	High	High	Enthusiastic	Peripatetic	Advanced
K	Male	27	High	Low	Skeptical	Occasionally travelling	Below average
L	Female	22	Medium	Low	Open	Occasionally travelling	Average
M	Female	28	Medium	High	Open	Occasionally travelling	Advanced
N	Female	26	High	High	Skeptical	Peripatetic	Average
O	Female	19	High	High	Open	Occasionally travelling	Average

Fig. 5 – Participants including relevant attributes as determined through pretesting

5.3 Allocation of Participants

Educational backgrounds were divided into *low, mediu*m and *high*, with *low* representing the German "Hauptschulabschluß" (lowest high school diploma) with little or no further education, *medium* representing the German "Realschulabschluß" (medium high school diploma) with some further education, and *high* representing the German "Abitur" (highest possible high school diploma) with further education such as university degrees or similar academic achievements.

Familiarity with the used technology was operationalized by the ownership and duration of ownership of a smartphone, GPS-based navigation system and intensity of app usage.

(1) *Low* represents a recent smartphone purchase, and/or no or low levels of experience with additional applications (meaning one to three additional apps).

(2) *medium* a smartphone purchase within the last twelve months and/or considerable experience with additional applications (meaning four to ten additional apps).

(3) *high* a smartphone ownership lasting longer than twelve months, and/or high levels of experience with additional applications (meaning more than ten additional apps).

Predisposition towards technology and/or technological innovation is determined by a number of specific interview questions, and is divided into four sub-categories:

(0) *dismissive*, meaning generally actively avoiding change and progress, in favor of long established methods of dealing with situations, and/or no interest in technological developments at all.

(1) *skeptical,* meaning generally being apprehensive and unconvinced of the potential benefits of innovation, and/or having low levels of interest in technology.

(2) *open*, meaning a generally open mindset with a noticeable interest in technology, and/or having a neutral attitude towards innovation.

(3) *enthusiastic*, meaning a curious mindset, strong interest in technology and/or a habit of regularly, actively looking for innovations.

Travelling habits were also established during the pretest interview, and are labeled into

(1) *sedentary*, meaning living, working and going out within a radius of five kilometers.

(2) *occasionally travelling*, meaning living, working and going out within a radius above ten kilometers, as well as occasionally visiting unfamiliar places.

(3) *peripatetic*, meaning travelling a lot, regularly visiting unfamiliar areas and/or different countries.

Hardware ownership is determined by the type of mobile phone the participants owns or uses for the purpose of the experiment.

(0) *Below average* smartphone, meaning a mobile phone with no Internet or app capabilities, or a participant with no internet contract.

(1) *average* smartphone, such as first generation iPhone or Android models.

(2) *advanced* smartphone, such as the iPhone 3GS or similarly evolved (third generation) Android devices.

(3) *State of the art*, only applying to the newest and most advanced models, such as the iPhone 4S, the Samsung Galaxy Nexus or similar devices.

The individual groups were formed, with participants being split into three groups, each containing five people. The main difference between these groups, and thereby the most relevant differentiation regarding the individual results, is the frequency of the participants' daily app usage. One group was designated as heavy Augmented Reality users (Exp. Gr. 1), with a minimum of three separate app-uses per day, one group was designated as regular Augmented Reality users (Exp. Gr. 2), who were not assigned with a minimum daily usage, but asked to use the apps regularly and least ten times overall, and finally one group was designated to be the non-AR app users (Control Group), who were asked to regularly (with a minimum of ten times) gather similar information with the help of apps, programs or services that do not employ any type of Augmented Reality perspective. In the end, the objective is to illuminate any links between individual experiences with the frequency and type of app used. Therefore the differences between individual groups as explained here is of utmost importance for the overall experiment design.

While selecting subjects for the individual groups it was of utmost importance to create comparability between the AR groups and the Control group, in order to accurately measure any differences occurring between those two: “As a general rule, […] the control and experimental groups should be comparable in terms of those variables most likely to be related to the dependent variable under study” (Babbie, 2008, p. 252). Therefore, participants in the individual groups needed to be as similar as possible, at least in respect to the for the experiment most important attributes. To achieve this, the following method of matching participants was employed.

At first the attributes relevant for the experiment were determined during the pretesting process, which were then equated to values:

Familiarity with Technology: Low: 1 – Medium: 2 – High: 3

Predisposition / Interest: Dismissive: 0 – Skeptical: 1 – Open: 2 – Enthusiastic: 3

Traveling habits: Sedentary: 1 – Occasionally travelling: 2 – Peripatetic: 3

Hardware ownership: Below average: 0 – Average: 1 – Advanced: 2 – State of the art: 3

Building a quote matrix through adding these values for every participant each allowed to determine an estimation of how well a participant is likely to respond to Augmented Reality, on a scale from 2 to 12. To demonstrate the gap between those numbers, and the purpose of this quote matrix, the following assumption clarifies the underlying logic:

a person that is often travelling, very familiar with technology, enthusiastic about technological innovation and in possession of state of the art technology is probably more likely to respond positively to Augmented Reality and its inherent effects than a person who never travels, knows very little about technology, dismisses technological innovations and owns a device without app capabilities. Fig. 6 shows the individual groups, including the values of each individual participants obtained by applying this quote matrix.

AR Exp. Gr.1 (min. 3 times a day)	AR Exp. Gr. 2 (no min. each day, 10 times min. overall)	Control Group (no min. each day, 10 times min. overall)
D (**11**)	J **(11)**	M **(9)**
E **(10)**	I **(8)**	O **(8)**
C **(9)**	F **(6)**	N **(8)**
B **(9)**	G **(4)**	L **(6)**
A **(9)**	H **(3)**	K **(4)**

Fig. 6 – Allocation of participants incl. individual values obtained through the quote matrix

During the experiment it also became clear that the more appropriate wording for the research method is "quasi-experiment", as within quasi-experiments "the researcher has less control over the independent variable than in the classical design" (Neuman, 2011, p. 288), which in the case at hand relates to the potentially unpredictable nature of the Augmented Reality apps' performance under real-life conditions. Testing for causal relationships under such uncontrollable conditions is harder to achieve; therefore the classical experiment design is inappropriate, and testing the performance and accurateness of Augmented Reality apps, thereby testing the independent variable itself, needs to be definite part of the experiment. Before elaborating more on the chosen AR/non-AR apps, the following segment will go into more detail about the pre- and post-tests, as well as the content of the questionnaires.

5.4 Focus of Pre-test Interviews

Both rounds of interviews consisted of “thematic” “in-depth” interviews (Evers, 2007), with depth mainly being employed to illuminate the multiple perspectives connected to the topic, in order to properly unearth its complexity (Johnson, 2001). Besides the aforementioned topics that were covered to construct the attributes used in the matching process, the main focus of the pretest interviews was the information gathering and navigation process of the participants: how do they inform themselves about potential activities, such as visiting restaurants, museums, sights, cinemas, etc.? How do they find their way to previously unvisited areas, how do they usually navigate through unfamiliar areas? What experiences have they made so far with their chosen navigational aids (Maps, SatNavs, etc.)? For what activities do they use their mobile phones usually, and in which situations? Where do these two areas intersect?

The 15 face to face pretest interviews were scheduled individually with the participants over a time-span of six days, at different locations that accommodated the participants’ schedules. The interviews took on average about 35 minutes each, with usually an additional 20 minutes spent on explaining the purpose of the experiment, how to fill out the questionnaires, and making sure the participants understood which apps exactly they were supposed to use.

During the pretest interview 25 printed copies of the questionnaires were handed out to each of the participant. The full, blank questionnaire can be seen in the appendix (see chapter 9.1). The participants were asked to fill out one questionnaire copy after every usage of their assigned app/service, with the advice of making some additional notes on the pages so that they later are able to remember and explain their individual ratings. The details of this process and the purpose of the gathered data were explained to them during the first interview as well.

5.5 Chosen Apps

The participants allocated to the Augmented Reality groups were recommended to use the AR apps **Wikitude**, **Junaio**, **Layar** and/or **Localscope**. The participants allocated to the non-Augmented Reality groups were recommended to employ the non-AR apps **Google Places**, **Neighborhoods**, **AroundMe** and/or **GelbeSeiten**.

The Augmented Reality apps were chosen based on their popularity, ease of use and functionality, which was tested by the researcher in advance. Three out of the four apps were free at the time of the experiment, with Localscope being the exception at a price of 79 cents. The last app was recommended in spite of being a paid app due to its quality, which was evaluated as above average during the pre-experiment research. Seven out of the ten participants allocated to the two Augmented Reality groups decided to buy Localscope at the beginning of the experiment with their own funds.

The non-Augmented Reality programs were chosen based on their functionality, which needed to include a “Locate me”-Feature, a location-based “point-of-interest”-Search, and navigation functions, like a map-based view of routes, or at least a function to directly access navigation software like Google Maps. All of the non-AR programs were free at the time of the experiment.

During the actual experiment any questions the participants had were answered via phone and/or email. Once the individual participants were approaching the end of their seven to ten days of regular app usage the posttest interviews were scheduled.

5.6 Focus of Posttest Interviews

The second round of face to face interviews focused on the following questions: how well did the apps work? How were the apps used in particular by the individual participants? Did, and if so, how did, the information gained by the apps affect the participants actions? How familiar were the participants with the displayed results? How relevant were the results to the individual participant? How were the participant's relations to (and perception of) their immediate surroundings and respective spaces affected by the regular app usage? How accurate was the information obtained by the apps?

The second interviews took on average about 50 minutes. No participants dropped out of the experiment, yet one participant had technical problems to such a degree that a thorough evaluation of the experiences could not be established. After both rounds of the interviews were conducted and 242 filled out questionnaires were collected, all 30 interviews were transcribed and translated from German into English, in order to subsequently analyze them effectively.

To further illustrate the general functionality and reasons for any specific performance issues encountered by the participants, interviews with developers of Augmented Reality apps were also conducted. Interviewing developers of AR apps helped gathering relevant information regarding not only the more technical aspects of the research, but also the vision behind Augmented Reality in the field of navigation. The motivation for this is to get a first-hand perspective on how these apps are supposed to function, what their limitations are, and how future iterations of AR technology will evolve. In order to produce an accurate and valid representation of the issues two developers directly involved in the inception, outlining, planning, developing and releasing of Augmented Reality apps and their features were interviewed. This endeavor is less motivated in a theoretical way, but by the importance and relevance of real world factors, such as the following: what are the current and potentially future hardware limitations? How do developers utilize the existing system to produce Augmented Reality, and what elements are in need of improvement? What is the relationship with external content providers, and how essential are these external services for current Augmented Reality apps? What future developments might influence the type of devices and kinds of applications Augmented Reality will be developed for?

These interviews were conducted via email, by sending questionnaires and responses back and forth with the individual developers, which are actively involved in the production of AR applications at Wikitude in Austria (see the appendix / chapter 9.2 for the interview questions). The questions that were posed were in large parts the direct result of the user experiences, and were formulated after the experiment. It was therefore possible to not only address the topics linked to the research questions, but to also cover any of the issues that participants potentially were to encounter (e.g. performance problems, etc.).

6. Findings

The following section reports the results emerging from the questionnaires, posttest interviews with users, and interviews with developers. At first, the data resulting out of the questionnaires is analyzed, after which the posttest interviews are evaluated based on a number of relevant topics. Finally, the expert knowledge obtained out of the interviews with AR app developers is connected to the previous findings.

6.1 Questionnaires

The ratings of the questionnaires (see appendix / chapter 9.1 for the full questionnaire) were entered into a digital spread sheet and clustered into the individual groups (Experiment Group 1, Experiment Group 2, Control Group). Out of this database the average number for each answer (in the spectrum ranging from -5 to +5) within each group was obtained. Fig. 7, 8 and 9 provide an overview of the results. Chapter 7.2 puts all results emerging from the questionnaires into context by providing the individuals' reasons for giving these ratings. This further helps to illuminate the relationships between the ratings.

Familiarity with Results

-5: every result was new to me
5: I was already familiar with all of the results

The first question dealt with the participants' familiarity with the displayed results. Results show that overall Experiment Group 1 (0,42) was less familiar with the results as Experiment Group 2 (0,97). This means that a more intense and regular usage of Augmented Reality is able to introduce more places and locations to its user compared to a less regular usage, though not by much: the difference in familiarity in percentages between Experiment Group 1 (54,2 %) and Experiment Group 2 (59,7 %) lies at 5,5%. Compared to the Control Group (1,51), which was already familiar with 65,1 % of the results, this illuminates one of the distinct advantages of Augmented Reality apps during the experiment: AR users were presented with considerably more locations that were still unfamiliar to them.

	Familiarity	Usefulness	Difference in Familiarity	Validity	Action
Exp.Gr. 1	0,42	-0,14	-0,22	-0,55	-2,48
Exp.Gr. 2	0,97	0,17	0,79	0,82	-1,08
Control	1,51	0,13	0,44	0,41	-1,28

Fig. 7 - Average values of individual groups on a scale from -5 to 5

It should be noted however that the difference between the average of both AR Groups combined (56,9 %) and the Control Group (65,1 %) is 8,1 % (see Fig. 9), meaning that while the overall difference is notable, it is not large.

Usefulness/Relevancy Of Results

-5: not useful at all/ completely irrelevant/not what I was looking for

5: very useful/absolutely relevant/exactly what I was looking for

The average usefulness of the assigned apps is as following: 48,6 % of the app usage experienced by Experiment Group 1 was considered as useful and relevant, meaning that slightly more than half of the results emerging from AR usage was considered to be not useful, and/or irrelevant. This was minimally lesser the case in Experiment Group 2, which experienced AR to be helpful and relevant in 51,7 % of all usage instances. Both groups however agree that AR was useful to them in roughly half of all usages. While this at first might be read as a very negative evaluation of the usefulness of Augmented Reality, the results from the Control Group put these findings into perspective: 51,3% of the experiences made with non-AR navigational POI apps were regarded to be useful, meaning that the overall usefulness and relevance of Augmented Reality apps (50,1 %) is comparable with, though not exceeding other currently available apps (51,3 %).

Difference Regarding Familiarity with Surroundings after Usage

<u>**-5**: more confused/less sense of familiarity</u>

<u>**0:** not changed at all</u>

<u>**5**: strongly improved Overview/remarkably better knowledge about surroundings</u>

Comparing the differences regarding the participants' familiarity with their surroundings after the usage of the assigned apps yields interesting results. Experiment Group 1, (i.e. heavy users of AR) is the only group that on average experienced more negative effects, and felt overall slightly more confused (-4,4%). This is the result of three participants feeling on average minimally to notably more confused (-0,2 / -0,5 / -0,8) and two participants feeling minimally more familiar (0,1 / 0,1). This is in stark contrast to what participants in the Experiment Group 2 (i.e. casual users) experienced, whose overall evaluations were more positive, with a notably improved familiarity with their surroundings (15,8 %). This results out of only one participant feeling slightly more confused by the information (-0,1), one participant whose familiarity was unaffected (0), and three participants with in parts notably increased familiarity (0,9 / 1,4 / 1,6).

The Control Group falls in between those two evaluations; users reported an overall slightly improved familiarity with their surroundings (8,8 %). This results out of one participant feeling notably more confused by the information (-1,4), one participant not being affected by the app usage (-0,01), and three participants noting slight to notable increase in their familiarity with their surroundings (0,7 / 1,1 / 1,4). In summary it can be said that the intense usage of Augmented Reality apps led to more confusion than clarity, occasional usage led to notably perceived feelings of increased familiarity, and non-AR apps produced only a slight, but still noteworthy improvement regarding the participants' feelings of familiarity. By combining the average results of both of the Augmented Reality Groups into one, the conclusion presents itself that both AR and non-AR apps are able to only slightly improve the user's familiarity with his/her surroundings, with 5,7 % by using AR apps, and 8,8 % by using non-AR apps.

Validity of Results

-5: no results/incorrect results or completely incorrect distance/direction-Information

5: extensive, correct results in realistic distance/direction

All groups experienced notable problems regarding the validity of the displayed results. This is especially the case for the intense AR using participants in Experiment Group 1 (-0,55). Over half of the results (56,5 %, see Fig. 8) were either lacking in quantity, or incorrect regarding distance, direction and/or content. The occasional usage applied by Experiment Group 2 resulted in notably better experiences (0,82), as 58,2 % of the displayed results were evaluated to be extensive and correct regarding distance, directions and content. The Control Group using non-AR apps once more fell squarely in between these experiences (0,41), by evaluating the experience as 54,1 % valid. Combining both of the Experiment Groups into one overall average leads to the realization that non-AR apps are perceived to be overall more accurate (54,1 %) than Augmented Reality apps (51,3 %).

Probability of Follow-Up Action

-5: definitely no actions will result out of the AR Usage

0: undecided

5: information obtained by AR usage will definitely lead to follow-up action

The intense usage applied by Experiment Group 1 led to a comparatively very low probability of follow up actions (-2,48), resulting in the overall average of only 25,2 % influence on actual actions. This however needs to be seen in the context of the minimal app usage requirements of three times per day for the first Experiment Group, resulting in more occasions where actions were not feasible, and thereby understandably lower values across most of the questionnaires.

	Familiarity	Usefulness	Difference in Familiarity	Validity	Action
Exp. 1	54,2 %	48,6%	-4,4 %	44,5 %	25,2 %
Exp. 2	59,7 %	51,7 %	+15,8 %	58,2 %	39,2 %
Control	65,1 %	51,3 %	+8,8 %	54,1 %	37,2 %

Fig. 8 - Average values of individual groups in percentages

	Familiarity	Usefulness	Difference in Familiarity	Validity	Action
AR	56,9 %	50,1%	5,7 %	51,3 %	32,2 %
Control	65,1 %	51,3 %	8,8 %	54,1 %	37,2 %

Fig. 9 - Average combined values of Augmented Reality Groups against average values of the Control Group

The occasionally AR using Experiment Group 2 showed a significantly higher probability for follow-up actions (39,2 %), though on average still in the negative area of the -5 to +5 range (-1,08). The results of Experiment Group 2 are comparable to those emerging out of the Control Group (-1,28), which in the end had an average of 37,2 % probability for any actions resulting out of the information obtained through the assigned apps. Combining both of the Augmented Reality Groups into one average equates to a 32,2 % probability for follow-up actions, which is slightly but notably lower than the 37,2 % achieved through non-AR navigational POI apps (see Fig. 9).

6.2 Posttest Interview with Users

To best describe the basic sentiments expressed by the participants during the interviews, each interview was reduced to its essential statements regarding a number of relevant topics (see appendix / chapter 9.3) (Hiermansperger, 2000). The relevant topics are the following:

a) *Changes in the Familiarity with Surroundings & Awareness of Surroundings*
b) *Immersion*
c) *Quality/Accurateness/Usefulness of Results & Trust into Validity of Results*
d) *Social Acceptability of Augmented Reality*
e) *Disruptive Elements for the Augmented Reality Perspective & Evaluation of Augmented Reality Perspective on User Experience*
f) *Level of Influence on Actions & Future Usage of assigned Apps*

All relevant statements regarding these topics are then, again, clustered into the groups they emerged out from, summarized and compared with the other groups. All numerical ratings given by participants during the posttest interview were evaluated using the same method as for the questionnaires. Finally, the overall results were then extrapolated from any valid consensuses that arose during this process. All quotes presented in this chapter are direct translations from German, and aim to preserve the participants' tone and intention as accurately as possible.

a) <u>Changes in the Familiarity with Surroundings & Awareness of Surroundings</u>

Overall, the evaluations of heavy AR users (Experiment Group 1) regarding changes in the familiarity with their surroundings were the most surprising ones. As reported above, heavy AR users were on average slightly less familiar with their surroundings after the app usage. During the posttest interviews it became clear that this is due to a number of reasons. First of all, four out of five of the group's participants felt that the digital representations of locations were unable to produce a real sense of familiarity with any given place. This was explained by one participant by stating that "*familiarity with a [place] comes out of travelling in it and living in it, by you actually going through the streets*" (Participant A).

Seeing textboxes representing locations was not able to achieve this effect for most of the participants: "*One might be able to obtain a virtual familiarity with the place, which hasn't all that much to do with reality*" (Participant D). Secondly, more AR usage led to more instances in which the results were incorrect. The following problems occurred regularly for some participants within Experiment Group 1: the results' positions on the screen changed constantly even while the device was held still and some of the results referenced locations that were non-existent anymore. This means that while the apps were generally felt to be unable to truly increase one's familiarity with places in general, the amount of instances in which Experiment Group 1 furthermore encountered confusing results led to the overall negative evaluation.

The participants from Experiment Group 1 furthermore were overall not considerably more aware of their surroundings. Some reported though that the frequent app use affected their interest in and understanding of spatial relations: "*One was surprised: 'What, that is in this direction? I would have guessed it were in that one!'*" (Participant C). This increased knowledge about spatial relations was confirmed by two other participants. In general it can be said that the linear distances, as displayed in Augmented Reality apps, influenced some participants' perceptions of space: places displayed in the Augmented Reality view seemed "*closer*" to two participants, one of who described the experience as surreal, due to the perceived closeness being in direct contrast to the camera image of reality. One participant though felt that distances were more comprehensible on maps, and that the pure meter/kilometer information employed in AR apps is more abstract.

One of the most surprising findings of the research was that almost all of the participants in Experiment Group 1 felt more disconnected from what was really immediately around them. The intensity of this feeling ranged from "*slightly*" to "*greatly*". This was caused mainly out of the need to shift one's attention entirely on the small screen, thereby largely ignoring one's real surroundings: "*It carries one away from reality for a bit, and it produces a distance, which in fact, since I still am standing somewhere, is not really there at all*" (Participant A). One participant in particular expressed a noticeable feeling of "*being more disconnected*" while using AR, because he noticed "*much less of the periphery*" (Participant E) and paid comparatively less attention to his actual surroundings.

Since the displayed results were often regarded to be of "*no interest, little relevance or too far away*" (Participant E) this attention split generally did not lead to an improved sense of awareness for some participants. Especially in very active areas, the "*amount and unspecific nature*" (Participant D) of the information being superimposed onto reality actually has the potential to create some confusion. In these instances of "*information-overkill*" (Participant D), one participant actually felt less aware of his surroundings than without the apps.

Experiment Group 2 repeated the sentiment that the digital representations of geography were generally unable to effectively influence one's familiarity with places. This explains the overall only slightly increased familiarity. While significantly increased familiarity was felt to be unachievable, the increase in knowledge about one's surroundings was regarded as being beneficial though. The lesser amount of usage employed by Experiment Group 2 led to lesser amounts of confusing results, which led to significantly improved evaluations of the trustworthiness and usefulness in comparison to Experiment Group 1. This then also caused a bigger increase in the familiarity. In addition it is also noteworthy that all participants whose familiarity with places actually increased had acted on the information, meaning instead of only looking at the results, they also visited the suggested location.

In contrast to the Control Group, Experiment Group 2 furthermore felt significantly more familiar with their surroundings after the app usage. This is most likely due to the very inclusive categories used in AR apps, as opposed to rather precise search terms required by many of the non-AR navigational POI apps. The option to simply show anything in one's surroundings, without any filters, which is a feature of all current AR apps, but not always possible in non-AR apps, is a definite factor contributing to this effect. Regarding the awareness of surroundings, the participants assigned to Experiment Group 2 noticed the previously mentioned disconnectedness much less, with only one participant remarking that he was so "*focused on the app that [he] noticed the [immediate] surroundings less*" (Participant I). One participant felt a "*small but definite influence*" (Participant J) on his awareness, especially regarding the comprehensiveness. Seeing various types of places that he individually was aware of, clustered together on the screen, produced a new awareness of the diversity of his neighborhood for him. After the usage the participant felt like having a different sense of "*direction, spatial relations and proximity*" (Participant J). He however also felt that classic maps had some distinct advantages over AR regarding the general overview about an area, such as also showing adjacent areas and not only one's surroundings. All other participants however did not notice any significant change regarding the awareness of their surroundings. Since the apps rarely displayed results that were in the participants' absolute immediate surroundings during the experiment (meaning 50 meters or less), they were unable to produce any kind of intimacy with spaces: what was shown was more often than not a considerable distance away.

The participants in the Control Group were also unable to connect the abstract information displayed by their apps to their sense of reality, thereby largely feeling like merely having additional information. Due to often irrelevant results and the need for search terms in a number of apps, a number of participants felt like they were now potentially in possession of "*more information, but not substantial information*" (Participant N). The Control Group participants furthermore felt the biggest increase regarding their awareness of space. A number of participants felt like having a better overview about the layout of their surroundings, due to the map-based view of the apps. This result is likely connected to the participants already being used to map-based views, and therefore being able to apply the gained information to their understanding of space more easily. In contrast to the AR groups the Control Group's perception of space was completely unaltered (e.g. no new understanding for distances). This, once more, is likely due to the fact that the participants are already used to read maps in order to orient themselves in their surroundings.

During the interviews the participants were also asked to rank any changes of their awareness of their surroundings on a scale from -5 to +5. Fig. 10 presents the results, which confirmed the findings resulting from the questionnaires and interviews.

Awareness of Surroundings	Experiment Group 1	Experiment Group 2	Control Group
Average Value on Scale (-5 to +5)	**-0.7**	**+0.5**	**+1.5**
Average Percentage	**-14%**	**+10%**	**+30%**

Fig. 10 – Average Value and Percentage regarding "Awareness of Surroundings" across groups

What this underlines is that the very frequent usage of Augmented Reality apps made its users feel less aware of their actual surroundings, due to their need to focus their attention entirely on their mobile phones' screens. Heavy users were also the ones that encountered incorrect and/or irrelevant information the most, which turned out to be the logical consequence of their intense usage, and also greatly affected the perceived usefulness of AR apps for them. This was less so the case within a more casual AR usage.

The map-based view employing Control Group in the end is the group with the most notably increased sense of awareness. This demonstrates that for most users maps are able to produce a better overview about locations, their adjacent spaces, and especially the layout of areas. Overall it can be said that participants across all groups experienced the best effects when using their assigned apps in lesser known areas. When participants believed to be already very familiar with an area additional information was quicker believed to be irrelevant, leading to a greatly diminished appeal to use the apps in those situations.

b) <u>Immersion</u>

None of the participants of Experiment Group 1 felt any sense of immersion. This was largely attributed to the small size of the screen, as well as the mistrust in the validity of results. One participant expressed that she felt AR apps were more fun than other kinds of navigational POI-apps, and cited this as the reason for more extended usage durations. Another participant neither felt more immersion nor did she feel that the information became more palpable or real in the AR view:

> *"I, for example, sit in this room, point it in any given direction, look at the app, and the app then tells me that 'Achmed Döner' is in my cupboard. He of course is not really in my cupboard, because he is 5 kilometers further away, in that direction. For me those things aren't really connected, it just is an approximation of direction."* (Participant C)

One of the participants felt "*actually really restricted, and limited*" (Participant E). The reasons cited for this were the small screen, and that the combination of hardware and software "*wasn't fast enough to produce a fluent and smooth representation of what's around [him]*" (Participant E).

Experiment Group 2 largely confirms the results from Experiment Group 1, as they were also unable to immerse themselves in the experience. One participant expressed though that the AR perspective made map information "*more comprehensible*" (Participant G) for her. Overall the unique perspective of Augmented Reality was regarded to be "*more of a gimmick*" and a "*neat toy to play around with*", but not as able to "*open up a whole new world*" (Participant E).

c) Quality/Accurateness/Usefulness of Results & Trust into Validity of Results

First it is important to note that a large amount of participants expressed the following general preferences during the pretest interviews: many people preferred the comfort of big screens and keyboards over obtaining important information with their mobile phones. The most important factors in these information gathering processes were speed, accuracy and clearness of results. Participants of all groups, including the Control Group, experienced major issues regarding these matters with their assigned apps. Therefore, the overall limited usefulness of AR and non-AR apps, as expressed on many of the questionnaires, is to be understood as a result of problems with the GPS, and limited amount of information displayable on portable screens.

As touched upon earlier, the overall negative usefulness experienced by Experiment Group 1 resulted out of a number of regular issues. These were; incorrect distance and/or directional information, unclear descriptions, as well as irrelevant results. One issue that was surprisingly often mentioned was outdated results, meaning places that the participants knew had (for instance) gone out of business years ago. This greatly influenced the participants' general evaluation of all results, notably decreasing their trust in the validity of results referencing unknown locations. A number of participants furthermore had problems clicking on results, due to the often erratic behavior of results on the screen even while holding the device still, and many of the results being displayed "*behind other results*" (Participant A). Using the apps while moving quickly and making many turns (in a car or train) was reported as "*impossible*" by one participant (Participant B). A number of participants felt that the accuracy of the apps worsened as "*one got closer to the actual place, they worked better from a distance*" (Participant E). This limited the apps' overall usefulness for those participants. A cluttered presentation of results especially in more densely populated areas was reported by a number of participants. The regular occurrence of these problems led to a growing frustration among the intense users, explaining the overall negative evaluation, though it should not go unnoticed that all of the participants also reported positive experiences, in which the apps were felt to be useful and of benefit. Overall the negative experiences outweighed these instances though.

Due to the more casual usage of AR apps employed by Experiment Group 2 the levels of frustration were considerably lower, though the same issues were reported. One of the participants was unable to receive any results while not logged into a WiFi network, thereby drastically decreasing the overall usefulness of the apps. Another participant noticed that even though the apps did not always work properly, he still made some interesting realizations. Another participant felt that for basic needs like finding ATMs or gas stations the apps were "*pretty accurate and useful*" (Participant J). Overall it can be said that Experiment Group 2 had a slightly better experience due to the more casual nature of their usage, which was mainly restricted to instances in which the participants had a genuine interest in the results.

The Control Group's overall experiences were surprisingly similar to the ones of the Experiment Groups. They however had much greater issues with the GPS, which often was responsible for very long load times (up to a couple of minutes), and in some cases even located the user incorrectly. Interestingly, the GPS' process of determining the user's location is hidden in the Augmented Reality apps. Overall all groups felt that the apps were missing big amounts of relevant information in rural areas, and delivering much more information in cities and other more densely populated areas.

The individual levels of trust into the validity of displayed results varied greatly from participant to participant, even within the same Experiment Groups. Since the frequency of app usage did not seem to affect the levels of trust directly, comparing the overall results from the Experiment Groups with the overall results from the Control Group is of greater benefit. Fig. 11 presents the average values of the employed scale as well as the average percentage for both groups.

Trust into Information	Experiment Groups	Control Group
Average Value on Scale (-5 to +5)	**-0.45**	**0.5**
Average Percentage	**45,5 %**	**55 %**

Fig. 11 – Average Value and Percentage regarding "Trust into Information" across groups

The overall trust into the validity of results found among the Augmented Reality users was low. In some instances initial great levels of trust decreased as users encountered outdated results. Another participant's distrust was less caused by inaccurate or outdated content sources, and more related to regular experiences with "*finicky and jumpy*" (Participant H) results. This participant very rarely felt sure about the actual location of the results presented in the apps. Other participants made mostly positive experiences, and were thereby very trusting into the obtained information. These disparate experiences led to the overall mixed evaluation of trustworthiness.

The Control Group's average level of trust was notably higher. Three out of the five Control Group participants described themselves as "*overall trusting*" (Participants K, O & M) while imprecise GPS functionality and incorrect labeling of places within apps (for example by listing diners or sandwich bars among restaurants) were cited as main reasons for the other participants to have lower levels of trust.

Overall the additional elements built into Augmented Reality programs (e.g. using the compass to display results in the appropriate direction) produce more possibilities for the technology to fail, thereby creating a greater potential for the user to be disappointed by the validity of what is displayed on the screen. This then subsequently leads to the lower levels of trust when compared to non-AR app.

d) <u>Social Acceptability of Augmented Reality</u>

During the preparation of this research it quickly became clear that the physical method of input required by Augmented Reality apps potentially might lead to some problems regarding the social acceptability of AR app usage in public. To cover this possibility the posttest interviews included this topic. The physical movement required by the Augmented Reality apps turned out to have a considerable impact on a number of participants' overall levels of comfort while using the assigned apps. Even though this aspect was not operationally predefined during the design of the experiment, the statements made by those participants during the posttest interviews led to the inclusion of this aspect.

Problems related to the social acceptability of the AR app usage were felt by both Experiment Groups, but were overall higher in Experiment Group 1. The more frequent usage led four out of the five participants to experience problems, ranging from low to significant intensity. One participant felt the need to explain his behavior to bystanders:

> *"I think they might even believe that I am making a video of them, which of course could also lead to someone approaching you and saying 'Hey, I don't want to be filmed', and other than that I think it just comes off as goofy"* (Participant A).

Another participant had regular problems related to the compass calibration process, which is sometimes needed for the apps to work correctly, and involves moving away from any interference, or re-calibrating by waving the phone in a figure 8 motion (see Fig. 12).

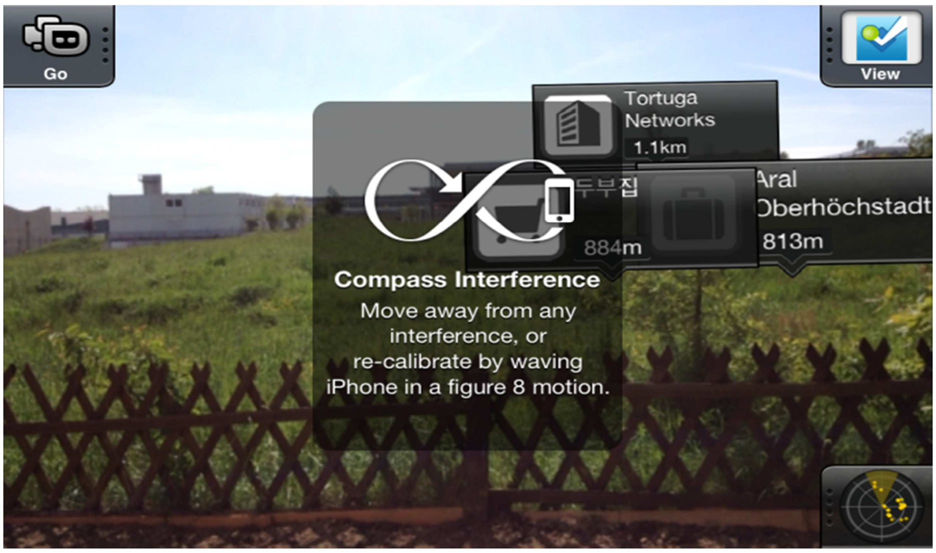

Fig. 12 – Compass problems requiring physical action from the user

The apps requested this calibration process of the participant several times, and greatly influenced her willingness to use the apps in public:

> *"[…]when one is standing somewhere, spinning around oneself with the phone in front of one's face, and then one also starts to make giant rotating movements with that phone, then some people might start to question one's sanity*" (Participant B).

The overall concerns regarding this matter might be best summarized by another participant, who had the impression that he was actually bothering the people around him with his behavior. These issues influenced one participant so much that he refrained from using AR apps in any situation with other people around him.

Due to the more casual usage of AR apps Experiment Group 2 experienced these issues less. Two participants had no issues at all, one had slight reservations, but no real problems, and one participant experienced the involved input method required by AR actually as enjoyable and was more motivated to use the apps regularly. Only one participant in the second Experiment Group experienced notable problems regarding this matter, these however were severe: he especially avoided using the apps in public situations "*where lots of people are in a small space together*", like on the bus or in a tram, due to his hesitation to "*hold the device right up into another passenger's face*" (Participant H), which he would have needed to do in order to know what was behind him. In several other situations he actively avoided using the apps as well, because he did not want to bring attention to his actions.

None of the Control Group participants had issues with social acceptability.

Social acceptability is therefore definitely a relevant factor for Augmented Reality apps. The involved input method (having to physically turn and point) can directly be linked to a decreased motivation to use AR apps in certain situations. It also might motivate users to keep the time spent using AR apps short, which in turn would also be prohibitive of any immersion or truly improved familiarity, due to a lower amount of information gained during short usages.

e) <u>Disruptive Elements for the Augmented Reality Perspective & Evaluation of Augmented Reality Perspective on User Experience</u>

During the posttest interviews all participants that used Augmented Reality apps were asked to position themselves on a scale from -5 to +5 regarding their agreement with two statements. One statement (represented by -5) was “Navigational Augmented Reality apps provide a different way to visualize search results”. The other statement (represented by the positive end of the scale; +5) was “Navigational Augmented Reality apps provide a new way to experience, navigate through and learn about space”. By positioning themselves somewhere on the scale from -5 to +5, according to their individual agreement with one of those statements, participants expressed their evaluations of the inherent possibilities of current Augmented Reality apps.

Fig. 13 shows the average values picked by intense users on the one side, and casual users on the other side. What these values once more make clear is that the more intense usage of currently available Augmented Reality apps is accompanied by a comparatively poorer assessment, meaning that the number of bad experiences made by Experiment Group 1 greatly influenced their overall evaluation of the potential of the technology.

Evaluation of AR Perspective on Experience	Experiment Group 1	Experiment Group 2
Average Value on Scale (-5 to +5)	**-3.4**	**-2**

Fig. 13 – Average Value regarding “Effects of AR Perspective on User Experience” across groups

During the preparation of the research at hand it furthermore quickly became apparent that currently available Augmented Reality apps often suffer from a certain degree of lag in the AR view. This can be observed when the user's physical movements are not in synch with the virtual movements of the results. This lag (depending on the intensity) can potentially lead to a very disruptive experience, as erratic result behavior might raise concerns regarding the validity of said results.

Two out of the five participants of Experiment Group 1 experienced "*strong*" (Participant A) and "*very strong*" (Participant E) lag. One of the two participants described the results as "always being left behind and then crawling back into space" (Participant A). The other participant found this issue also to be "*very disruptive*": "*When I was turning more quickly, and then I saw something interesting, and I tried to go back, then it took very long, like 1 or 2 minutes, for it to calm down, until it showed it again*" (Participant E).

Interestingly, more participants of Experiment Group 2 experienced this disruptive element in the Augmented Reality view, which leads to the conclusion that this issue is less related to the time spent with the apps and more to the type of device Augmented Reality is run on, or situation Augmented Reality is used in. Three out of the five participants in Experiment Group 2 experienced this AR lag, ranging from slightly noticeable and barely disruptive lag, to very heavy and very disruptive lag. Two out of the three participants having severe issues with lag used an iPhone 3GS, which by now is an almost three year old device. The third participant however used an iPhone 4S; one of the currently most advanced hardware available. Therefore the evidence for this issue being purely related to hardware is inconclusive.

f) Level of Influence on Actions & Future Usage of assigned Apps

Experiment Group 1 displayed a comparatively very low probability for follow-up actions. This though is directly related to the frequency of usage: free time was limited for all participants, more usage therefore did not lead to more actions, with the overall average thereby decreasing. Three out of the five participants noted though that information obtained by the apps led to the formation of plans for the future, and one participant actually acted on the received information in two instances. However it is important to note that inaccurate and irrelevant results, which were encountered more often by the intense users, negatively influenced the overall likeliness of actions.

Within Experiment Group 2 the app had significant influence on one of the participants (notably the one with the most free-time at hand), leading him to visit a café he has never been to before, going to a photographer that was closer to him than the one he used to visit, as well as navigating to gas stations and ATM machines he did not know about before using the apps. The apps assisted in actions another participant would have done anyway, and did not lead to any noteworthy actions for the other participants.

The Control Group made similar experiences to Experiment Group 2, allowing the conclusion that probability of follow-up action is related to quality of results, frequency of usage and amount of disposable time. One participant went to a new hairdresser, and tried to find a supermarket that he previously was unfamiliar with. He stated that he "*definitely would not have done, or known about these things without the additional information obtained through [the assigned app]*" (Participant K). Three other participants stated that the apps or services had "*no direct influence*" (Participants O, L & M) on them during the experiment, but that the information obtained led to the planning of future actions.

Overall it can be said that the influence of the apps on their users is greatly limited due to the lacking quality and insufficient specificity of the information. The experiment also showed that this problem is not relegated to Augmented Reality, but inhabits all kinds of currently available POI-apps.

In Experiment Group 1 only half of the people were motivated to keep using AR apps (Yes: 2 / No: 2 / Maybe: 1). As is the case with many of the other findings, this is directly related to the (more negative) experiences made during the experiment.

On the other hand, four out of five of the participants of Experiment Group 2 were planning on continued usage of Augmented Reality apps after the end of the experiment. The amount of future usage ranged from "*from time to time*" (Participant L) and "*after they have been updated*" (Participant H) to "*definitely*" (Participant J) and "*absolutely*" (Participant I). The one participant that was "*absolutely not*" (Participant F) planning on continued usage was the one participant whose apps did not display results when the device was not logged into a WiFi network.

Overall the continued usage was also often prefaced with the expectation that Augmented Reality apps will improve over time, and that any issues that are currently plaguing the overall experience might be fixed in the near future, explaining the willingness of some participants to come back to the apps in spite of their regular negative experiences.

Three out of five participants of the Control Group had no inclinations to keep using their assigned apps. The other participants expressed their intent to keep using the apps, but with a greatly diminished frequency. This significantly smaller interest in continued usage found in the Control Group can possibly be explained by the participants' impression that the assigned apps are finished products, and not evolving in any major way anymore.

Overall, Augmented Reality was seen as having much more potential for future improvement, though this is possibly only due to the (misguided) belief of many participants that AR is something completely new, and thereby naturally not yet perfect.

6.3 Expert Knowledge: Interviews with Application Developers

The interviews were conducted with two female employees of the Austrian developer company Wikitude GmbH (formerly Mobilizy GmbH), who published the Augmented Reality app of the same name in late 2008.

One of the most apparent findings of the experiment was that users made some vastly different experiences regarding the stability and functionality of the apps. This impression was confirmed by the developers, one of whom noted that "*one of the biggest challenges today is making it work on many different devices. You have to test the software with different screen resolution, CPU speed, RAM, camera spec […]*" (Developer A). According to developers there is a huge difference in technical capabilities between a three year old smartphone and a recently released one, technical differences that users are often not fully aware of. This then often might lead to confusion or frustration, because the apps may look identical across devices, but the actual functionality, and thereby the overall experience, might vary greatly.

This issue intensifies when the app is supposed to function not only on different devices, but also with different operating systems. All iPhones for example run the iOS operating system, while many of the currently available Samsung models use Android software. Nokia on the other hand recently focused on using the Windows mobile platform. Developing for a number of different operating systems is to be expected on a market as fragmented as the mobile phone market, but it still poses a challenge: "*We share a common design, but the codebase evolves according to the specific platform, and users expect the program to behave consistently across different hardware."* (Developer A)

In general, those involved in the production of Augmented Reality apps see AR "*at the beginning of its adventure*" (Developer B), thereby adapting to new technical developments is essential for improving and evolving the experience. "*The challenge is always being prepared for new possibilities"* (Developer A).

During the experiment many users experienced outdated results, as well as unclear descriptions of locations. The interviews with developers confirmed that this is indeed an issue, which however falls outside the responsibilities and capabilities of Augmented Reality app developing companies. Any and all points-of-interests are obtained from external data sources (such as the social "check-in" network Foursquare, or venue-review sites such as Qype or Yelp), while the AR apps are only responsible for determining which of these points-of-interests are currently relevant to the user (based on location and search terms): "*Several policies determine the meaningful subset for the user*" (Developer A). The content itself however (with the exception of fully user-edited databases like Wikipedia) is under the control of those partners. The AR apps are furthermore fully synchronized with the data of external platforms, meaning that if a content provider changes its content, the effects are immediately visible in the Augmented Reality app.

What this means for the evaluation of the experiences made by users during the experiment is that any issues regarding outdated or otherwise incorrectly labeled or insufficiently described locations are not directly related to Augmented Reality apps, but apply to a number of digital online databases. Though this issue directly influences the usefulness of AR apps and validity of search results, the source of the problem lies elsewhere, and is currently not directly attributable to Augmented Reality apps themselves.

Regarding the general functionality of AR features, which were regularly evaluated as being unreliable and erratic by users during the experiment, the interview with developers confirmed that "*better sensors, for example a better compass, would help a lot*". It was also expressed that AR "*is a very CPU-intensive task*", and new features that Wikitude GmbH is currently working on "*will require a good amount of computational power*":

> *"This also means battery draining faster, and in some cases, heating and other side-effects. In this regard, the single improvement that would help us most is a better, faster, more efficient CPU"* (Developer A).

Regarding the future of Augmented Reality, the developers expressed their belief that AR is still in its infancy. According to them, big IT actors have only recently started expressing interest in the potential of Augmented Reality, and up to this point "*only a bunch of small companies [have] arisen around this technology*" (Developer B). The need for new, useful and affordable hardware to support the growth of Augmented Reality was expressed in the interviews, meaning that software is believed to, while certainly contributing to the proliferation of the technology, be unable to push it mass market adoption alone.

One developer's prediction is that

> *"AR will have a super burst when the Industry will push out a useful and cheap hardware for AR (glasses, car windshield, etc.), when Semantic Web and AR will converge together and when the fields of application of AR are definitely clear"* (Developer B).

In this endeavor however it is supposedly of utmost importance to keep the user's best interest in mind. The recently unveiled Heads-Up Display project from Google, Google Glasses, for example was seen as a potentially very suitable product by the developers. The risk though lies in missing the consumer's true motivations for purchasing and using such a technology: *"[…] the industry of advertisement is looking quite closely to AR technology. However, why should the user wear a pair of glasses and be bombarded with advertisement?*" (Developer B). According to the developers, keeping a balance regarding the benefits for consumers and advertisers must therefore always be kept in mind.

What the interviews made undoubtedly clear is that developers on the one side are aware of the issues reported by the experiment's participants, but on the other side are unable to directly address some of these issues, as they are related to external systems beyond the control of Augmented Reality app developers. What the interviews however also made clear is that there is a great sense of optimism regarding the future of Augmented Reality, as many of the current issues were believed to be of temporary nature, and soon to be released hardware is expected to truly make use of Augmented Reality's potential.

7. Discussion

The theories that constructed the framework at the beginning of the research at hand were able to produce mostly valid expectations about the effects of navigational Augmented Reality apps. For instance, the assumption that AR apps would contribute to the compression of time and space was confirmed, as AR app users were able to learn more quickly about a variety of places in their surroundings compared to non-AR app users, thanks to the inclusive presentation style of AR apps.

The effects of time-space compression were also observable in context of the theoretical concept of nearness vs. distancelessness. AR apps made things seem closer for a number of participants. It collapsed the world inwards, with the user at the center of a plethora of options that all seemed within reach.

What AR apps however were unable to do, was to aid as additional filtering mechanism for the information-overload found in urban spaces. On the contrary, it actually added to the amount of informational input that needed to be mentally processed: it effectively doubled the amount of space to deal with for many participants. They now not only had to filter reality itself, they also had to decide what was useful or irrelevant in the augmented version of reality. Intense usage in densely populated, urban areas therefore actually created more confusion, especially due to the often cluttered presentation style. Thus, AR apps are unable to decrease the intensity of the blasé attitude, as described in the theoretical framework.

One of the biggest assumptions at the beginning of this research was that the unique perspective employed in Augmented Reality apps would enable the user to feel immersed in the experience; this though has been proven to be false during the experiment. But there are some unique effects produced by this distinctive approach to visualize map information: on the one hand, AR's first-person perspective was able to make looking at location information more fun for some users. This increase in enjoyment might in the long run lead to prolonged and more regular app usages, with the side effect potentially being an eventual increase in the user's awareness of and familiarity with their respective surroundings, especially compared to non-AR apps.

On the other hand, the involved method of interacting with AR apps produced some significant issues related to social acceptability, as summarized in the findings chapter. This dichotomy between “fun to use” and “awkward to use” is not necessarily only dependent on the type of person using the app, but also on the context of the app usage. In the end the issues experienced by many of the participants during the experiment were less related to simply using their mobile phone outwardly in public to access location information, but much more to the way they had to behave in order to see more than 25 % of the results. In certain situations (like while being in densely crowded places such as busses or cafés) this inherent prerequisite for using AR apps is hugely disadvantageous, especially compared to navigational POI apps that can be interacted with by touch. It is not the purpose of this research to predict whether such interactions, which might be considered as rude or weird, might be just as strange today as talking on a cellphone in public was 20 years ago. It is however one of Augmented Reality’s greatest obstacles at the moment.

One of the earliest realizations emerging out of the interviews was that the growing proliferation of smartphones also led to a growing proliferation of navigational POI search apps. Nearly all of the participants had already made experiences with one of those kinds of apps prior to the experiment. The term and concept of Augmented Reality on the other hand was familiar to only two out of the 15 participants. This shows how largely unknown these apps and their features are still at this point. The unique features found in these apps were however only able to improve the participants' familiarity slightly. Considering how regular and extensive the use of these apps was for all experiment groups, it is remarkable how little they actually affected their users' familiarity with their surroundings. As demonstrated by the Control Group though, this is not a problem unique to Augmented Reality. Problems regarding the accurateness and speed of the GPS's locating-process, the relevancy of displayed search results, and clearness of result-descriptions are some of the biggest factors currently prohibiting the experience from being truly beneficial.

Other apps, designed with more specific purposes in mind, such as finding emergency pharmacies or franchises of specific shops/restaurants, are currently able to significantly alleviate these issues. This shows that by focusing on small amounts of data, the content sources stay manageable, presentation is less cluttered, and results are of overall much increased usefulness and relevancy.

Thereby however those apps' general applicability is greatly limited, and having to download, install and manage a plethora of apps for very specific needs has many disadvantages. Improving on the issues currently affecting broadly employable Navigation- and POI-apps should therefore be the main objective.

Another factor further underlines the importance of usage context for Augmented Reality apps. During the experiment the participants with the most free time were also those that made the best overall experiences. Although this was not a direct focus of the questionnaires or interviews, comparing the instances in which participants were actually influenced by the obtained information, and felt that the apps were truly beneficial, quickly made clear: a relaxed and pressure-free usage with genuine interest in the results produced the best evaluations. This can be brought into direct relation to another aspect that was covered during the pretest interviews.

The level of importance of a planned activity had a big influence on the thoroughness and intensity of navigational preparation for the majority of the interviewees. More important activities, like job interviews or doctor's appointments, were prepared with considerable more effort than going out to eat or buying groceries. Although this realization is not revelatory by any means, it supports the reasoning that the right context is of great importance for the enjoyable and beneficial usage of navigational Augmented Reality apps. Outside of experiments users will employ AR apps most likely in their leisure time, in moments with "time to kill", and while having genuine interest in the results with a feasible possibility of acting on the given information. This is important to note, as any significant changes regarding the awareness of or familiarity with one's surroundings most likely only result out of regular app usage, something that is much less probable when the apps are only used in one of the moments that were just described, namely moments that occur rarely for most people. This insight also directly relates to the process of technology negotiation covered within the Social Shaping of Technology perspective, as it proves that the most compelling and unique benefits of navigational AR are still in the process of determination, and the most appropriate use of the technology is indeed still "in negotiation". At the same time it illustrates which paths are most likely to be irreversibly closed off: navigational AR will neither replace dedicated navigation and route-planning systems (such as SatNavs), nor will it be able to compete with specific location search engines (such as Foursquare, Yelp or Qype).

Other topics that were contextualized within the theoretical approach, such as *changes in awareness,* or *level of immersion*, have been thoroughly answered in the findings chapter of this work. The same is true for the question whether places can be experienced remotely, mediated by technology, which has been undoubtedly answered negatively.

Nevertheless, Augmented Reality has a distinct advantage over other navigational POI apps. Due to the unique perspective employed in AR, the actual inner workings of the apps are more behind the scenes compared to apps employing map-based views. The Augmented Reality view provides the user with no feedback regarding his actual GPS position, as opposed to isometric views in which the user is immediately confronted with any inaccuracies related to his actual position. During the experiment this led some participants to the impression that Augmented Reality apps were better at locating them correctly compared to previously used apps, though this is in fact technically impossible. This perceived increase in reliability resulted in higher levels of trust for some participants. Furthermore, the inclusive nature of the results displayed in AR apps especially lends itself for the exploration of areas that are unknown to the user. During these usages with no clear intent, AR apps have a significant advantage over non-AR apps, which require the user to know more about what is being looked for. Absolutely precise GPS localization is also less important in these situations, as the user would not need to be localized with pinpoint accuracy just to get a broad overview about the places around him/her. On the other side, depending on the user's prior experiences with and attitude towards similar apps, the more hidden functionality of GPS functions might also lead to greater levels of distrust, as the accuracy of the GPS is harder to verify. AR is thereby more likely to confirm any predispositions the user brings to the experience, and less likely to change preconceived notions.

One last issue that needs discussion is how surprisingly big the impact of small, negative experiences was on some participants' overall evaluations. Single instances where outdated results or bad directions were given greatly affected the way participants thought about the whole concept of navigational Augmented Reality. At first these participants' strong, and possibly unreasonable, reactions might lead to question the validity of their evaluations. Their reaction however is far from abnormal, as has been proven by many academic studies, and possesses its own representative qualities: “Bad impressions and bad stereotypes are quicker to form and more resistant to disconfirmation than good ones” (Baumeister, Bratslavsky, Finkenauer, & Vohs, 2001, p. 323). Furthermore, “the chronological order of the component events influences overall evaluations of these experiences”, and “an experience consisting of a positive and a negative event is evaluated as more satisfactory if the positive event occurs last” (Ross & Simonson, 1991, p. 273). The implications of these findings for the research at hand are easy to see: since a number of participants encountered outdated results towards the end of the experiment, this, accompanied by single, but regular instances in which other problems occurred, led to an overall more negative evaluation, even though the actual proportions of good vs. bad experiences could also imply the opposite. People wanted and expected the technology to work, and were greatly disappointed when it did not. These mechanism however also apply to non-experiment settings, they are therefore also representational of user experiences and evaluations under real-life conditions.

By combining the insights gathered by this research with the general concept of Augmented Reality, as defined in the beginning of this work, an interesting conclusion presents itself: depending on the strictness of the interpretation regarding the definition of Augmented Reality, currently available Augmented Reality apps for smartphones are not really augmenting reality.

> “One difficulty in augmented reality, as defined here, is the need to maintain accurate registration of the virtual objects with the real world. This requires detailed knowledge of the relationship between the frames of reference for the real world, the camera viewing it and the user.” (Bulent, 2010, p. 4)

The experiment demonstrated that the sensors built into modern smartphones are not capable of producing enough reliable information to always superimpose virtual objects with 100 % accuracy and, most importantly, flawlessly onto images of the real world. But, as one could argue, since this exact functionality is a defining requirement for Augmented Reality, the position that (as of now) Augmented Reality has not been fully realized on smartphones holds considerable weight.

The problematic issues currently plaguing navigational AR apps need to be approached by a multitude of angles: hardware manufacturers, online map platform providers as well as app developers share an individual responsibility for the functionality of these apps. Only by combining their efforts will it be possible for users to experience the full potential of these new ways to learn about and navigate through spaces. Furthermore, the content providers (FourSquare, Qype, etc.) need to not only focus on aggregating as much content as possible, but also on keeping the acquired content current, in order to not simultaneously be library and archive. In its current form, navigational AR's tremendous potential to overcome the "shortcomings of […] maps' ability to represent space 'as time goes by'", as formulated by Hägerstrand and discussed in the time-space compression chapter, has not been achieved.

These issues are overall unlikely to be overcome on the current hardware generation. Future smartphone devices, or entirely different types of hardware, such as the recently unveiled Heads-Up display from Google; Google Glasses (Schroeder, 2012), are more likely to introduce the much needed hardware changes to fully realize AR's potential. Google, for instance, promises a completely transparent screen, wearable like ordinary glasses, which is connected to the user's mobile phone, and capable of superimposing relevant information on the user's field of view. Thereby another issue, namely that of social acceptability, might also be completely dealt with, as one would not need to hold up and point one's device in any direction. Simple looks and head turns would suffice to obtain the needed information. Bystanders would not even notice this action, and the user's behavior would feel much less intrusive.

New hardware like this might become the real opportunity for Augmented Reality to hold up to its potential. Considering how long Augmented Reality has been developed and experimented with across many fields, the following conclusion presents itself as reasonable: Augmented Reality is closer than ever to becoming the mass-employable technology, changing the way we interact with and perceive our world, it has been touted to be for decades. But only though the combined efforts of hardware manufacturers, software programmers and platform providers will it become possible to utilize Augmented Reality's full potential. As of the time of writing, such collaborations have unfortunately not started to properly form.

8. Conclusion

The research at hand dealt with the potential effects of navigational point-of-interest Augmented Reality apps on their users' perception of, and familiarity with space. To establish a deeper understanding of this topic, theories concerned with online web mapping practices, time-space compression and the effects of a location-enhanced internet were discussed and applied. Furthermore, the history and development of Augmented Reality were presented, a working definition of Augmented Reality was given, and the current fields of application, basic AR functionality and the relevance of the topic were explained. These theories in the end proved to be suitable to inform expectations about the effects of navigational Augmented Reality apps.

The research's main objective was to answer what the effects of Augmented Reality applications are on the users' perception of their surroundings, with the focus lying on any changes regarding their awareness of and familiarity with spaces. Determining the level of immersion experienced by users, the influence of AR apps on users' actions, as well as the state of Augmented Reality on currently available smartphones were additional research motives. This was done with the help of an exploratory experiment, during which participants were split into groups of "heavy" AR users, "regular" AR users and "regular" non-AR users, who documented their experiences on questionnaires. The participants were furthermore individually interviewed before and after the experiment, while interviews with Augmented Reality developers provided an additional perspective on any and all findings.

This method was appropriate to provide an exploratory approach to the largely un-researched topic of Augmented Reality effects on its user. The research questions posed at the beginning of this work are to be answered in the following ways.

First of all, AR users are more aware of their surroundings than people who do not use any navigational POI apps, but less aware than non-AR navigational POI app users. Any potential increase in user's awareness of their respective surroundings is often counteracted by the erratic nature of Augmented Reality on currently available smartphones. The unique and novel perspective of AR initially has the potential to motivate more frequent and prolonged usage sessions; it however is unable to provide the same amount of information and clarity of map-based apps. AR apps however have the ability to slightly alter users' understanding of proximity, directions and spatial relations, as they present information unlike any other navigational apps or services: inclusive filters display results in linear distances, in direct relation to the user.

Currently available Augmented Reality apps do not allow their users to immerse themselves in the experience. The reasons for this are the small screen size as well as the overall quality of the experience in its current form.

The same issues affect any possible changes in familiarity. While the inclusive nature of Augmented Reality apps' filters has the clear potential to inform its users about more new places than the rather specific search criteria needed by non-AR apps, these effects are watered down by technical problems plaguing the experience. Overall cluttered and confusing presentation, erratic result behavior, as well as some severe compass and GPS issues make the information often unreliable, and decrease the user's trust. Since non-AR apps need to only rely on a fraction of the underlying systems to work (GPS and Internet), their overall reliability and therefore usefulness is greater.

Finally, the information obtained through regular use of AR apps did not influence user's actual actions significantly.

However, all types of apps (including non-AR) suffered from often irrelevant results, an issue that was completely unexpected at the beginning of this research, and proves that it is not only Augmented Reality apps that are currently significantly limited in their benefits to users. The issue is directly connected to the validity of external databases, which are maintained by entirely different companies.

Also unexpected were some severe issues related to the social acceptability of AR apps, as a number of participants expressed rather significant concerns about how they were perceived by the people around them while using Augmented Reality apps. The physical requisites for AR usage (turning one's body and pointing the device in specific directions) are much more significant compared to non-AR navigational apps, and were felt to be inappropriate by some participants in a number of situations. Since this input method is inherent to the concept of Augmented Reality on mobile phone devices, these issues will remain even as the technology itself becomes more reliable. It will therefore remain to be problematic for AR until either new technology reduces the extent of observable actions (e.g. by integrating AR into wearable computing devices, such as glasses), or until the actions needed for mobile phone AR apps become as common as already established mobile phone related behavior (e.g. talking with a headset in public, taking photos and videos, etc.).

What these elaborations make undoubtedly clear is that the current state of Augmented Reality Applications in the field of navigation and 'point-of-interest' search is in need for improvement. In essence, Augmented Reality regularly does not work well on currently available hardware, and this is greatly diminishing the extent of any possible effects. Not only are singular usage instances rendered useless by the unreliable implementation of Augmented Reality on currently available hardware, these experiences have the power to taint the users' evaluation of the concept of Augmented Reality as a whole.

It should be noted though, that the research's representational value is limited, due to a rather small number of participants involved in the experiment. Furthermore, none of the participants were either unemployed or on vacation during the experiment, meaning that due to the absence of considerable amounts of free time, the opportunities for action were inherently limited. More usages therefore naturally led to more instances of low probability for follow-up action, a result that might have been different under different circumstances.

Additionally, all participants (with a few occasional exceptions) were generally already familiar with the environments they used the assigned apps in. The perceived benefits might have been very different if the usage had exclusively occurred in unfamiliar areas, in which the participants would have had to actually rely on the apps' information. Having a larger number of participants, dedicated entirely to the experiment, explore areas completely new to them would have potentially yielded even more informative results, and is therefore recommended to future researchers exploring navigational AR's effects.

Furthermore, all findings stand in direct relation to the current state of the used technology. As explained during the Augmented Reality background chapter, a number of systems (camera, GPS, compass, online databases, accelerometer and CPU) are responsible for the functionality of AR. As many of these systems are constantly evolving, and future hardware generations might significantly improve on certain aspects of the technology, all findings described in the research at hand need to be seen as a snapshot of the state of navigational Augmented Reality on modern smartphones in the year 2012. Further research at future points in time is therefore highly desirable, in order to determine whether the full potential of Augmented Reality has yet been achieved.

Any future research in the effects of Augmented Reality on its users is advised to keep testing the employed AR tools regarding quality, validity and reliability prior to the research, or at least accompanying it.

Furthermore, closer tracking of the effect individual usage experiences have on the user's overall AR experience is to be recommended. This way a more thorough understanding of the elements that have the strongest influence on the users' evaluations of Augmented Reality is attainable, which in turn would shed more light on the type of activities navigational AR technology is potentially most beneficial for.

9. Appendix

9.1 App. 1) Questionnaire

Please rate the following factors on scales from 1 to 10 after every AR use (at least 3 times a day, if possible in different surroundings)

1. Familiarity with results (**-5**: every result was new to me /// **5:** I was already familiar with all of the results)

   -5 / -4 / -3 / -2 / -1 / 0 / 1 / 2 / 3 / 4 / 5

2. Usefulness/Relevancy of results (**-5**: not useful at all/ completely irrelevant/not what I was looking for /// **5**: very useful/absolutely relevant/exactly what I was looking for)

   -5 / -4 / -3 / -2 / -1 / 0 / 1 / 2 / 3 / 4 / 5

3. Difference regarding Familiarity with Surroundings after Usage (**-5**: confused/less sense of familiarity/surroundings /// **0:** not changed at all /// **5**: strongly improved Overview/remarkably better knowledge regarding respective surrounding)

   -5 / -4 / -3 / -2 / -1 / 0 / 1 / 2 / 3 / 4 / 5

4. Validity of Results (**-5**: no results/incorrect results or completely incorrect Distance/Direction-Information /// **5**: extensive, correct results in realistic Distance/Direction)

   -5 / -4 / -3 / -2 / -1 / 0 / 1 / 2 / 3 / 4 / 5

5. Probability of Follow-Up Action (-5: definitely no actions will result out of the AR Usage /// 0: undecided /// 5: information obtained by AR usage will definitely lead to follow-up action)

   -5 / -4 / -3 / -2 / -1 / 0 / 1 / 2 / 3 / 4 / 5

9.2 App. 2) Interview Questions for Developers

- What were/are the biggest technical obstacles in developing AR for modern smartphones?

- How are the data-sources (Qype, Yelp, etc.) implemented? Is there any selection process going on regarding which points-of-interest to include, or are all venues including geotags implemented into Wikitude?

- Who is responsible for maintaining these databases (keeping them up to date, etc.)? How much are the results displayed in Wikitude “in-synch” with the data of external platform providers, such as Qype?

- If you had direct influence on the underlying hardware of the next generations of smartphones, what would suit the needs of AR the most? (Screen Size/ Type of Compass/?)

- What do you predict for AR's future? Has AR reached its full potential, or will new software/technology keep improving the experience? To what extent can the premise of AR ultimately be realized on mobile phones?

- Might new devices (such as the recently unveiled Google Glasses) deliver new ways to experience Augmented Reality in the foreseeable future, or do you have reservations regarding the potential of such developments?

9.3 App. 3) Summaries of individual Interviews

Results – Experiment Group 1 – Intense AR Usage (min. 3 times a day)

(Participant A)

Awareness:

The participant felt more disconnected from reality due to his attention being focused on the small screen. “It carries one away from reality for a bit, and it produces a distance, which in fact, since I still am standing somewhere, is not really there at all.” An enhanced awareness of surroundings was not achieved, mainly due to distrust in the technology, which formed and increased over time as more and more results were found to be incorrect, out of date, or inaccurate.

Familiarity:

Knowledge about/of a number of singular places was increased, but overall the additional information was regarded as irrelevant. An increase in familiarity was not achieved, “because I think the familiarity with a city comes out of travelling in it and living in it, that you actually go through the streets, and then know it, and look around at the shops to your left, and the restaurants to your right, and that is something these apps in the end don’t offer”. Digital representations of reality are believed to be unfit for increasing one’s actual familiarity with a place.

Immersion:

No Immersion was achieved, reasons being the limited size of the screen, as well as too many incorrect and erratically behaving results, which negatively influenced the trust in and relevance of the apps.

Quality/Accurateness/Usefulness:

Directions were often perceived to be wrong, and many instances were brought up in which the results were much too far away to be relevant. The participant had regular problems clicking on a specific result when it was “behind other results”, or moving erratically.

Because of these problems he grew more and more frustrated with the apps towards the end of the experiment.

Influence on actions:

No actual influence on actions, due to a tight schedule, familiarity with many results, and disinterest in the remaining, new results. However, the participant felt like he learned additional aspects about places he was already familiar with. “Yeah, more often, because usually I don’t use such programs, and that definitely led to me checking things more in detail. But that was mostly superficial, I didn’t really do that much additional research.”

Social Acceptability:

Social acceptability was regarded as low, usage was preferred in private situations. The participant felt the need to explain his behavior while using AR apps to bystanders: “I think they might even believe that I am making a video of them, which of course could also lead to someone approaching you and saying ‘Hey, I don’t want to be filmed’, and other than that I think it just comes off as goofy.”

Trust:

The direction and distance information was often mistrusted, the information about places however was seen as trustworthy: “So what I read in those apps, I would generally trust, […] because they are mainly offering links, instead of producing their own content.”

2 Perspectives:

AR was regarded solely as a new way for displaying information. No change in the experience of space was felt. “If it had a bigger screen, and 3D would be ideal of course, and if the accurateness and the amount of information was increased greatly, and it were displayed maybe a bit differently, then that would be an entirely different thing. “

AR Lag:

Lag was noticed by the participant, and regarded to be very disruptive:“I would expect the locations shown in the app to stay always there where it is supposed to be, so when I move the camera that moves accordingly, but it was more like some icky goo, always being left behind and then crawling back into space."

Continued Usage:

The apps will definitely not be used after the experiment by the participant: "Well, let's say the time comes where I hear that it there was some major breakthrough, and now it all works perfectly, then I would maybe try it out again, but in its current state, no."

(Participant B)

Awareness:

On the one side, spatial knowledge was increased, and things seemed to be closer in AR: "[…] partly I was suddenly aware of the direct direction to things at different locations, so sometimes I definitely had a better feeling for how far away things really are." On the other side the participant felt like she was paying attention only to the screen, thereby potentially missing relevant things in her immediate, real surroundings.

Familiarity:

The participant felt like having learned a lot of additional information during the experiment, and felt like having vastly overestimated her familiarity with some places during the pretest interview. Due to information obtained through AR the participant felt like knowing areas half as well as she expected. However, true familiarity was believed to not be achievable with AR and a digital representation of reality: "For me familiarity builds by being somewhere, touching something, you know, just because I know that there is a pizza place in 500 meters in that direction, and I haven't been there, don't know how the pizza tastes, how the prizes are, you know, just by that I am not more familiar."

Immersion:

The participant did not feel immersed in the apps, however navigational POI search was felt to be "more fun", although potentially less efficient, with AR.

Quality/Accurateness/Usefulness:

One app (Wikitude) did not work on the participant's phone. Screen reflections were felt to be disruptive, especially due to the involved input method of AR: "[…] but it wasn't doable, because I had to turn in such a way that I was able to read the results, but couldn't access the results in the other direction". Using AR apps while driving was regarded to be impossible, due to strong erratic behavior of the results in a high speed, frequent change-of-direction environment. The participant had some additional problems with the relevance of some results, "because once for example I was looking for Parks, and recreational areas, and it gave me the "Park-Pharmacy", which had nothing to do with what I was looking for". Overall however, the results were evaluated as mostly correct, accurate and relevant.

Influence on actions:

The apps had no actual influence on the participant's actions. The participant stated that she made several mental notes about interesting things she wanted to check out at some point in the future, but did not act on any information obtained through AR during the experiment.

Social Acceptability:

The participant experienced some issues regarding social acceptability, especially related to the compass calibration process, which is sometimes needed for the apps to work correctly, and involves moving the phone in "Figure 8" motions. This calibration process was requested of the participant by the apps several times, and greatly influenced her willingness to use the apps in public: "[…]when one is standing somewhere, spinning around oneself with the phone in front of one's face, and then one also starts to make giant rotating movements with one's phone, then some people might start to question one's sanity". The participant however did not feel the need to explain her actions to bystanders, but also due to her "low attention raising" approach to using AR: "[…] usually I kept spinning constantly, so that no single person would feel offended by my actions".

Trust:

The participant overall trusted the results shown in AR apps.

2 Perspectives:

The participant was undecided, but leaning to the positive site, meaning "experiencing space in a new way", because one has to "physically move to see everything, and by that I think the info is easier to memorize".

AR Lag:

R: No lag was noticed by the participant.

Continued Usage:

One out of three apps was deleted after the experiment, with the other two apps remaining for the "right situation" for AR usage, which was seen as definitely less often than during the experiment.

(Participant C)

Awareness:

Overall the participant did not feel like having an altered or improved awareness of her surroundings. Some information were felt to be accessible more quickly with AR than previously used navigational apps, and in some instances the participant was interested in the spatial relations of places (“From time to time it was interesting, to know ‘this is in this direction, and that in this one’, or one was surprised ‘What, that is in this direction, I would have guessed it were in that one’.”). In general “but a feeling of being more connected to my surroundings didn’t emerge” though.

Familiarity:

The participant was familiar with about 60 % of the results, and did not feel like having improved the overall familiarity through the intense AR app usage. This unchanged familiarity stands in direct contrast of having learned about a remarkable number of previously unfamiliar places, as stated by the participant on multiple occasions. The participant however felt like AR apps alone are generally not capable of producing actual familiarity with places, because “you actually then need to do it, one would actually need to go there” to improve one’s familiarity.

Immersion:

The participant did not feel an actual sense of immersion, nor did she feel that the information became more palpable or real in the AR view: “I for example sit in this room, point it in any given direction, look at the app, and the app then tells me that ‘Achmed Döner’ is in my cupboard. He of course is not really in my cupboard, because he is 5 kilometers further away, in that direction. For me those things aren’t really connected, it just is an approximation of direction.”

Quality/Accurateness/Usefulness:

The participant had some problems with the readability of results in more densely populated areas, due to overlapping text boxes and small, not easily clickable, results. Furthermore, the participant experienced outdated results on several occasions, being presented with locations that went out of business sometimes years ago. A number of filters were regarded as “nonsense”, while some others were felt to be “of benefit”, such as ATMs and emergency pharmaceutical stations. Results were felt to be mostly accurate, though the presentation was often felt to be “confusing” due to a cluttered display style and hard to click result boxes (“they were sometimes being very finicky, that was sometimes like at a markmen’s festival, to try to hit the thing.”).

Influence on actions:

The intense usage of AR apps had no actual influence on the participant’s actions, though it led to an increase in information that at some point in the future might lead to some actual actions. In one instance this action was definitely planned.

Social Acceptability:

The participant had some slight issues with the social acceptability of the apps, stating that the need for explaining one’s behavior to friends and colleagues definitely arose, though this did not affect the overall frequency of usage:”[…] it’s strange when a colleague starts spinning around in circles, [so] with people that know me there was a slight need to explain my behavior, with others not so much”.

Trust:

The participant’s trust into the validity of the results was high at the beginning of the experiment, but decreased after she experienced a number of outdated results.

2 Perspectives:

The participant was confident in her evaluation that AR is merely a new way to visualize search results.

AR Lag:

The participant did not notice any lag, but mentioned that she usually turned very slowly and carefully.

Continued Usage:

The participant expressed a comparatively strong interest to keep using one of the AR apps in appropriate situations, meaning in an unfamiliar area with time to spare, while de-installing the ones of perceived lesser quality.

(Participant E)

Awareness:

The participant expressed a noticeable feeling of "being more disconnected" while using AR, because he noticed "much less of the periphery" and paid comparatively much less attention to his actual surroundings. Since the displayed results were often regarded to be of "no interest", "little relevance" or "too far away" this attention split generally did not lead to an improved sense of awareness for the participant. He noticed however a couple of instances (mainly in very unfamiliar areas) where the apps were able to produce interest in previously unnoticed places. ("It definitely had a positive influence on how I perceived Frankfurt, and what I saw in it. […] I used it to check out museums and it showed me some museums I had never heard of before. […]Maybe I am a bit more aware, but not much.")

Familiarity:

The participant's familiarity with results depended largely on his surroundings, ranging from "knowing most of the things" to "not knowing anything, or maybe one thing". The obtained results however did not "open up a new world" to the participant, mainly due to him being only specifically interested in certain places, and disregarding the vast majority of results. The overall familiarity increased only slightly.

Immersion:

The participant did not feel any sense of immersion, he actually felt "really restricted, and limited". The reasons cited for this were the small screen, and that the combination of hardware and software apparently "wasn't fast enough to produce a fluent and smooth representation of what's around me". Furthermore the AR view produced a "worse overview about [his] surroundings compared to a top-down map view", and the involved input method was regarded as detrimental to the process.

Quality/Accurateness/Usefulness:

The participant was unable to properly start one of the downloaded apps and experienced frequent crashes. While the other apps worked as intended, and produced mostly accurate results, several factors influenced the usefulness and quality of the displayed results for the participant: Results being displayed on top of other results, which therefore became impossible to read and/or click, a cluttered presentation, long load times, frequent irrelevant, missing and/or too far away results and an erratic behavior of the results while moving (e.g. jumping around, not staying in place) all resulted in an overly negative experience. Directions and distances were felt to be mostly correct as long as a considerable distance was between the user and the locations itself, with accuracy worsening as one gets closer. “ I think […] it is not really helpful, like [for] getting an idea of all the things around me […] it’s rather useless, more of a gimmick, a toy to play around with”.

Influence on actions:

The intense app usage had very little actual influence on the participant’s actions, with only one occasion where the apps was used to assist in the search for an ATM. No other actual actions occurred during the experiment, however the participant could not rule out any possible future actions based on information gained through the app usage. The participant generally felt insecure about the validity of the results, directly leading him to mistrust the information, thereby lessening his motivation for action. “I never felt sure that something is actually where it was shown”.

Social Acceptability:

The participant felt that the social acceptability was low, due to other people not knowing the purpose of the actions needed to interact with the AR apps: “I always felt kind of stupid, holding the phone up to my face, because people felt like they were being photographed, or filmed, that was always a bit awkward. […] I think lots of people around me might be bothered by my behavior”.

Trust:

The participant trusted the AR apps very little, felt the strong need to double-check any potentially relevant information, and in doing so often made the experience that things were inaccurate.

2 Perspectives:

The participant felt very strongly that AR in its current form is merely a new way to visualize search results. In his experience the underlying concept might be able to produce a new experience of space, however for the participant current technologies seemed to be not ready yet.

AR Lag:

The participant experienced a very strong lag and found this to be “very disruptive”: “When I was turning more quickly, and then I saw something interesting, and I tried to go back, then it tool very long, like 1 or 2 minutes, for it to calm down, until it showed it again.” This again influenced the participant’s trust in the results: “it was hard to say where something actually was”.

Continued Usage:

The participant will not continue to use any of the Augmented Reality apps.

(Participant D)

Awareness:

Although the participant felt an increase in the amount of information available to him, this did not lead him to feel more aware of his surroundings. This is ascribed by the participant to the irrelevant nature of the additional information: "I use the app and see that there is an Architectural Office and a PR Company nearby. That is surely something a non-user wouldn't know, but is knowing that in any way of benefit to me? I wouldn't say so." Especially in very active areas, the "amount and unspecific nature" of the information being superimposed onto reality actually created more confusion for the participant. In these instances of "information-overkill" the participant actually felt less aware of his surroundings than without the apps.

Familiarity:

The participant's overall level of familiarity with his respective surroundings did not increase. Although the participant learned about a couple of shops and locations he was unfamiliar with before, overall the apps did not prove to be useful, because "without filters there was too much information, which in the end confused me more than it was helpful." The participant furthermore felt the need to differentiate between "virtual reality" and reality: "One might be able to obtain a virtual familiarity with the place, which hasn't all that much to do with reality."

Immersion:

The participant did not feel immersed, due to the small size of the screen.

Quality/Accurateness/Usefulness:

Besides the aforementioned confusing effects resulting out of information-overkill, the participant felt that the quality, accurateness and usefulness overall is not really reliable. The different content sources proved to be too complex for quick and efficient usage for the participant and the cluttered presentation in dense metropolitan areas worsened the experience further. Additionally, some outdated and inaccurate results tainted the participant's general impression. On the other side, the apps were able to bring the participant’s attention to useful and previously unknown places in two instances, and distance information was regarded as being mostly correct.

Influence on actions:

The apps had some notable influence on the participant’s actions, with two instances where he located a shop that was presented in an AR app, and one instance where the participant did some additional research about a place found in an AR app. The participant found AR to be of benefit in these moments, even though one of the two shops had been shut down.

Social Acceptability:

The participant experienced some heavy issues regarding the social acceptability of AR, for example feeling “awkward to stand in the middle of the central station in Hannover and hold this thing in front of [him]”, which “definitely would keep [him] from using it often”, especially “in all kinds of situation in which there are lots of people around [him]”.

Trust:

Overall the experiences the participant made with some outdated and negative results negatively influenced his general trust into the accurateness of the results.

2 Perspectives:

The participant regarded AR in its current form to be mostly a new way of visualizing search results, but sees a clear potential for this to improve as technology gets better: “The amount of information is too complex and too high for such a small mobile phone screen. If different ways of displaying it would arise in the future, then I could easily imagine it having more of an effect”.

AR Lag:

The participant barely noticed any lag, and did not experience it as disruptive.

Continued Usage:

The participant will keep one out of three apps installed, but does not expect to keep using it after the experiment, stating that “maybe when I am again in another city where I don’t know what is around I will try it again, but in my day-to-day life it will surely not play any role”.

Experiment Group 2 – Augmented Reality App Usage (no min. each day)

(Participant F)

(The participant did not receive any results when using AR outside of a Wifi Spot)

Awareness:

The participant did neither feel more aware of, nor more in touch with her surroundings. She suspected the lack of results while travelling prohibited her from doing so.

Familiarity:

The participant felt like having learned a number of additional things, however she did not feel that this led to an overall increase in her familiarity with her surroundings.

Immersion:

The participant did not feel any immersion while using the apps.

Quality/Accurateness/Usefulness:

The participant was unable to see any results while her device was not logged into WiFi, even though she is able to access the web via 3G with any other app. The results she got from within WiFi spots were in parts outdated, leading her to doubt the validity of the remaining results. Since she was not able to access the app while outside, overall Usefulness for her was very low.

Influence on actions:

The apps had no actual influence on the participant's actions.

Social Acceptability:

Although the participant acknowledged some issues regarding the social acceptability of AR usage ("the impression one would get is probably that I am taking a picture, so it's not so bad, but it definitely looks quite goofy"), she did not feel the need to explain her behavior or less motivation to try the apps in public spaces.

Trust:

After experiencing some outdated results, the participant's trust in the apps greatly diminished.

2 Perspectives:

The participant was unsure regarding this question, but made clear that she evaluates the experience more as a new way of visualizing search results. She however noted that prolonged use (and properly functioning apps) might change her mind regarding this matter.

AR Lag:

The participant did not note any lag.

Continued Usage:

Due to her negative experiences the participant could not find any reasons to keep using AR.

(Participant G)

Awareness:

The participant did not experience any change regarding her awareness.

Familiarity:

The participant was already familiar with many of the results, but was also able to learn about a number of additional locations, especially in places where her already established familiarity was lower. The participant found the apps to be “helpful” in these instances, because they enabled her to find “things with it [she] wasn’t familiar with before using the app”.

Immersion:

The participant preferred the way AR visualizes navigational results over map-based views, because it made it “more comprehensible” for her, but she did not actively feel immersed.

Quality/Accurateness/Usefulness:

The participant did feel that AR was of decent benefit to her, but she also had some issues that worsened her experience: In some places displaying results took so long that she closed the app before the process was finished, leading to an overall lessened motivation to use the apps in moments with little spare time. The participant furthermore experienced a number of outdated results, which made her question the validity of other results. She furthermore did not feel that the apps provided a unique service to her, stating that “Most of the times I felt like I would have found my way just as well without the apps. Or maybe I would have asked someone local.”

Influence on actions:

The participant did not do anything solely based on the information provided by the apps, she was however able to find places with the apps she was planning on visiting anyway. The apps therefore did not change her behavior, but aided her in completing already planned activities.

Social Acceptability:

The participant experienced no issues related to the social acceptability.

Trust:

Experiences made by the participant in which she realized that displayed results were in reference to shops that had been shut down “two or three years ago” led to an overall strongly decreased trust in the validity of all results.

2 Perspectives:

Although the participant enjoyed the new display style inherent to AR, she felt that it did not change the way she experienced space, and agreed more with the statement relegating it to a new way of visualizing search results.

AR Lag:

The participant noticed a slight lag, but she did not find it to be disruptive to her overall experience.

Continued Usage:

The participant will continue to use the apps, in cases when she is “looking for something specific”, less so for “just gathering information generally”.

(Participant H)

Awareness:

The participant was not more aware of his surroundings, which is largely due to irrelevant, unclear and/or obscure results. Erratic result behavior as well as inaccuracies diminished the overall quality of the experience so much for the participant, that he was not able to gain any additional awareness about his respective surroundings.

Familiarity:

The overall familiarity increased only slightly. This is due to a number of interesting results, which however were far outweighed by the "plethora of results consisting solely of names and acronyms with no indication about what these results actually stand for". A greater sense of familiarity did not emerge also due to the untrustworthy and erratic behavior of results ("rarely in the same direction twice"), as well as bad performance while moving at a higher speed (e.g. in a car, tram, etc.)

Immersion:

The participant felt no direct sense of immersion, he did notice however that using AR apps is more fun than more conventional navigational POI apps. He felt that this led him to spend more time with the apps, thereby keeping him within the experience longer, although not actually feeling immersed.

Quality/Accurateness/Usefulness:

The participant felt that the overall quality of results was lacking, in relevance as well as accurateness. He did however notice that even though the apps worked worse than hoped in his experience, he still made some interesting realizations. This he contributes though to the more intense engagement with geography and his surroundings as needed from him during the time of the experiment, and less to the specific apps themselves. He furthermore expressed that actually navigating to any point-of-interest using the AR view would be very hard to do.

Influence on actions:

Using AR apps on a regular basis did not lead to any direct action for the participant, though he passed on information learned during the usage to friends on a number of occasions.

Social Acceptability:

The participant felt very heavy issues regarding the social acceptability of the involved input method connected to AR. He especially avoided using the apps in public situations “where lots of people are in a small room together”, like on the bus or in a tram, due to his hesitation to “hold the device right up into another passenger’s face, which [he] would have needed to do to know what is behind [him]”. In several other situations he actively avoided using the apps as well, because he did not want to bring attention to his actions. In private or in more impersonal public spaces he experienced no problems though.

Trust:

Overall the trust in the results was very low for the participant. This was less caused by inaccurate or outdated content sources, and more related to regular experiences with “finicky and jumpy” results. The participant very rarely felt sure about the actual location of the results presented in the apps.

2 Perspectives:

The participant believes that in its current form AR is merely a new way of visualizing information “at best”, though he believes that more customizable filters, better data sources and generally improved reliability “might very well be able to change this”.

AR Lag:

The participant experienced heavy lag, which was not only disruptive, but also led him to mistrust the results, “even after they had calmed down”.

Continued Usage:

The participant will continue to use AR apps "at some points in the future", after updates have been released, or after the purchase of a new phone, to see how it evolves, as he was generally impressed about the potential and believes that the overall experience will "surely improve over time".

(Participant I)

Awareness:

While the participant felt like he was paying “more attention to what’s around oneself”, learning about places one “wouldn’t know [about] without the app”, he also noted that he was so “focused on the app that one notices the [immediate] surroundings less”.

Familiarity:

The participant found the apps helpful to increase knowledge about certain aspects of areas, but did not gain an overall improved familiarity with his surroundings.

Immersion:

The participant thought that it was theoretically possible to be immersed in the app, he however did not feel very strong feelings of immersion.

Quality/Accurateness/Usefulness:

The participant was positively surprised by how well the apps worked in comparison to his SatNav, though he experienced some issues with long loading times. Overall however, he felt that the apps were useful and “able to lead [him] to whatever”.

Influence on actions:

The apps had no direct influence on the participant’s actions, this however was more a result of his tight schedule, as the participant proclaims. He generally was very optimistic about the possibilities of direct influence in cases of more time to spare.

Social Acceptability:

The participant had no issues with the social acceptability of the apps, stating that “by now it’s completely normal to take photos or something with one’s phone”, therefore he did not feel like standing out.

Trust:

The participant would not trust the apps "blindly", and continued to feel the need for separate navigational or informational devices and/or services.

2 Perspectives:

The participant felt that the apps were a new way of experiencing space, rating it with a "0 to 2 or 3".

AR Lag:

The participant did not notice any lag.

Continued Usage:

The participant was absolutely sure that he would continue his usage of the AR apps even after the experiment.

(Participant J)

Awareness:

The participant felt a “small but definite influence” on his awareness of his surroundings, especially regarding the comprehensiveness: Seeing all kinds of places, that he individually was aware of, clustered together on the screen produced a new awareness of the “diversity” of his neighborhood. “That is something you only realize by using such an app.” After the usage the participant felt like having a different sense of “direction, spatial relations and proximity”. He however also felt that classic maps had some distinct advantages over AR, such as also showing “adjacent areas” and not only one’s “immediate surroundings”. This would enable a much improved overview for him. He also noted however that AR apps produced a “doubling of space”, focusing his attention on “all the spaces that at first [were] not visible to [him]”, which he sees as “clearly advantageous”.

Familiarity:

The participant felt like needing to differentiate between urban and rural areas: In densely populated, urban areas he felt like being familiar with most of the results, due to their closeness to his actual location. In rural areas he was very unfamiliar with the results, mainly due to the results actually being quite a distance away, and thereby not relating to his actual location. The participant felt like he significantly increased his familiarity with an urban area he was very unfamiliar with before the experiment, due to actively using the apps while walking through the area and checking out results.

Immersion:

The participant did not feel any real sense of immersion, stating that the AR view to him was more of a “gimmick”, and not essential to the experience.

Quality/Accurateness/Usefulness:

The participant was regularly bothered by the involved method of input, lessening the perceived usefulness due to the “inconvenience” of interacting with the apps. For some purposes however, the participant felt that the apps were “pretty accurate and useful”, for example when “looking for a bank” or “gas stations”. In urban areas the participant was sometimes confused by the amount of results, while in rural areas he was regularly disappointed by the lack of relevant results. Results that were “too far away” were the main problem in the latter case. Search phrases returning irrelevant results occurred from time to time in urban as well as rural areas (“I couldn’t make out the relation between what I was looking for and what it was showing me”). He however felt that the things listed were always “very correct”. The participant felt that the AR apps worked better in determining his actual location than Google Maps.

Influence on actions:

The AR apps directly influenced the participants actions on a number of occasions, leading him to visit a café he has never been to before, going to a photographer that was closer to him than the one he used to visit, as well as navigating to gas stations and ATM machines he did not know about before using the apps.

Social Acceptability:

The participant experienced no issues at all regarding the social acceptability of the apps, on the contrary, he felt that using them was “fun”.

Trust:

The participant generally trusted in the validity of the results, based on double checks that confirmed the AR app’s information, remarking that his trust in the apps was unusually high for him.

2 Perspectives:

The participant felt that AR was more of a new tool to visualize information.

AR Lag:

The participant sometimes noticed some lag, this however “wasn’t too bad” in his opinion.

Continued Usage:

The participant will delete two of them, and will keep using the paid app, which he also felt to be the best one.

Control Group – Non-AR navigational POI-Search (no min. each day)

(Participant K)

Awareness:

The participant felt like his overall awareness increased, but only insignificantly. In single instances he was more aware of additional things, but in general he felt that "actually travelling through the spaces" would be the only way to actually increase his awareness: "I would not say that I could become more aware of or familiar with my surroundings through digital representations of geography." The participant however stated that he had a general problem with "connecting maps with reality and applying map knowledge to [his] understanding of space". Overall the participant did not gain any different sense of direction or spatial relations.

Familiarity:

The participant knew "a bit more than half [of the results] already". After the experiment he felt "a bit more" familiar with his surroundings, though most of the results were "irrelevant" to his day-to-day activities.

Quality/Accurateness/Usefulness:

The participant found the process of locating oneself in the map very complicated and cumbersome, and he was often unable to find what he was looking for. Search results were often irrelevant to his actual search interest. A number of locations were missing from the results. The participant often felt that the results were "related to reality, they [were] correct, but [were] less related to my search terms. "

Influence on actions:

The information obtained by the regular usage of Gelbe Seiten led to some direct actions: The participant went to a new hairdresser, and tried to find a supermarket that he previously was unfamiliar with. He stated that he "definitely would not have done, or known about these things without the additional information obtained through Gelbe Seiten".

Trust:

While the participant generally trusted the accurateness of the service, meaning that “most of the times the things were [actually] there”, he however greatly mistrusted the efficiency of the search process: “The things it showed were mostly completely irrelevant to me”.

Continued Usage:

The participant will most likely not continue to use the service after the experiment, stating that “maybe one day [he] will use it again, just to browse through an area, but generally [he] prefers to spend [his] free time differently”.

(Participant O)

Awareness:

The participant felt like being "marginally more aware, but definitely more aware" though the regular usage of Google Places. She regarded the information available in the app to be "too little" to actually increase her awareness, though she felt that the regular usage demonstrated to her that there is "something more behind the routes that I always take", leading to a greater curiosity in already known areas. However no different sense regarding spatial relations was achieved.

Familiarity:

The participant was unfamiliar with many of the results, even though they were in close proximity to her home. A number of results were relevant to the participant, leading to an overall improved familiarity with her respective areas.

Quality/Accurateness/Usefulness:

The participant experienced some issues with long load times, due to bad GPS signal, which led to her using the app less often than she initially wanted to. Especially compared to other devices, such as the PC or the participant's SatNav, the experience was slow and sometimes frustrating. The participant furthermore had regular issues with big amounts of irrelevant results, producing inconveniences by flooding the screen with useless results. The participant was however usually able to alleviate these problems by entering more specific search terms, leading to better results.

Influence on actions:

Although the app had no direct influence on the participant's actions during the experiment, the app brought the participant's attention to a number of places which she plans on checking out in person at a later point in time.

Trust:

The participant overall trusted in the validity of the results shown in the app, though if given the option of alternative devices or services she would generally prefer to double-check any given information.

Continued Usage:

Due to the amount of irrelevant results and time it took to display these, the participant will not keep using the app after the experiment.

(Participant L)

Awareness:

The participant felt like having an improved awareness of her surroundings through the regular usage of the app, especially compared to non-users. She furthermore felt like having a better overview about the layout of her surroundings, due to the map-based view of the app. Although the participant frequently felt that places were further away than she expected, she overall did not feel like having a significantly changed "sense of direction, spatial relations and/or proximity".

Familiarity:

Using the app on a regular basis led the participant to an only slightly improved familiarity with her respective surroundings, mainly due to the fact that she was already familiar with most of the displayed results.

Quality/Accurateness/Usefulness:

The participant had regular issues with the app incorrectly locating her position, as well as frequent internet connectivity problems, which led to some inconveniences. When the app worked as intended, the participant however found the app generally "quite useful", as it was able to briong her attention to previously unknown places. Incorrect GPS results affected her overall evaluation greatly though, leading to a negative impression regarding the accurateness, and thereby usefulness of the app.

Influence on actions:

Though the app did not influence the participant's actions directly during the experiment, the information obtained through the app led the participant to make a number of plans for the future (such as; visiting a zoo, a museum, and a Mexican bar), as well as to research these locations in more detail separately (regarding opening hours, ticket prizes and menus).

Trust:

Imprecise GPS functionality led the participant to greatly distrust the overall usefulness of the app, thereby lessening the motivation for future usage.

Continued Usage:

The participant will "definitely use [the app] less", but "will keep it", since "from time to time it definitely can be of use"

(Participant M)

Awareness:

The participant felt that “the interest in one’s surroundings gets heightened”, and made frequent realizations about the untapped potential for activities located in her respective areas. She however did not feel like being more “in touch” or more “strongly connected” to her surroundings through the use of the app.

Familiarity:

At the beginning of the experiment the participant was surprised by many of the results, realizing she was less familiar with some places than she suspected. This lessened though as the experiment progressed, mainly due to an increasing familiarity with the places she inhabited the most through the constant use of the app. Her overall familiarity increased slightly during the experiment.

Quality/Accurateness/Usefulness:

The participant was overall very satisfied with the accurateness and usefulness of the app, though she had frequent issues with the GPS taking up to a couple of minutes to locate her. In some instances she felt that the app was more useful than in others, especially in moments when she “didn’t know the way and learned new interesting things”.

Influence on Actions:

The regular usage of the app had no direct influence on the participant during the experiment, but she made a number of “mental notes about places [she will] check out more closely sometime soon”.

Trust:

The participant overall trusted the results shown by the app.

Continued Usage:

The participant will continue to use the app after the experiment.

(Participant N)

Awareness:

The participant did not feel like the digital representation of her surroundings were able to increase her awareness, "because to be more aware of anything I would have to see it for myself, I would need to walk through the street for example, and look at the things with my own eyes." She furthermore had problems relating abstract numbers (like distance information) to her understanding of real world relations, thereby she was not more aware of her surroundings through the regular use of the app.

Familiarity:

The participant was generally pretty familiar with the results, noting only a few exception where the app was able to show her interesting, new things. Her overall familiarity with her surroundings did not change during the experiment. Generally the participant felt like having "more information, but not substantial information", due to a lack of relevant additional information, like reviews and pictures. The information stayed abstract for the participant, and thereby irrelevant.

Quality/Accurateness/Usefulness:

The overall quality and usefulness of the app was low for the participant. Besides general problems with accurateness of the GPS and long load times for the results, the participant was especially put off by "too broad and inclusive filters", leading to huge amounts of search results with often little or no relevance for the participant. Furthermore, the participant felt like several important locations were entirely missing.

Influence on actions:

The app had no actual influence on the participant's actions, besides one instance where the app reminded the participant of a restaurant she had planned on visiting a long time ago, but subsequently forgot.

Trust:

Even though the participant did not make many negative experiences regarding the overall validity of results, she generally did not have much trust in the app. This was mainly caused by incorrect labeling of places within the app (for example by listing a “snack-bar” among “restaurants”), which led the participant to doubt the appropriateness of the search results.

Continued Usage:

The participant will „under no circumstances“ continue to use the app.

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