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A Comparative Analysis of Augmented Reality Technologies and their Marketability in the Consumer Electronics Segment

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Abstract

In this paper, we analyse past approaches in designing and marketing Augmented Reality apps or devices, and we discover key issues that prevented their mainstream adoption. We offer insights into novel approaches to marketing consumer technology products; in particular Augmented Reality devices. We analyse marketing strategies in order to understand which have been successful and which problems should be avoided in future campaigns. Although other papers have discussed some of these topics, none of them has discussed them with an interdisciplinary lens. We also attempt to understand how recent Augmented Reality and Virtual Reality devices have been perceived in society and reported by media. This research includes human-computer interaction expert interviews, historical evolution models for consumer technology, and socio-cultural and political analyses.

Keywords: Augmented reality; Marketing; Computer vision; Artificial intelligence; Computer interfaces; projections; Media campaigns; Magic leap; meta; Google glass; Stanford; Microsoft hololens; Military interfaces; Marketability; Oculus rift; Pokemon go

Introduction

What is augmented reality?

During this research project, Augmented Reality has become a hot topic, partly because of the Pokemon Go phenomenon (a popular game for mobile phones), since it incorporates some AR elements. Previously, Oculus Rift (VR) has been paving the way for more advanced devices. Augmented reality (AR) refers to the juxtaposition of graphics or digital information onto what an individual is seeing in real-time. It is a live view of an environment in the physical world, with computer-generated or virtual elements that augment or supplement that environment. This often looks like a hologram, where, for example, on top of a real table or cardboard sign, the user could see a tridimensional virtual object. The object would appear to be on top of the table or sign, integrated into the real physical environment (Figures 1 and 2).

Another popular form of Augmented Reality (or AR for short) in the visual space, looks more like Terminator's field of view, with information overlaid on top of objects and people. In Terminator, this overlaid information is about personal or object identification, face recognition, object identification and tracking. For example, in the picture, we can see the edges of the bike are identified and information about the motorcycle model is overlaid on top. This could be particularly useful for technicians or workers in multiple fields, as well as sight-impaired, cognitively-impaired or deaf people.

Figure 1: 3D augmented reality maker.

In essence, Augmented Reality changes the world around the user as they know it. Google famously entered into the augmented reality sphere with Google Glass. This highly sophisticated pair of frames uses a prism to project partially opaque images onto a screen, cleverly hidden on top corner of the right eye [1]. Google designed them this

Figure 2: Augmented reality is reality augmented.

Figure 3: The UX of Google Glass.

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way so that the information does not cover most of the users' field of view (so they don't walk into oncoming traffic by mistake).

Already-existing AR technologies that have been widely adopted include heads-up displays for military plane pilots, navigation bots (including GPS assistants), and a number of tools for car driving such as auditory feedback for detecting incoming cars in blind-spots, or distance measuring interfaces for parking (Figure 3).

Sci-Fi

When reading about augmented reality, fans of science fiction might be reminded of the interactive hologram environment seen in the film, Minority Report. In the futuristic dystopian blockbuster, citizens can interact with holograms and other forms of AR at almost every turn (Figures 4 and 5).

In the real world, Microsoft has developed a pair of glasses called HoloLens [2], which are beginning to bring the sci-fi vision of the film into reality. These cool-looking shades allow the user to interact with HD holograms in real life. Voice control functions further enhance the immersiveness of this incredible technology.

The use of Augmented Reality surprisingly dates back as far as the early 1990s but has only recently been thrust into the limelight by the emergence of smartphone applications and wearable interfaces which make use of the technology [3]. Some simplistic versions of AR (which include phone apps like Pokemon GO and others similar to it) use a camera to capture the surrounding environment, and using data from Google Maps or software, they are able to project a virtual universe onto of everyday locations [4]. AR is now widely used for entertainment purposes, but we have only scratched the surface of its full potential (Figure 6).

Evolution

In the last few years we have seen many companies trying to realize their vision for the next step in the evolution of consumer electronics devices: augmented reality headsets. Google attempted to popularize their Google Glass device. Epson made a heads-up display called the Moverio. Meta added sensors and made a more functional prototype. Despite all these attempts, they have not been able to make augmented reality mainstream yet (Figure 7) [5].

Figure 4: Minority report.

Figure 5: Microsoft HoloLens.

Figure 6: Smartphone applications: Pokemon Go game.

Figure 7: Epson-Smart Glasses.

We will analyse three different case studies in both AR and VR: Google Glass, Oculus Rift and Magic Leap. Why did Google Glass fail to cause a good impression in the consumer market? Why does Oculus Rift seem to be succeeding in social acceptance so far? We will try to gain a deeper understanding of the social processes so that we can better understand or predict what marks successful adoption.

Research objectives

Some Augmented Reality applications exist for mainstream devices such as phones and tablets. For example, some car manufacturers have made AR applications for phones that allow the customer to visualize a car colour change on their phone. Other companies have used AR phone apps to show 3D models of their products, placing them as if they were floating on top of the product box. Other applications have been made for consumers, such as "Layar", which overlays store information on top of the camera view, therefore allowing the user to point around themselves with their phone and seeing indicators for where stores are located and what they sell.

However, these simple phone applications are still not being widely adopted by consumers as anything else than a gadget. In other words, users find the applications entertaining but not useful, and they stop using them quickly. When Google unveiled its Google Glass device, a wearable small screen on the top-right of their glasses, which allows users to read notifications without taking out their phone or watch, most of the audience was ecstatic, while there were a few skeptics. However, when it started shipping, it faced harsh social and cultural reactions, ridiculing users who wore them, and resulting in low adoption rates. We have requested the opinion of multiple people about why they think Google Glass has been deemed socially unacceptable and why Glass users have been ridiculed. We have performed a quantitative survey on their perception, and we have analyzed other authors and HCI faculty who are familiar with the topic. We will go more in detail into why Glass was received negatively in our HCI analysis and the social analysis sections.

We have performed an in-depth analysis of what scholars are saying about the design, history, and social perception of consumer interfaces, particularly related to Augmented Reality and Virtual Reality devices. We have also interviewed users with varying levels of exposure to augmented reality applications. Other interviews we conducted were with faculty in human-computer interaction, to provide expert opinion on the user experience challenges faced with these platforms. The purpose was to learn what cultural and design factors might be preventing an incorporation of augmented reality into daily lives, and most importantly how they might prevent widespread adoption in the future.

Methods

What are the social, governmental or economic factors limiting or shaping the way augmented reality technology is being developed? Which features or key technologies are missing that is necessary for widespread adoption? What are the personal reactions and views of individuals when trying existing augmented reality solutions and how do they react to those they did not know about?

In order to answer our research questions, we will first analyse the history of personal computers, mobile phones and the internet, and how those models can apply to augmented reality devices. Then, we will try to understand the problem from the perspective of Human-Computer Interaction specialists. After that, we will move on to a social analysis, including political, economic and cultural factors affecting the perception of these devices. And finally, we will attempt to combine these theories and reach a conclusion with a cohesive theory.

Context

Current uses of augmented reality: Visual Augmented reality systems mostly have a few common core components. They require a processor (computer), a display, and spatial sensors and/or an input device, as well as a viewer (a person) who will observe the processed or filtered reality [5]. There are many different variations of this blueprint, but the general concept of AR technologies revolves around this setup.

The United States military has been implementing augmented reality for quite some time now. One example of AR usage by the US Navy is a wearable interface for soldiers [6].

This interface captures a soldier's surroundings (input), and projects data on top of it using sensors which help the processor calculate the correct amount of distance between the environment object and the display. This gives soldiers an extreme tactical leg up when traversing through territory that may be alien or unfamiliar to them. The projected data can include things akin to street and building names, or crucial mission intelligence.

On the opposite extreme in applications of AR, there are phone games such as Pokemon GO, which use GPS data from the user's phone as its spatial sensor, and the phone's camera as the input device. The processor and display are both contained within the phone itself. The game, which is developed by Niantic Labs, superimposes characters from the cult-hit of the 1990s onto the user's real surroundings [7].

The goal of the game is to go around finding the virtual critters in the real world, and then catch them in a mini-game by throwing a virtual capturing device at just the right spot on the screen. The implications of this usage of AR are far less dire than the usage of AR in a military setting, but the basic structure of the technology is unchanged between the two (Figures 8-11).

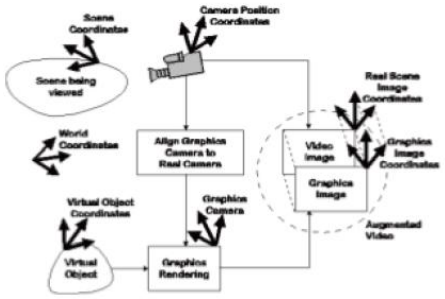

Figure 8: Current issues of Augmented Reality.

Figure 9: A new AR helmet Designed by US navy for underwater missions.

Figure 10: Wearable interface captures a soldier's surroundings.

Figure 11: Applications of AR such as phone games.

Launching augmented reality into the mainstream: Despite recent advances in Augmented Reality technology, the public at large has been slow to embrace the new products. The failure of Google Glass to catch on with the masses has many believing that AR is not here to stay [8]. Buyers have called the gadgets overwhelming and socially invasive, leaving the public to wonder if AR is just a gimmick, with no real world application [9]. Some, however, believe that by creating

software that has immediate utility, the public will be ready to conduct their lives in the realm of enhanced reality [10].

The virtual world exists for users in their Head Mounted Displays (HMDs). Recent HMD product launches have been less than impressive, with many users blatantly disappointed with the long-awaited technology. Studies have found that customer loyalty drops considerably when hardcore-users don't feel a product lives up to its hype [11]. Merchandisers need to resist the impulse to rush an AR app to the market, which could dampen user's enthusiasm if it fails to excite (Figures 12 and 13).

The opportunities for Augmented Reality in retail are endless. Companies like Ikea, Ray-Ban, and Cover girl are already using AR to enhance their customer's experiences [12]. Buyers are using this new technology to virtually try-out a product before buying it, and the results are quite positive [13]. The key to success seems to be the application's ability to immerse and engage customers significantly more than just seeing a product virtually overlaid on a photo. Users are ready to jump into the world of enhanced virtual shopping, which may spur the online shopping movement to new heights.

Promising AR projects: Microsoft's HoloLens is a wearable interface that is widely acclaimed as the best commercial augmented reality system created to date. HoloLens is a form of wearable AR technology that makes use of holograms the user can interact with in real time. The impressive headset also makes use of gesture recognition, and spatial awareness of sound to create an immersive experience for the user [14]. A company called Meta has a similar headset model, which also captures the gestures of the user to interact with augmentations [15]. Meta boasts a significantly higher resolution than HoloLens (2560 × 1440 compared to 1268 x 720) [16]. HoloLens does have a wider field of vision, by 30 degrees [17]. However, it will be around three times the price as Meta's upon its release [18].

While HoloLens and Meta are already well into their development, and being implemented for things like film, design, brainstorming, and more, there is buzz around a startup that's creating an AR device so realistic, that it blurs the line between what's real and what's augmented. The company, called Magic Leap, is headquartered near Ft. Lauderdale, Florida. Their approach to augmented reality has created so much hype, that Google (whose AR project, Google Glass, failed in many respects) led an investment of $542 million in Magic Leap in October of 2014 (Figures 14 and 15) [19].

What makes the project so exciting is the realism of the augmentations, which set it apart from other AR interfaces. The nuts and bolts of the project are still being kept under wraps until the company has devised a way to make the interface more portable. A patent that Magic Leap applied for in January of 2015 suggests that the interface will have two main sections - a set of glasses which will act as the display and perhaps serve additional functions, and a separate processor, which will be small enough to fit in the user's pocket [20].

Augmented reality in the car industry: Augmented Reality (AR) is permeating every facet of industrialized life. People are playing AR games on their phones and using AR technology to help make buying decisions. Applications for its use are being developed in every economic sector from the military to medicine. The entire AR Market is expected to surpass $100 billion by 2024 [21]. One of the fastest growing sectors of AR technology is the Automotive Industry, which is expected to have over 70% compound annual growth rate over the next 8 years. Driving the rapid growth is the consumer demand for safer vehicles and a more enriched driving experience.

Car manufacturers are changing the way drivers interface with their vehicles, attempting to make driving safer and more fun. With current navigation displays, drivers are forced to take their attention off of the road to look at the display, which can be distracting and dangerous. AR improves vehicle safety by bringing that display to eye level with heads-up display (HUD) technology [22].

Projecting a map overlay on the windshield of the vehicle allows drivers to see their next turn without taking their eyes off the road. AR

Figure 12: Google+Glass owners.

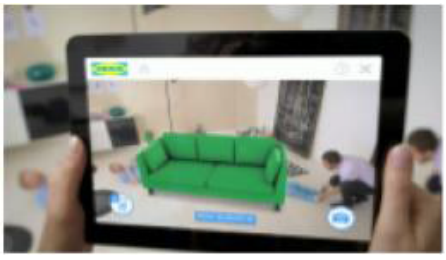

Figure 13: Augmented Reality in retail.

Figure 14: HaloLens being used for 3D modelling.

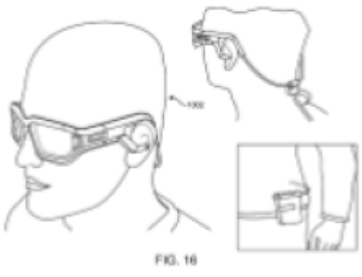

Figure 15: Magic Leap's patent.

can also be used to highlight road hazards, warning drivers of obstacles in plenty of time to change course [23]. Proponents of the windshield display call it the most ergonomic and intuitive navigation system yet. While safety is always first, some drivers are looking for AR to provide excitement behind the wheel.

Drivers are looking for more than safety. They want a fully immersed driving experience. With virtual reality overlays, drivers can interact with both real and virtual content while driving. One could set the display for a winding country road or a thrilling ride on the Audubon. The possibilities are endless. Whether used to enhance vehicle safety or create a gaming experience in the vehicle, HUD full-windshield systems could be available as early as 2017 [22].

The promising future of augmented reality: Augmented Reality has become a hot topic, and as of even more recently a hot product, in the last few years that is currently projected to explode further, with a projected $90 billion dollar industry in the next 4 years [24]. There are many promising products currently in the works for big name technology corporations and also for smaller start-ups quickly making a name for them. Indeed, the failure of Google Glass hasn't seemed to discourage the AR community at all [25].

There are many promising Augmented Reality products expected to roll out in the relatively near future. In fact, the European based start-up, Infinity AR, has won several awards in tech innovation for their ventures into AR [26]. The company is in the process of developing a sort of AR "engine" that solves the problems of both energy efficiency and cost, which can be used with light, somewhat fashionable glasses frames. Using two 2D cameras instead of complicated and battery-draining 3D depth gauges and their powerful mini-engine, the company is hoping to create a device that will aide in the growth of the AR industry [26].

Another promising application for AR is in the design and construction field. The interactive nature of augmented reality technologies allows for better contextual awareness for architecture and the building and designing process. The Inition AR app for iPad can create work with 3D printers to create architectural models of potential building projects, including floor plans and environmental factors such as geographical location and windflow around the building [27].

Not only is there success in the future of AR, it's actually projected to surpass the super-popular virtual reality technologies in coming years. With so much potential in entertainment, medical, architectural, military, and other fields, this comes as no surprise. As long as we can overcome the practical application problems that are holding back the mass-production of many AR projects, such as health and safety concerns, poor battery life, and clarifying their practical purpose, the future of AR is looking big and bright.

Health issues of augmented reality products: Ever since the infamous disappointment of the Google Glass revolution, many companies are working to overcome the present downfalls that are hindering production of Augmented Reality products. Among these concerns are the complications that could arise from the device's effects on the wearer's eyesight, and day-to-day distraction and the effects of that distraction on safety of the user and others [28].

How real are these concerns? The unfortunate answer: we don't really know yet. Since Augmented Reality (AR) hasn't been as practical a technology until recently, we as a society haven't had much of a chance to research the effects it could have on health and daily life. However, more basic studies on the way humans interact with the world around them without an AR device have raised some preliminary concerns.

The distraction element is a common issue raised with AR products as well. The human brain is, for the most part, pretty easy to distract. What's to stop someone from becoming distracted by notifications while crossing the street? Or, even worse, driving? These "slips" are a valid argument, definitely deserving of the special attention most companies are giving to perfecting before mass-production.

Literature Review

Discussion among scholars

Some authors argue that although the relationship between technology and society is often viewed under the lens of "technological determinism", where technology follows a natural course and society adapts to it, there are other factors that shape technology in the first place. Technology is "inherently political" and social factors play a role in shaping technological development and adoption [29].

Governments can often fund or de-fund specific research fields and shape technology in this way. Technology adoption is also heavily regulated and can function in multiple different ways. Technology can be adapted and modified before adoption to comply with norms and regulations. Most scientific and technological advances have their roots in war research, and as such, are mostly government-funded or originate in academia. It is only the specific adaptation of that technology to real world widespread usage that is often performed by private companies [29].

Augmented Reality applications have been explored in entertainment fields, military, visualization, manufacturing and medical fields [30]. The military is often the first field that technology advances are implemented in. Because having the technological edge in the military can be a priority, especially in times of war, big economic powers' governments invest a vast majority of their gross domestic product in technological advances for war. In the present, the military is making use of Augmented Reality heads-up displays to facilitate the display of information to soldiers while they are in the field [31].

For example, the Nepali military is one of the first ones to adopt Google Glass technology for their soldiers [32]. The Gurkha military uses the technology to track animals and birds in the jungle and tackle poachers [32]. After the military, many technological advances are then applied to the medical field. Since the United States has created a medical system that is relatively expensive, and patients are used to spending vast amounts of money on healthcare, there is a substantial and redituable market for healthcare technology innovation. Augmented Reality has been used to show bone structures to doctors, and also to educate medical practitioners and patients. However, Augmented Reality solutions have not been very effective and usually have low adoption rates in the medical industry. Part of the problem might be related to the high number of regulations and bureaucracy in the healthcare industry that prevents, among other things, the easy gathering of data to train artificial intelligence algorithms.

Additionally, perhaps higher focus needs to be placed on the human-computer interaction of those solutions in order to help with adoption. One of the factors that could be slowing down AR adoption might be that existing devices do not do anything substantially useful as of yet, so as to encourage doctors to wear them despite their limitations. They are not yet widely available, and the technology is not developed or polished enough to apply it reliably to a particular use-case. We will see that all of these factors are interconnected and depend on each

other for the development and evolution of consumer interfaces. A technology needs to start by providing a very useful skill or solve an important problem, in order to make up for its initial limitations, and only then, once adopted by a few passionate users (early adopters, in marketing terms), can it be improved and perfected for the mainstream audience (late majority, in marketing terms).

Other authors argue that Augmented Reality should be viewed as a concept rather than a type of technology [33]. By doing so, we can broaden the field to include technologies that would not traditionally be thought of as augmented reality, such as in-car navigation devices, or guided tours of Paris, triggered by the environment. Some argue whether most key features of Augmented Reality are unique to the field or they could be found in other technological systems [33]. Some authors have found issues in the implementation of augmented reality for education, stating it has been mostly used as a flashy but uncomfortable marketing platform [33]. For example, there might be too much information that overloads students, and the technology might be hard to use.

Augmented Reality many times produces a "wow" effect and has great aesthetic impact, and because of that, many companies try to adapt it to multiple fields. However, if the effect and the application are not useful and the interface polished with an emphasis on usability, it becomes a simple aesthetic gimmick. Often times, augmented reality applications provide the same exact content that you could find without augmented reality. For example, a 3D model of the atom can be viewed on a computer screen or it can be viewed through an augmented reality application on a phone or tablet, superimposed on top of a table or real world object. This does not truly provide an enhanced experience that is better than simply looking at the 3D model on a computer screen and navigating with the mouse; what's more, it adds complexity and requires more steps to access the material. In order to make Augmented Reality experiences that are massively adopted, developers need to polish the user interaction to make it easy and fast to access content.

Augmented reality on the news

When Google unveiled its Google Glass device, a wearable small screen on the top-right of their glasses, it stimulated people's imagination. Google Glass "was, and is, a stunning technological accomplishment" [34]. Google glass promises to allow users to read notifications without diverting their attention to a handheld electronic device every few seconds. The implication was that people should be able to pay attention to everyday life (the physical world) without checking their phones for unimportant notifications.

However, when it started shipping, it faced harsh social and cultural reactions. Users who wore these glasses were often being ridiculed, resulting in low adoption rates. How much of this could be due to the high initial retail price of $1500? How much can be based on a poor design for the interface, or an unrealizable promise? And how much can be based on the particular political and cultural circumstances of their initial market?

Probably, part of the issue was that the prototype was very expensive and notorious, purposefully trying to make it into a status symbol, while still not living up to expectations and thus seeming useless for such a high price. A person who paid $1500 for an almost useless device was possibly looked down upon by their peers and was thought of as a try-hard. Also, the aesthetics of the device were not appealing enough to justify wearing it despite not solving any specific important problem for the wearer.

However, according to Forbes writer Ian Altman, Google Glass "didn't fail because of the technology" but rather because "it wasn't clear to the customer what problem it solved or why they needed it" [35]. Despite Google Glass being "cool", Google Glass failed to explain why users needed such a device. "If enough people have had the experience they are seeking, then as a customer, they feel more comfortable making the purchase" [35]. In other words, for Altman, Google Glass failed because it could not communicate the reason for buying it, and the problem it could solve.

Simon Reynolds, also from Forbes, says that "it's not enough to show a product off and engender desire for purchase. You have to have a specific day when the public can get it". Also, he points out that no "mainstream advertising campaign" was used [34]. Google gave some prototypes to celebrities and early adopters but never used advertising. If Google wanted to "sculpt public perception exactly to [its] specifications", it should have used paid media to get its "key points across in the clearest way" [34]. The "core benefits" of a product must be spelt out, and "no more than three key points should be emphasized again and again". Any product that "needs the public to spend time working out for themselves why it's valuable has already lost the battle". After the product was announced, it should have been available in stores. Otherwise, "you lose the buzz and then when the product is finally introduced in stores, the launch energy has been lost".

Besides these factors, Fox News reports that Google also "had to deal with a firestorm of objections about privacy rights", like "surreptitious recording of private conversations" and that some institutions started to ban the product within their facilities [36]. The media also "began to play with the term glasshole, finally mainstreaming it" [36]. There were safety concerns such as "driving with Glass" and health concerns like having "a WiFi signal inches away from your head for hours at a time" [36]. The article also argues that there was too much "hoopla", "hyperbolic write-ups in magazines, sky divers, fashion shows, Glass-wearing royalty" but not much progress "in bringing the product out of beta" [36]. This could explain why people ended up using the term "glasshole" to describe glass-wearers.

Users might have thought that Google Glass was an invasive way to read notifications. Instead of flicking one's wrist like with a smartwatch, or taking out one's phone, notifications would pop-up at random points in time, entering one's field of view and interrupting conversations. Also, even if notifications were only visible by pressing a button or saying something, it seems like that is a lot of effort to go through compared to simply taking out a phone or looking at a watch? The glasses would have to be worn the whole time despite only being useful for a small fraction of the day. Users considering buying it also probably asked for references and got negative reviews for it.

Microsoft, despite Google's initial failure, is currently working on the HoloLens prototype, which will create a wider screen for each eye which users will overlay on top of their field of vision. This way, it will augment the real world with information and virtual objects. The product looks like a big heads-up-display, so it is not yet ready for users to carry it around every day. On-stage demos have been successful and cheered but the impact on soci ety still needs to be seen.

Apple, on the other hand, recently acquired metaio, a well-known augmented reality service provider. Metaio was born from a division of Volkswagen and was developing augmented reality applications for multiple customers, mostly in the marketing sectors [37].

Metaio was developing many Augmented Reality applications for phones and tablets, using these devices as visors. It is possible that

Apple is interested in the computer vision and scene-understanding technology (which would let the software make a tridimensional model of the room the user is in, in order to superimpose virtual objects on it without intersecting existing physical objects in the room). It is reported to be preparing an augmented reality feature for its Apple maps app where the user would point the iPhone to a street and see information overlayed about nearby stores and their menus. An alternative theory is that Apple might be planning to use heads-up displays to run those applications [37].

Sony has also created some Augmented Reality software, for entertainment (their PlayStation console) using a paper book to overlay 3D models on top [38]. The purpose is to create a virtual storybook that is placed on top of the real one and, together with its computer vision gaming platform (PlayStation Move), it will place virtual models and characters on the book [38].

Magic Leap is another company that is working in the field of Augmented Reality, but it is creating a hardware device similar to the Microsoft Hololens [39]. The company has been in stealth mode and currently has only shown a few basic demos [39]. Its biggest promise is that it will use a technology to project images directly onto the user's' retina and thus make images seem more realistic [39]. Some new patents reveal that the 3D content to augment the real world content will be organized in "virtual rooms" and one patent shows an example of a civil engineer using the software to read emails and work [39]. This looks similar to the holographic interfaces shown in Iron Man movies or Avatar.

Magic Leap's vision for the future, according to its patents, is that Augmented Reality software will be used to show additional information on top of a TV set when watching a sports game, or it could be that exercise bikes will show a "virtual Tour de France" [40]. However, on its website, it shows whales and dragons flying on the sky in outdoor settings [40]. This could suggest a technical impediment that prevents current applications in large scale outdoor spaces [40]. We cannot really know what kind of experiences the company is already able to provide, since it is working in stealth mode. What we know is the startup is well-funded and has large ambitions. Another older patent shows the use of "totems", which are physical objects that act as "placeholders" for the virtual augmented 3D models that will be placed on top [40]. For example, they show a plant pot (without a plant inside), and the computer vision software will identify the object and place a virtual plant inside of it, which will work as an analogy to navigate one's emails [40]. Each branch is a person and each leaves a message. One can reorganize leaves and branches and put them in the back of the tree to read them later [40].

Data gathering

Interview: We have interviewed multiple users. We have attempted to reach out to these categories: gamers (computer and console gamers), Iphone users, virtual reality users (who have used oculus rift), VR/AR developers, early adopters in general (geeks, hackers, etc). The method for the interview has been to first craft a simple list of questions, a survey about augmented reality and virtual reality devices, and how the user thinks about them. The first discussions helped improve the questionnaire. Then, those questions have been asked in a similar fashion to all following interviewees. The interviews helped us understand what kind of questions we should measure quantitatively.

Quantitative survey: We have created a quantitative survey, in which users are asked about their perception of augmented reality and virtual reality devices. Questions are based on the qualitative interviews. The responses were varied, and although there were only 23 responses, a small sample size which is not enough to find correlations between different demographic attributes and their perception of AR technologies, it is useful to understand how the different technologies are perceived by a group of Stanford students, a population characterised for its openness to technology innovation (early-adopters). These are the questions and responses:

Questions and answers with analysis: In order to better analyze the issue of social acceptance of augmented reality and virtual reality devices, we decided to compare user opinions on Pokemon Go, Oculus Rift, Google Glass, and MagicLeap or HoloLens. These are the survey questions and their answers, as well as our analysis:

What do you think of augmented reality?

You are invited to participate in a research study on augmented reality and the social, cultural and economic factors for its acceptance by the public. Questions that might be asked include your speculation over how augmented reality and consumer products will work, whether they will be useful and any judgement you hold on them. Other demographic questions might include education, gender, and major. The purpose of the research will be to understand the factors that impact public perception of augmented reality or virtual reality devices. You will be asked to answer questions and expand on your own experiences and thoughts about the products.

Demographic questions

What is your age (years only) - optional: As we can see, most respondents were quite young, and therefore were likely exposed to new technologies. Research has shown that children, teenagers and young adults are the age group most likely to explore and exploit new technological trends (Figure 16).

What is your gender? - We had a diverse group of respondents, although we have still received a higher amount of interest from males. If we had a higher amount of data, we should inspect demographic factors besides those explored here, such as income, and geographic location, and we could perform regressions to find interesting trends (Figure 17).

How tech savvy do you consider yourself? - We can see that a majority of respondents considered themselves to be tech-savvy, since the survey was advertised in the context of the Silicon Valley and Stanford University. This is not a problem, since we are trying to understand the impact of the marketing campaigns and product strategy in the innovator and early-adopter audiences that made up mostly of young and tech-savvy users. Hence, there are more tech savvy respondents/users than any other class of respondents. This is understandable, as the survey was conducted in a top-tier university, so the majority of the respondents are students who are very accustomed to technology (Figure 18).

As we can see in the graph and based on in-person interviews, many users feel comfortable taking selfies in public while traveling, while fewer do it when not on travel. Many have argued that taking selfies in public is considered to be socially justified when there is a purpose (take a vacation picture) and not every day. Consequently, we can infer that this level of social shyness can be a factor when dealing with wearable that lie on one's face: they need to be justified for a specific purpose (Figure 19).

Few of the respondents are gamers or use virtual simulators, which

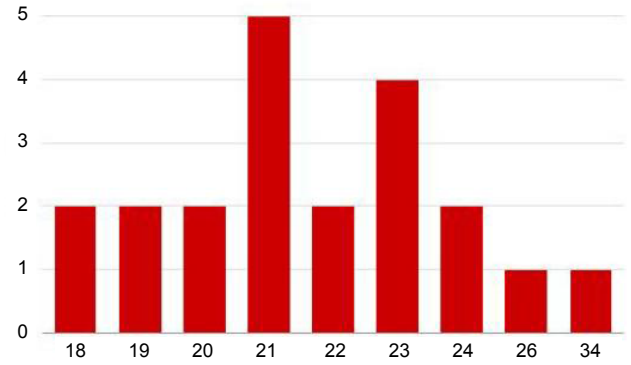

Figure 16: Age distribution.

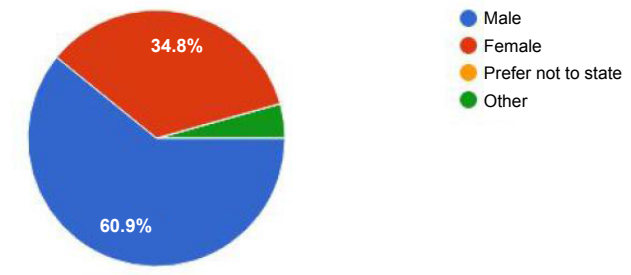

Figure 17: Gender distribution.

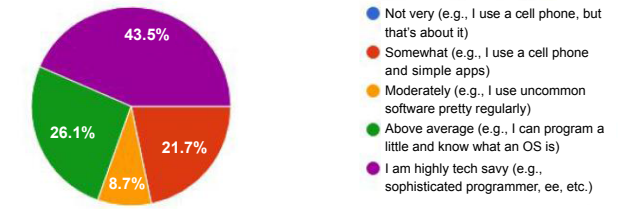

Figure 18: Tech savvy.

mean they are not early adopters for gaming devices such as the Oculus Rift. Despite this, we will see that their perception of the device is positive.

Many of the respondents seem to be casual readers, and casual gamers. Therefore, this is not an audience that would be interested in the latest gaming gear or entertainment devices.

Technology opinions

Please fill in this table for each of the technologies (rows) using the choices given (columns). If you don't know anything about a particular technology, leave the appropriate row blank (Figure 20).

Most respondents are familiar with Pokemon Go, Google Glass, and Oculus Rift. This might have to do with the way the media has continuously talked about the products. Microsoft HoloLens and MagicLeap are less known, as expected, since HoloLens was only recently released to the public and MagicLeap is still behind closed doors.

Pokemon Go seems to be the rave on the internet, as we see celebrities like Justin Bieber and others engaging in the Augmented Reality game. Google Glass and Oculus Rift, whether via advertising or word of mouth, seem to be familiar. As for Hololens, it only recently hit the mainstream and MagicLeap is still in production. This could help explain why HoloLens and MagicLeap are not familiar for many respondents (Figure 21).

From the chart we find that respondents think Pokemon Go, Oculus Rift and Google Glass have clear purposes. In part, it could be because they are the three most popular of the five Augmented Reality Gadgets listed. Most respondents likely know that Pokemon Go is a game, thanks to the mainstreaming media, and Oculus Rift seems to already be synonymous with virtual reality, although it's less known than Pokemon Go. Google Glass had some bad PR, which probably led to a lower clearness in purpose, but at least the familiarity helps (Figure 22).

Pokemon Go as an augmented reality game is considered somewhat useful by the majority of the respondents, probably because it provides entertainment, although a number of respondents consider it not useful. Equal numbers consider it very and slightly useful. Oculus Rift is considered very and extremely useful as a virtual reality headset (likely for entertainment). Google Glass was considered somewhat and slightly useful despite it being well-known. As for Microsoft Hololens, it is considered useful, perhaps based on users' imagination of what augmented reality could entail, and Magic Leap is majorly considered somewhat useful as most probably don't even know what technology is being developed (Figure 23).

Most respondents seem to have no interest in purchasing Pokemon Go, probably because of a prevalent culture of not paying for apps or games, whereas more respondents said they will probably buy an Oculus Rift. Most respondents seem to have no interest in purchasing Google Glass (likely due to the bad publicity it had). As for Microsoft Hololens, most respondents have no interest in it, and the few that do said they will buy it immediately (maybe those few appreciate Holograms and are early adopters). Regarding Magic Leap, most respondents have no interest in it, probably because they don't really know it, and it has had very little advertising (Figure 24).

Most respondents feel that Pokemon Go will not affect local inequality, perhaps because mobile phones are quite democratized in most communities. For Oculus Rift, most respondents feel it will increase local inequality, perhaps because of its exclusive price tag that opens a virtual world only to the rich. A fair few feel it won't affect local inequality and others feel it will decrease local inequality, and it is unclear what could lead them to believe this. Perhaps access to opportunities in the virtual world will be more democratic than in the physical world. As for Google Glass, respondents feel it will slightly increase local inequality. Regarding Microsoft Hololens and MagicLeap, most respondents feel they won't affect local inequality, though a good amount feel that it will increase inequality (Figure 25).

Most respondents have stated that Pokemon Go won't affect Global Inequality. Quite a few think it will decrease inequality. This could be because it gets more people used to technology. For Oculus Rift, most respondents feel it will decrease global inequality, perhaps because it will offer access to better remote collaboration tools, encouraging technology and knowledge transfer to developing nations. This is in contrast with what they reported for local inequality, where the virtual world would likely provide more of a barrier between classes.

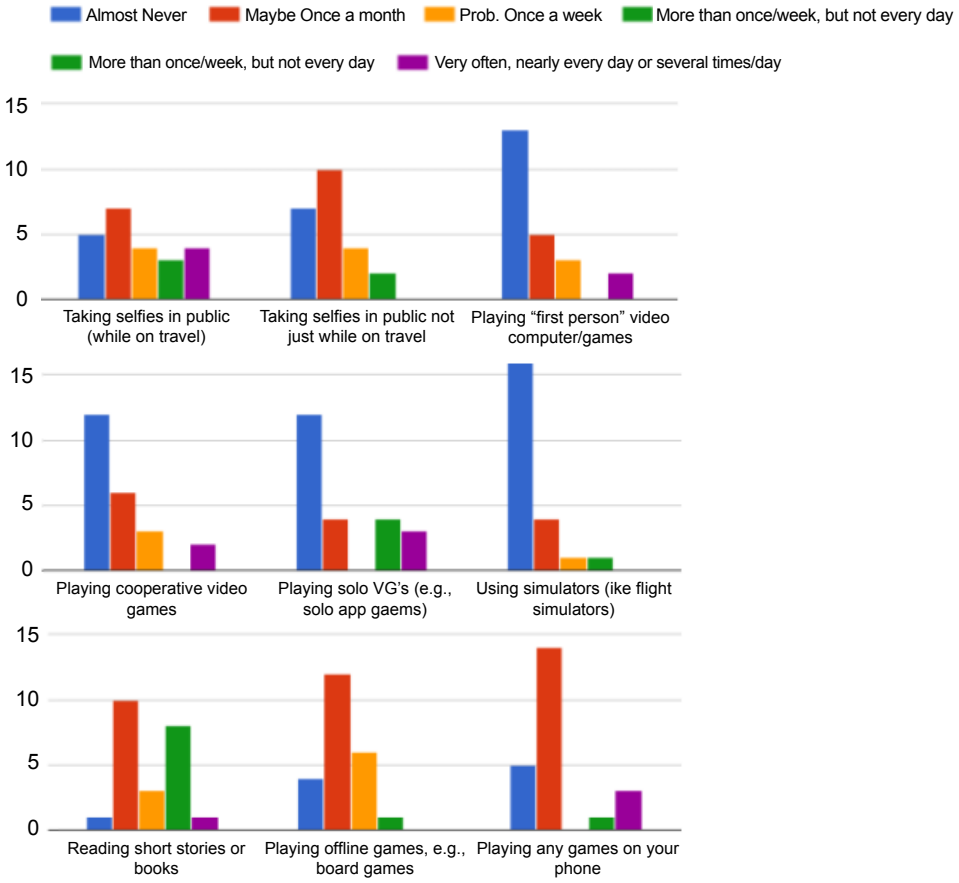

Figure 19: Graphs based on in-person interviews.

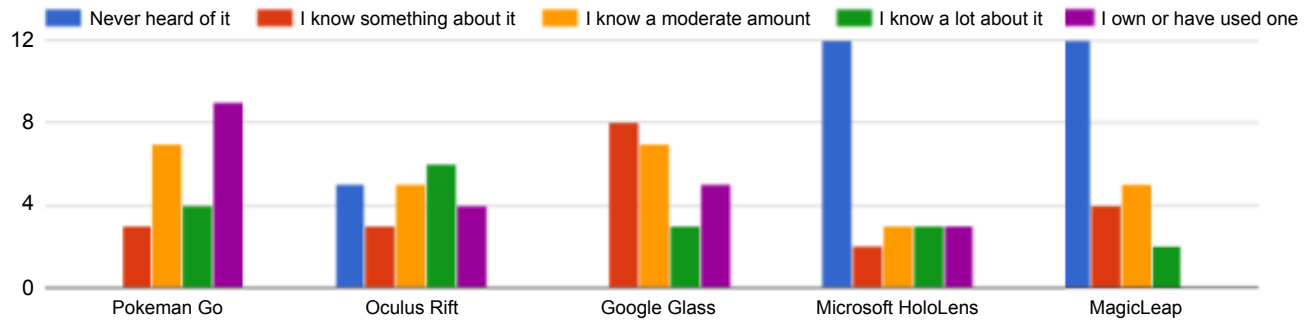

Figure 20: Familiarity survey.

The same goes for Google Glass and Microsoft Hololens. As for MagicLeap, the indifference could be related to the lack of information about the product and the uncertainty it creates (Figure 26).

What do you think others would think of you if they knew you owned or used this device? (If you haven't even heard about one, just don't choose an option for it) - Most respondents think that people will have a neutral appreciation of them if using Pokemon Go. For Oculus Rift, because of its varied uses (Non-Gaming uses like viewing movies), most respondents have slight appreciation for its users and quite a few are neutral. As for Google Glass, most have neutral feelings, with thick tails at the end of the distribution. And as for Microsoft Hololens and MagicLeap, respondents think they will elicit admiration when wearing these devices.

Qualitative Interviews with Faculty

In order to better understand the issues in human-computer interaction, product design, and optics, I reached out to faculty in these areas.

Dr. Terry Winograd: Co-director of the Stanford human computer interaction lab and advisor for Google's original PageRank algorithm used in the search engine [41].

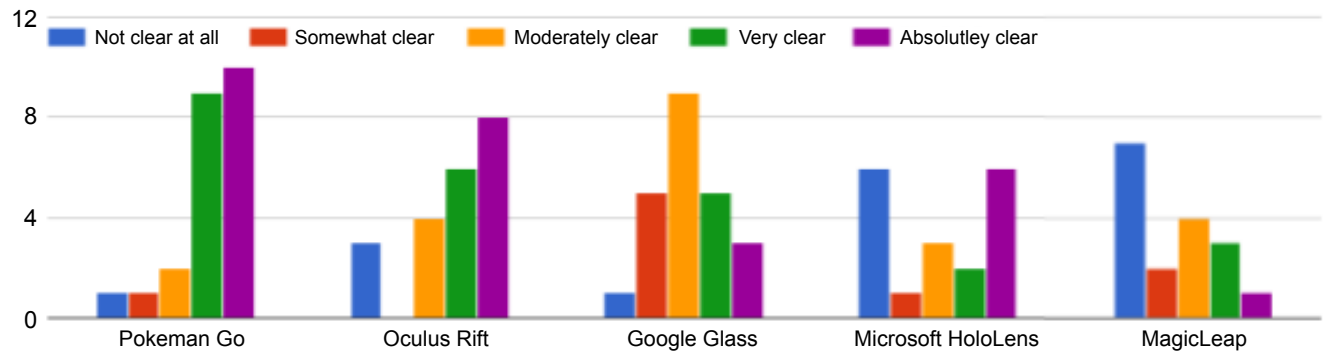

Figure 21: Survey on purpose of device.

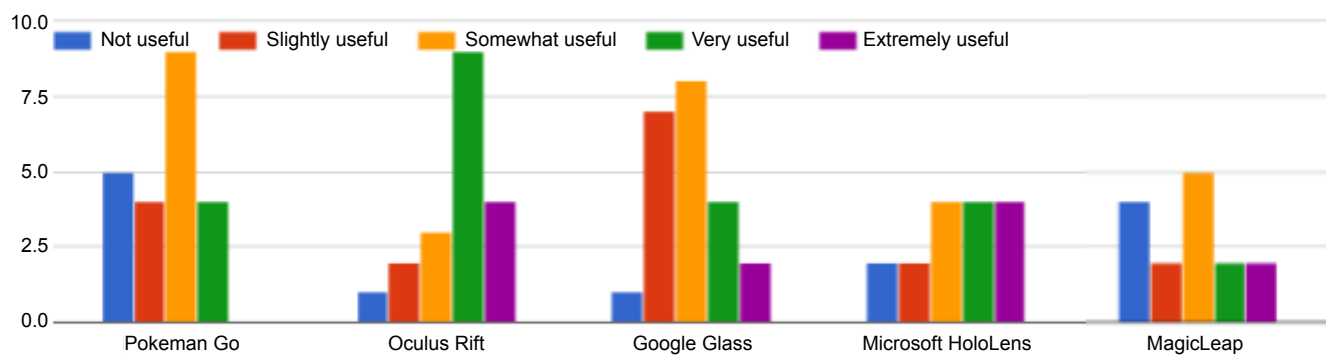

Figure 22: Survey on Usefulness of technology.

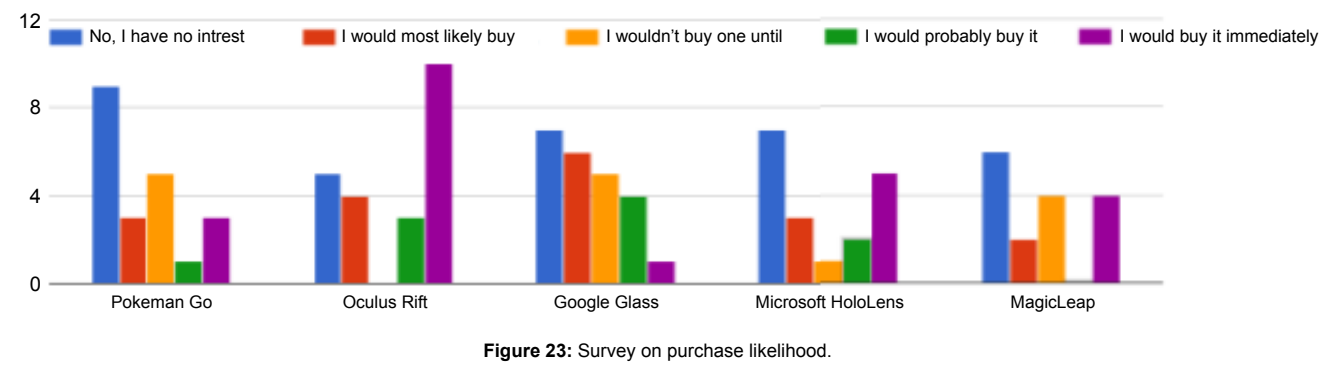

Figure 23: Survey on purchase likelihood.

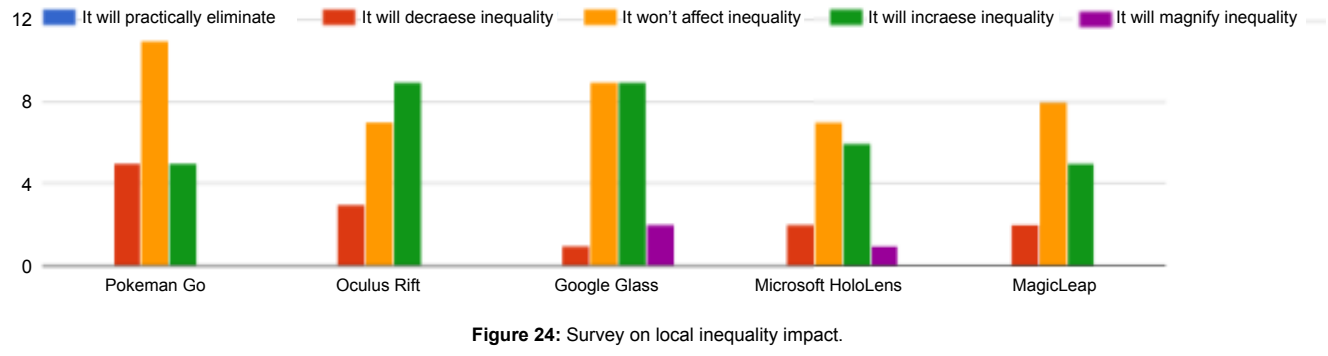

Figure 24: Survey on local inequality impact.

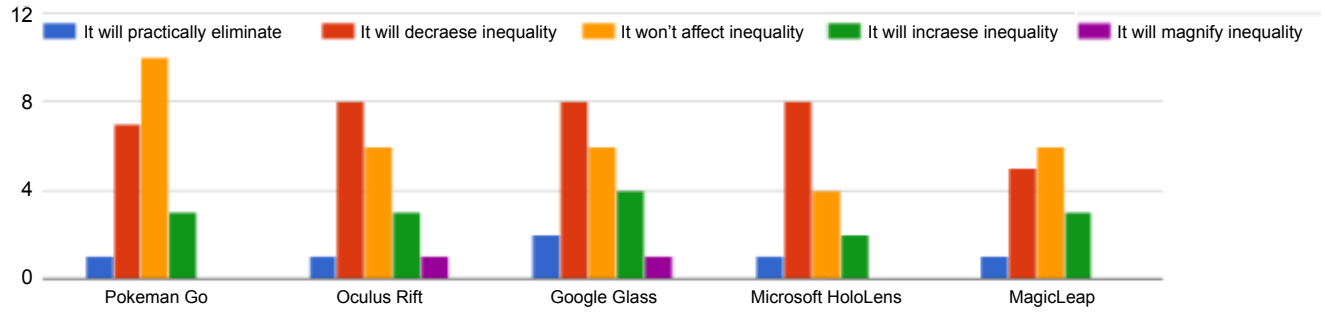

Figure 25: Survey on global inequality impact.

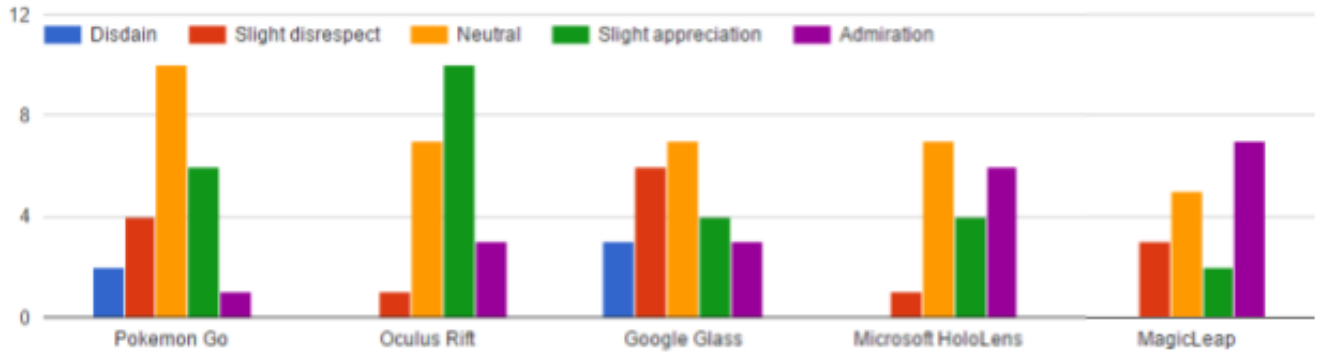

Figure 26: Respondents about using other devices.

The problem with current augmented reality devices, according to Terry Winograd, will be related to latency; that is, the delay between our head movement and the image update on the screen. He says in Virtual Reality, latency is not a huge issue, since the user is only looking at a virtual world. However, when it comes to Augmented Reality, the user must believe that the virtual objects they see are part of the real world. Therefore, if the image in the screen is not exactly adjusted to fit where they are supposed to be in the real world (e.g. a virtual character sitting on a chair), the virtual object will not be convincing and will look fake. In other words, the device needs to solve the "tracking problem", so that when users move their head, they can see the virtual objects moving along with the background (the real world) in perfect alignment with no perceived delay. Any perception of a delay will nullify the illusion that the virtual object is part of the real world [41].

Virtual Reality, he argues, will be used mostly for gaming, while Augmented Reality could perhaps have more work-related applications instead, since it allows the user to free their hands for work while still communicating with a computer [41].

We have asked Winograd whether augmented reality could provide a way to replace real-world objects and whether society could eventually fill empty rooms with only virtual objects [41]. He argued that most of the features of physical objects that are useful to us cannot be replicated with existing augmented reality techniques. For example, besides visual aesthetics, objects also have tactile aesthetics. People often like to feel an object in their hands before they will pay for it. Virtual objects will likely have a hard time replacing physical ones if the user needs to pay for them. People prefer to pay for tangible items.

Other properties of physical objects that are hard to replicate are taste, smell, tactile feedback, etc. Moreover, physical objects that are purchased for aesthetic reasons very often are used as a symbol of status, which is currently tied to scarcity. Their price is determined by their scarcity and the owner is rewarded by showing to others or knowing themselves that they are part of a selective group that can afford the particular object. In the Augmented Reality world, where scarcity of virtual objects has to be completely artificial, selling aesthetic items is not much more useful than using physical items, since the cost of producing them in mass is not an important factor.

When asked about the impact of Google Glass on public perception, he said the main problem with the device was related to privacy concerns. Someone wearing a Glass device gives the impression that they could be easily recording people in their field of view, and their device could be showing them information about those people. This might feel analogous to a person secretly Googling their interlocutor without them noticing. The other person might think wearing a heads-up display like Google Glass is similar to constantly holding a phone and tapping on it without showing what one is doing.

He mentioned a couple possible initial use-cases for Augmented Reality devices, such as existing systems of blinking lights for cars that indicate there are other cars hidden in the blind spots. Other examples included exercise machines that provide the user with a gamified experience by showing a virtual cycling game on the screen of a cycling machine.

Other applications for Augmented Reality headsets such as text-editing software will likely not be easily adopted in the short term, because we have "spent decades optimizing word processors for the big screen", it is optimized for computer monitors.

Other more specific applications might be better suited for the

Augmented Reality space, such as domain-specific video editing, where a user could browse among multiple "action shots", and with heavy use of artificial intelligence helpers, the user could use an intuitive interface to construct videos quickly. The immersive AR environment could make the process more engaging or even provide multiple virtual screens and present better interfaces.

Artificial Intelligence, he states, "will likely play an important role in allowing for more intuitive interfaces in the Augmented Reality world". He mentioned that at some point he was attempting to take a picture with his phone of multiple kids but he "couldn't get them all to look at the camera at the same time" to capture the perfect shot. Thus, he took multiple pictures, one after the other, from the same position. He quickly received an email from Google with an animation, automatically generated with artificial intelligence algorithms, grouping the various pictures he took into a short looped video (gif animation) [41].

Currently, he argues, there are two different types of video editing. One is in-camera or in-phone editing, which is supposed to be quick, easy, and not very precise. It is meant for the consumer market to create videos easily. The other type is professional screen editing, in which professional or amateur filmographers edit videos, add special effects, carefully craft sequences and compositions, and this often happens on a workstation, using traditional computer screens and interfaces. He argues that the latter type is already very developed and it might not be the best place to start working on in Augmented Reality, but the former, in-phone editing, might benefit from the added capabilities of AR devices [41].

Another possible first use-case for Augmented Reality might be an application that helps in partially replicating the experience of "brick and mortar stores", in which customers can easily see products from different angles and understand their size in context of the real world [41]. Of course, Augmented Reality technology as it is now will not be able to completely replicate the experience of trying clothes on or feeling the weight and the texture of products, but it will bring the world of brick and mortar stores closer to the virtual world and the cloud. Users should be more comfortable buying products online if they can see their 3D models in AR, placed in their room, for example.

When asked about the history of computers, their spreading, and mainstream adoption, he also said that computers were initially very good for text, but not good at keeping in touch with friends. However, as technology developed, after decades, social networks were created, in the software realm, and finally they became good at it. This software was based on browsers as well.

In AR, he says, "if it's not functional, it feels frivolous". The iPhone, for example, was aesthetic but also functional, and that is the reason for its adoption [41].

PhD. Jeff Shrager-Consulting professor in the symbolic systems department at Stanford

Shrager argued that street signs can already be considered Augmented Reality. He said AR can interfere with the normal functioning of people. It might call their attention and lead to accidents.

He suggests making AR glasses "lightweight in the beginning and then transitioning to a full heads-up display" [42]. This would avoid the problem of AR being too intrusive. Once the device becomes polished and its software becomes more applicable to everyday problems, it will be more useful to have a prevalent heads-up display. Before that, when first adopting Augmented Reality, users will not want to have information displayed to them constantly, because they will only use the technology for specific purposes, and thus will not want a full heads-up display.

He also mentioned that Virtual Reality will affect industries. People who work in the tourist industry could use the platform to create virtual tours of many places in the world. This, however, would centralize work in the best tour guides for every area, and cause problems for wealth distribution. To this, he noted, "human ethics make systems inefficient" [42].

These tourist guide jobs could be localized, and adding personalized customization to the tour could be the key to creating jobs for more than a few guides. Another potential job that could be decentralized is that of tutoring or personalized teaching. With better VR or AR communication technology, tutors in any other part of the world will be able to perceive body language and gestures, as well as any other response and feedback that the learner may show, and thus adapt their teaching methods based on those [42]. This could improve the economics of distance-learning by closing the geographic gap between teacher and learner markets, as well as making it cheaper to live in any part of the world while accessing a teacher or a student in a more expensive area.

In order to replace human tutors, Shrager argues, we would need a great artificial intelligence, that excels at "personal interaction". An effective teacher needs to be "very responsive to the human attention and mental model". He argues that being a one-on-one tutor feels like being "inside their head". Computers are not very good at following the Gricean maxims and adapting them on a case-by-case basis [42].

Another possible use for AR or VR can be distance medicine, where patients in third world countries could have access to more experienced doctors in first world nations, or patients in the first-world could have access to more affordable doctors in the third world for easier treatments. By using AR, doctors could see the patient as if they were next to them, making for easier communication [42].

When asked about whether AR or VR might radically change the way politics or the economy works, Shrager said that "politics and economics morph to adapt after the initial disruption", and therefore, they will likely stabilize and return to their normal way of functioning despite technological improvements. He concluded that the first Augmented Reality devices should focus on a "specific purpose" [42].

Historical models

There are three other technologies that have developed in the past and we can analyze: the personal computer, the web browser, and mobile phones. Based on their evolution history, we will craft a model for how consumer interfaces evolve over time, and how that evolution relates to their adoption. These interfaces rely on technological advancements and consumer adoption.

Initially, after mainframe computers were invented, the first consumer-oriented computers were personal computers. Personal computers are the first technology we will analyze following the consumer technology model. Next, the internet was popularized, and f0069nally, mobile phones became popular. Augmented reality devices might become the next technology wave and might start to replace mobile phones. AR could replace or transform web browsers with its own version of the web, adapted to AR, and it could eventually replace desktop computers too.

These three interfaces have evolved over time. They started with niche markets, barely improving on existing technologies that people were accustomed to at the time. These products appealed only to a small segment of the population at first. After they were adopted by a specific niche market, money was channelled into research and development, growing the budget for optimization of technology, innovation, and for manufacturers and designers to improve the interface design. With better, more polished technology, these devices could then evolve to become more advanced, appealing to a more mainstream market. This cycle would continue indeterminately until the market stabilized and innovation stagnated due to decreased marginal returns from new features, and increased competition from cheaper manufacturers and generic copies of the devices.

Personal computers: In the case of the personal computer, the consumer version was derived from corporate mainframe computers and from game consoles such as the Atari. For example, Steve Wozniak and Steve Jobs worked together on the electronic design of some Atari consoles, and they both worked at Hewlett Packard [43]. Wozniak was working in the mainframe division of that company. He found a way to adapt knowledge from mainframe computers and game consoles to create his own version: a personal computer, as a personal project [43].

Wozniak's project was a computer that would be smaller and cheaper than the existing mainframes. He did not initially create a device for the mainstream consumer, as that would have been likely too early for this young technology it to be adopted by the regular citizen for any use-case.

His device, the Apple I, was initially used by early adopters who would program in a language called "BASIC" and use the platform to play simple video games. These early adopters would also adapt the hardware to their own personal projects and mostly use it as an early development platform.

Its biggest innovations and deviations from existing products were its ability to connect to a television screen and to an external keyboard, making it cheaper and more versatile [44]. Other computers at the time, called "calculators", would use built-in "notoriously slow displays (60 characters a seconds)" and built-in keyboards as well [44].

The next step in the personal computer evolution process was the Apple II, which included a "color display, sound, and greater expandability". Steve Wozniak built the machine to be able to play a videogame called "Breakout", but all the "features that made the Apple II a good Breakout platform" also directed technology in a path to become a "good personal computer" [44].

As we can see in this case, the initial market was a niche, composed primarily of early programmers, electronic engineers and hackers, and after those people purchased enough units, and Apple Computers thus received investment, the technology was able to be further developed, resulting in a product that was now more appealing to a broader set of consumers. Wozniak worked to eliminate every "superfluous chip", reducing the amount of circuits so that the "resulting machine was inexpensive enough that most users could afford it" [44].

Even then, the main purpose for buying an Apple II was to use it for finance spreadsheets and document writing [43]. Then, it became more widespread since there were already-existing needs for computers in businesses. Only after users adopted the technology for these specific purposes did they start to use it for computer graphics, design, and other more personal use-cases [43]. In a similar way, any VR or AR product needs to find a need in a core user group that is able to use it despite its limitations, and only then expand to a mainstream audience.

Internet browsers: The history of the internet started with a DARPA (Defense Advanced Research Projects Agency) funding the ARPANET project, and was used in the military as a decentralized communication network. After it proved useful and the technology seemed to have potential, it was adopted by private businesses.

Mosaic, one of the first browsers, "had been designed with relatively high-speed university connections in mind, since browsers were almost exclusively found and used in an academic setting" [45]. People could use it despite its limitations, for research purposes. The browser was initially meant to be a research tool, only being able to show text and images, and it was Netscape that turned it into a tool "aimed squarely at ordinary users with PCs and a dial-up Internet connection" [45].

Netscape distributed their browser for free and expected to make money from charging private businesses for support, but most importantly, from selling a web server technology. Because the browser was available for free, it was easy for it to become viral. Then, as other browsers gained more popularity in the corporate environment, Ben Horowitz, CFO of Netscape at the time, explains that the company had to adapt its business model [46]. It decided to release the source code for the browser as open-source, so that corporations would accept using it. Then, the browser became more and more prevalent, with many users doing most of their work on the browser instead of native software.

As we can see, the history of the browser, although purely a software product, has been similar to that of any other technology: they need to be used by a few people (academics, researchers, and the military, in this case) who find it so useful that they are willing to overlook its flaws and limitations (basic text pages and later basic images were working, but one could not pay online, watch videos or run computationally heavy software like word processing on the browser). It was only after these technologies matured that they could be adopted by a mainstream audience.

Smart phones: Smart phones started with the Apple Newton, which was a failure [43]. The reason for its failure was that Jobs tried to create a device that promised too much, too many features, before the market was ready for it, suffered from its high price and problems with the handwriting recognition element [47].

The Palm Pilot was used for a short period, but its reliance on Bluetooth and then Wi-Fi prevented it from being much more useful than simple paper notebooks.

Early mobile phones were useful as basic voice communication devices. Then, they gained the ability to send and receive text messages. There were big "brick" white phones that businessmen would carry around in order to do business while traveling.

Other technologies like the digital camera and music players were also starting to gain traction, and mature. Only once they were mature did phone manufacturers start incorporating them into what they called "feature phones". At that point, they started to become more popular. With the introduction of Java apps and games, and basic internet connectivity, phones became mainstream.

But it was internet connectivity that most heavily transformed mobile devices into the widespread device that it is today. Another company created the "Blackberry" mobile phone, which became popular among business managers because it allowed them to continue working, reading and sending emails away from the office.

Finally, when Blackberries were popular, and other brands such as Sony-Ericsson had created phones that could be used as music players, Apple released the iPhone. Apple had been leading the market for mobile music players with the iPod, but realized that mobile phones were going to replace the iPod as music devices, so it decided to create its own phone. The only improvements on top of the Blackberry and the Sony-Ericsson phones were the improved touch-screen (other phones had no capacitive touch screens yet, meaning one could not use their fingers on the screen), and the improved web browser rendering abilities, which allowed for a web experience more similar to that of a laptop or desktop computer. Other phones at the time would only be able to show text and images, with only basic rendering of backgrounds, fonts and they could not reproduce the look of websites as visualized on personal computers.

As we can see, attempts to introduce mobile devices to a wide audience failed until both the market and the technology were ready for that device to become a feasible product. When the iPhone was introduced, it was a better market fit than when the Newton was introduced. There were specific use-cases for mobile phones already in place, such as communication via texting, voice, and email, web browsing, and music reproduction, and these were only improved by the innovative interface design of the iPhone.

Again, with phones, all technologies had to mature first (digital cameras, music players, mobile browsers, mobile internet connectivity, and capacitive touch-screens), before the iPhone could be introduced as a revolutionary device, connecting them all in a usable manner.

Social analysis

What happened with Google Glass?

Google Glass was one of the earliest, most ambitious commercial augmented reality interfaces that has been launched. However, the project never reached the heights it set out to, and eventually, Google decided it was time to send Glass back to the drawing board. There has been talk of Google revamping the technology and launching a new version, but with Google's recent massive investment in Magic Leap, it's hard to tell where Glass will go from here.

The interface, which looks like a pair of standard eyeglasses from a distance, is no longer in production. Google launched a beta of the technology in 2013 -- a limited release -- which helped identify many unforeseen issues that Google Glass both had with itself and that it created with the outside world. Many privacy concerns arose over the recording of video and taking of photos on Glass; the concern being that the subjects of Glass's recordings would likely be unaware they were being filmed.

Moreover, the hardware of Google Glass was found to be far too easy to manipulate. Users of the beta test were able create alternative operating systems, and create applications that would create even further privacy concerns, including a facial recognition app, and "Winky", an app that snapped a photo on Glass every time the user winks their eye. Additionally, a security researcher found that the entire system could be taken over by a hacker, by getting the user to scan a malicious QR code with the camera [48]. On top of these security concerns, there are those who have concerns about public safety with Glass. Lawmakers in many places have deemed the technology a hazard to drive while operating, and have made the practice of doing so illegal. A San Diego woman was ticketed for the offense in 2013, but the case was eventually thrown out, because the officer could not prove the device was turned on at the time the ticket was issued [49].

Although Google Glass failed to break through in a commercial sense, it was undoubtedly a groundbreaking exercise in what commercial AR should and should not be. Fittingly calling its beta testers, "explorers", Glass found many faults in the concept of wearable computers that will surely be avoided in future AR ventures.

Glass holes and the economic divide

Some people believe that Google Glass was experienced bad reception because of inherent technophobia in a society that associates technology and innovation with growing inequality. Google Glass was announced and distributed mostly to Google I/O developers in San Francisco. That is, the device was sold to developers, primarily in the Bay Area, who attended a Google conference. And it was sold for the exorbitant price of $1500. It was also then given to some TV stars and early adopters who applied to be able to buy it. There was a huge air of exclusivity, which was arguably part of the intended campaign, but combined with a high price, huge expectations and promises, and poor actual performance, it was destined to fail.

When users look at someone wearing Google Glass, they project all their anxieties created by these ideas of technological dystopias onto the wearer. San Francisco and the Bay Area in general, in the last years has seen sky-rocketing housing prices, and most citizens are blaming the price rise on Silicon Valley, and specifically, Google. Google employee commuter buses from San Francisco to Mountain View have been attacked and vandalized by local citizens in the city, and fliers have been spotted around the mission district encouraging vandalism against new tech workers and their fancy cars. This problem is also tied to the increasing gentrification in San Francisco.

The whole country is going through a phase of economic stagnation and even decline for the middle and low classes, while experiencing higher perceived wealth inequality. The 2008 housing crisis left many people riled up against financial firms and some are turning to blame Silicon Valley too, simply because of the wealth disparity.

Google's advertising, marketing and PR team were out of touch with the reality of most Americans in the Bay Area, who lean towards liberal ideologies, now focused on inequality. Part of the fear of Google Glass had to do with privacy issues. The device has a camera pointing forward, allowing it to record the wearer's field of view at every moment. Phones have a light indicator while filming. Also, it is easy to make sure that someone is not filming you, as long as they are not holding the phone pointing the camera in your direction. However, with Google Glass, the device rests pointing at your face, able to film every moment you spend with someone.

Techno-optimism *vs.* techno-phobia

Most online articles dealing with announced augmented reality technology that has not come out yet, adopt the role of "techno-optimists", who think augmented reality will encourage positive social values such as helping the environment and society. However, even though they mention that some people are more skeptical about the technology, they often do not expand on those problems.

For some users, the idea of living in the real and the virtual world at the same time is scary. A person wearing Google Glass could be sitting next to you and still have access to a completely different experience, without bringing you with them. It is this idea of "choosing to be separate from you, while being next to you" [50]. The increasing anxiety about the real world and the inequality and exclusivity that technology can create culminate into a device that secretly provides information

and experiences only to a selective few who can afford the price of $1500. Users are "projecting fears and anxieties about technology onto someone wearing Google glass" [50].

HoloLens and MagicLeap, on the other hand, are having better acceptance than Google Glass. Glass was possibly asking for too much from users - too big of a leap from existing technologies into something completely new, unpolished, that provides marginal improvements to user experiences. Oculus Rift, being solely a virtual reality device for the gaming market, is likely a more manageable step at this point in time. The internet is governed by a couple institutions in a decentralized manner. However, domain names remain centralized under control by the United States.

When thinking of a world with Augmented Reality, we have to care about its regulation and government. If the system is centralized in a single state or entity, it can be abused. One example of a dangerous online system is that of Bitcoin. The system might allow for anarcho-capitalism to take over, above other government systems such as nations.

Wealth inequality can become a problem when it creates power inequality. For example, as more areas of our life become commoditized, wealth more closely reflects power and advantages. When a person is looking for someone to marry, recent studies show their wealth has a strong impact on their chances to find another wealthy individual.

Some parts of our world are not commoditized. Public goods such as streets, sidewalks, squares, parks, and public infrastructure often do not charge a fee for citizens to enter. However, many de-commoditized spaces require a minimum in wealth or a special permit to enter that community. For example, living in the United States requires a visa, and living in Palo Alto or attending public school in Palo Alto requires a house or residence there.

Augmented reality will be at the center of our day-to-day experiences. While looking at a water fountain, for example, augmented reality lenses can show a "hologram" instead of the fountain. Multiple people could look at the same fountain and see the same hologram instead. This will allow for a lot of luxurious architecture and furniture to be replaced by their virtual counterparts. That can result in a return to the old form-follows-function design philosophies for the physical world, while creating other designs in the virtual world. However, if different users installed different software or used different incompatible devices, they could look at that fountain and see different virtual objects. People without access to the technology will be excluded and, by looking at the fountain will see nothing else. Therefore, users without access to the device might live in a completely different world, while still geographically in the same place.

Potential social problems of augmented reality

Another interesting phenomenon is that, as seen in current social media, there is an inherent confirmation bias in the artificial intelligence algorithms used to recommend news feeds. For example, on Facebook, after one click on a specific news article, Facebook will remember the choice and show similar articles in the future. This has created ideological bubbles where users keep confirming their existing views and see no opposing articles because Facebook knows they would not click on them. This trend is exacerbated with the incorporation of big data and machine learning techniques.

In this way, when augmented reality becomes prevalent and shows information on top of the real world, users will be exposed to this confirmation bias for longer periods of time. Imagine seeing floating text information on top of a cup of coffee linking to an article that suggests that coffee might cause cancer. After reading the article, the software would keep linking you to more research on the topic that confirms that thesis, every time you are about to drink coffee.

You meet your friend at Starbucks and they tell you that coffee actually can *cure* cancer and improve your health. Your friend says every time they look at a cup of coffee, the software reminds them that it's beneficial for their health and can reduce or cure cancer. You and your friend have an argument. In the following days, you keep seeing people, half who claim coffee causes cancer and half who claim it cures cancer. You realize the problem but you are not willing to take off your augmented reality goggles because you have grown dependent on them to find transportation, remind you of your schedules communicate with other people and even buy goods and services!

After a few years, the world is divided, and political movements try to censor the sale of coffee, while other movements attempt to make coffee consumption mandatory on a daily basis. Could this eventually lead to war, especially if it affects more than just coffee? How could the government or other democratically-run or socially-motivated organizations intervene in the system?

Augmented Reality as reported by the media

Generally, the media perceives augmented reality as an unknown entity that is destined to become the next big thing. Many are very excited by the prospect of AR, but seek to know more about it. There is a lot of buzz about the new technology, and much speculation about how it may or may not reshape society as we know it. The reception is mixed. Some view the implementation of more and more augmented reality as something that may lead to isolation [51], while others believe that augmented reality will only simplify and enhance the way we interact with computers [52].

An article written in the Guardian claims those advertisers are most excited about AR of anyone in media, because of its potential for more targeted, direct ad space [53]. This is a logical leap to take, given the way the internet has already transformed the way advertising works, and it does seem to be a consensus within the media that there is a lot of money to be made off the new technology. Brent Molina at USA Today implies that the success of the AR title Pokemon GO marks a paradigm shift in video gaming. He conducted an interview with Brian Blau, a technology and business analyst, who said of the Pokemon GO phenomenon, "Video games have mainly been played on a flat screen. That's changed today" [54].

Whether they fear the changes that it will bring, embrace them, or they're somewhere in the middle, one thing is uniform in the media's perception of AR: they are anxious to see where it will go from here. The media as a whole, for one reason or another, has a vested interest in the fate of augmented reality, more so than the general public.

Augmented reality as perceived by the public

Augmented Reality, a view of the physical world that has been altered by computer generated images, is a fast-evolving technological wave that is quickly becoming a part of daily life in our society. As early as 1967, we as a species have attempted to supplement the world around us with tech-simulated experiences [55]. Now, first down lines move with a football game on TV in real time and you can catch Pokemon in your own backyard. But what is the general public's reaction to these innovations?

Although Augmented Reality technologies have the potential to revolutionize the way we teach, think and experience the world we live in, a lot of the application and reaction are concerned with media and entertainment and why wouldn't they be?

Most of the successful ventures in Augmented Reality thus far have been for marketing ploys, a special code or object recognition software that makes a movie poster or part of a product come to life in any number of ways. Who wouldn't want a tiny symphony to pop up on their carton of Haagen-Dazs? Unfortunately, because so much AR technology has been used for "silly" marketing gimmicks, many average people don't perceive it as anything other than just entertainment [56].

However, with many other applications of AR technology being developed every day, that perception is likely to change. General Motors is currently in the process of creating an AR windshield overlay, which if developed properly could allow the driver of the car to better navigate in poor driving conditions. The technology would be able to recognize rain, fog, and other external factors that could make driving difficult, while clearly outlining the road and alerting the driver of upcoming street signs, stoplights, etc. Hopefully in the coming years, the general public will begin to understand and appreciate the many practical uses of this amazing innovation and AR technology will fall in seamlessly with day to day life in all the incredible ways that it has the potential to do.

The Pokemon go phenomenon

Why did it work better than other previous AR apps like Layar or others?

The popularity of Pokémon Go has lead millions to the streets, while others struggle to understand its allure. An immediate global phenomenon; it took only six days to attract more than one hundred million users [57]. Skeptics of augmented reality apps have dismissed the fad as a waste of time and money. Savvy marketers, however, see an opportunity to promote their brands and bring foot traffic into their stores.

Niantic, co-owned by Nintendo and spun-off from Google in 2015, successfully integrated AR in the Pokémon Go game without requiring the user to purchase a virtual reality headset. This allowed the company to tap into an already established smartphone customer base. This is an important milestone, as having to purchase special hardware may be a deterrent to mainstream adoption. While some are annoyed by the swarms of people who chase these mythical creatures, others see a marketing opportunity.

One needs only to look around their community to see how successful Pokémon Go is as a game. Niantic has done more than launch a game, however. They have parlayed the game's popularity into a marketing strategy that grossed the company more than $200 million in its first month after release [58]. While the game is free, players have the option to make in-app purchases that enhance their gaming experience. Even more revenue is generated by selling lures to retailers and restaurateurs, which attract the collectible virtual creatures, thereby creating more foot traffic than traditional advertising ever could.

The Pokéconomy, as the market created with Pokécoins is often called, has the potential to go skyrocket, as retailers compete for lures drawing rare Pokémon and request Pokéstops and Pokégyms be set in their close proximity [59]. The price they are willing to play will only rise as the game integrates more immersive capabilities. Business owners are content, at this time, to pay for Lure Modules in small quantities. However, many expect that the value of virtual real-estate will only grow, making the Pokéconomy a tangible reality.

Technology and the potential for dystopia

The idea of a "dystopia", or an imagined place or state in which everything is unpleasant or bad, typically a totalitarian or environmentally degrading, is a popular theme for science fiction writers as well as futurists and technological theorists [60]. As the advances in the field of technology have exploded in the past several years, so has the potential for technology to actually surpass its creators.

To put it in perspective, DeepMind's AI technology, AlphaGo, was able to beat the world champion in five games of Go, an ancient and extremely complex game common in eastern countries such as Korea [61]. While computers have been programmed to beat humans at games ranging from chess to poker almost as long as there have been computers, this technology stands out for a very big reason: It actually taught itself to play the game. Deep Mind themselves had to admit to the brilliance of the revolution, the technology wasn't projected to reach that point of self-learning for at least another decade. There are almost infinite possibilities for a self-programming computer system, but not all of them are good. What happens when a computer can train itself to beat humans? That computer's potential for productivity will begin to surpass our ability as humans to do our jobs. Also, the computers doesn't need to be paid, as they don't have material needs or desires. What happens to the job market?

Economists are beginning to warn of a potential oncoming wave of unemployment. As companies perfect more ways for machines to ramp up productivity and drag down cost, the efficiency increase is going to be impossible to ignore. Much like the mass redundancies in the 1990's at the invention of power looms and spinning frames in the textile factories, many hard-working people will soon be finding themselves jobless [62]. Serious forecasts of fifty to seventy percent unemployment are looming on the horizon, and the fear is that, unlike prior technology related redundancies, the job market might not evolve with it. Computers will have the ability to train themselves for any job we may need. So where does that leave us?

In all likelihood, as a society, we will be just fine. Working, too. Possibly the most incredible thing about us as human beings are our adaptability. While the world may shift and change around our robotic employee counterparts, it's assured that mass unemployment is, at least for now, an unrealistic fear [63].

We have discussed the potential impact of self-learning artificial intelligence and mechanization could have one the world economically. However, there are many other ways that technology could cause distress and eventual downfall in our society. What about the potential to alter the human race as we currently know it? [62]

Thanks to the advances that have been made in the medical field, humans have a greater understanding of the body and our genome than we've ever had before. In fact, many scientists are calling for a public debate of the creation of "designer babies", offspring specifically created to carry certain genes of the parents choosing, now that DNA editing has been perfected as early as conception in mice [64]. While it is still only a prospective venture with humans, science is quickly catching up to make certain parts of this unnatural procreation process possible. These technologies present a complicated ethical question: can we use it to remove "faulty genes" to prevent children from living a life with diseases like cystic fibrosis or cancer, or is the temptation

to change up genetic codes to create more desirable traits in a healthy offspring too great?

The biggest problem facing the genetic altering community today, other than the ethical debates, is that we're nowhere near ready to move onto humans. While we have mapped most of the human genome, the key word there is still most. For example, the sickle-cell anemia issue. The genetic "mutation" that causes the anemia is actually the duplication of the sickle cell gene. So why not just eliminate the sickle cell gene? Thankfully, we never did because, as it happens, the original single copy of the sickle cell gene actually helps prevent against malaria [65]. This example serves to prove that before any kind of "master race" can evolve due to genetic engineering, we have a lot to accomplish in figuring out exactly what we can and can't do to change the human body.

While this topic is sure to spark many debates in the coming years, the likelihood that genes will become available for purchase and babies will be designed that way is very low in the near future. Hopefully, the technology will be reined in to its practical uses in eliminating disease and improving human life a relatively natural amount.

In Augmented Reality, however, other problems such as creating a class divide between those living in the "augmented" world and those living in the real world (left behind), can be cause to serious concerns in the population, as exhibited by the concept of the "Glasshole".

HCI analysis

Product comparison: What most HCI faculty have suggested is that Google Glass didn't really solve an important problem as it was launched. It would only marginally improve our lives by showing notifications and being slightly useful in our every-day lives, but the cost of adopting the technology was too high for that small marginal improvement. New or immature technologies often have a high cost for adoption, because of being an uncomfortable or not completely aesthetically appealing, like Google Glass. Therefore, users are often only willing to adopt the device if it makes a significant impact on their lives that compensates for its flaws (looking unfashionable or feeling uncomfortable).

For example, if the device was first targeted to consumers with special needs such as handicapped people, or workers in specific industries who have their hands occupied and thus cannot use them, then these users would be willing to tolerate imperfections in the technology and the product itself. Once users start adopting the product despite its imperfections, researchers and manufacturers will improve it and it will slowly become mainstream.

Google Glass, for example, was targeted and marketed for the masses, directly as a consumer device, while very innovative and revolutionary products are often targeted to very niche markets, like the Oculus Rift, as we can see with personal computers, which were first adopted in offices, mobile phones, first big and uncomfortable, and used by people who needed constant communication, and the internet, first used by the military, then researchers, then businesses, and only then, finally, the regular person.

Pokemon Go is likely an exception because it uses very small elements of AR, it requires no new unproven hardware (it runs on a phone), and it is tied to an important franchise like Pokemon. Microsoft HoloLens has not caused a big surprise after offering development kits, since it was already in the news far before this release. This gradual opening to the media allowed them to be careful about how they would portray the product to the media. Finally, they have decided to focus on the corporate market, selling HoloLenses that can assist workers. This likely ties into the age-old tradition of Microsoft doing most of its business in corporate environments.

MagicLeap has been providing much closed controlled betas for the press, which suggests that the journalists who covered their products might have been biased. We have yet to see how their strategy affects adoption once they release a product to the public.

Magic Leap's technology

The decrease in price of smartphones, and smartphone technology, has created opportunities for mass production of Augmented Reality (AR) systems. AR takes virtual images and overlays them on a display of the real world shown through the devices camera on a display. Magic Leap is a company that seeks to take this technology from your phone and utilize it in a lightweight headset, perhaps someday replacing the smartphone [66].

Up until now, much of the hype surrounding AR has circled around gaming and entertainment. At a recent conference in China, however, Magic Leap CMO Brian Wallace released video showing a woman using their product in an innovative way.

Using the Magic Leap headset and voice commands, the shopper was able to measure the space for a sofa and then review a list of products that would fit. She then "tried out" a few options in the space to get a realistic picture of how it would look before purchasing one. Buyers say that having the ability to interact with the product before purchase may take virtual shopping to new levels.

Magic Leap is not alone in its quest. It seems tech companies everywhere are scrambling to release their own AR devices. Co-founder and CEO Rony Abovitz claims that Magic Leap's technology will differ from its competitors in a big way [67]. While other companies have developed head-mounted displays for users to view the augmented reality, Magic Leap's technology, dubbed "light-field" tech, is shaking things up with an experience that makes your brain the display.

The technology at Magic Leap mimics the human brain's ability to judge distances, even manipulating the focus reflex of the user's eyes [68]. The result is a realistic looking object that users don't just see, they feel. While the company has yet to release a prototype, Magic Leap insists that its product will take AR to the next level, making it more of an activity than a viewing experience [69-75].

Based on patent filings, the way MagicLeap display technology probably works is by using multiple projection planes at different distances from the eye [20]. This would allow for the eye to focus on virtual objects closer and further in space, making eye accommodation feel more natural [20]. This means that, if the user is focusing on an object further behind, in the physical or virtual world, then a virtual object that is closer to the eye will look blurred, defocused, and vice versa, if one looks at an object that is close to the eye, virtual objects that are far will looked blurred, like in the real world [20].

The projection planes at multiple distances are likely enabled by a fiber-optic camera technology developed for medical purposes and adapted to the computer vision field. This technology projects an image by shining individual pixels through an optic fiber, making the fiber vibrate in a spiral, in a controlled manner, alternating or multiplexing the pixels that are projected through the fiber, one at a time, so that they are emitted when the fiber is pointing in the right direction. This projects a full resolution image, while allowing for the projection

device electronics to be in the user's pockets and the screen on their head, connected only by a fiber and cables [20].

This image is projected onto a set of prisms that act like transparent mirrors so that the user can see the virtual image overlaid on top of the physical world [75-85].

Significance of augmented reality

Augmented Reality is going to extend mobile computing and make it more prevalent and pervasive. It will populate our visual fields with information, connecting us more closely with the cloud and all the data-analysis power that it can provide. It can provide for an interface between humans and computers that is more intuitive, thus strengthening a symbiotic relationship, where humans can have their abilities "enhanced" by artificial intelligence rather than being replaced by it.

Augmented reality will be the first step in the path of people becoming more than human, and their cognition becoming part digital and part biological. However, society and culture need to shape the development of this technology so that it can benefit, not hurt, humanity. For example, if augmented reality experiences follow the path that phones and the web has taken, we will constantly be bombarded with advertisements overlaid on top of the real world, which might become annoying.

Moreover, if we become dependent on the extra information overlays in our daily lives, we might become easily distracted when someone sends a Facebook message. If companies are deregulated and end up gaining monopolistic control over mainstream software that society depends on, our daily lives will be affected by that company a lot more than they currently are, since the real world will mainly be seen through the lens of augmented reality; that is, through a lens that corporations control.

People might be seeing these issues projected on augmented reality devices such as Google Glass and that might be part of the rejection that the product experienced in the market.

Conclusion

As we have seen, Augmented Reality is a field with open possibilities and it is relatively unexplored. Although some AR applications exist for mobile devices, very few heads-up displays are currently available, and they have mostly failed to engage a mainstream audience. This does not mean that the technology will always be rejected by society, but it means that some changes in the marketing and product design need to be made.

A marketing strategy for any consumer technology product needs to start with a niche market of passionate customers who will use the product despite its flaws, and then it can expand into other areas.

More research should be performed with a higher number of survey participants to determine which demographics could potentially benefit from AR technology in its early phases. However, personal interviews with different groups in various industries can prove better suited to determining what segment of the market a new AR device should target.

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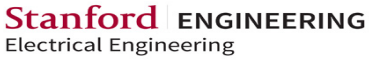

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