CHAPTER 4

Augmented Reality and Mixed Reality Technologies

Paul Hancock

4.1 Introduction

There is some debate as to the exact meaning of *augmented reality* (AR). The Oxford dictionary provides the following definition: "A technology that superimposes a computer-generated image on a user's view of the real world, thus providing a composite view".[1] This differs from virtual reality, which completely replaces the user's view of the real world with computer-generated images (see Chap. 3).

AR gained initial success in smartphone applications due to the fact that smartphones typically have rear-facing cameras. By utilising this feature, AR is available without the need to make an additional hardware purchase. Well-known smartphone applications that utilise AR are Snapchat, a social media application that can add computer-generated effects to human faces, and the computer game *Pokémon Go*, which renders computer-generated characters that appear to be standing in front of the player's

[1] https://en.oxforddictionaries.com/definition/augmented_reality

P. Hancock (✉)
CENTRIC, Sheffield Hallam University, Sheffield, UK
e-mail: ph5218@exchange.shu.ac.uk

B. Akhgar (ed.), *Serious Games for Enhancing Law Enforcement Agencies*, Security Informatics and Law Enforcement,
https://doi.org/10.1007/978-3-030-29926-2_4

Fig. 4.1 Impression of augmented reality game RoboRaid. (Picture credits: https://docs.microsoft.com/en-us/windows/mixed-reality/case-study-using-spatial-sound-in-roboraid)

phone. There is a wide spectrum of additional AR devices from wearable devices like headsets and watches to tablets. In the future, these technologies could be expanded with contact lenses or potentially even implants (Buhr, 2017). The term *mixed reality* (MR) is often used to describe a form of augmented reality in which the real world and digital objects interact (Franklin Institute, 2017). The Microsoft HoloLens family of devices offers MR experiences, for example, a game called *RoboRaid* (see Fig. 4.1) in which computer-generated robots break through the walls of the player's room creating a unique video game experience. This is possible because HoloLens devices are able to scan the environment and determine where the walls and furniture are whilst the game is played.[2]

Whilst *RoboRaid* is a game intended for entertainment purposes, it provides an excellent example of what can be achieved from a serious game perspective. The way in which the computer-generated images interact with the real world can be used to create powerful training simulations to train practical skills, tactical thinking and decision making, whilst fixed position overlays can be used to provide additional information and guidance to increase subject knowledge and enable more informed decision making.

By allowing users to see the outside world alongside computer generated images, AR creates an effective platform to provide instructions, guidance and training. VR can provide a similar service (see Chap. 3), yet

[2] https://docs.microsoft.com/en-us/windows/mixed-reality/spatial-mapping

considerable work is required to create an accurate 3D representation of an object or scene, and there can be ambiguity and errors in 3D models. AR removes these problems, since activities such as training sessions can take place within the actual environment, which remains visible to the user whilst they wear the headset. AR has the added advantage that the user can observe their own body and hand movements, which makes it easier to interact with real-world objects. Using AR, it is also possible to attend meetings or participate in a collaborative exercise, in which participants are in separate locations using a technique called holoportation. (Microsoft, n.d.) uses a type of 3D capture technology that allows high-quality 3D models of people to be reconstructed, compressed and transmitted in real time. When combined with mixed reality displays, this technology allows users to see, hear and interact with remote participants in 3D as if they were present in the same physical space. It is claimed that communicating and interacting with remote users in AR becomes as natural as face-to-face communication (Orts-Escolano et al., 2016).

This chapter will discuss some of the most popular technologies available for AR-based serious game developments. It will then go on to explore current applications of AR in both research and industry and offer considerations for AR-based serious game design. Finally, it will discuss some of the current issues around AR including ethical implications.

4.2 Current AR Technologies

The most popular platforms currently available for AR are mobile devices such as smartphones and tablets. However, this chapter will focus primarily on wearable AR technologies as these are better suited to most serious game applications. The following section will discuss the features of a selection of wearable AR devices as well as possible software solutions and plug-ins that can be used to develop AR applications.

4.2.1 Hardware for AR Technologies

Wearable AR headsets come in a wide range of designs. Whilst the technology itself is still very much in its infancy, each headset has its own shortcomings as well as areas where it may excel over other products. For this reason, it is important to consider carefully which elements are most important for the purpose of the AR application that will be developed. Two main types of wearable devices can be differentiated: *AR overlay*

Fig. 4.2 Example of an AR overlay headset. (Picture credits: http://www.x.company/glass/)

devices, which effectively project a mobile phone screen onto the lens of a pair of glasses (as, for example, in Fig. 4.2), and *holographic headsets,* which can support MR applications where computer-generated images interact with the real world.

AR Overlay Technologies

Overlay devices are a popular style of AR device. These are normally available in the form of a pair of glasses (which can even include prescription lenses). They include a small screen close to one of the lenses, so that the user sees a small translucent screen in their vision. A well-known example of this type of device is the Google Glass headset, first demonstrated by Google in 2012. Google Glass is a lightweight wearable computer with a small prism-based translucent screen mounted above the right eye that brings information into the wearer's line of sight. The screen floats in the top right-hand side of the wearer's vision, appearing as a small display projected in front of the user. This device essentially provides a hands-free smartphone-like display with content similar to what would be seen on a smartphone. The device can be used for sending and receiving calls, messages and photos. It can also be used for navigation, for which a map is displayed on the screen with information that updates with the user's movements. In addition, a camera is mounted on the device, which can be used for taking photos or capturing video. Audio is provided by a microphone situated just behind the user's right ear using bone conduction. This means that sound is generated by vibrating bones near the ear (Warr, 2013). One benefit of this conduction system is that environmental noise is not blocked out in the way it would be if headphones or earphones were used, this makes having conversations easier and also improves safety whilst walking around outside, in particular whilst crossing roads.

Whilst Google Glass was initially launched as a consumer device, it failed in this regard. This was mainly due to three reasons: the high price, the lack of any functionality not already provided by smartphones and privacy. Especially significant were privacy concerns, as people could not be sure whether someone wearing the headset was filming them. As a result, the wearing of the device in movie theatres, banks, schools, bars and some other public spaces was banned (Gray, 2013).

Whilst this type of headset has so far failed as a consumer device, it still has considerable potential as a professional device, either for training or enhancing communication: In 2014, Google announced that Google Glass would be relaunched as a business only device (Kastrenakes, 2014). At the time of writing, Google restricts sales of the device to developers, who are referred to as 'Glass Partners'. If a business requires a Glass solution, they have to contact a 'Glass Partner' who will sell the device with whatever software the business requires pre installed. One business who has made use of this possibility is Hewlett Packard Enterprise (HPE), which uses Glass to provide technical support to their business customers via a service called 'HPE Visual Remote Guidance'. This service enables staff to collaborate virtually with a support engineer. The engineer is able to observe what the camera on the headset of the staff member records. They can then send images to the staff member's headset, which shows what they should do to resolve their issue (HPE, 2015).

One major advantage of a headset that provides smartphone functionality is that workers in wide-ranging fields such as manufacturing, logistics, field services and healthcare may find it useful to consult a wearable device for information and other resources leaving their hands free. The way in which the user is able to communicate remotely with other people makes this type of device suitable also for instructional training or support.

Holographic Technologies

Holographic headsets project 3D computer-generated holograms onto a visor in front of user's eyes. The user interacts with these objects by moving their hand to the position in the real world where the holograms appear to be. These holograms can be set to remain locked in their position in the real world or be made to track the user's movements. For instance, an engineer may wish to review the design of an engine. Wearing a holographic headset, they could load a 3D model of the engine and then place it in front of themselves. By locking the position of the model, they would then be able to walk around the engine so they can investigate it from all angles. Alternatively, a user may want to have a head-up display (HUD) with relevant information about the application they are using. This HUD could track the user's movements, so that information is always displayed in a convenient position in front of the user so as not to obscure their vision. These devices can be either AR or MR. Holograms generated on AR headsets will still appear to exist in the real work but will not interact with their environment. By contrast, sensors mounted on MR headsets allow the device to map and understand physical spaces. This enables the computer-generated holograms to interact with their environment.

4.3 Software for Developing AR Applications

There are multiple software platforms to develop AR applications. Apple and Google, who are currently the main players in the smartphone industry, each have their own software development kit (SDK), which can be used to create software for devices running their own operating systems (primarily phones and tablets). Another popular solution is Vuforia, which is a cross-platform SDK meaning that applications developed this way can be deployed to a wider range of devices (including wearable devices like HoloLens).

4.3.1 Apple ARKit

Apple's approach to AR is to view the screen on a mobile device as a lens that allows the user to see a computer-generated world which augments the real world. This approach is not as immersive as a headset approach but means that there is no requirement for additional hardware beyond a phone or tablet. ARKit works by tracking 'feature points' which are visually distinct features in the real world that can be tracked by the camera on a device. By triangulating the relative positions of these feature points, it is possible to calculate the position of objects in the real world. The real-world position is calculated relative to the position of the device when the application starts. This together with the accelerometer and gyroscope that are available on most modern devices can track a user's motion (Goode, 2018).

In order to understand the world around the devices, the application will initially scan for horizontal and vertical surfaces (e.g. floors, tabletops and walls). These surfaces can then be used to position computer-generated images, so that they appear to be placed on a surface. There is also functionality to provide an estimation of light levels and the positioning of light sources using camera exposure information to determine relative brightness. This can be used to correctly light the computer-generated images, so that they blend in with the real-world and cast shadows appropriately.

Positional tracking works best in well-textured environments, as visual complexity is required to find features which the camera can track. If facing a white wall or in a room with insufficient lighting, it becomes challenging to track feature points, in consequence reducing tracking accuracy. Static scenes work best, since if too much of what the device's camera can see is in motion, visual data will not correspond to motion data, which can cause projected objects to drift. ARKit can detect when these problems occur. This makes it possible to give users feedback and make them aware of why tracking has become unreliable and to allow them to make improvements. ARKit can also recognise images and objects. An example of this could be a museum app that adds interactive 3D visualisations when the user points their device at a displayed sculpture or artefact. At present, applications developed using ARKit are only compatible with devices running the iOS operating system, which includes iPhones and iPads.

4.3.2 Google ARCore

Google have their own SDK called ARCore. As a user experience, it is almost identical to ARKit. ARCore has some advantages due to Apple having more control over hardware and software with their devices. ARCore has some advantages with respect to how real-world environments are mapped but these differences are trivial for the average user (Miesnieks, 2017). Applications developed using ARCore are compatible with devices running the Android and iOS operating systems, which means they are compatible with more devices than applications developed with ARKit.

4.3.3 Vuforia

Vuforia is a cross-platform AR and MR application development platform. Due to its cross-platform nature, it is possible to deploy a Vuforia application to devices running iOS, Android and Windows (including HoloLens) operating systems. Vuforia has been integrated into Unity, which at the time of writing is the world's most popular game engine. The cross-platform nature of Vuforia eliminates the need to create separate applications for use on different AR/MR platforms, in contrast to specialised applications such as ARKit and ARCore. A useful feature of Vuforia applications is that 3D virtual content appears when a device's camera recognises either a 3D object in the real world (e.g. a specific industrial equipment or a home appliance) or a 2D image (e.g. a magazine page or trading card). Vuforia has been used in a variety of applications, aimed at both entertainment and serious games.

4.3.4 Considerations for Selecting Software Platforms

When deciding which software platform to use to develop an AR application, it is important to consider which device it needs to be compatible with. If the application has to be compatible with iOS, Android and Windows (or Windows plus either iOS or Android) devices, then a multi-platform software solution is a good choice, as this reduces the work required to make an application compatible with every device. If an application only needs to support a single operating system, then a software platform designed specifically for this operating system will provide a slightly better experience in terms of motion tracking, light detection and object anchoring.[3]

4.4 AR Innovation Examples

The following section explores a range of innovative ways AR has been used for education, marketing and enhanced situational awareness.

4.4.1 AR in Education

AR has great potential for educational purposes, as it is ideal for delivering instructional information: AR applications can be designed to recognise objects or images and then display computer-generated images to a user. For instance, an application could teach users how to replace a machinery component whereby the application can detect the correct component, highlight it to the user and also indicate the fixing points holding it in place. Whilst such an application could also be developed in VR, users may

[3] https://skywell.software/blog/vuforia-vs-arkit-vs-arcore-choosing-an-augmented-reality-sdk/

find it easier to engage with the platform if they can physically touch and explore the objects they are learning about. Concrete examples of this approach already exist.

AVATAR Partners
A company called AVATAR Partners develops AR training systems based on Vuforia, which are being used by the US Department of Defence as well as the commercial sector. One such application is aimed at training maintenance personnel. Military combat aircraft present unique challenges for maintenance personnel given that space within the aircraft is optimised to allow a large number of hardware systems in a very tight, crowded space. Traditionally, if a trainee wished to see the wiring within an aircraft, it would be necessary to bring in equipment specialists to remove, reinstall and test systems which are in the way of the respective wiring. This takes time and can cause additional wear and tear on sensitive equipment. An AR system allows the trainee to see the positions of the wiring (and other internal components) without having to touch an actual aircraft. Another benefit of such a system is that it works on scale models as well as actual aircrafts (AVATAR Partners, 2017).

Japan Airlines
Japan Airlines (JAL) employs an AR application to train engine mechanics. This training is delivered to trainee engineers using the Microsoft HoloLens device. Traditionally, hands-on training for mechanics required the trainee to wait for an appointment when a plane is in the hangar for maintenance. This creates challenges in coordinating training schedules with maintenance schedules and locations. Additional challenges are factoring in time to deal with tasks such as removing the engine's cover, known as a cowling, to get to the engine itself. Koji Hayamizu, senior director of the planning group for JAL's Products and Service Administration Department, explains the benefits of AR for training:

> The engine looks real, in front of you ... Mechanics can learn an engine structure by extracting important parts with the simulation, learning names of parts and studying the structure of engines and surrounding systems, regardless of location or time of day. (Choney, 2016)

Whilst it is an important training tool, this application differs little from what could be achieved in a VR application. The advantage of using AR/MR in this instance is that, because the experience is not fully immersive, collaboration between trainer and trainee becomes simpler. In this example, a trainer would be able to walk around an engine (or an extracted component of an engine) and point parts out to the trainee.

Daimler Mercedes-Benz 'Ask Mercedes'
The car manufacturer Daimler Mercedes-Benz has created a smartphone AR application aimed at helping its customers to learn how to take advantage of the features of their car. The application called *Ask Mercedes* is marketed as a 'virtual assistant for immediate help'.[4] It makes use of artificial intelligence (AI) and combines a chatbot with AR functionality. The user can ask questions by typing on a virtual keyboard or by using the voice recognition feature supported by the app. The AR aspect of this app allows the user to use a smartphone camera to scan the car's controls and displays. The user holds their smartphone in front of the car's steering wheel or dash board. The application then identifies various controls and displays by scanning the image captured by the smartphone's camera. Once the objects have been visually identified, an explanation of the corresponding functionality is provided.

Military Usage: AITT
Military applications are another area that are making increasing use of augmented and mixed reality technologies, both in terms of training and in active warfare. One example of a military training application using AR/MR is the *Augmented Immersive Team Trainer* (AITT) system developed by the US-based Office of Naval Research (ONR). *AITT* is delivered via a helmet-mounted display and supports a wide range of live, virtual and cutting-edge training scenarios. There have been live demonstrations of this system in which US Marines using the AITT display could see realistic battlefield effects such as aircraft, ground vehicles, opposing forces and explosions from mortar shells and similar munitions. Dr. John Pazik, head of ONR's Expeditionary Manoeuvre Warfare and Combating Terrorism Department, expects that:

> the AITT system will be an enormous assist to our Marines, giving them the ability to train more often, and in more places, than ever before … New technologies like this increase war fighter preparation for different scenarios, and reduce training costs at the same time. (cited in Duffle, 2015)

[4] https://media.daimler.com/marsMediaSite/en/instance/ko/Intelligent-dialogue-technology-combined-with-augmented-reality-Ask-Mercedes-the-virtual-assistant-for-immediate-help.xhtml?oid=30345702

Prior to *AITT*, Marine Corps combat training was costly and time-consuming to set up. Additionally, there were often long waiting times for a test range to become available and poor weather could lead to the training being cancelled. The *AITT* training is considerably easier to coordinate, also removing the logistical problems of having to manoeuvre land vehicles, aircraft and munitions. Training using *AITT* also allows for realistic visual effects from explosions, which would not be as easy to accomplish using traditional training methods.

4.4.2 AR for Marketing

The promises of AR technology and the rapid development of AR platforms have led to its uptake as an effective marketing strategy in many industries, as it is believed that AR can be very persuasive. Below are examples of the effective implementation of AR in this area.

Pepsi Max
Pepsi Max demonstrated an innovative example of how AR can be used for marketing purposes. Pepsi Max used augmented reality on a bus shelter advertisement space to gain the attention of passers-by. A camera hidden in a static Pepsi Max advert on the exterior of the bus shelter recorded footage from the street. This footage was displayed on the reverse of the static advert to give the appearance of a transparent window. An AR overlay was then used to illustrate abstract scenarios such as an alien abduction, a robot invasion or a tiger walking through the street. This demonstration worked by grabbing the attention of passers-by causing them to question what was happening. By forcing the passers-by to investigate, they are more likely to remember the advert. Moreover, the novelty value of this ad should encourage audiences to tell others about their experience, leading to a secondary, extended form of advertisement (Abramovich, 2017).

Disney Colouring Book
Disney released a colouring book for children that utilises augmented reality to bring the characters to life as soon as the children colour them in. The underlying system creates a textured 3D model of the characters in real time. The aim is to extend children's engagement with the Disney franchise whilst also raising parents' interest and attention (Cox, 2015).

Pizza Hut
Pizza Hut created an augmented reality menu, bringing a 3D representation of the prospective meals directly to the table in front of the user. The user can select their meal and place an order to their table, all through the app. It also includes an augmented reality treasure hunt style game to encourage customers to engage with the app on a longer basis (Engine Creative, n.d.).

4.4.3 AR for Improved Situational Awareness

Situational awareness is the knowledge of what is happening in surrounding areas. Inherent in this definition is a notion of what is important (Endsley & Garland, 2000). By not obstructing the view of the real world, AR has the capability to improve situational awareness by supplying the user with a constant stream of important information that otherwise may have required interaction with other forms of technology.

Military TAR
Military field officers have to maintain continuous awareness of their environment, which makes fully immersive VR applications unsuitable. In this situation, AR/MR headsets are better suited. The US Army has created an eyepiece to improve soldiers' situational awareness, called *TAR* (Tactical Augmented Reality). *TAR* enables soldiers to see the position of team members and enemies on a map, which is overlaid on their field of view. When a weapon is drawn, additional information will be supplied such as the target's distance. The eyepiece combines functionalities of night vision goggles and GPS into one piece of hardware. In addition, the eyepiece enables rear view vision. This allows soldiers to have a holistic view of their surroundings (Haridy, 2017). There are also potential applications for AR in command and control centres (CCC) and militaristic planning. For instance, AR devices can allow generals to see a tabletop representation of live battle scenes.

Vehicles
Another area in which AR aims to improve situational awareness is driving vehicles. Byoung-Jun Park and colleagues (2015) developed a system that uses colour coding to illustrate the threat level other vehicles pose on the road. This information is overlaid onto the windscreen. BMW created their own wearable AR headset, which also presents information from the

dashboard to keep the driver's attention on the road. Another function is to draw attention to any low objects under the car that may otherwise be obscured making use of external cameras; that is, the driver can see through the car, as the glasses essentially offer drivers 'X-ray vision' (Baldwin, 2015). Baldwin (2017) cautions, however, that such applications could rather act as a distraction by blocking the user's field of vision with information that is not overly important, at the same time blocking the view on potential hazards.

4.5 Current Issues and Limitations of AR

AR has been referred to as a persuasive technology. For this reason, augmented reality can be subjected to numerous ethical concerns. For instance, computers can be more effective persuaders, as they are not susceptible to social cues or emotions and are more persistent than any human could ever be. Giving them the ability to trial different persuasion techniques in a methodical manner, computers can collect data on their audience and therefore are able to target their arguments very specifically. A frequent reason for discussion is thus whether using technology to persuade is an ethical concern[5],[6]. Persuasion can be used to affect the way people behave or what they believe in. This is a form of manipulation, which causes concern (Pase, 2012). Whilst audiences may believe that they are strong and able to resist manipulation, there is a high risk to vulnerable groups who may also be more susceptible to misinformation or misdirection. Surveillance is another persuasive technique available to an AR application that creates concerns, depending on the context and purpose for its use. If used in order to covertly observe, collect private information or to punish, then its use should be avoided (Pase, 2012; Sabelman & Lam, 2015).

Related to the above, there has been a rise in concerns about privacy. The public is growing increasingly concerned about the use of their data and are more aware of their online presence. Due to this, the EU's General Data Protection Regulation (GDPR) was introduced, which provides stronger rules on data protection giving people more control over their personal data. Most AR applications require the use of a camera to overlay

[5] https://becominghuman.ai/six-ethical-problems-for-augmented-reality-6a8dad27122

[6] https://medium.com/inborn-experience/what-are-the-ethical-considerations-of-augmented-reality-243de50a3f9

the computer-generated elements on top of the view of the real world. The majority of these systems utilise outward-facing cameras. This could raise concerns about the public not being aware of being filmed, which can cause anxieties about not knowing if one is on camera or not. With wearable AR, there is also a concern about what data may be collected and stored about the user. If the data is not securely stored, it would be possible for rogue actors to obtain highly personal and/or sensitive information (Pase, 2012).

Allowing users to still see their surroundings, yet partially obscuring their vision with information, can cause distractions. In an uncontrolled environment this could be a safety risk, for example, if the user is crossing a road and they do not see a car, because the augmented reality content has created a blind spot in their vision. Such scenarios outline potentially life-threatening consequences of faulty AR designs.

4.6 AR Development Processes and Methodologies

A basic AR development process can be relatively fast. Camba and Contero (2015) created a methodology for the rapid development of marker-based AR tools, which illustrates the main milestones for creating an AR application. The stages are split into two main components: 3D content creation and AR content creation (see Fig. 4.3). The first stage of this methodology uses image-based modelling, which is convenient for recreating real-world objects, although in some circumstances, this will not be possible (e.g. if an object is transparent or overly reflective, the image processing software may struggle to recreate the object in 3D). In addition, the object

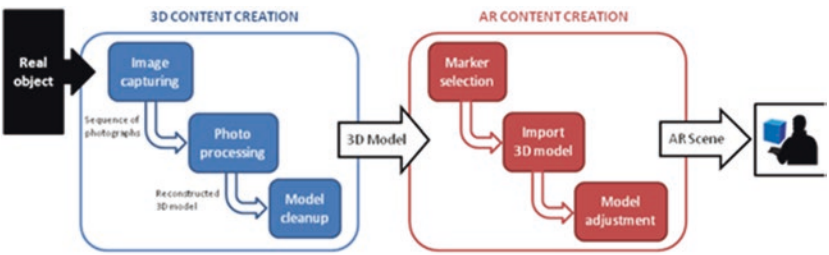

Fig. 4.3 Methodology for the rapid development of marker-based AR tools (Camba & Contero, 2015)

may not be readily available. In this case, the object will need to be modelled from scratch, which may slow down the development speed. Once the object has been captured in 3D, there will probably be clean-up work required by an artist to ensure that the model is efficient and will not require too much processing power to render.

Once the 3D content has been created, the second stage of AR content creation begins. The methods used to create content may vary depending on the software, although the general principles will remain the same. Firstly, a marker must be chosen and printed if necessary; then a camera needs to be set up and pointed towards the marker. Once the marker has been recognised, the area will be highlighted. The 3D content can then be dragged and dropped into the scene.

As AR is a relatively new field of research, the current methodologies are rather basic. With the maturing of the field, more comprehensive methodologies for developing AR applications should be available in the future. These will likely address aspects such as design, interaction and the evaluation of the product.

4.7 Interacting with Wearable Augmented Reality

Interactions with augmented reality should feel natural. Whilst current efforts are still in their infancy, given progress in gesture tracking, speech recognition, motion tracking and eye tracking, it can be expected that improved interaction methods will become available in the not too distant future.

According to Engine Creative (2017) there are three ways to add augmented reality elements to a scene:

1. *Fixed screen* – This form of interaction works exactly as current standard interaction interfaces such as mobile or desktop app. No matter what happens in the scene, the augmented elements will remain in the same location.
2. *Real world related* – In this method the app analyses the real-world scene and places the augmented elements inside. This means that as the camera moves, the augmented reality aspects will remain in the same relative position.
3. *Object related* – Here the augmented reality elements are attached to a real-world object. If the object is moved, the augmented element will move with the object.

In any standard design, interactions should be intuitive to avoid users becoming frustrated. This is possibly even more important in the context of augmented reality, as the user is interacting with the real world and therefore will expect to interact with the augmented objects in a way that is familiar with the real world. In comparison with traditional human-computer interactions, augmented reality thus attempts to replicate naturalistic interactions. This comes with a higher chance of error due to how gestures, speech or eye movements are interpreted by the system (Curran, 2016).

An issue for interactions with wearable AR is that the augmented elements are often overlays of videos. Therefore, the user's hands often obstruct the augmented reality aspects. Another aspect to take into consideration is background lighting (e.g. will the elements still be visible in both poorly lit and overly bright environments?).

4.8 Choosing Between AR and VR

Augmented reality is a powerful platform for educational purposes. It allows trainings to be conducted at real locations in which people interact with computer-generated characters (either as a 3D representation of another human at a different location or as an AI-controlled character). Because AR is not fully immersive, the problems with simulator/cybersickness some people experience in VR are less prevalent.

That is not to say, however, that AR is always a better choice than VR. VR can be a better choice for training in hazardous environments, for instance. Also, AR is an up and coming technology, and there are still numerous hurdles to overcome before the true power of its capabilities can be realised. For example, AR headsets are still largely in development and have not yet reached their full potential. Also, considerably more research is needed to achieve naturalistic interactions with AR. In addition, ethical questions could cause issues for augmented reality in the future.

Despite these concerns, AR undoubtedly carries potential as an approach for training. Future iterations of AR headsets such as HoloLens will be more comfortable to wear and offer more immersive experiences. Interactions between human users and holograms will also improve with advancements in eye tracking technology and by incorporating haptic feedback.[7]

[7] https://www.cnet.com/news/the-future-of-ar-according-to-microsoft/

References

Abramovich, G. (2017). *5 innovative examples of augmented reality in action*. Retrieved from https://www.cmo.com/features/articles/2017/7/13/5-realworld-examples-of-augmented-reality-innovation.html

Engine Creative. (n.d.) *AR menu experience*. Retrieved from https://www.enginecreative.co.uk/portfolio/ar-menu-experience-pizza-hut/

Engine Creative. (2017). *AR UI best practice- designing for augmented reality experiences*. Retrieved from https://www.enginecreative.co.uk/blog/ar-ui-best-practice-designing-for-augmented-reality-experiences/

Baldwin, R. (2015). *Mini's weird-looking AR goggles are actually useful*. Retrieved from https://www.engadget.com/2015/04/22/bmw-mini-qualcomm-ar/

Baldwin, R. (2017). *Driving with AR glasses may be information overload*. Retrieved from https://www.engadget.com/2017/09/26/driving-with-ar-glasses/

Buhr, S. (2017). *Omega ophthalmics is an eye implant platform with the power of continuous AR*. Retrieved from http://social.techcrunch.com/2017/08/04/ophthalmics-is-an-eye-implant-with-the-power-of-continuous-ar/

Camba, J. D., & Contero, M. (2015). *From reality to augmented reality: Rapid strategies for developing marker-based AR content using image capturing and authoring tools*. Paper presented at the IEEE Frontiers in Education Conference (FIE). pp. 1–6. https://doi.org/10.1109/FIE.2015.7344162

Cox, J. (2015). *Disney is using augmented reality to bring coloring books to life*. Retrieved from https://www.theverge.com/2015/10/5/9453703/disney-research-augmented-reality-coloring-books

Duffle, W. (2015). *ONR's augmented reality system gives marines new perspective on combat training*. Retrieved from https://www.onr.navy.mil/en/Media-Center/Press-Releases/2015/AITT-Demo-Oct-2015

Endsley, M. R., & Garland, D. J. (2000). Theoretical underpinnings of situation awareness: A critical review. In *Situation awareness analysis and measurement* (Vol. 1, p. 24). Mahwah, NJ: LEA.

Goode, L. (2018). *Apple's AR system can now recognize more real-world objects*. Retrieved from https://www.theverge.com/2018/1/24/16925640/apple-arkit-ar-iphone-ipad-update-1-5-ios-11-3-vertical-plane-image-recognition

Gray, R. (2013, Dec 4). *The places where google glass is banned*. Retrieved from https://www.telegraph.co.uk/technology/google/10494231/The-places-where-Google-Glass-is-banned.html

Microsoft. (n.d.) *Holoportation*. Retrieved from https://www.microsoft.com/en-us/research/project/holoportation-3/

Curran, C. (2016). *How will people interact with augmented reality?*. Retrieved from https://usblogs.pwc.com/emerging-technology/how-will-people-interact-with-augmented-reality/

HPE. (2015). *HPE visual remote guidance for the enterprise*. Retrieved from https://h20195.www2.hpe.com/v2/GetPDF.aspx/4AA5-8053ENW.pdf

Choney, S. (2016). *Japan airlines creates yet another first-class experience, this time using microsoft HoloLens*. Retrieved from https://blogs.microsoft.com/transform/2016/07/11/japan-airlines-creates-yet-another-first-class-experience-this-time-using-microsoft-hololens/

Kastrenakes, J. (2014). *Google launches 'glass at work' program with five partners making apps for business*. Retrieved from https://www.theverge.com/2014/6/16/5814980/google-glass-at-work-first-partners-announced

Miesnieks, M. (2017, September 1). *How is ARCore better than ARKit?* Retrieved from https://medium.com/6d-ai/how-is-arcore-better-than-arkit-5223e6b3e79d

Orts-Escolano, S., Rhemann, C., Fanello, S., Chang, W., Kowdle, A., Degtyarev, Y., et al. (2016). *Holoportation: Virtual 3d teleportation in real-time*. Paper presented at the Proceedings of the 29th annual symposium on user interface software and technology, pp. 741–754.

Byoung-Jun, Park., Changrak, Yoon., Jeong-Woo, Lee., & Kyong-Ho, Kim. (Jul 2015). *Augmented reality based on driving situation awareness in vehicle*. Paper presented at the 593–595. https://doi.org/10.1109/ICACT.2015.7224865. Retrieved from ieeexplore.ieee.org/document/7224865

Pase, S. (2012). *Ethical considerations in augmented reality applications*. Proceedings of the 2012 EEE international conference on e-learning, e-business, enterprise information systems, and e-government.

Sabelman, E. E., & Lam, R. (2015). *The real-life dangers of augmented reality*. IEEE Spectrum, 52(7), 48–53.

Haridy, R. (2017). *US army's TAR head up display to give soldiers a tactical edge*. Retrieved from https://newatlas.com/army-heads-up-display-soldiers-tar/49726/

AVATAR Partners. (2017) *Vuforia model targets application in aircraft maintenance*. Retrieved from https://www.vuforia.com/case-studies/avatar-partners.html

Warr, P. (2013, Feb 4). *Google glass to use bone vibration instead of traditional headphones*. Retrieved from https://www.wired.co.uk/article/google-glass-bone-vibration