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The challenges of making educational video games accessible.

A case study on the video game *Immune patrol*

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Ondergetekende Rani De Vadder, talencombinatie Engels-Chinees in de opleiding Master in het Vertalen, verklaart dat deze masterproef volledig oorspronkelijk is en uitsluitend door ondergetekende is geschreven. Bij alle informatie en ideeën ontleend aan andere bronnen, heeft ondergetekende expliciet en in detail verwezen naar de vindplaatsen.

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ABSTRACT

The Universal Declaration of Human Rights stipulates that receiving education is a human right that is firmly embedded into today's society (UNESCO, n.d.). Education is constantly evolving, making increasingly use of audiovisual learning materials, including video games (Kirriemuir & McFarlane, 2003; Rieber, 2005; Taylor, 2023). These educational video games—a subgenre of serious games—have now laid the foundations of game-based learning (Becker, 2021). However, this tendency brings about the challenge that the game content has to be made accessible and understandable to all users, regardless of circumstances or age (Bierre et al., 2005; Hersh & Leporini, 2013; Peña-Miguel & Sedano, 2014). This way, educational games can function as a tool to comply with the human right of education (Rueda & Cerero, 2021; Salvador-Ullauri et al., 2020a). Although work by Greco (2018), Hersh and Leporini (2013) and Torrente et al. (2014), stress a social viewpoint in which the product's content is to be made accessible, game accessibility guidelines still lack consistency (Larreina-Morales, 2023). Not only do these guidelines have different approaches and purposes (Larreina-Morales, 2023), they are often applied to commercial games and pay little, if any, attention to educational games, which may very well have different accessibility requirements (Salvador-Ullauri et al., 2020b). As a result, many pupils are still being stigmatized because of the temporal and/or permanent barriers they face when accessing educational gaming content (Hersh & Leporini, 2013; Mangiron & Zhang, 2016). Therefore, the aim of this dissertation is to research what possible accessibility barriers exist in video games and how to overcome them, followed by an analysis of the educational video game *Immune Patrol*, developed by the World Health Organization (Copenhangen Game Lab, n.d.). The dissertation draws on a number of existing accessibility guidelines to examine the current level of the game's accessibility and offers solutions where needed. The study shows that accessibility has not been considered at the onset of the game design, since *Immune Patrol* does not yet provide accessibility measures for the visual, aural, and tactile channel, the three channels it uses to transmit information (Mejiías-Climent, 2021). In consequence, visual, aural, tactile, linguistic, and textual barriers are immanent to the product. The four basic accessibility features—subtitling, text scaling, color blindness settings and remapping (Game accessibility guidelines, n.d.-c)—are missing in the game. Furthermore, the game offers its video content—animated videos—through

YouTube, meaning that available accessibility measures are provided by the online platform only. As such, these measures are not offered by *Immune Patrol* itself through in-game accessibility tools. Moreover, the absence of accessibility features may cause the loss of a multisensory experience (Edwards, 2018b) and the unavailability of accessing characteristic features of educational games that contain scientific information—features that are part of *Immune Patrol*. The dissertation ends with some points of interest for future research and adaptions for *Immune Patrol*, including the need for user opinions (Larreina-Morales, 2023) after accessibility measures have been taken.

Keywords: video games, media accessibility, (video) game accessibility, serious games, educational video games, game-based learning

WORD OF THANKS

Writing a dissertation is not an easy task. Quite the opposite, in fact, for it takes time, effort, and dedication. However, indulging myself in the inspiring and creative world of video games has been a great pleasure and an enriching experience. Learning more about the gaming industry and serious games in particular, has shown me why I used to love my *Nintendo* and *Wii* when I was a little girl. I was not addicted, I am sure of it, although I sporadically smuggled my *Nintendo* into my room, hiding it under the covers when I was supposed to sleep. I even recalled a computer game we played at elementary school—a helpful mathematics game that almost made me 'like' math. As soon as I remembered those times, I realized how important it is that other people, whether young or old, are also able to enjoy these wonderful games. Not only are they fun and relaxing, but they also offer great learning opportunities. I am therefore very glad that I was able to write my dissertation on the topic of accessibility in educational video games and I hope my research will be a help to all those who love playing games.

However, I would not have been able to finish this work without the support of others. First, I would like to thank my supervisor, Mr Vercauteren, for his pleasant guidance and support. I also want to give credit to Mike and Britt. Special thanks go to my mum, who is always the first to listen to all my ideas and troubles. I also want to thank my dad for his great enthusiasm and my boyfriend for being my stress management coach. Lastly, thanks to my aunt, for helping me out when I doubted my English and Margot, one of my best friends, for your trained eye—you manage to spot even the slightest mistake!

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1. INTRODUCTION

The importance of education is firmly embedded in today's society (UNESCO, n.d.). Indeed, to receive education is therefore a human right, as set out by the Universal Declaration of Human Rights (UNESCO, n.d.; United Nations, 2015). This means that any person—regardless of their social, economic, cultural, physical, or mental background—has the right to learn (United Nations, 2015). UNESCO (n.d.) describes education as "one of the most powerful tools" when it comes to marginalized and excluded groups of both children and adults in poverty and underlines its great importance in bridging the gap to other fundamental human rights.

Since education is such an important tool in our lives, it is also constantly evolving and adapting (Rueda & Cerero, 2021; Taylor, 2023). For instance, in the 21st century, an era of modern technology, the use of audiovisual materials has become widespread in various contexts, including education (Kwegyiriba, et al., 2022; Selwyn, 2013). For instance, most pupils and teachers are nowadays familiar with projectors, visuals, the internet, and computers (Raja & Nagasubramani, 2018). Due to this trend, the concept of multimedia learning has become a part of education (Rieber, 2005), as it stands for "multiple modes that include visual and auditory information and student use of this information to construct knowledge" (SEG Research, 2008, p. 1). Apart from more traditional learning methods and the previously mentioned digital resources, video games are becoming another modern technology that is used in education (Martí-Parreño et al., 2018; Rueda & Cerero, 2021). These games aim to offer pupils a motivational and pleasurable learning experience (Martí-Parreño et al., 2018), supporting multimedia learning through the use of visual and aural content (SEG Research, 2008). In addition to the positive effect of video games on pupils' motivation (Peña-Miguel & Sedano, 2014), this multimedia learning also helps with information processing and pupils fulfill a more active role, as they interact with the learning software (Rieber, 2005; SEG Research, 2008). The Covid-19 pandemic is another clear example of rapid changes in education, as schools had to close and offer online solutions (European Education and Culture Executive Agency et al., 2022). Not only did teachers and pupils use computers to overcome these difficulties, but the World Health Organization also developed an educational video game for children aged 10 to 12 in light of this crisis (WHO, 2023). The aim of the game is to

teach children about viruses, the immune system, and infectious diseases, partly with the Covid-19 pandemic in mind, through images, text, and animated *YouTube* videos (Copenhagen Game Lab, n.d.).

Now that game-based learning, as an emerging field, is becoming increasingly popular in education (Becker, 2021; Begg, 2008), the trend also brings with it the challenges of making its content—in the form of video games—accessible and understandable to all pupils in any situation and of any age as a tool to comply with the human right of education (Bierre et al., 2005; Peña-Miguel & Sedano, 2014; Salvador-Ullauri et al., 2020a; UNESCO, n.d.). It is therefore essential that pupils can access information provided by video games used in education, as it is part of their curriculum, sets learning goals and provides them with knowledge that is relevant outside the classroom (Copenhangen Game Lab, n.d.; Zyda, 2005). However, many pupils are still being stigmatized as various barriers impede them from accessing educational gaming content (Hersh & Leporini, 2013; Mangiron & Zhang, 2016). Therefore, due to the diverse and wide-ranging audience that uses video games nowadays, the concept of video game accessibility was introduced (Hersh & Leporini, 2013; Pallavicini et al., 2018). Video game accessibility implies that anyone should be able to play a game, even when faced with permanent and/or temporal barriers (International Game Developers Association, 2004). Although various sources, including work by Greco (2018) and Hersh and Leporini (2013), argue for the adaptation of a social viewpoint which starts from the product and aims to make its content accessible to all, many game accessibility guidelines still take on diverse approaches and purposes (Larreina-Morales, 2023). This makes it hard for game developers to decide which guideline to follow (Larreina-Morales, 2023). Moreover, these guidelines are often designed with commercial games in mind, as designers of educational video games are not generally concerned with accessibility at the game's design phase (Aguado-Delgado, et al., 2020; Salvador-Ullauri et al., 2020b), although Grammenos (2014) argues for accessibility-making at the start of the development process. In consequence, this lack of common ground still causes many educational games to not be accessible to their users (Grammenos, 2014; Yuan et al., 2010).

The aim of this study is to formulate solutions to make the game content of the educational video game *Immune Patrol* accessible to its users. Although there is a lack of consistent

existing guidelines specifically aimed at educational video games (Larreina-Morales, 2023; Salvador-Ullauri et al., 2020b), it is characteristic to video games that game and player interact through three main information channels (Mejiías-Climent, 2021). These are the visual, aural, and tactile channels (Mejiías-Climent, 2021). However, these three channels all create possible barriers, such as visual, aural, tactile, linguistic, and textual barriers (Grammenos, 2014). In this dissertation, I want to study whether and to what extend the game's three information channels have already been made accessible and what other measures can be taken to increase its accessibility. Therefore, the research question of this dissertation is: in what ways have or can the different information channels in the educational game, *Immune Patrol*, be made accessible to pupils?

In order to provide an answer to this question, several steps will be taken. Firstly, chapter 2 will provide a brief overview of the current popularity and widespread use of video games to stress their relevance, followed by an explanation of the subgenre of serious games, concentrating on what they are and the different contexts in which they are used. In addition, several advantages of serious games are underlined. Given that *Immune Patrol* is an educational video game, the focus of the study will narrow down to serious games applied in an educational context—called educational video games. Based on previous studies, the dissertation considers several definitions of serious games in an educational context to emphasize the importance of their motivational purposes, supporting the claims that serious games—and educational games in particular—ought to not only train and educate learners, but also engage them (de Freitas & Liarokapis, 2011; Grammenos, 2014). To further underline their significance, multimedia learning and its advantages are considered as well, followed by a section that elaborates on scientific information in serious games and how this information is presented in an understandable way. Next, in chapter 3, the focus will shift to accessibility—video game accessibility, specifically—to investigate what research on the topic has already been done, as it is essential to make audiovisual (educational) content accessible to pupils (Chakraborty et al., 2014; Hersh & Leporini, 2013). The chapter examines the medical and social approach on accessibility and explains why the dissertation takes on the latter view (Hersh & Leporini, 2013), followed by a brief overview of universal game design in chapter 4. Then, the audiovisual nature of video games is discussed in chapter 5. This chapter aims to explain the three main information channels of video games. These are relevant for the

analysis in chapter 8. Afterwards, in chapter 6, accessibility is looked at in more detail from a medical viewpoint—to better understand different impairments—and through a social viewpoint. Drawing on existing literature and guidelines, the chapter then provides solutions to overcome visual, aural, tactile, linguistic, and textual barriers. The literary research ends with a short summary of the main findings, which will be used to analyze *Immune Patrol*. The methodology is explained in chapter 7, followed by the analysis in chapter 8. Since the analysis is split up in numerous subcategories with barriers often specific to one item, accessibility solutions are already discussed in the analysis in order to keep a clear overview. However, a brief summary follows in chapter 9. It repeats the main findings, but it also underlines research limitations and offers suggestions for further investigations. Finally, chapter 10 ends with the conclusion and some recommendations for future research.

2. VIDEO GAMES

Video games are often associated with entertainment and, on many occasions, the believed main target audience are children and young adults (Pallavicini et al., 2018). Interestingly enough, due to recent developments, this is no longer the case. Video games are now enjoyed by a very broad audience instead of only selected groups of people (Mangiron et al., 2014; Pallavicini et al., 2018) and this new tendency reveals the ongoing and increasing presence of gaming in our everyday lives, also referred to as 'gamification' (de Freitas & Liarokapis, 2011). Moreover, gaming is no longer exclusively aimed at entertaining but also at motivating and training, bringing forth a new game genre known as serious games (Michael & Chen, 2006).

2.1 THE NATURE AND USE OF VIDEO GAMES

Video games center around experience, engagement, and immersion, making them a captivating activity to many people (Cardona-Reyes et al., 2021). Mejiías-Climent (2021) writes: "video games display an essential ludic intention from which their name originates: video (media) and game (human ludic activity)" (p.3), although some games provide more than merely pleasure and joy. For many people, video games have now become an important and

indispensable part of their daily lives, so when talking about video games, people can easily explain what they mean or they have at the very least heard of them (Pallavicini et al., 2018). It is no longer so that only certain niche groups, such as hardcore gamers or specific age groups, use video games as a pastime and means of enjoyment (Mangiron et al., 2014). Moreover, video games are increasingly fulfilling other purposes in various sectors besides entertainment, including education and health (Mangiron et al., 2014; Yuan et al., 2010) and their broad application can be further demonstrated by the fact that they are also used more often in areas such as the military field (Susi et al., 2007). *America's Army*, for instance, is a military game designed by the U.S. Army to inform and educate recruits about policies in the army (Huntemann & Payne, 2009). However, despite their growing importance and diversified application in modern times, it is a harsh truth to know that many people still face difficulties when playing video games, regardless of genre or aim (Yuan et al., 2010), or that they are unable to access the provided information offered through the different semiotic channels (Torrente et al., 2014).

With the ongoing rise of educational games centered around game-based learning (Becker, 2021; Begg, 2008), the present dissertation will make a clear distinction between two main categories of games: commercial video games and serious video games. The following section will sketch a brief overview of the rising popularity of the industry, including some information on commercial video games. After that, the dissertation will go into more detail about how serious video games are used in an educational context specifically, outlining their learning advantages, to later focus on the even more pressing importance of accessibility in these games, considering the potential benefits they can have as an inclusive teaching tool (Hersh & Leporini, 2013; Rueda & Cerero, 2021; Salvador-Ullauri et al., 2020a).

2.2 THE GROWING POPULARITY OF THE GAMING INDUSTRY

When one thinks of video games, one may automatically recall certain brands of popular entertainment consoles such as *Nintendo*, *PlayStation*, or *Xbox*. According to the Entertainment Software Association (ESA, 2022), two thirds of Americans play video games. That is over 215 million people in the United States alone. However, the use of video games

stretches much further than the American continent, as it has turned into a worldwide phenomenon (Costales, 2014; Mangiron, 2012). A report by Cardona-Reyes et al. (2021) shows that by the end of 2022, the gaming industry will have reached an estimated revenue of 196.0 billion dollars and is growing each year, as shown in the image below (Wijman, 2019).

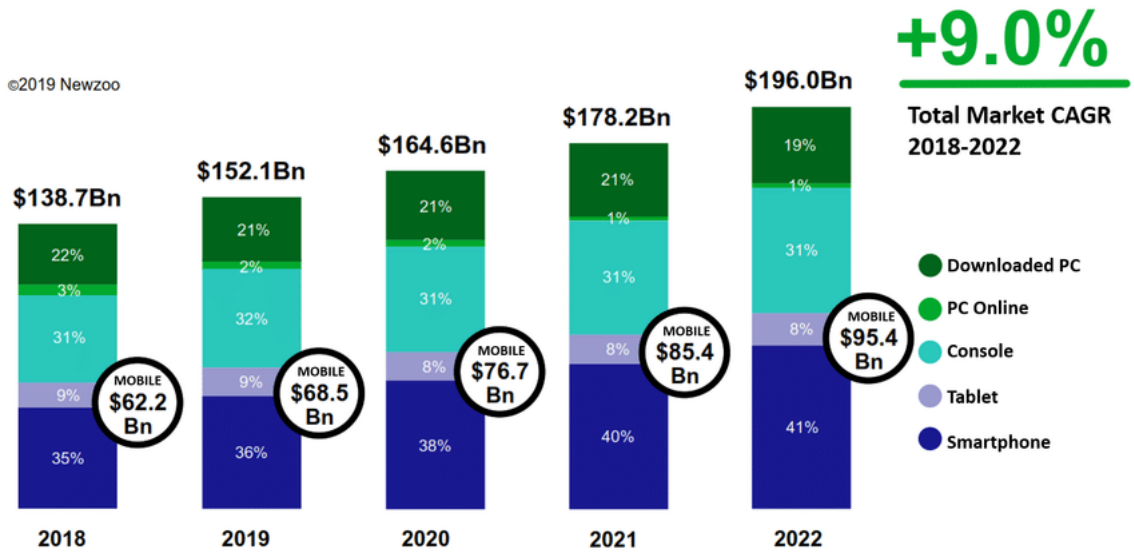

Figure 1: Annual growth rate of the total video game market, Wijman T. © 2019 Newzoo.

Not only its revenue is impressive, also the number of people who play video games is characteristic of the popularity of the industry. In 2020, this number reached around 2.7 billion (Wijman, 2020), proving that the 'gamification' of society can no longer be denied (de Freitas & Liarokapis, 2011).

This ubiquitous presence of 'gamification' in our lives has also paved the way for the utilization of games in contexts other than entertainment, such as the development of games that are designed to fulfill educational purposes (de Freitas & Liarokapis, 2011), which will be discussed in the following section.

2.3 SERIOUS GAMES AND THEIR BENEFITS TO LEARNERS

As already mentioned in the previous sections, various studies showed that games and gaming features used for training and learning is increasing, with a specific emphasis on their appliance in educational contexts (National Research Council, 2011; Torrente et al. 2014; Yuan et al., 2010). These games are called serious games. The use of these games encompasses a

form of entertainment but also training in different areas such as the medical, technical, or industrial field (Mejiías-Climent, 2021). In their study on serious games, Susi et al. (2007) state that there are a lot of concepts and domains that are associated with the term or sometimes even used in an overlapping manner, with the term *edutainment* also being used to refer to serious games as an example. However, according to Michael and Chen (2006) and Susi et al. (2007), serious games go further than mere *edutainment*—which centers around the idea that the user's motivation increases with the pleasure of the experience (Peña-Miguel & Sedano, 2014)—and instead comprise all educational aspects.

There is, however, no single established definition of what a serious game is, and most sources offer only vague descriptions, though the term became widespread with the development of the Serious Games Initiative (SGI) (Susi et al., 2007). The SGI refers to serious games as: "uses for games in exploring management and leadership challenges facing the public sector. Part of its overall purpose is to help forge productive links between the electronic game industry and projects involving the use of games in education, training, health, and public policy" (Center for Digital Games Research, n.d.), supposedly including no form of entertainment. Conversely, although further research is needed on the effectiveness of serious games, more and more studies show that serious games do engage learners of all ages despite their serious nature (de Freitas & Liarokapis, 2011; Kato, et al., 2008). They provide high levels of motivation and transmit topics and facts in a very efficient way (Peña-Miguel & Sedano, 2014). Torrente et al. (2014) even stress that serious games *must* capture the learner's attention in order to create motivation to begin or do a certain task. A clear example is the following definition by Zyda (2005), who describes a serious game as "a mental contest played with a computer in accordance with specific rules that uses *entertainment* to further government or corporate training, education, health, public policy, and strategic communication objectives" (p. 26), therefore underlining that although one of their purposes is to improve understanding, serious games still create a feeling of amusement, offering users a pleasurable and motivational experience (Acosta-Vargas et al., 2020). What makes serious games 'serious' to Zyda (2005) is the addition of activities that help learners to develop new skills or knowledge by instructing or teaching—pedagogy. Video games can also arouse competing desires among players (Chakraborty et al., 2014), which sounds promising when it comes to interaction and cooperation among pupils. More probable benefits have to do with the recognition of

problems and solving them, decision-making, and even the improvement of memory (de Freitas & Liarokapis, 2011). Begg (2008) and Sugimoto (2007), too, point to this valuable combination of education and entertainment. Begg (2008) explains that educational video games, specifically, contain a form of game-informed learning, which seeks a way to maintain engagement and motivate players to replay or redo different tasks. Whereas game-based learning aims for the use of games for learning (Becker, 2021), game-informed learning adds playful elements—entertainment—to these games, often based on a narrative scenario in which the player fulfils an active role (Begg, 2008).

Educational games fall under this category of serious games, but the biggest difference within this subcategory is that educational games are developed explicitly with one or more learning goals in mind, whereas serious games in general can be designed for various educational purposes, for instance to inform, to create changes in behavior or to raise understanding (Becker, 2021). Educational video games also share a lot of similarities with (interactive) multimedia learning (Rieber, 2005). Multimedia learning refers to the idea that people learn better from words and images than merely words in their own right (Mayer, 2005; SEG Research, 2008). This has to do with the fact that information processing takes place through two channels, namely the aural and the visual channel (Barak & Dori, 2011; Mayer, 2005). Information that is heard is processed by the aural channel, whereas information that is seen—such as images—falls under the visual channel (Gambier, 2019). Thus, by adding images to text, and as such combining different learning channels, learners will be able to visualize certain concepts—often abstract in nature, which can make understanding harder, as explained in the ICC-project by Vandenbroucke et al. (2022)—more easily (Barak & Dori, 2011). In this sense, educational video games do fall under multimedia learning (Barak & Dori, 2011; Rieber, 2005) as they use a visual and aural channel to transmit information (Gambier, 2019). This will be discussed in more depth in section 5. *The Audiovisual Nature of Video Games.*

2.4 SCIENTIFIC INFORMATION IN EDUCATIONAL VIDEO GAMES

Immune Patrol, the educational video game that will be analyzed in this dissertation, specifically contains scientific information on health education (WHO Regional Office for Europe, 2022a). When defining educational games centered around science, the National

Research Council (2011) writes: “these games are designed to accurately model science or simulate scientific processes, and interactions within the virtual world of the game are governed by established scientific principles” (p. 10). Firstly, according to Eshach and Fried (2005), science adds to conceptual knowledge, meaning that children will better understand the world when they also understand specific scientific concepts. In the case of health education, children might better grasp the reality of the recent Covid-19 pandemic when they have learned about diseases and viruses or contamination, which is information the game *Immune Patrol* provides (Copenhagen Game Lab, n.d.; WHO, 2023). Secondly, scientific knowledge also nourishes children’s general skills in domains other than science alone (Eshach & Fried, 2005). For instance, learning about science teaches children to be more critical and think analytically (Eshach & Fried, 2005). Avci and Kamer (2018) found that science teachers believed decision-making, analytical and creative thinking, teamwork, and communication were some of the skills that could be obtained through science classes, and the research also highlights that teachers are of great importance in helping pupils to obtain these skills.

In health education games, a popular phenomenon contributing to pupils’ engagement in science is the use of virtual patients to create a narrative scenario (Begg, 2008; Ellaway et al., 2009). Virtual patients are: “An interactive computer simulation of real-life clinical scenarios for the purpose of medical training, education, or assessment” (Ellaway et al., 2006, p. 2). These patients have detailed background information, thus making them seem more realistic, and activities may include diagnoses and treatments (Ellaway et al., 2009). In science games, virtual laboratories and environments can also be present, which adds to their value when teachers face logistic difficulties (National Research Council, 2011). Moreover, science often deals with very abstract concepts that are hard to visualize or grasp (Barak & Dori, 2011; Vandenbroucke et al., 2022) and all of these possibilities help pupils to “visualize, explore, and formulate scientific explanations for scientific phenomena that would otherwise be impossible to observe and manipulate” (National Research Council, 2011, p. 20). Thus, in addition to the main goal of creating motivation, the game also sets a learning goal (National Research Council, 2011). As an example, the National Research Council (2011) talks about *WolfQuest Episode 1*, in which the game aims to teach users about wolves and their habits by stimulating their curiosity.

Furthermore, research by Barak and Dori (2011) indicates that animations, such as animation movies, help pupils in their scientific thinking and increases their curiosity. *BrainPOP* is a good example of this. *BrainPOP* (n.d.) is a learning resource that combines animation, games, and activities in order to engage pupils and explain concepts to them, aiding their learning process. In the previously mentioned research by Barak and Dori (2011), these animated movies can be used in various ways: as an introduction video to attract attention or to summarize the topic of the day, used later during the class to make learners gather information, or in a concluding manner at the end of a topic. Research results in fifth grade showed an increase of 16.4% in conceptual understanding of science in pupils compared to the control group after working with the animations of *BrainPOP* (Barak & Dori, 2011). Animation videos are also used in the game *Immune Patrol* (Immune Patrol, n.d.).

In conclusion, despite the fact that there are still many ongoing discussions on what the exact purposes of serious games and educational video games ought to be (Susi et al., 2007), the recognition of the advantages of video games and the multifaceted purposes of game-based learning is increasing in education (Becker, 2021; Begg, 2008; Grammenos, 2014; Rueda & Cerero, 2021). To summarize, serious games and educational video games for science—and health in particular—not only offer the possibility to visualize abstract concepts or scientific knowledge (National Research Council, 2011), but their purpose can also be implemented into learners' daily lives as these games help develop children's general skills and understanding of the world (Barak & Dori, 2011; Eshach & Fried, 2005). This recognition makes the need for them to be accessible of vital importance, higher even when it comes to games fulfilling purely entertainment purposes (Grammenos, 2014; Hersh & Leporini, 2013). Another reason, apart from the way educational video games can help learners to learn (Begg, 2008), revolves around the gaming audience. The serious games' market has become very broad and now includes both experienced gamers and a general audience of 'learners' who would not necessarily be gamers, but who all need to be able to play the game (Pallavicini et al., 2018; Susi et al., 2007). Also, access to educational technologies can have a serious impact on the future of every person, specifically on the opportunities of individuals with limited access (Grammenos, 2014; Hersh & Leporini, 2013). It is therefore highly important that these games are accessible to all pupils so as not to stigmatize disabled (or minority) learners, making it impossible for them to receive parts of their education (Hersh & Leporini, 2013; Peña-Miguel

& Sedano, 2014). This need for serious games to be made accessible, will be further discussed in the next section.

3. ACCESSIBILITY

Accessibility means that products, services, and environments are made in such a way that they are understandable to all people and that every individual is able to use them (Aguado-Delgado et al., 2020). Mangiron (2012) mentions that concepts such as "access, within reach, easy to communicate or deal with, capable of being used or seen, being understood or appreciated" (p. 45) can all be linked to media and modern technologies, referring to media accessibility. More specifically, media accessibility makes products that include audiovisual media content accessible to users (Greco, 2016). Although media accessibility is still looked at from very different points of view (Greco, 2018; Greco & Jankowska, 2020) and game accessibility in particular is prone to two very different approaches when it comes to game development (Mangiron & Zhang, 2016), research on media accessibility is increasing due to the focus on a more inclusive society and several universal rights (Aguado-Delgado et al., 2020; Greco, 2016). This will be discussed in the following sections.

3.1 MEDIA ACCESSIBILITY AND HUMAN RIGHTS

Traditionally, media accessibility adopted a 'disability focus' as a starting point when examining accessibility (Greco, 2016). This means the focus was on a specific disability and ways to solve it, as such creating a very staggered approach, rather than a 'universalist' view derived from human rights, which starts from the product and aims at making it accessible to all (Greco, 2016; Greco, 2018; Mangiron & Zhang, 2016). Taking human rights as a starting point when considering accessibility gives way to various arguments and interesting observations. Greco (2016) states that human rights are now deeply embedded in the life of every individual. *The European Accessibility Act* (European Commission, 2019) offers a clear elaboration on the fact that being able to access information, services and products is a human right and specifically adds the right to access audiovisual media services. Another significant

human right is the right to receive education, as set out by the Universal Declaration of Human Rights (UNESCO, n.d.; United Nations, 2015), which underlines that any person—regardless of social, economic, cultural, physical, or mental factors—has the right to learn.

There are, nevertheless, still ongoing discussions on whether accessibility is a human right per se or rather a tool to receive human rights, feeding the occurrence of two groups of scholars: those adapting a staggered approach on accessibility and those taking on a more universalist approach (Greco, 2018; Greco & Jankowska, 2020). The former applies accessibility to specific groups of people or barriers, mostly sensorial barriers, whereas the latter defines accessibility as a broad concept and as a tool to guarantee the human rights of every individual (Greco & Jankowska, 2020). Although both movements are still present today, the universalist account is undergoing an upward trend since the particularist approach is very limited on both modalities and audiences (Greco & Jankowska, 2020). Grammenos (2014) also defines accessibility in a much broader sense, referring to it as "providing any person access to something" (p. 22). Therefore, this universalist approach is "steadily grounded within the instrumental view of accessibility and does not limit itself to any specific group" (Greco & Jankowska, 2020, p. 64). As a result, more research now "adopts a holistic approach in which media accessibility does not tackles *[sic]* exclusively sensorial barriers" (Media Accessibility Platform, 2017). In this sense, instead of making a person's disability the cause of the disadvantage from a medical point of view, it is more fitting to start from a social model in which different barriers created by society are the issue, not the person experiencing them (Hersh & Leporini, 2013). This means that the different needs people have are merely part of human diversity (Greco, 2016; Greco, 2018; Hersh & Leporini, 2013).

3.2 MEDIA ACCESSIBILITY IN VIDEO GAMES

Video games, too, are a type of audiovisual media—that everyone should be able to access (European Commission, 2019). Therefore, video games play a vital role in today's society when it comes to cultural or leisure activities (Greco & Jankowska, 2020) but also learning purposes (Grammenos, 2014). However, this growing prominence in audiovisual content brought with it the risk of exclusion, segmentation, or stigmatization due to its diverse audience (Costales, 2014; Hersh & Leporini, 2013; Mangiron, 2012), raising more awareness to its connection with

human rights (Greco & Jankowska, 2020). Nonetheless, there is still a major gap in research on accessibility in video games (Chakraborty et al., 2014) and the existing research is often very partial (Mangiron & Zhang, 2016). What makes this gap even wider, is the fact that current guidelines take on different approaches and can vary in purpose, therefore recommending both similar and differing solutions (Larreina-Morales, 2023). As a result, this tendency makes it challenging to pick a single guideline when working on or analyzing accessibility in video games (Larreina-Morales, 2023). Moreover, many of these guidelines have not been designed with educational games in mind (Salvador-Ullauri et al., 2020b). Companies such as *Microsoft* now do offer their own specific accessibility guidelines, but they also note that the industry is still at an initial phase (Microsoft, 2023). A work of interest are the Game accessibility guidelines, providing accessibility references on basic, intermediate, and advanced level related to how much work and adaptations are needed (Game accessibility guidelines, n.d.-c). The living document also offers an Excel checklist on all three levels (Game accessibility guidelines, n.d.-c). The guide explains that basic accessibility features refer to adaptations that are applicable to most games, with remapping (reconfiguration of controls), text size, adaptations for color deficiencies and the way subtitles are the main considerations to include in order to already make a noticeable change (Game accessibility guidelines, n.d.-c). Still, according to Grammenos (2014), many games have been and are still being developed on the 'myth of the average player' or the process of development focuses firstly on developing the game to only later find out what the problems are. Although guidelines on accessibility in (commercial games) are still very limited, interest on academic and development levels is rising in the last ten years (Grammenos, 2014; Porter & Kientz, 2013). For instance, a recent work by Larreina-Morales (2023) centers around the development of a game analysis tool based on two steps: a checklist on game accessibility features that integrates existing guidelines, followed by user reviews. This way, the paper lays emphasis on the key role of users in the design of accessibility features in games (Larreina-Morales, 2023).

In general, there is a clear tendency when it comes to the level of accessibility in the different games that are developed. Often, there are mainstream games that do not take accessibility into account or only under limited considerations (Grammenos, 2014). The second group can be described as specialized games that are made accessible only to specific users, often to people with impairments, feeding stigmatization (Grammenos, 2014; Mangiron, 2012; Porter

& Kientz, 2013). Particular interest is shown in visual impairments (Porter & Kientz, 2013), thus creating even more categorization. These games offer no visual stimuli, instead providing solely aural impulses, hence called audio games or text-based games (Costales, 2014). Additionally, there is also the repeated tendency to start from people's impairments instead of barriers created by society (Hersh & Leporini, 2013).

3.3 THE NEED FOR GAME ACCESSIBILITY IN EDUCATION

The International Game Developers Institution (IGDA, 2004) defines game accessibility in their whitepaper as "the ability to play a game even when functioning under limiting conditions. Limiting conditions can be functional limitations, or disabilities—such as blindness, deafness, or mobility limitations" (p. 5). But both Grammenos (2014) and Hersh and Leporini (2013) explain that although accessibility is mainly associated with disabilities that are physical, sensory, or mental, not all of these are permanent. The latter can be described as 'diversified needs' or 'limiting conditions', which can occur due to the environment, the used devices or software, or the skills and preferences of the user (Game accessibility guidelines, n.d.-i; Grammenos, 2014; Grammenos et al., 2009). It would be even better to see these disabilities—whether permanent or not—as problems created by society, not by the person facing them (Hersh & Leporini, 2013), which echoes Greco's (2016) claim for a universalist approach to accessibility. Zárate (2021) states this as: "disability is seen as a social construct whereby the individual is disabled by the obstacles posed by society" (p.22).

As such, in the context of video game accessibility, a person should be able to play a video game even when these forces are at play. Examples of limiting conditions can be loud noises in a classroom drowning out the game audio, unavailable headsets when not allowed to play with sound, a pupil with a broken arm or a bruised hand being unable to use a mouse and keyboard and many more (Grammenos, et al., 2009). These constraints can also include playing the game in a different language, as such creating a language barrier (Grammenos, 2014; Torrente et al., 2014). This linguistic barrier points at the fact that accessibility may benefit all individuals and goes further than disability alone, for some pupils may not speak the game's original language, thus needing interlingual subtitles, or intralingual subtitles could

be of aid in a noisy environment or to migrants who are learning the language (Díaz-Cintas, 2020; Grammenos et al., 2009; Greco & Jankowska, 2020). As a result, the need for accessibility is clearly pressing, for access to educational content may affect the future and possibilities of all pupils (Hersh & Leporini, 2013; Peña-Miguel & Sedano, 2014; UNESCO, n.d.). Furthermore, as mentioned before, the main purpose of games used in an educational context, containing scientific information, is to create motivation with a strong emphasis on engaged learning (Begg, 2008). If a player has no or only very limited access to the game, this can lead to frustration and have a negative impact on motivation and engagement (Hersh & Leporini, 2013), and thus on learning (Bierre et al., 2005).

After taking the previously discussed information into consideration, this dissertation will support the claims that accessible video games are of vital importance in education since they aid all individuals (Grammenos, 2014; Hersh & Leporini, 2013; Peña-Miguel & Sedano, 2014) and game accessibility is as such heavily embedded in the human rights framework, with specific interest in the right for education (Greco, 2016; Greco, 2018). Therefore, the dissertaton will take different barriers of the product (the video game) as a starting point, adopting a social model, instead of viewing a person's disability as the cause of their disadvantage (Hersh & Leporini, 2013), in accordance with the limited scope of the research.

4. UNIVERSALLY ACCESSIBLE GAMES

The dissertation previously mentioned two very different approaches on game design (Grammenos, 2014; Mangiron & Zhang, 2016). While Mangiron and Zhang (2016) support a staggered approach as a more suitable starting point—targeting different users and their needs in separate research—they do believe that universally accessible games should still be the preferred design aimed for in the future, since it has become clear that universally accessible games have the potential to be beneficial to all users (Greco & Jankowska, 2020; Torrente et al., 2014). Universally accessible games are based on a game design that considers every individual—every potential user and every possible disability (Mangiron & Zhang, 2016) and these games "can be enjoyed by all kind of users, regardless of their (dis)abilities" (Mangiron & Zhang, 2016, p. 77). What makes universally accessible games stand out, is the

option to adapt their interface, gameplay and content to be most suitable for each individual user (Grammenos, 2014). Grammenos (2014) compares this versatility to a 'palette' that consists of all game elements, which can be selected and customized accordingly. In addition, taking into account accessibility features during the development stage instead of making these considerations much later also bolsters accessibility and inclusion and reduces the work needed (Game accessibility guidelines, n.d.-k).

However, it must be considered that it is, indeed, very hard to develop games that are playable by anyone, regardless of one's differences (Mangiron, 2012) and the lack of consistent guidelines further exacerbates this problem (Larreina-Morales, 2023). It is important to keep in mind that as long as awareness to accessibility is raised and is considered from the onset of the design, change is possible (Grammenos, 2014; Mejiías-Climent, 2021).

5. THE AUDIOVISUAL NATURE OF VIDEO GAMES

Before we can start examining different ways of designing accessible games, the audiovisual nature of video games must be discussed further. This dissertation will support the claim that educational video games, too, use a visual and aural channel to transmit information (Gambier, 2019; Mejiías-Climent, 2021), thus falling under multimedia learning (Barak & Dori, 2011; Rabier, 2005).

As such, video games are audiovisual products, since they consist of audiovisual elements (Gambier, 2019; Vandenbroucke et al., 2022). An audiovisual text contains information that is expressed through different channels: images (visual) and sounds (audio) (Mayer, 2005; Zabalbeascoa, 2008). Audiovisual products also contain verbal and non-verbal signs that create meaning (Gambier, 2019). Both these verbal and non-verbal signs can be expressed through the different channels, thus creating four types of signs through which to express meaning: audio-verbal, audio-nonverbal, visual-verbal, and visual-nonverbal signs (Zabalbeascoa, 2008; Zárate, 2021). As an example, verbal content could be spoken word (audio), expressed through audio-verbal signs or written text (visual), thus consisting of visual-verbal signs (Zabalbeascoa, 2008). Audio-nonverbal signs could be sound effects and music,

whereas pictures consist of visual-nonverbal signs (Mejiías-Climent, 2021; Zabalbeascoa, 2008). The following figure with examples from Zabalbeascoa (2008) further clarifies this:

	Audio	Visual
Verbal	Words heard	Words read
Non-verbal	Music + special effects	The picture Photography

Figure 2: the four elements of audiovisual products, Zabalbeascoa, P. © John Benjamins Publishing Company 2008

However, video games can also consist of a third channel, namely the tactile channel, which can embody a vibrating controller when one thinks of gaming (Mejiías-Climent, 2021). Thus, according to Mejiías-Climent (2021), video games work through audiovisual content and this content is sometimes transmitted through three channels, namely the visual, aural, and tactile channel. What makes video games stand out even more from other audiovisual products, is the fact that this transmission goes two ways and is therefore called bidirectional, from the player to the game and from the game to the player (Mejiías-Climent, 2021). To keep this transmission smooth, the game needs to be accessible (Mejiías-Climent, 2021). However, in most audiovisual products, the audience does not play an active role, think of movies or radio, while video games allow users to become the main-characters of the ongoing action, making accessibility more complicated (Mejiías-Climent, 2021). When the player transmits information to the game, they can do this through the tactile channel—for example the controller—but also through the audio channel—think of speech—or the visual channel—think of written text (Mejiías-Climent, 2021; Torrente et al., 2014). If we consider these three different channels, it becomes clear that users can encounter various problems in interacting with the game, all due to the different channels involved in the communicative process:

- Due to human diversity, the user cannot receive visual, aural, or tactile stimuli from the game—whether stimuli from one, two or all three channels,
- The user does not know how to respond to the stimuli,

- Or the user cannot interact with the game because they unable to manipulate the game's available settings, thus having no way to provide input (Hersh & Leporini, 2013; Mangiron & Zhang, 2016).

Guidelines on universal design include the requirement that the maker of a product should make sure that essential information can be offered through different channels to prevent these problems (Udo & Fels, 2009). Given the right to access information (Vandenbroucke et al., 2022), it is clear that these different channels need to be accessible to all users, so that they can receive the audiovisual product's proper output and additionally transmit their proper input to the product (Hersh & Leporini, 2013; Mejiías-Climent, 2021). Edwards (2018b) calls this a multisensory experience, explaining that it is indeed best if the same message is conveyed through the different information channels. This means that the game is offering the player information twice, through two different mediums (Edwards, 2018b). It must be noted that Edwards (2018b) only mentions the aural channel and visual channel, although designers may also be able to include the third channel, which is the tactile channel (Mejiías-Climent, 2021). As an example, information would then be transmitted to the player through vibrations (Mejiías-Climent, 2021). The dissertation will further elaborate on this in the next section.

6. DESIGNING ACCESSIBLE VIDEO GAMES

To make the audiovisual content in video games accessible, studies suggest the following approaches (Hersh & Leporini, 2013; Mejiías-Climent, 2021; Torrente et al., 2014).

6.1 COMMON PROBLEMS FACED BY DISABLED USERS: A MEDICAL VIEWPOINT

Most work on game accessibility starts by addressing people with impairments and various ways to make content accessible to them, as discussed in chapter 3, 4 and 5 (Hersh & Leporini, 2013; Mangiron & Zhang, 2016). The reason for this is that they are usually the main audiences affected by whether a game has been made accessible or not (Costales, 2014). Starting from this medical point of view, IGDA (2004) provides a popular whitepaper on game accessibility and its importance to disabled players. In general, four main impairments are addressed in

accessibility research, which are visual, aural, mobility and cognitive impairments (Costales, 2014; IGDA, 2004; Mangiron & Zhang, 2016). It is only very recent that more guidelines have been created, which now focus on the channels through which information is transmitted from game to player and player to game, starting from the product (Hersh & Leporini, 2013; Mejiías-Climent, 2021), such as the Game accessibility guidelines. However, it must be noted that these guidelines are usually developed with commercial games in mind (Salvador-Ullauri et al., 2020b).

6.1.1 VISUAL IMPAIRMENT

Visual impairment is subdivided in blindness, low vision, and color blindness (IGDA, 2004). Mangiron & Zhang (2016) make a fair point that the gap between blind and seeing people in gaming is very wide, because video games are still becoming progressively video based and a person who is fully blind cannot perceive any form of visual stimuli (Mangiron & Zhang, 2016).

Low vision refers to people who have very limited sight. Important to the case of gaming is that this loss of vision requires adjustments as it can negatively affect the performance of activities (IGDA, 2004). Common visual problems occur when all hints in the game are given as text without any sound options, when the game has important cut scenes that offer no audio description, when accessibility options are only available in specific languages, when the game does not offer color adjustments, when there is no option to use a screen reader or self-voicing (the game provides all information by voice) or works with voice commands, when there are no audio cues for sound effects or no available sonars to indicate objects and locations (Game accessibility guidelines; n.d.-e-h; Grammenos et al., 2009; IGDA, 2004; Mangiron & Zhang, 2016; Torrente et al., 2014).

Color vision deficiencies occur when cones, eye cells that are used to distinguish color, do not function properly with the color they respond to (Genetic and Rare Diseases Information Center, 2023). There are three types of colors to which three types of cones respond, and these colors are red, green, or blue (Genetic and Rare Diseases Information Center, 2023; Hasrod & Rubin, 2016). A person can have problems with one cone or multiple, thus having a different view from another person (Hasrod & Rubin, 2016). Trichromats is a term that

classifies people with normal color vision, while people with achromatopsia have cones that function abnormally or not at all (Hasrod & Rubin, 2016). Dichromats have only two functioning cones while anomalous trichromats can perceive all three colors but the sensitivity of one of the cones is altered (Hasrod & Rubin, 2016). For example, a person with a monochromatic view, is usually totally colorblind (Hasrod & Rubin, 2016) or they have one functioning cone, which is the case in blue cone monochromatism (BiopticDriving, 2010; Genetic and Rare Diseases Information Center, 2023). Regarding the color that causes trouble, three terms are used, two of which refer to different types of red-green color blindness (Colblindor, n.d.-d). Protanopia is used for people who have difficulty with red light (red-green color blindness) (Colblindor, n.d.-b). Deuteranopia (red-green color blindness) refers to people who are sensitive to green light (Colblindor, n.d.-a). The third form of color blindness is tritanopia (also called blue-yellow color blindness), which refers to troubles with blue light, creating difficulties to see yellow (Colblindor, n.d.-c; Game accessibility guidelines, n.d.-d). For instance, the combination of green and red is often problematic, for it can be hard for those people to distinguish the difference (Colblindor, n.d.-b-d; Game accessibility guidelines, n.d.-e; Harolds, 2012).

6.1.2 AURAL IMPAIRMENT

Although visual elements are still of highest relevance in video games, a recent development has brought forth the use of complex and deeper storylines, so that sounds increasingly carry meaning as well, additionally creating aural barriers (Costales, 2014; Mejiías-Climent, 2021).

Aural impairment is split up into two main categories, ranging from hard of hearing to deafness, although these categories are very diverse themselves (Costales, 2014; IGDA, 2004). When talking about deafness, a distinction has to be made between the terms deaf and Deafness (Doof Vlaanderen, n.d.). Deafness refers to the medical condition of deafness or hearing loss (Doof Vlaanderen, n.d.). People who are deaf may use natural languages to communicate or they are familiar with hearing aids or other assistive devices (The Deaf Health Charity SignHealth, n.d.; Zárate, 2021). The term Deafness with a capital letter is used to refer to a minority group using sign language to communicate, as these people have been deaf from birth or are pre-lingually deaf, meaning that they lost their hearing before they mastered

natural languages (Doof Vlaanderen, n.d; The Deaf Health Charity SignHealth, n.d.; Zárate, 2021).

Hearing loss, unlike deafness, can vary from mild to profound hearing loss and, as such, it creates very diverse barriers as well (IGDA, 2004). For instance, different levels of hearing loss in gaming occur in players who can still distinguish all sounds but need to turn up the game volume or in players who can only distinguish certain sounds with higher volume and need other accessibility methods for sounds they are unable to hear (IGDA, 2004). Common problems faced by these people are no sound indications on screen or no subtitles (whether interlingual or intralingual) (Hersh & Leporini, 2013; Mangiron & Zhang, 2016; Torrente et al., 2014). Moreover, sounds or music are seldom subtitled, even when they carry meaning (Hersh & Leporini, 2013; Mangiron & Zhang, 2016; Torrente et al., 2014). Again, some of these barriers may also be temporal, such as pupils not being allowed to use sound in class or a noisy background (Grammenos et al., 2009).

6.1.3 MOBILITY IMPAIRMENT

When it comes to mobility impairments, the need for accessibility usually increases with the severity of the impairment as immobility can manifest itself on many different levels (Mangiron & Zhang, 2016). Possible issues are difficulties when using a mouse or keyboard, consoles, or joysticks, or even being unable to use any of these devices due to problems with upper limbs (Accessible.Games, 2022b; Mangiron & Zhang, 2016; Torrente et al., 2014). Some of these difficulties may be temporal: think of a broken arm or finger (Grammenos et al., 2009). However, if players cannot replace the standard input device with an alternative, this can greatly affect their gameplay and enjoyment (Game accessibility guidelines, n.d.-i; The AbleGamers Foundaton, 2012).

6.1.4 COGNITIVE IMPAIRMENT

Cognitive impairment is another highly discussed category. It refers to how well a person can execute a mental task (Costales, 2014). Although cognitive issues are of high importance in gaming, since cognition and learning are closely linked, there is still a lack of research on the

issues it creates and the problem is discussed even less when it comes to commercial games (Torrente et al., 2014). What makes cognitive impairments challenging is that they consist of a broad spectrum, for instance from attention deficit disorder (ADHD) and dyslexia to memory loss, and all of these are subjected to different levels of severity (IGDA, 2004). This makes them very complex and difficult to measure and test (Torrente et al., 2014).

In spite of these categories being commonly used, they take the disability as the cause of disadvantage and do not lay emphasis on the product, and they also do not consider linguistic or textual barriers. (Hersh & Leporini, 2013; Torrente et al., 2014).

6.2 COMMON BARRIERS FACED BY USERS: A SOCIAL VIEWPOINT

In earlier sections 3.2 and 3.3, Greco (2016), and Hersh and Leporini (2013) point out that a staggered approach to accessibility starting from the person's disability can create stigmatization. In a universal approach, the game should be designed from the onset in such a way that it is accessible to all and not just adapted specifically to people with impairments, or created solely for them (Grammenos, 2014; Greco & Jankowska, 2020; Torrente et al., 2014). As such, it is important to consider impairments as barriers created by society instead of adopting a medical point of view in which the cause of the disadvantage is the person's disability (Hersh & Leporini, 2013; Torrente et al., 2014). While a more medical point of view tends to leave out contextual and temporal barriers, a more social approach takes temporal barriers into account as this perspective leaves room for barriers to be permanent and temporal (Gramennos et al., 2009; Torrente et al., 2014). The ICC-project is a good example of not starting straight from disabilities, hence isolating people, as it instead indicates the different meaning-making channels in the audiovisual product as well as which barriers possibly occur when accessing the product's content (Vandenbroucke et al., 2022). Since children learn through visual and aural channels in multimedia learning (Mayer, 2005), we should start from these semiotic channels by indicating possible sensory barriers they may bring forth and how they can be overcome (Mejiías-Climent, 2021).

6.2.1 DIFFERENT BARRIERS CREATED BY THE PRODUCT

That being the case, a social approach makes it easier to include contextual barriers, which are often temporal (Torrente et al., 2014), such as the ones that were mentioned in section 3.3. The ICC-project identifies both temporal and permanent sensory barriers (aural and visual), linguistic barriers (this refers to language related issues, such as not mastering the offered languages), cultural barriers (the way in which a different background may affect how a person interprets or receives a message) and textual barriers (which centers around clarity and difficulty of the audiovisual text) (Vandenbroucke et al., 2022). Instead of describing these as 'disabilities' or 'impairments', they are called barriers because they are problems created by the product (Udo & Fels, 2009). The next two sections will further elaborate on textual and linguistic barriers.

6.2.2 TEXTUAL BARRIERS

Textual barriers offer a useful lens when discussing scientific information in a game, because information being presented understandably is also a way of offering access (European Accessibility Act, 2019; Vandenbroucke et al., 2022). In the ICC-project, these barriers refer to terminology—complex sentences, for example—and non-linguistic elements (Vandenbroucke et al., 2022). Non-linguistic problems that occur include "the use of abstract concepts, the density of the information, the lack of clear priorities in the text, the separation of main points and details, the lack of (terminological) consistency, textual coherence and clarity, and an ill-structured layout" (Vandenbroucke et al., 2022, p. 16). Section 2.4 also offered different ways of how scientific information is effectively added in multimedia learning, which highlights the importance of taking textual information into account in educational video games as this may affect the pupil's understanding (Mayer, 2005).

6.2.3 LINGUISTIC BARRIERS

Since translation also plays a big part in the accessibility of games, linguistic barriers are of vital importance to discuss (Mangiron & Zhang, 2016). After all, translation grants access to more players by providing them with a game version in their birth language (Costales, 2014). However, there is still a lack of research on the gaming experience when playing in one's mother tongue or the original language (Costales, 2014). Also, some games do not offer

accessibility solutions in all languages, which creates an even bigger language barrier (Mangiron & Zhang, 2016). Additionally, even though subtitles are often created for people without disabilities in the game industry, translating games is also beneficial to people who face an impairment, such as subtitles for the deaf and hard of hearing (SDH) (Costales, 2014; Díaz-Cintas, 2020; Zárate, 2021). It is clear that translation forms a key element in providing the user with a pleasurable gaming experience (Costales, 2014).

6.3 APPROACHES TO SOLVING THE BARRIERS FACED

In order to make games accessible, existing accessibility guidelines tend to split their guidelines into categories, which differ. For example, the Game Accessibility Guidelines (n.d.-k) include accessibility solutions on a basic, intermedia and advanced level while the guidelines by the AbleGamers Foundation (2012) are split up into three different levels, ranging from bare minimum accessibility solutions to what an ideal accessible game would look like. Torrente et al. (2014) do not use specific tiers but mention two approaches. They state that "compatibility with assistive technologies" (Torrente et al., 2014, p. 58) is the most common accessibility feature and the other approach is to adjust the game settings without needing a specific device, for example subtitles (Torrente et al., 2014). On the contrary, an article by Marie Dealessandri (2022) on a beginner's guide to creating accessible games, prioritizes the "big four" of accessibility, which are believed to be: subtitles, text scaling, color blindness settings and remapping of controls. The Game accessibility guidelines (n.d.-c) mention these four as well, adding that addressing them can already have an impact on a large number of users. *Can I Play That?* (CIPT, n.d.) is an initiative that also offers accessibility information and guidelines by using the different categories discussed in section 6.1, but this means that these guidelines place emphasis on disabilities and take those as a starting point. This approach comes close to the guidelines by IGDA (2004) as mentioned in section 6.1, although CIPT includes a Game PR and marketing accessibility guide on top of these (CIPT, n.d.).

This dissertation also elaborated on how a game provides output to the user and how the user needs to provide input to the game, an interaction that has to be smooth (Mejiías-Climent, 2021). To facilitate this smooth interaction, the product should provide output to the player through different solutions if the player cannot access all channels (R8S ENTERTAINMENT LTD,

n.d.). Torrente et al. (2014) discuss three input models in their accessible game design: the Mouse Interface Module (MI), the Voice Interface Model (VI) and the Natural Language Interface Module (NLI). MI is the classic input module in *point-and-click* games and revolves around mouse movement and clicking on objects to trigger interaction, which can create both visual and mobile barriers (Torrente et al., 2014). An alternative can be the use of VI, which is controlled by speech. This way, pupils can give orders to the game (Torrente et al., 2014). Another option is NLI, with the keyboard as input device (Torrente et al., 2014). The third module is also useful in a noisy environment (Torrente et al., 2014). The Game accessibility guidelines (n.d.-d) add that users should consistently be able to use the same input device for the game menus as well as for the gameplay. Likewise, the game provides output through a visual, sound and speech synthesis module (Torrente et al., 2014). In conclusion, this specific method by Torrente et al. (2014) highlights the importance of both the input and output channels for product and player and the need to make them accessible.

6.3.1 ACCESSIBILITY-MAKING: VISUAL BARRIERS

All significant visual elements can be described by utilizing audio description (AD) (Mejiías-Climent, 2021). Not only is AD useful for people with a visual impairment, but AD also aids other individuals by providing them with visual descriptions even when their focus is elsewhere (Udo & Fels, 2009). Moreover, AD helps people with learning difficulties because it singles out the most vital visual elements (Udo & Fels, 2009). As such, AD could be added to audio menus, which only provide text-to-speech, to fill in visual components that are also of significance (Mejiías-Climent, 2021). All of the reasons above also show why AD is beneficial to language development in children (The Royal National Institute of Blind People, 2009). Even so, AD remains challenging because it must fit within the game without interfering with other sounds, such as dialogues and music, while at the same time keeping up with the game's speed (Matamala, 2021; Mejiías-Climent, 2021). This is why a distinction has to be made between the game mode itself and cut scenes in the game. Cut scenes and cinematic scenes more commonly provide AD, as this is less challenging than offering AD during the gameplay itself (Game accessibility guidelines, n.d.-g; Mejiías-Climent, 2021). More difficult is real-time content generated by gameplay, as it is more dynamic and not set, because it is also depended on the input of the player (Game accessibility guidelines, n.d.-g). The online video platforms

YouTube recently offers the addition of an audio track (Google, 2023a). This way, creators can include AD in their video. Although it is often used for music, it also supports AD (Google, 2023a). However, because the feature is not yet available for many videos as it is new in use, not many people know of it, so the question remains whether it will be used (VocalEyes, 2020).

Another option, which is useful not only to people with visual impairments, is a screen magnifier or high contrast mode, making it possible to zoom in on objects or make them clearer (Torrente et al., 2014). In addition, vibrations can help guide the player to relevant objects or locations, which is useful when overcoming both visual and aural barriers (Hersh & Leporini, 2013; Mejiías-Climent, 2021; Torrente, et al., 2014). Voice-overs, or self-voicing, can also greatly aid players, as text is read out loud by the game itself (Game accessibility guidelines, n.d.-h). Edwards (2018b) states that every piece of text should have this option. If this is too difficult, screen readers are useful, too, when overcoming these visual barriers (Mangiron & Zhang, 2016). *Chrome*, for instance, offers a web-powered screen reader that reads out web content (Google, n.d.). Other, more comprehensive screen readers are *Narrator* on Windows or *VoiceOver* on Mac (Google, n.d.). Although screen readers are an efficient accessibility tool, it must be stressed that text-to-speech should go hand in hand with image description, although not all screen reader software has this option (Vandenbroucke et al., 2022). Image description explains the contents of an image in more or less detail, and a screen reader could then use that input to read it out to the user (Vandenbroucke et al., 2022). Otherwise, the software would only be able to mention the presence of an image, lacking descriptions of what it portrays (Vandenbroucke et al., 2022). Another difference between screen readers and voice-overs, is that voice-overs can be built into the game (Game accessibility guidelines, n.d.-h). Therefore, players do not have to use an external device, which adds to the user's overall enjoyment (Game accessibility guidelines, n.d.-h).

When it comes to visual barriers created because of color blindness, the game should offer an option to change, add or prevent certain color combinations (The AbleGamers Foundation, 2012). As another possible adaptation, symbols can be added to make it easier to distinguish different colors (Game accessibility guidelines, n.d.-e). It is also helpful to choose a different color for text and title (Harolds, 2012) and a plain background helps readability (Game

accessibility guidelines, n.d.-e). Or, in the case of low vision, higher contrast could make the foreground and background stand out clearer (The AbleGamers Foundation, 2012).

Subtitles are also significant when discussing visual barriers, as subtitle design can affect the experience of the user (Hamilton, 2015). When subtitles are used to solve aural barriers, they can, however, create visual barriers when hard to read (Hamilton, 2015). Different color schemes, font sizes, and more variations can make subtitles difficult to comprehend (de Linde & Kay, 1999). For instance, when there is no high contrast between the subtitles and the background or when the subtitles are too small (Hamilton, 2015; Game accessibility guidelines, n.d.-b). Small subtitles can be problematic both in permanent (long sightedness) and temporal (using a small screen, such as a phone screen) situations (Game accessibility guidelines, n.d.-b). Therefore, it is helpful if players can choose a font size for themselves, as there is no set font size that works for everyone (Game accessibility guidelines, n.d.-b, n.d.-f). Letterboxing also helps to give extra contrast over a background (Hamilton, 2015). This is done by adding a black stroke or box behind subtitles or other text. Lastly, it is best that all of these adaptions can be done by using a game menu (Grammenos, 2014).

6.3.2 ACCESSIBILITY-MAKING: AURAL BARRIERS

Subtitling is still used as the main tool to overcome aural barriers (Costales, 2014). In that case, subtitles for the deaf and hard of hearing audiences (SDH) are generally used (Díaz-Cintas, 2020; Zárate, 2021). SDH also has to consider the translation of non-verbal sounds, such as music, soundtracks, and sound effects but also intonation or accents—a complex task (Zárate, 2021). When there is more than one speaker, these subtitles also indicate who is speaking (Neves, 2019). However, many subtitles still do not consider the subtitling of important sounds, which can be crucial to playing the game, even when the subtitles are not designed for deaf and hard of hearing audiences specifically (Díaz-Cintas, 2020; Mejiías-Climent, 2021).

Apart from vibrations to simulate or point out sounds (Mejiías-Climent, 2021), indications on a screen or a map can also help guide players towards significant sounds or objects, for example the indication of dangerous situations in a shooting or fighting game (Costales, 2014).

6.3.3 ACCESSIBILITY-MAKING: MOBILITY BARRIERS

As seen in section 6.1.3, players may not be able to use the game's standard input device (The AbleGamers Foundation, 2012). As this can affect their enjoyment, they are therefore in need of alternatives (The AbleGamers Foundation, 2012). Full remapping of keyboard, mouse and/or console is classified as "mobility level 1—good" by The AbleGamers Foundation (2012) and the Game accessibility guidelines (n.d.-c), too, classify this option as accessibility on a basic level. The game accessibility guidelines (n.d.-d) also stress that players should be able to access the user interface through the same input method as the gameplay. To make this clear, this means that if players can play the entire game using mouse only, they should also be able to use mouse only when making adaptations in the game settings. A user on *Reddit* explains this very clearly: "If I can perform 90% of in-game actions using only the mouse, don't make me pick up a keyboard for the remaining 10% (radiosilents, 2017)".

Lastly, Edwards (2018a) stresses the in-game autosave feature and states that it "can be especially helpful to players with mobility disabilities who find menus cumbersome to navigate" (Section Autosave).

6.3.4 ACCESSIBILITY-MAKING: LINGUISTIC BARRIERS

On linguistic levels mainly regarding translation, audio could be conveyed through recorded voices, providing dubbing (Costales, 2014; Mejiías-Climent, 2021). Despite the possibility of dubbing, subtitles are still most commonly used in video games (Costales, 2014). Apart from SDH, players may need interlingual subtitles if the game is not available in their native language (Costales, 2014). In addition, intralingual subtitles (whether SDH or not) can also be helpful to non-native speakers, such as migrants (Díaz-Cintas, 2020). These subtitles, however, are also very challenging because subtitling standards are often not applied in game translation (Mangiron, 2018). When subtitling, the game accessibility guidelines advocate for a maximum of 40 characters per line and not more than two lines per subtitle (Hamilton, 2015; Game accessibility guidelines, n.d.-f). However, many gaming companies do not allow reductions in the subtitling (Mangiron, 2018) and so, despite these findings, a general occurrence is that one-line subtitles can still go up to over 70 characters per line and some

consist of more than two lines (de Linde & Kay, 1999). Subtitle compression can be affected by other factors as well, one of them being relevance between what is simultaneously shown as images and what is shown as text, also known as subtitle synchronization, which can also make it harder to reduce text (de Linde & Kay, 1999; Zárate, 2021). However, too much text can have a higher cognitive impact because comprehension becomes harder (Hamilton, 2015). Textual presentation will be discussed further in section 6.3.4.

Due to the rise of Artificial Intelligence (AI), subtitles generated through automatic speech recognition (ASR) have also been on the rise as an alternative to human subtitling (Malakul & Park, 2023). Nowadays, they are used in educational settings as well (Malakul & Park, 2023). Since the game that will be analyzed in this dissertation also makes use of educational videos, the matter is very interesting to look at. A recent study by Malakul and Park (2023) investigated the use of automatic subtitles in Thai language for English educational videos and found them to have a positive impact on pupils. Other studies apart from the one by Malakul and Park (2023) also show that subtitles facilitate learning as learners receive information visually and aurally (Cao et al., 2019; Liao et al., 2019). Additionally, by bridging the gap between hearing, seeing, and reading, subtitles can help learners to visualize what they see even more efficiently (Danan, 2004; Garza, 1991; Malakul & Park, 2023; Mayer, 2005).

YouTube is one of many online platforms now using automatically generated subtitles through voice recognition (Google, 2023d). However, automatic subtitling is not available in all languages and not all videos can make use of the feature (Google, 2023d). In addition, automatically generated subtitles still lack quality in comparison to subtitling done by professionals (Chan et al., 2019). Moreover, these automatically generated subtitles often contain no punctuation (Song et al., 2019) and a recent study by Datta et al. (2020) on subtitling discovered that the availability of punctuation improved the viewing experience not only for people with hearing deficiencies but also for hearing people, thus helping to overcome probable aural barriers. Smith et al., (2017) also investigated how the level of errors in automatic captioning affected comprehension of the materials. The study showed that a higher error rate, lowered comprehension (Smith et al., 2017). However, it must be noted that *YouTube* now gives creators the option to add and edit their own subtitles, and they can also edit subtitles generated by the ASR (Google, 2023b-c).

6.3.5 ACCESSIBILITY-MAKING: TEXTUAL BARRIERS

Firstly, when it comes to textual barriers, it is important that information is presented understandably to all (European Commision, 2019; Vandenbroucke et al., 2022). In this dissertation, this is linked back to section 3.2 and 3.3 on scientific information and how it is presented in the audiovisual product. It needs to clarify abstract scientific concepts, be useable during different phases of the learning process and create clear visualizations of these concepts (Barak & Dori, 2011).

Secondly, subtitles were discussed earlier in this chapter. However, the way subtitles are presented can also impact comprehension (Hamilton, 2015). It is, for instance, better to create breaks within a text according to the natural flow and punctuation of a sentence (Hamilton, 2015). Lastly, the Game accessibility guidelines' (n.d.-j) living document points at plain language, providing examples for the English language. Sentences should be short, around 15 to 20 words, consisting of one main idea and perhaps one related point (Plain English Campaign, n.d.).

6.3.6 ACCESSIBILITY-MAKING: A SHORT SUMMARY

To summarize, there is a clear increase in accessibility guidelines and accessibility measures with both guides offered by gaming or computer companies (e.g., *Microsoft*) and through collaborative efforts such as guidelines by the Game accessibility guidelines, CIPT or The AbleGamers Foundation. In general, earlier studies and guidelines tend to take on a medical viewpoint, hence starting from the person's disability, whereas more recent guidelines adopt a social approach which starts from the product (Greco & Jankowska, 2020; Hersh & Leporini, 2013). However, discussing the medical viewpoint is relevant as well to better understand different impairments when making a product accessible (IGDA, 2004). Therefore, it was also included in the chapter.

Because this dissertation supports a social viewpoint, this research will focus on the main findings in section 6.2 and 6.3. In more detail, this means the research will take in account all

accessibility-making measures that were explained in section 6.3 when they are applicable to the case study. These measures are taken for five different barriers: visual, aural, tactile, linguistic, and textual barriers. These barriers are discussed via the three information channels: the visual, aural, and tactile channel. Since various sources, including the Game accessibility guidelines (n.d.-c) and the article by Dealessandri (2022), emphasize the four most common accessibility measures, these will specifically be looked at in the case study and the research will investigate whether they have already been considered. As a reminder, these four adaptions are: color blindness settings, remapping, subtitle (presentation) and text scaling (Dealessandri, 2022; Game accessibility guidelines, n.d.-c).

7. METHODOLOGY

7.1 RESEARCH QUESTION AND RELEVANCE

The increasing popularity of game-based learning has made way for the widespread use of serious games in education (Becker, 2021; Begg, 2008; de Freitas & Liarokapis, 2011; Yuan et al., 2010). Although research on game accessibility is increasing, Grammenos (2014) states that many games are still initially being developed on the 'myth of the average player'. Besides this believe, the process of development focuses firstly on developing the game to only later find out what the problems are, although it is more feasible to consider accessibility from the start of the design process (Game accessibility guidelines, n.d.-k; Grammenos, 2014). Moreover, companies such as *Microsoft* note that the industry is still at an early stage (Microsoft, 2023) and guidelines vary in purpose and approach (Larreina-Morales, 2023). Also note that most of these guidelines are generally designed with commercial video games in mind, as guidelines for educational games still lack specific focus on accessibility (Hersh & Leporini, 2013; Salvador-Ullauri et al., 2020b). All of these reasons make it hard for many learners to overcome the various barriers they face, since the different channels that are used to communicate information are not always designed in such a way that they are accessible to all (Grammenos, 2014; Yuan et al., 2010). When it comes to education, the need for accessibility is even more pressing as various studies have pointed out different advantages of games for learning (Begg, 2008; de Freitas & Liarokapis, 2011; Mayer, 2005; Peña-Miguel &

Sedano, 2014; Zyda, 2005), including their benefits in daily life (Eshach & Fried, 2005). The game that will be analyzed in this dissertation, *Immune Patrol*, is a project of the World Health Organization and an example of such an educational game that holds relevance to life outside of the classroom (Copenhagen Game Lab, n.d.). The game aims to teach children of ages 10 to 12 more about diseases, vaccination, and the immune system, simultaneously exposing them to various ways on how to analyze and assess offered information (Immune Patrol, n.d.) Given the Covid-19 pandemic, the accessibility of this game is even more pressing (WHO, 2023.). As such, it is of vital importance that the provided information is accessible to all pupils, since education is a human right as set out by the Universal Declaration of Human Rights (United Nations, 2015). Therefore, the research question of this dissertation is: in what ways have or can the different information channels in the educational game, *Immune Patrol*, be made accessible to pupils?

7.2 SCOPE: CHANNELS AND AUDIENCE

Since there has been a shift in the way accessibility is approached, meaning that is no longer tackled in a stigmatizing way based on impairment alone (Greco, 2016), this dissertation takes on a social viewpoint. Accessibility of the game content provided through the visual, aural, and tactile channel will be discussed. Since the game content is transmitted through three information channels, this means I will focus on what barriers occur within these channels in the educational video *game Immune Patrol.* I will explain in what ways these barriers can be overcome by offering solution or pointing them out if they have already been added to the game. I will specifically start from the source text and its message content, indicating what barriers people may face through the visual, aural, and tactical meaning-making channels, instead of taking impairments or limitations as a starting point. This means that when information is provided through the visual channel—think of symbols—this may create visual barriers and these can be solved through the aural channel, hence making the audiovisual product more inclusive. These solutions will all be taken from chapter 6. Also, note that not all of these barriers are permanent (Grammenos et al., 2009). As such, the dissertation raises awareness to the presence of limiting conditions and the relevance of accessibility to all.

It is also important to keep in mind that the analysis always starts from the source text. Although solutions to barriers may be provided through other channels, these solutions will be added to the discussed information channel. For instance, if the analysis focuses on barriers that occur in the visual channel and these hinderances can be solved through the aural channel, they will still be discussed under the visual channel. This is because the analysis starts from the source text—the text as it is at the moment of the research.

The selected barriers in this work are:

- Sensory barriers (IGDA, 2004; Vandenbroucke et al., 2022) which are subcategorized as follows:
    - Visual barriers,
    - Aural barriers,
    - Tactile barriers.
- Linguistic barriers: these barriers refer specially to available languages in the discussed game. Linguistic barriers pertain to how well a person masters a language as a native or a foreign speaker (Vandenbroucke et al., 2022).
- Textual barriers, which have to do with the way textual information is presented (Vandenbroucke et al., 2022).

In sections 2.3 and 2.4, I also explained some interesting features in serious games and health education specifically. Because *Immune Patrol* presents information on healthcare (WHO, 2023), I will also briefly discuss whether the game contains these features, because these can have a positive effect on learning and because they are an essential part of educational video games (Begg, 2008).

Throughout the analysis, I will keep in mind the intended target audience of the game, which are children aged 10-12 (Immune Patrol, n.d.).

7.3 DESIGN OF THE FRAMEWORK

To examine the availability of accessible features in the game as well as the way scientific information is presented, a theoretical framework was developed based on the literature

research of game accessibility measures carried out in chapter 6. As I discussed earlier, the literature research makes a distinction between two game categories: commercial video games and serious video games. In this dissertation, I focus on serious games as the game I will analyze in chapter 8 is an educational video game. After discussing both the medical and social viewpoint, the analysis will be based on the social approach. The findings at the end of chapter 6, in section 6.3.6 specifically, are used in the analysis. I will categorize the game content into three output channels: the visual channel, the aural channel, and the tactile channel. Then I will discuss possible barriers that may occur, which are based on the literature research in sections 6.2 and 6.3. For every barrier that I mention, I will identify existing adaptations or suggest possible measures, that I explained in section 6.3, to make the three communication channels accessible.

7.4 CASE STUDY: IMMUNE PATROL

Immune Patrol is a digital game-based educational platform and a project of the World Health Organization (Copenhagen Game Lab, n.d.) Developed in light of the recent Covid-19 pandemic, *Immune Patrol* teaches children of ages 10 to 12 more about healthcare, specifically providing information on diseases, vaccinations, and the immune system (Copenhagen Game Lab, n.d.). In addition, pupils will also learn how to critically analyze and assess sources (Copenhagen Game Lab, n.d.; WHO, 2023). Pupils work in groups, defending their avatar from diseases (Copenhagen Game Lab, n.d.). By solving different tasks, pupils will receive points which they can use to boost their avatar's immune system, making their game character more resilient (Copenhagen Game Lab, n.d.).

The game offers a *Teacher's Manual* and an Introductory video on *YouTube* (Immune Patrol, n.d.). According to the Manual, each lesson should be structured the same way. First, pupils watch an animated video which explains the topic (Immune Patrol, n.d.). Then, pupils can log in to the game using a specific code and create their avatar (Immune Patrol, n.d.). During the class, pupils have certain tasks to complete after which they are to do an assessed presentation (Immune Patrol, n.d.). Lastly, they play a (battle) game related to the lesson (Immune Patrol, n.d.). At the beginning of the game, Lieutenant Juliet is introduced as the

pupils' trainer (Immune Patrol, n.d.). The character guides the audience through the game in videos and also functions a pop-up giving instructions and hints (Immune Patrol, n.d.).

The game consists of six different modules, each elaborating on information regarding healthcare (Immune patrol, n.d.). The different modes are called: diseases and transmission, the immune system, vaccination, herd immunity, vaccine development and source criticism. The teacher has full control over the game through a group page so that they can start the game, end it, or refresh it (Immune Patrol, n.d.). The game can be played on a computer or tablet for the pupils and the teacher can use a smartboard, projector, or computer to supervise (Immune Patrol, n.d.).

Figure 3: Training grounds of *Immune Patrol* © Copenhagen Game Lab

Since *Immune Patrol* is an educational game, with specific focus on scientific information, it also provides learning goals (Immune Patrol, n.d.). The main goal is the development of scientific literacy, which includes the explanation and understanding of phenomena, re-organizing information, discussing information, preparations for presenting information and critical thinking (Copenhagen Game Lab, n.d.; Immune Patrol, n.d.; WHO, 2023).

It is important to note that the World Health Organization is still revising and optimizing the game (WHO, 2020). The WHO is requesting for revision of the current modules in the game, performance optimization, aiming to specifically add a section regarding Covid-19, translating the game into 60 different languages, and making visual elements easier in use (WHO, 2020).

7.5 PROCESS OF ANALYSIS AND DISCUSSION

Since the dissertation is too limited to take the full game into account, seven different parts have been selected for the analysis. In all of these parts, content provided through the different information channels will be identified—the visual, aural, and tactile channel. I will use these three different items, as some game parts provide only visual information, whereas others offer visual and aural information, which can be presented verbally and/or non-verbally. There will also be sections in which players will have to interact with the game. Then the game content will be analyzed in regard to whether it has already been fully or partially adapted to the target audience or, if not, how the content can still be made accessible to the audience.

To keep a clear overview, I will point out the channel's accessibility problems on one hand and on the other hand propose solutions offered in the guidelines discussed in chapter 6. I will do this because, in most cases, these solutions are specific to one item. Therefore, I choose to combine the analysis and discussion in chapter 9, as it is more convenient if the solutions are proposed immediately after identifying hindrances. To end with, a brief overview follows in chapter 10 to highlight main findings and indicate limitations of the study.

Be aware that some of the barriers and solutions may overlap for different parts. When this is the case, the corresponding sections will be mentioned but they will not be considered in greater detail as these barriers and accessible features have already been discussed previously or will be discussed later on. This way, repetition can be avoided. Lastly, the most significant observations will be brought together in the conclusion in chapter 10, which ends with suggestions for further research.

8. ANALYSIS

In this chapter, I will analyze and discuss the educational video game *Immune Patrol*. With the recent Covid-19 pandemic in mind, the game aims to teach children of ages 10 to 12 more about healthcare and it exposes them to various ways on how to analyze and assess information sources (Immune Patrol, n.d.). Pupils must work in groups, defending their character from diseases (Copenhagen Game Lab, n.d.).

8.1 TITLE SCREEN: TEACHER MODE/PUPIL MODE

This part is controlled by the teacher, but the pupils will also get to see this screen when they open the game following an assigned link. This means they will have to select the game language as well, regardless of the language chosen by the teacher.

8.1.1 VISUAL CHANNEL

When starting *Immune Patrol*, the audience first gets to choose the language of the game. At the moment of this research, there are six available options. From left to right, these are visually shown as English (British), Danish, Armenian, Romanian, Uzbek and Georgian, represented as country flags. This availability of six playable languages, however, can have a significant impact on the game audience, not only causing a linguistic barrier for people who have to play the game in a foreign language that they do not master well enough (Vandenbroucke et al., 2022), but it can also limit the audience down to only native speakers of these six languages (Vandenbroucke et al., 2022). Although this lack of translation may have an impact on the audience, it is important to note that the World Health Organization aims to extend the available languages to an amount of 60 (WHO, 2020), therefore reducing this linguistic barrier in the future.

For the sake of this research, the game will be played in English, since the author's native language—Dutch—is not yet available.

Figure 4: Title screen and language selection of *Immune Patrol* © Copenhagen Game Lab

As seen earlier, video games express information and meaning through images (visually) and sounds (aurally) and verbal and non-verbal signs (Gambier, 2019; Mayer, 2005; Zabalbeascoa, 2018). However, the game's title screen does not offer any form of aural information, meaning that information is presented through the visual channel only. In *Immune Patro*l, this information is presented in a visual non-verbal way only, as it solely shows different countries' flags indicating available languages. This way of presenting information may create visual barriers.

Firstly, a player with color vision deficiencies may have trouble distinguishing the flag's colors, consequentially not knowing what language they represent. This can especially be the case with the Romanian flag. These troubles become clear when using a color blindness simulator, which displays different color blindness deficiencies depending on what view is selected (Colblindor, 2006-2021; Wickline & Human-Computer Interaction Resource Network, 2000-2001). The following generated pictures show that the Romanian flag can be easily confused with a seemingly Italian flag (figure 5) because of tritanopia (Hasrod & Rubin, 2016) or a seemingly Belgian flag (figure 6) because of blue cone monochromacy (Genetic and Rare Diseases Information Center, 2023; Hasrod & Rubin, 2016).

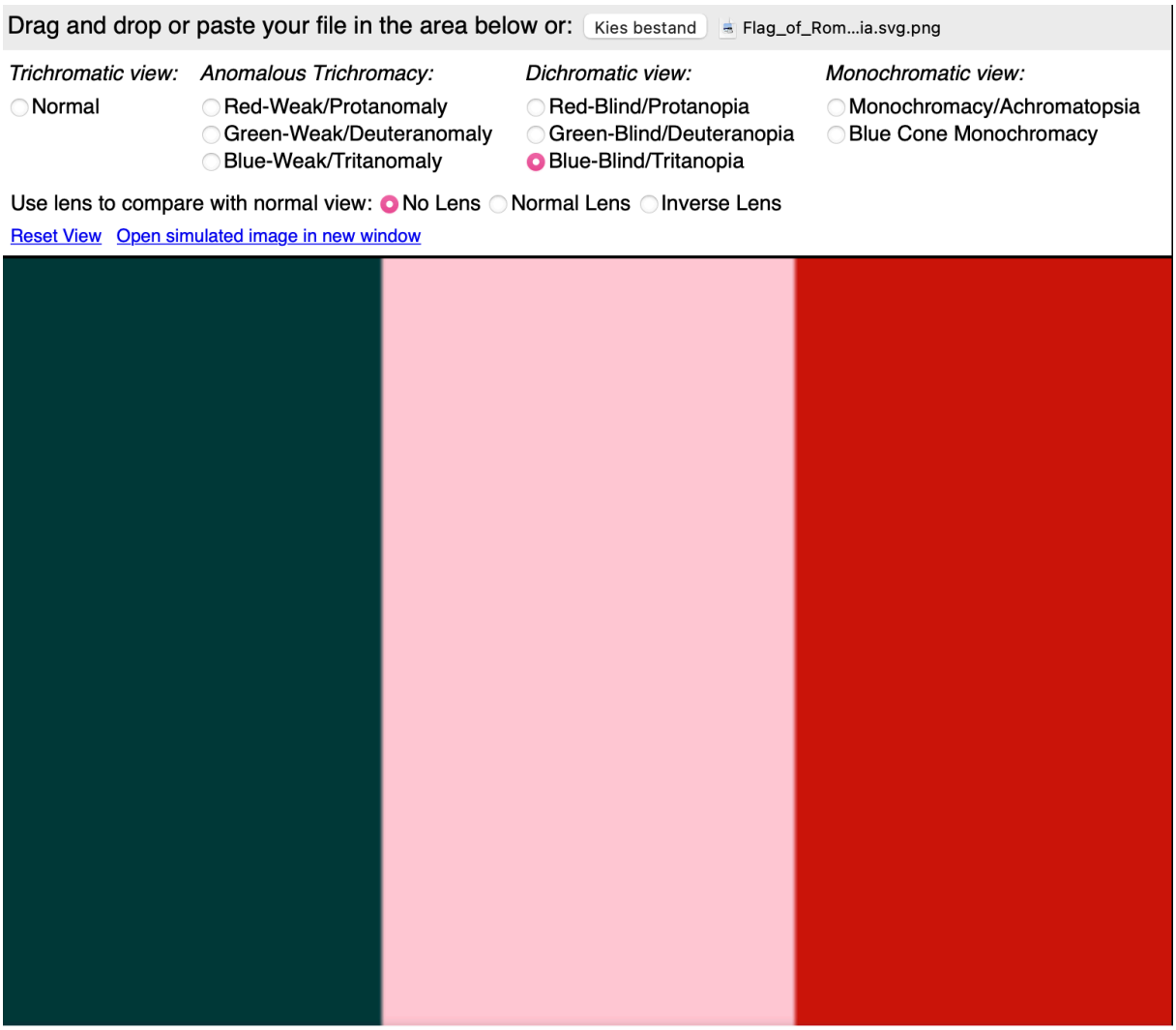

Figure 5: Romanian flag through dichromatic view: Blue-Blind/Tritanopia © 2000-2001 Matthew Wickline and the Human-Computer Interaction Resource Network

Figure 6: Romanian flag through monochromatic view: Blue Cone/Monochromacy © 2000-2001 Matthew Wickline and the Human-Computer Interaction Resource Network

To overcome this visual barrier faced by people who experience a form of color blindness, the language or country name could be added above or underneath the flag in written text, or a symbol could be designed to clarify the flag's exact meaning (Accessible.Games, 2022a; The AbleGamers Foundation, 2012). Nonetheless, a combination of information presented visually and aurally would still be the preferred option. Not only could this combination overcome other visual barriers than color blindness alone, but also because it similarly combines different learning channels, which can additionally aid information processing for pupils who can access both channels without any barriers (Barak & Dori, 2011). Edwards (2018b) calls this a multisensory experience, in which output is provided through both the visual and aural channel.

The use of the aural channel will be discussed in this section also, as it makes the visual output channel available in this game part. Firstly, if the text were to be added underneath the corresponding language, a great feature would be the addition of the text being voiced out loud to the user through voice-overs (Game accessibly guidelines, n.d.-h; Mangiron & Zhang, 2016). To preserve the game's authentic feeling, Lieutenant Juliet, for instance, could take on that function, as she fulfills the roll of being instructor. Throughout the game, she is used as a pop-up to give instructions and tips, although these are not voiced out loud, and she is also the game character who explains all information in the *YouTube* videos pupils will have to watch (Immune Patrol, n.d). This feature would create a multisensory experience, and the game would additionally offer output through two channels: the visual channel and aural channel (Edwards, 2018b). Therefore, in the case of the language-selection menu, Lieutenant Juliet could point out the different available languages both through aural output (spoken text) and visual output (written text).

Another option could be the addition of an audio menu (Grammenos, 2014). However, since the game currently does not support this feature, another possibility would be the use of a separate screen reader, which would already aid enjoyment (Mangiron & Zhang, 2016). Users could install it on their device, for instance the screen reader offered by *Chrome* (Google, n.d.). Keep in mind that this screen reader must be able to offer image description because, at the moment of this research, the visual information is still only presented as non-verbal images (Vandenbroucke et al., 2022).

8.1.2 AURAL CHANNEL

The language-selection menu initially does not offer any form of output information through the aural channel. Therefore, it is not used in this game part.

If the game were to include the aural channel, it could make the language-selection menu into an audio menu, use voice-overs, or mention that users would have to turn to a screen reader (Game accessibility guidelines; n.d.-h; Mangiron & Zhang, 2016; Vandenbroucke et al., 2022), as discussed in section 8.1.1.

8.1.3 TACTILE CHANNEL

In this menu, players can only use a mouse to interact with the game. At this point, the game does not offer any form of vibrations to provide helpful output, for example when the mouse pointer is hovering over different languages (Mejiías-Climent, 2021). Although a mouse and keyboard are essential to play, there seems to be no option to use a controller or other haptic devices. Thus, a tactile barrier is created for people who are unable to use a mouse and/or keyboard (Torrente et al., 2014). Control remapping is not offered either (Game accessibility guidelines, n.d.-a). As another alternative, it would be helpful to make the game work with voice input (VI) for pupils who cannot use mouse and keyboard (Torrente et al., 2014). However, as seen in section *8.1.2 Aural Channel,* this option is currently not supported because there is no information transmission through this channel.

8.2 WELCOME SCREEN: TEACHER MODE

This part is controlled by the teacher. Yet it is still important to discuss, since these elements ought to be as accessible as possible too, regardless of which user is consulting them. Moreover, pupils will also get to see it when the teacher projects in on the screen in class (Immune Patrol, n.d.).

Once the player has selected a language, a 'Welcome' screen appears. For this part of the game, there is also an animated video on *YouTube*, which elaborates on the basic textual information provided on the 'Welcome' screen through audio and images. This way, the game does provide aural-verbal information by using spoken text, and at the same time it visually shows how the game is played through video. This combination of channels is a very effective way of introducing pupils to the game, since people who learn through both channels are provided with visual images that additionally clarify the information that is communicated through spoken text (Barak & Dori, 2011; Mayer, 2005). This is the first example of the game utilizing the two main channels at the same time, adding pictures to words (Barak & Dori, 2011; Mayer, 2005). However, it remains essential that these channels can be modified, so that they all offer the same information to users who cannot access every channel (Edwards, 2018b).

8.2.1 VISUAL CHANNEL

The “Welcome” screen offers some more information on *Immune Patrol*. Again, this information is provided through the visual channel only and presented as text (Immune Patrol, n.d.). This means that the audience will have to use a screen reader if they have trouble accessing the visual channel (Mangiron & Zhang, 2016), although the use of a voice-over (Edwards, 2018b; Game accessibility guidelines, n.d.-h), for instance by Lieutenant Juliet, would aid enjoyment even more. This feature was discussed in greater detail in section 8.1.1.

Addressing the visual channel of the video mentioned in section 8.2 here, there is no AD available. This means users who cannot access the visual channel will miss out on a lot of information. This is also the case for the other videos in the game, which is why the use of AD will be further elaborated on in section 8.4.1 *Visual Channel*. Observations made there are applicable to the video in this section as well. The audio in this video will be discussed in section 8.2.2.

8.2.2 AURAL CHANNEL

With regards to the aural channel, the game does not provide in-game subtitles for this video. This may cause an aural barrier. Although this barrier can be temporal on some occasions, it still needs to be considered. A noisy classroom when playing the game is an example of a possible temporal aural barrier and subtitles would greatly reduce this problem both temporarily and permanently (Grammenos, et al., 2009).

Since *Immune Patrol* does not offer its own subtitles, pupils will have to consult the subtitle options in *YouTube*. However, in spite of the fact that *YouTube* offers automatically generated subtitles (Google, 2023d), these should not be used as the standard, for they can still consist of errors (Chan et al., 2019). Furthermore, the automatically generated subtitles are available in other languages than the video language—English—but this availability does not fully solve the previously mentioned linguistic barrier in section 8.1.1 *Visual Channel* (Grammenos, 2014; Grammenos et al., 2009; Torrente et al., 2014). The reason for this is that although these interlingual and intralingual subtitles may aid native and non-native speakers (Díaz-Cintas,

2020; Grammenos et al., 2009), it is questionable whether these subtitles will have a positive effect considering their lack of quality, as *Google* itself admits that the feature is prone to misinterpretations, and it omits punctuation (Google, 2023d; Song et al., 2019). This can increase the cognitive load (Smith et al., 2017). The dissertation will further elaborate on *YouTube* generated subtitles in other languages in section 8.4.2.

What does make *YouTube* an interesting platform to use, is the fact that it offers subtitle customization (Google, 2023b-d). It also gives creators the option to add their own subtitles and edit them, or the possibility to edit the subtitles generated by ASR (Google, 2023b-d). SDH subtitles can also be added (Google, 2023b), although they are not available for this video. As a result, significant sounds and/or music, elements that may be essential to the game, are not indicated (Mejiías-Climent, 2021). It would be interesting to add this feature to the videos, as closed captions can also aid players who have no problems accessing the aural content to differentiate between what is important and what is not (Mejiías-Climent, 2021). This option to add SDH does, however, show that accessibility of the existing subtitles can be improved. As such, the game developers may have made a good choice of not adding their own subtitles to the *YouTube* video by burning them onto the screen—then, users would not be able to customize them through the online platform, likely causing an overlap between the original subtitles and the added subtitles if they prefer the *YouTube* subtitles. Therefore, a trade-off has to be made between the fact that the presence of these subtitles can facilitate learning by connecting hearing, seeing, and reading (Cao, et al., 2019; Danan, 2004) and the errors generated by the ASR if the designers do not revise these subtitles or add their own subtitle files to *YouTube* (Smith et al., 2017). If *Immune Patrol* were to fully add the videos in-game—without linking to *YouTube*—subtitle customization and the selection of interlingual, intralingual and SDH subtitles would only be possible if the game offered all of these settings itself.

In addition, the way these *YouTube* subtitles are presented must be further discussed. When they are used to access the aural channel, their design can still affect the user experience visually (Hamilton, 2015). Text scaling, for instance, is one of the "big four" stressed by Dealessandri's article (2022) and the Game accessibility guidelines (n.d.-k). Therefore, it is good to know that the automatically generated subtitles by *YouTube* offer a lot of

customization settings (Google, 2023c). The audience can change their size, which is helpful if the subtitles are not large enough when watching on a small screen or when the user has troubles with vision (Game accessibility guidelines, n.d.-b). Subtitle presentation is another main categorization mentioned in Dealessandri's article (2022) and the Game accessibility guidelines (n.d.-k), and *YouTube* does offer the option to change font style, color, and contrast (Google, 2023c). These are all very helpful tools. Users can also add or delete letterboxing and they can additionally adapt the transparency and color of the box (Google, 2023c). This is a valuable feature, because letterboxing and high contrast help to make subtitles stand out clearer from the background (Hamilton, 2015).

If all of these findings are taken into consideration, the use of automatically generated subtitles by *YouTube* is a good choice to start with, because *YouTube* offers valuable customization options, although it is best if these are revised by the game designers to avoid grammar and spelling mistakes (Song et al., 2019).

8.2.3 TACTILE CHANNEL

Once again, apart from using a mouse, there is no option to choose another (haptic) device or to remap controls or buttons.

8.3 TEACHER INTRO AND CONTROL PANEL: TEACHER MODE & PUPIL MODE

This part is firstly controlled by the teacher, although pupils will also get to use the control panel later on. Here, the visual channel will be briefly discussed, as it holds importance in regard to user settings, which are an essential part of making games accessible (Grammenos, 2014).

When coming to the teacher intro, the user can consult the control panel for the first time. The panel offers various adjustments, which are: changing the language of the game, starting a new module, jumping to different modules, deleting the account, logging out, and downloading the *Teacher's Manual*. However, there seem to be no settings that take on a universally accessible game design offering and supporting adjustments that can fulfill the

needs of individual users (Grammenos, 2014). This is the so called ‘palette’, as mentioned by Grammenos (2014), consisting of all customizable gaming elements. To go into further detail, the user has no access to visual settings (e.g., color adaptions), sound settings or even subtitle or control settings. The settings menu is therefore not comprehensive enough, as it does not offer any settings that aid accessibility apart from language setting in regard to linguistic barriers (Grammenos, 2014).

8.3.1 VISUAL CHANNEL

The control panel is only accessible as visual information. This means that the audience cannot access it properly if they have difficulties with this channel. Firstly, there is no audio menu or voice-over available, reading out the control panel options (Game accessibility guidelines, n.d.-h; Mejiías-Climent, 2021). As a result, the only option for troubled pupils is to use a screen reader (Mangiron & Zhang, 2016). Secondly, users are also unable to adjust text size for in-game text if they have low vision (Game accessibility guidelines, n.d.-b-f).

The game does use contrasting colors for the background and the foreground (The AbleGamers Foundation, 2012). In this case, mostly white and purple. Here, the plain white background aids readability (Game accessibility guidelines, n.d-e).

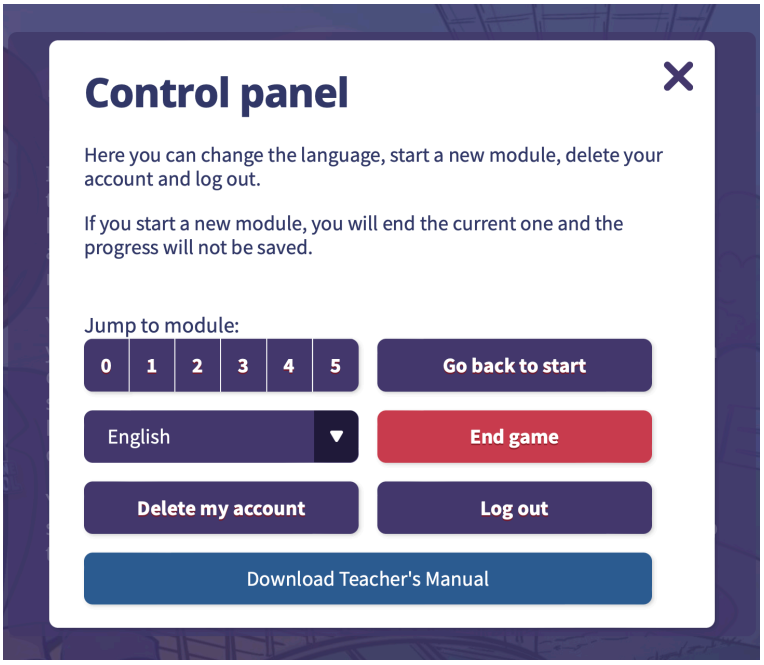

Figure 7: Control panel *Immune Patrol* © Copenhagen Game Lab

8.3.2 AURAL CHANNEL

This part of the game does not offer any form of information through the aural channel. The user is also unable to change any settings related to audio.

8.3.3 TACTILE CHANNEL

The Game accessibility guidelines (n.d.-d) highlighted the importance of being able to use the same input device for both game menus and gameplay. However, the game menus are only controllable by mouse, whilst some game parts demand the use of mouse and keyboard. It is important that this usage is consistent, meaning that if the game has been designed for solely using mouse, then the entire game and game menus should be able to be played by mouse only (Game accessibility guidelines, n.d.-d). In the case of *Immune Patrol*, the use of different haptic devices, such as controllers, and consistent use of these devices in particular needs to be taken into consideration to broaden accessibility. Additionally, there is no option to reconfigure keyboard controls in the menu, although this would be beneficial when it comes to temporal barriers, for example if pupils are using an AZERTY keyboard instead of a QUERTY keyboard when writing a text (Game accessibility guidelines, n.d.-a).

8.4 LOG IN SCREEN: PUPIL MODE

Although, according to the *Teacher's Manual*, the game should be played in groups, it is still essential that information can be provided through all different channels, because every pupil should be able to enjoy the game to the fullest (Mangiron & Zhang, 2016). Moreover, the fact that the game is primarily designed to be played in a group makes it more likely that the product needs to adhere to multiple requirements (Greco, 2018).

Firstly, pupils can log in by using the code the teacher provides them with (Immune Patrol, n.d.). This code consists of numbers only. After they have logged in, the game shows a 'Welcome screen' with a brief overview of *Immune Patrol*. It mentions a video that the pupils should watch before starting the game (Immune Patrol, n.d.). In section 2.4 *Scientific*

information in serious games, Barak & Dori (2011) already wrote that the addition of a video at the beginning of a class attracts attention and helps to summarize the topic before they pupils dive into it. It is clear that *Immune Patrol* also follows this effective way of including animations in learning environments. The video will now be discussed in greater detail, focusing on information transmission.

8.4.1 VISUAL CHANNEL

As mentioned in section 8.4, the visual channel offers an animated movie. As seen earlier, animations, including animated videos or movies, not only increase scientific thinking and curiosity in pupils (Barak & Dori, 2011) but the combination of images and words also aids information processing and will help pupils to visualize abstract concepts (Barak & Dori, 2011; Mayer, 2005; National Research Council, 2011). Some examples: when the game mentions vaccines, the video pictures an image of a needle filled with medicine, or when the game refers to viruses, the video provides the viewer with a drawing of a virus (WHO Regional Office for Europe, 2022a). This way, children get to see an image of scientific concepts—here, viruses—that they would be unable to observe in their daily lives (National Research Council, 2011).

However, if pupils cannot access the visual channel, they would miss out on a great amount of valuable information. In that case, the use of AD could be beneficial, for instance, by describing all visual elements that are of importance in understanding the game, as Mejiías-Climent (2021) argues. Not only would the presence of AD help lift this visual barrier, but it could potentially aid all pupils as seen in section 6.3, where it was pointed out that AD can aid a sighted audience, too, to focus on what is actually important by grasping their attention and guiding their gaze toward significant elements (Udo & Fels, 2009). However, this process will be challenging as AD needs to be added between speech and sound without creating any overlap (Mejiías-Climent 2021).

The addition of AD can also be applied to the introduction video for teachers, as seen in section 8.2.1. Keep in mind that AD is recently offered by *YouTube*, but the feature is not yet widely known (VocalEyes, 2020).

8.4.2 AURAL CHANNEL

A considerable amount of information in the video is transmitted through speech. Although the visual channel provides numerous clear visualizations of the concepts and activities presented, the aural channel is still essential, too, to understand the presented information., Similarly to the video discussed in section 8.2.2, subtitles are not automatically visible on screen to help make the information accessible through other channels when a player is faced with an aural barrier. At first glance, the subtitles that are provided by *YouTube* have been generated by speech recognition and are intralingual (Google, 2023d; WHO Regional Office for Europe, 2022a), meaning that they are available in the original language of the video which, in this case, is English. Additionally, the video consists of a lot of sounds that grasp attention, but these are not subtitled either, as there are no closed captions available. Although *YouTube* supports SDH, it was mentioned earlier that creators have to manually add SDH via the creator menu (Google, 2023b). This means the product is still prone to creating both temporal barriers, for instance in a noisy classroom (Grammenos, et al., 2009), but also to lasting barriers, such as for people with hearing impairment (Costales, 2014; IGDA, 2004). Moreover, these automatic captions provided by *YouTube* have no punctuation, which may negatively impact the viewing experience of the pupils (Datta et al., 2020; Song et al., 2019). This was also the case for the subtitles in section 8.2.2, although this can be fixed if these subtitles are edited by the creators.

As briefly mentioned in section 8.2.2, there is a possibility to choose automatically generated subtitles in other languages (Google, 2023b). This will now be discussed in more detail. The dissertation will look at the Dutch subtitles because Dutch (Flemish) is the author's native language. Although the ASR does not make any considerable mistakes in its accuracy, non-existing punctuation may lower readability (Datta et al., 2020), which also means that the subtitles do not follow the natural speech flow (Hamilton, 2015). There are also still some slight translation errors that could negatively impact comprehension (Smith et al., 2017). The following examples (Figure 8, 9 and 10) show how the absence of punctuation makes these subtitles very confusing to read. Correspondingly, they contain grammar mistakes due to slight misinterpretations by the ASR.

Figure 8: Automatically generated interlingual subtitles by *YouTube* © WHO Regional Office for Europe, 2022a

Figure 9: Automatically generated interlingual subtitles by *YouTube* © WHO Regional Office for Europe, 2022a

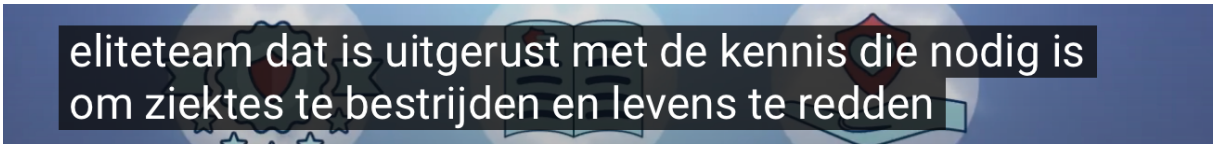

Figure 10: Automatically generated interlingual subtitles by *YouTube* © WHO Regional Office for Europe, 2022a

The original sentences, in spoken English, were: “This is why we need your help. As a patroller, you will be part of an elite team equipped with the knowledge needed to fight diseases and save lives” (WHO Regional Office for Europe, 2022a). The English subtitles generated by the ASR did not include punctuation. The Dutch subtitles, according to the non-existing punctuation with mistakes included, could be translated into English as: “that’s why we need your help as (next line) patrol you will be part of of an (next line) elite team that is equipped with the knowledge needed (next line) to fight diseases and save lives.” Note that the double ‘of’ is also a mistake by the ASR. Not only the absence of punctuation lowers readability (Datta et al., 2020), a clear example of an error by the voice recognition system is the translation of

'patroller' as 'patrol', which changes the meaning of the sentence and can affect comprehension (Smith, Crocker & Allman, 2017).

8.4.3 TACTILE CHANNEL

Again, the only useable devices in this part of the game are mouse and keyboard. No control remapping is available.

8.5 AVATAR CHARACTERIZATION: PUPIL MODE

In this part of the game, the users can create their own avatar. This is worth mentioning, as the game's avatar characterization holds similarities to the concept of the 'virtual patient', described by Begg (2008) and Ellaway et al. (2006) in part 2.4 *Scientific information in serious games*. As was discussed there, virtual patients are frequently used in health education games, and they are made as realistic as possible by adding specific information about their age, gender, and more (Ellaway et al., 2006; National Research Council, 2011). The avatars in *Immune Patrol* could in fact be categorized as virtual patients since they can be customized, which helps making them feel more real in the pupils' eyes (Immune Patrol, n.d.). Players get to choose the avatar's gender, clothing, and facial features (Immune Patrol, n.d.). Just like virtual patients and real people, these avatars can become ill throughout the game, and the player has to function as the immune system, protecting their avatar from infections (WHO Regional Office for Europe, 2022a). In order to do this, the pupils are part of a patrol, and they learn how to protect their avatar in the *Immune Patrol Academy*, which is discussed in this video (WHO Regional Office for Europe, 2022a). This way, a virtual environment is created, with laboratories and tools that aid teachers because these resources would not be available otherwise (National Research Council, 2011). Later on in the game, these virtual training grounds are presented. These are: a briefing room, a combat simulator, an infection simulator, a laboratory and a press room (WHO Regional Office for Europe, 2022a).

8.5.1 VISUAL CHANNEL

The character customization consists of only visual information. The menu is designed in such a way that it does not really create linguistic issues, as players can fully customize their character by using symbols only. However, the absence of textual information does create a visual barrier as it consequentially means that a screen reader would not be able to turn text on screen (visual signs) into speech (aural signs), only if the screen reader supports image description (Gambier, 2019; Mayer, 2005; Vandenbroucke et al., 2022; Zabalbeascoa, 2018). In addition, as was the case in section 8.1.1, it would be viable to add text underneath the symbols to create meaning in both verbal and non-verbal signs (The AbleGamers Foundation, 2012), which would likewise make the use of a screen reader more feasible (Mangiron & Zhang, 2016). Another option is to turn this menu into an audio menu, to point out visual components that are necessary in the characterization process (Mejiías-Climent, 2021). Lieutenant Juliet could also help in this process by using voice-overs (Game accessibility guidelines, n.d.-h), for instance when giving instructions.

Furthermore, the pupils have no option to change any settings in this part of the game. Consequentially, this means that there are no color settings to overcome visual barriers in regard to color blindness deficiencies (IGDA, 2004). The entire color spectrum can be selected for skin color, when customizing an avatar, whereas for hair, clothing and lip color, there are only a few set options. If these settings cannot be changed, this can cause very different output results for pupils. The following two pictures provide an example of this: figure 11 shows the original screen for a person with no color blindness deficiencies, whilst figure 12 and figure 13 have been dragged through the color blindness simulator, rendering a color output for two specific forms of color blindness, namely the game's colors through dichromatic view (tritanopia) and a trichromatic view (deuteranomaly) (Colblindor, 2006-2021; Hasrod & Rubin, 2013; Wickline & Human-Computer Interaction Resource Network, 2000-2001).

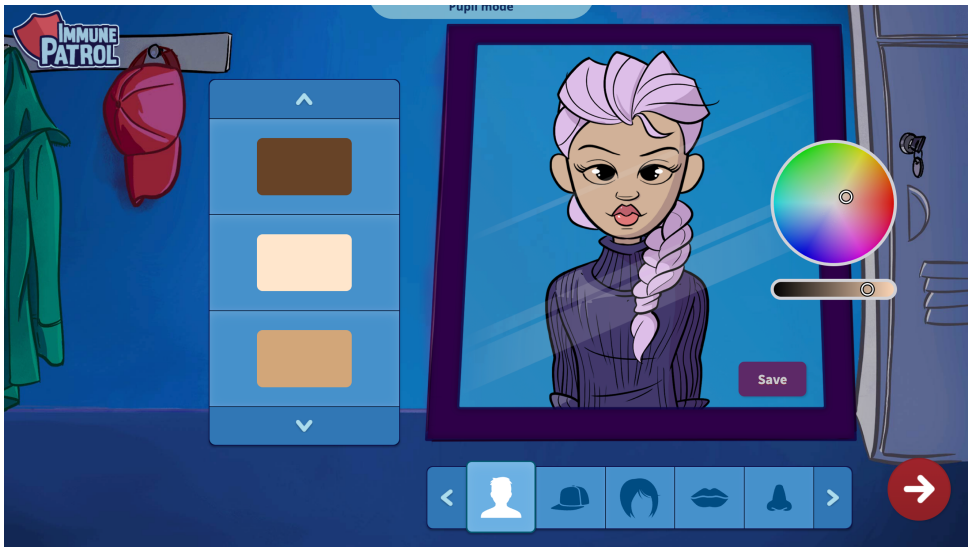

Figure 11: Avatar characterization *Immune Patrol* © Copenhagen Game Lab

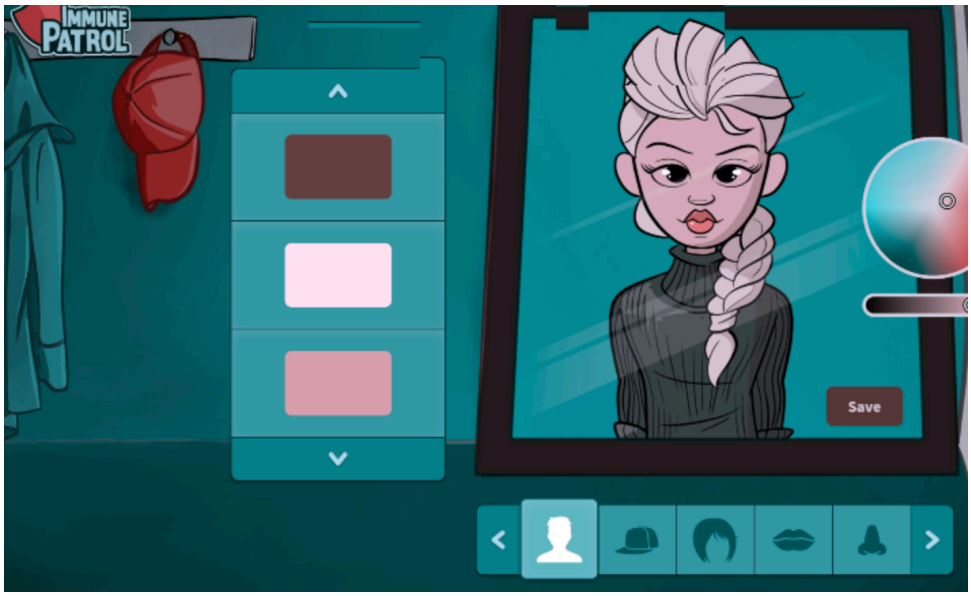

Figure 12: Avatar characterization through dichromatic view: blue-blind/tritanopia *Immune Patrol* © Copenhagen Game Lab, 2000-2001 Matthew Wickline and the Human-Computer Interaction Resource Network

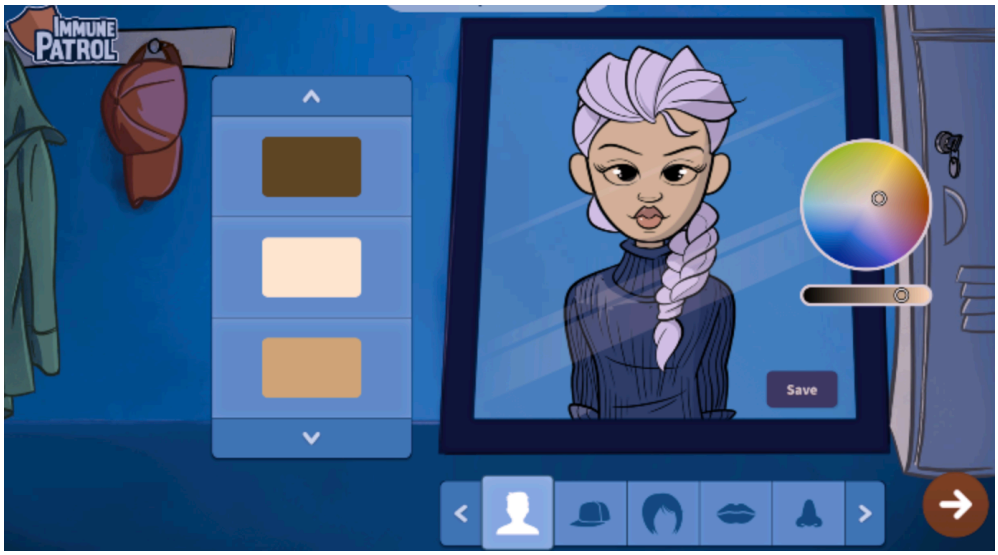

Figure 13: Avatar characterization through anomalous trichromatic view: green-weak/deuteranomaly *Immune Patrol* © Copenhagen Game Lab, 2000-2001 Matthew Wickline and the Human-Computer Interaction Resource Network

The presence of color adjustments could greatly aid pupils with varied needs (Grammenos et al., 2009). Even when working in a group, the pupils could change the color settings to make sure everyone agrees with the chosen colors.

8.5.2 AURAL CHANNEL

The video game does not present information through the aural channel in this part.

8.5.3 TACTILE CHANNEL

Although there are no other haptic devices to use, apart from mouse and keyboard, it is interesting to note that the game does save by itself. This means pupils do not have to press a specific button to save the game. This occurs throughout the entire game and aids accessibility (Edwards, 2018a).

8.6 MODULE 0 ON DISEASES AND TRANSMISSION: PUPIL MODE

This section focuses on the way a game module is presented and played. As seen in the *Teacher's Manual*, every module is briefly discussed and information on the theme is provided for the teacher (Immune Patrol, n.d.). When starting the first module, the game has a teacher

and pupil mode (Immune Patrol, n.d.). The dissertation will provide an analysis on the pupil mode, as this is the target audience related to the research.

In light of scientific information in serious games addressing health care topics, the game is clearly designed in such a way that it teaches scientific principles and helps model science in an accessible and understandable way (National Research Council, 2011). In the first module, the pupils firstly have to do a task, which in this case is taking a quiz (Immune Patrol, n.d.). Pupils have to match definitions about diseases and transmission to the corresponding terms, and these are printed on paper (Immune Patrol, n.d.). This is a good combination of presenting information in a visual-verbal way and an aural-verbal way at the same time (Mayer, 2005). This helps overcome visual and aural barriers because pupils who are faced with aural barriers can read the definition on paper—while the quiz master covers the right term—and pupils faced with visual barriers can listen to the definition being read out loud. Secondly, the groups have to fulfill an online mission (Immune Patrol, n.d.). During this mission, the audience will have to fill in a report on a specific disease, just like scientific reports modeling diseases (National Research Council, 2011). This shows that children will additionally develop general skills (Eshach & Fried, 2005), for example learning how to work in a team, how to think analytically, how to make decisions and how to communicate (Avci & Kamer, 2018), as the pupils will have to pick a disease to work on. *Immune Patrol* itself refers to learning goals and certain skills to be obtained, such as writing skills or using scientific knowledge to fill in a report (Immune Patrol, n.d.). Additionally, Covid-19 is an example of a real-life situation they can learn more about in the game (WHO, 2023).

8.6.1 VISUAL CHANNEL

Before the pupils can start the game, they first get to see a lesson overview. It provides them with a task, explained in a step-by-step manner accompanied by an example picture and a mission they have to fulfill. This information is presented in two ways, namely as text (visual-verbal information) and through an image (visual-nonverbal information). However, this information is not provided aurally, and consequentially the game does not offer a solution for visual barriers. Although a screen reader or voice-over would significantly improve accessibility in this case (Game accessibility guidelines, n.d.-h; Mangiron & Zhang, 2016), it is

important to note that the teacher's role must not be left out, because the teacher can follow tasks in the teacher mode and explain the objectives aurally to the pupils (Immune Patrol, n.d.). Regarding the possible use of a screen reader as mentioned before, an image description would also have to be included, otherwise text-to-speech readers would merely be able to tell the user that there is an image, without describing what exactly it portrays (Vandenbroucke et al., 2022).

The second important game element pupils are provided with, is the resources tab. It offers players a *YouTube* video on diseases and transmission and a mini encyclopedia. The pupils first have to watch the video as an introduction, which is very effective as a learning method before starting their tasks (Barak & Dori, 2011). The mini encyclopedia, too, creates meaning through the combination of visual-verbal signs (words) and visual-nonverbal signs (pictures) (Mayer, 2005). More specifically, the pictures visualize the term the encyclopedia refers to (Immune Patrol, n.d.). For instance, a picture of bacteria is shown in combination with the more abstract term—if it is new to the audience—bacteria itself (Immune Patrol, n.d.). In regard to textual barriers, the information on various scientific terms is presented in short sentences, mainly consisting of one main idea and a related point, as favored by the Plain English Campaign (n.d.).

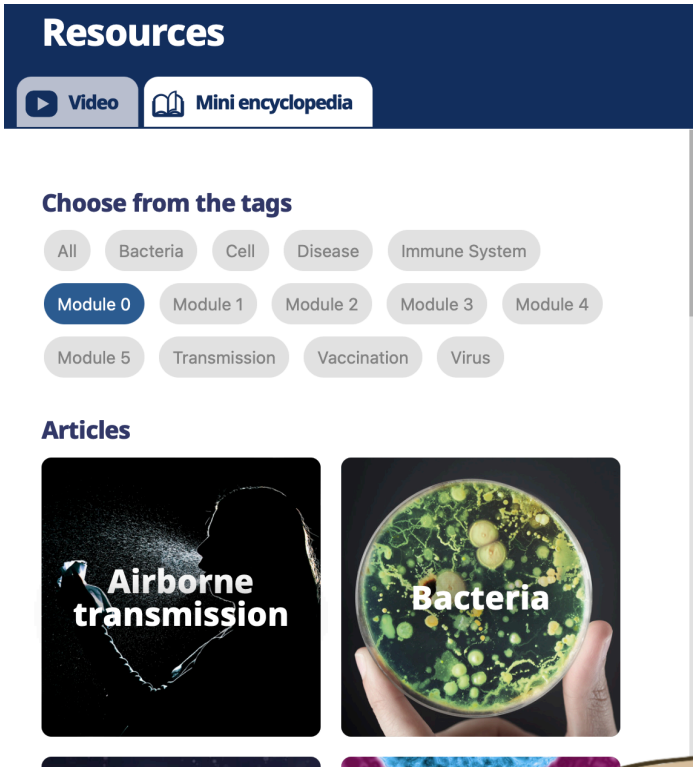

Figure 14: Mini Encyclopedia, *Immune Patrol* © Copenhagen Game Lab

In both cases, voice-overs, and screen readers (Game accessibility guide, n.d.-h) could be helpful. However, there is still no menu for the pupils to change any game settings or activate these features.

Lastly, the introduction video on *YouTube* offers no AD track.

8.6.2 AURAL CHANNEL

Aural information is available through the *YouTube* video only, with no subtitles provided by the game itself. When watching the video, automatically generated Dutch subtitles by *YouTube* were used, which was also the case in section 8.4.2. The subtitles instantly consisted of a spelling mistake. The English word “welcome” was translated as “Welkome” instead of “welkom”, creating a textual barrier and linguistic barrier. This is shown in figure 15.

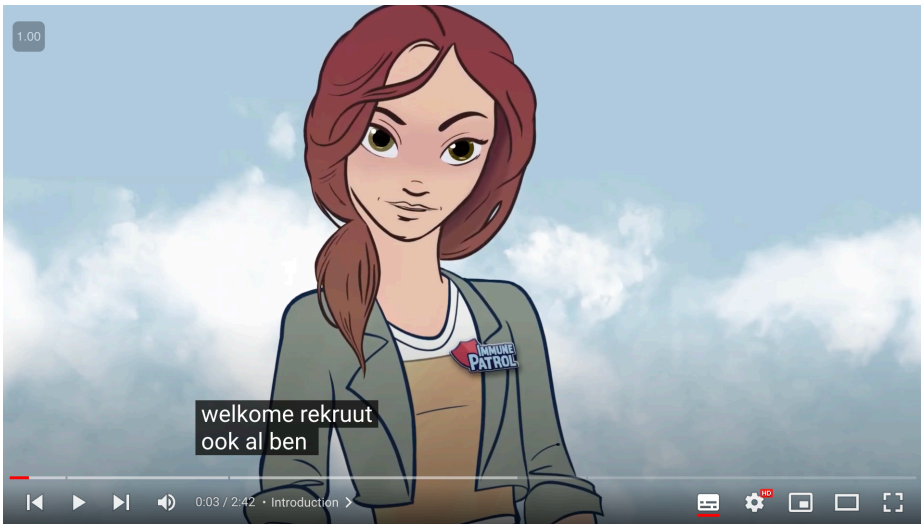

Figure 15: Automatically generated interlingual subtitles by *YouTube*: spelling mistake welcome © WHO Regional Office for Europe, 2022c

Figure 16: Automatically generated interlingual subtitles by *YouTube*: translation mistake patients © WHO Regional Office for Europe, 2022c

The subtitles have even more grammar mistakes, lowering comprehension (Smith et al., 2017) and various sentences can become confusing as they have no punctuation. The Dutch subtitles in figure 16 consist of an interpretation mistake by the generating system. The English sentence was: "(…) if they don't have enough doctors or nurses to take care of all the patients" (WHO Regional Office for Europe, 2022c) and the Dutch subtitles translated "patients" as "het pati", a word that is not available on woordenlijst.org or *Het Groene Boekje*, the official spelling guide for the Dutch language, meaning that it has no proper meaning. This can become confusing to pupils who do understand the source language but have hearing deficiencies and need the English audio (also note that closed captions are unavailable) to better grasp the context and all details, but also to people who have no problem accessing the aural channel but may have insufficient understanding of the original language and therefore need these subtitles as well (Díaz-Cintas, 2020). What is more, in the middle of the video, the subtitles do randomly have punctuation, but this lasts for no more than 2 sentences, which is shown in figure 17.

Figure 17: Automatically generated interlingual subtitles by *YouTube*: punctuation © WHO Regional Office for Europe, 2022c

8.6.3 TACTILE CHANNEL

No other devices apart from mouse and keyboard can be used. Any other (haptic) devices are not supported, or this is not clearly indicated.

8.7 MODULE 4 ON VACCINE DEVELOPMENT: PUPIL MODE

This part of the game takes places in a virtual laboratory, making the game more realistic and these environments are valuable when it comes to logistic difficulties (Ellaway et al., 2009; National Research Council, 2011) as children get the chance to explore these scientific settings.

Pupils are to watch two *YouTube* videos before starting their task and mission (Immune Patrol, n.d.).

8.7.1 VISUAL CHANNEL

Firstly, there is no option to include AD for the two *YouTube* videos. This takes away a lot of the pupils' understanding if they cannot access the visual channel, because the videos are highly important in order for pupils to fulfill their tasks and mission. They will have to watch both videos and then point out differences and similarities in the vaccine development process (Immune Patrol, n.d.). Although the video also discusses this verbally, the visual

representation of these steps is a great help for their understanding (National Research Council, 2011) even when the process would be described by using AD, because AD, as seen earlier, can aid all pupils as it guides the gaze to the most important steps of the process (Mejiías-Climent 2021).

Secondly, the pupils are provided with the mini encyclopedia once more, offering them visual representation of textual information, which is an asset to understanding (Barak & Dori, 2011). However, the effectiveness for all users depends on whether these images can be described via text-to-speech through image descriptions on the screen readers (Vandenbroucke et al., 2022). Another option would be the addition of voice-overs (Game accessibility guidelines, n.d.-h), similarly to section 8.6.1, for instance through Lieutenant Juliet.

When it comes to providing pupils with information on what to do, this is always presented in a short and clear way. As an example, see figure 18 below. The sentences are usually no longer than 15 to 20 words and the main topic is easily identified (Plain English Campaign, n.d.). Also, text is shown on a plain background (Game accessibility guidelines, n.d.-e). Now looking at the pop-up screen in more detail, it would still be a better option to choose different colors for the box and the written text. Currently, both box and text are different shades of blue. This combination is not that easily distinguishable, whereas more contrast and a different color for text and background helps readability (Game accessibility guidelines, n.d.-e). Additionally, as seen in earlier sections on the visual channel, it would be helpful to include a voice-over that reads out the instructions on the pop-up screen (Edwards, 2018b; Game accessibility guidelines, n.d.-h) when lieutenant Juliet is telling pupils what to do, as the information is currently only provided visually. This is also applicable to all the other sections in which lieutenant Juliet gives instructions. Likewise, this would aid a more multisensory experience (Edwards, 2018b).

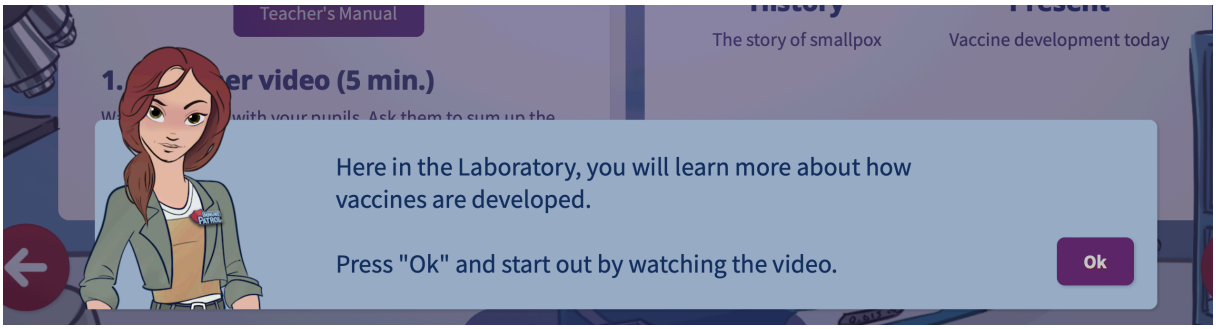

Figure 18: Plain and clear language © Copenhagen Game Lab

The actual, interactive game itself is played through the visual channel and presented in both symbols and written text. This time, however, terms are added underneath the symbols, which was not the case in section 8.5 on *Character Customization*. When pupils press these symbols, they receive some extra information on the vaccine development stage, which they can use as tips (Immune Patrol, n.d.). However, this extra information often consists of one very long sentence for many of the different stages, and it would be better to break them down into parts, all containing a main idea (Game accessibility guidelines, n.d.-j; Plain English Campaign, n.d.). An example of this is the following hint on the stage 'large tests': "The vaccine can now be tested on a large group of healthy people to find out how well the vaccine protects against the disease it was developed for, while still keeping an eye on safety" (Immune Patrol, n.d.). A more feasible option would be to break this sentence down into: "The vaccine can now be **tested on** a large group of **healthy people**. This way, we can find out **how well the vaccine protects against the disease** it was developed for. At the same time, we can keep an eye on **safety.**" Then, we would have three sentences which all contain a main idea, short and clear, yet still related to each other, as prescribed by the Plain English Campaign (n.d.).

8.7.2 AURAL CHANNEL

As was the case in previously discussed *YouTube* videos provided by *Immune Patrol,* these two videos do not include subtitles that have been added by the designers. The automatically generated Dutch subtitles by *YouTube* repeatedly leave out punctuation, except for one sentence in the middle of the video, which also happened in the video on infection diseases, mentioned in section 8.6.2. Apart from this aural barrier and linguistic barrier, the subtitles

also create a textual barrier. However, these problems can mostly be solved if the game developers edit and adapt these subtitles through *YouTube*.

8.7.3 TACTILE CHANNEL

The vaccine development game itself can only be played by using a mouse. Therefore, users can only interact with the game through the tactile channel, as there are no options to provide input by voice or another haptic device and there is no control remapping option either (Game accessibility guidelines, n.d.-a-d-i). Players have to drag different steps of the development process in a box, placing them into a specific order. It would be a great addition to the game if players could use voice input (Torrente et al., 2014) or another haptic device (Game accessibility guidelines, n.d.-i) to arrange the different steps into the right order. Vibrations could also help the player determine where the steps are located and what is important (Mejiías-Climent, 2021), as could audio cues when hovering close or over a step (Edwards, 2018b).

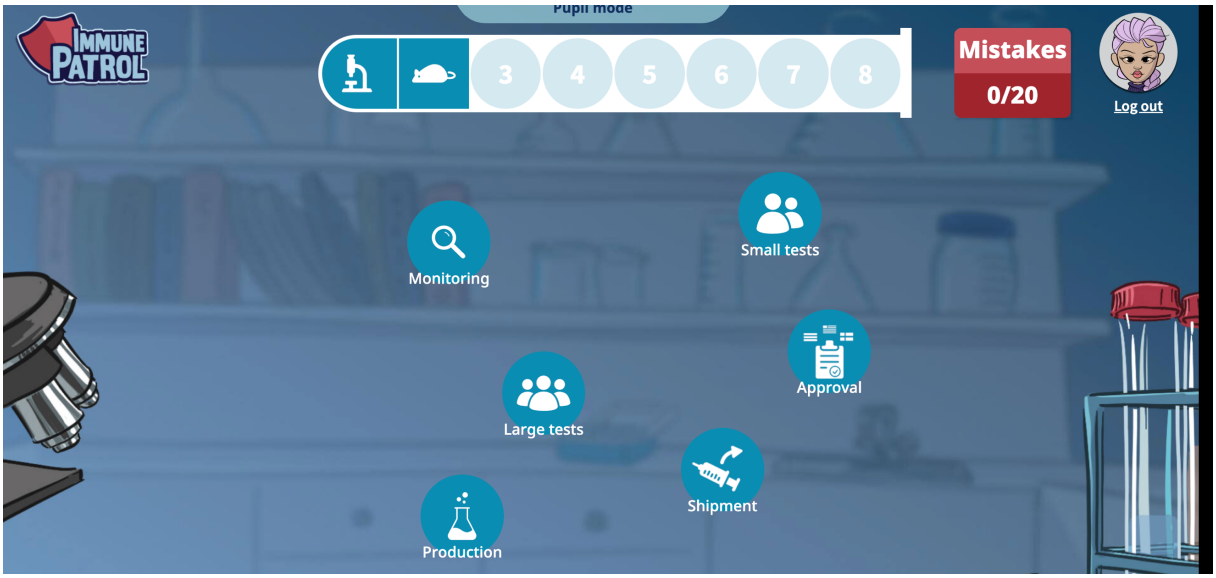

Figure 19: Vaccine development game © Copenhagen Game Lab

9. OVERVIEW OF THE ANALYSIS

The analysis shows that, to a large extend, the three main information channels of the educational video game *Immune Patrol* are not yet accessible. This suggests that, in the case of *Immune Patrol*, accessibility has not been considered from the start of the design phase, as strongly suggested by the Game accessibility guidelines (n.d.-k) and Grammenos (2014). Because of this, the game creates visual, aural, tactile, linguistic, and textual barriers as identified in the chapter 8. However, various accessibility solutions can still be considered. Because a discussion on the game's current accessibility level and the addition of solutions are already included in the previous chapter, this part will come to a brief overview. This overview will also include research limitations and suggestions for further research.

The main finding that the game lacks accessibility measures becomes clear when looking at the four basic accessibility settings stressed in Dealessandri's article (2022) and the Game accessibility guidelines (n.d.-c), since none of these are currently available. Firstly, the game does not offer color blindness settings. Secondly, the crucial feature of text scaling for in-game text is unavailable. Thirdly, control remapping is not an option, and the only usable devices are mouse and keyboard. Lastly, subtitle presentation cannot be discussed in regard to the game itself, as the game does not offer animated videos in-game. The videos have to be watched on *YouTube* and they are only available in English.

It must be noted that *Immune Patrol* makes use of many features that are typical for serious video games and games on healthcare in particular, which has been discussed in section 2.4. It contains virtual laboratories and virtual patients (National Research Council, 2011) and it offers visual and aural information in an efficient way through the combination of spoken word and animations in *YouTube* videos (Mayer, 2005). It also provides a combination of written text and images in-game. As seen earlier, the combination of spoken word and animations presented through the visual and aural channel creates a multisensory experience (Edwards, 2018b), which has a positive effect on learning and the gaming experience itself (Barak & Dori, 2011; Mayer, 2005; SEG Research, 2008). However, this multisensory experience is largely absent in the game itself, since the game almost exclusively provides

information through the visual channel. Therefore, we must also keep in mind that corresponding accessibility measures for animated videos, aiming to make the visual and/or aural channel accessible, have not been provided by *Immune Patrol* itself but are offered by *YouTube*.

Finally, it has to be noted that there are some limitations to this research. Firstly, an essential part of assessing accessibility features is also dependent on the user and user reviews (Larreina-Morales, 2023). This research only laid focus on examining existing guidelines, because adding user opinions to test game's accessibility was beyond its scope. However, in the case of *Immune Patrol*, it would be useful to hear user opinions after the suggested measures in this dissertation have been added to the game, since it has become clear that the game has not yet considered accessibility-making tools. Furthermore, this dissertation briefly looked at characteristic elements of educational video games and their learning advantages and although it noted that the game does offer these features, it has not been tested in practice whether these truly have a positive impact on different users with different needs. Lastly, no screen reader was used to access the game's visual information in this research. Therefore, it would be interesting to test its effectives when used in game parts that contain only visual-nonverbal information.

10. CONCLUSION

The research question of this dissertation was: in what ways have or can the different information channels in the educational game, *Immune Patrol*, be made accessible to pupils?

To underline its relevance, the research firstly provided an overview of the rise in popularity of video games and their broad appliance in other contexts than entertainment alone, such as the military, medical and educational field (Michael & Chen, 2006; Yuan et al., 2010). Then several learning advantages of serious games with specific information on games for science and healthcare in education were described. Because education is a human right (UNESCO, n.d.; United Nations, 2015), it is essential that every person can use and enjoy video games designed for educational purposes and access its content (Peña-Miguel & Sedano, 2014; Salvador-Ullauri et al., 2020b). Additionally, accessible games are even more pressing in times

of crisis such as the Covid-19 pandemic, as *Immune Patrol* is partially designed with the pandemic in mind (WHO, 2023). The game teaches children about healthcare, with specific focus on viruses and the immune system (Copenhagen Game Lab, n.d.). Therefore, all pupils must be able to access this information.

The analysis was based on a literary research of existing accessibility guidelines for video games. However, accessibility is still approached in contradicting ways (Greco, 2018; Greco & Jankowska, 2020) and current game accessibility guidelines need consistency as they take on various approaches and purposes (Larreina-Morales, 2023). Moreover, these guidelines are mostly applicable to commercial games, as little attention is paid to guidelines specifically designed with educational video games in mind (Salvador-Ullauri, et al., 2020b). The reason for this is that accessibility is generally not considered by developers of serious games, although many of the features of existing guidelines for commercial games are applicable to educational games as well (Salvador-Ullauri et al., 2020b).

In order to provide an answer to the research question, this study examined in what ways the content in the educational video game *Immune Patrol* had already been made or could still be made accessible to its target audience of pupils aged 10 to 12. Therefore, the author took on a social viewpoint in which making the product's three information transmitting channels accessible to all was the main aim (Hersh & Leporini, 2013). The analysis focused on the three main information channels of the source text, which are the visual, aural, and tactile channel. For each channel, visual, aural, tactile, linguistic and/or textual barriers were identified. In addition, the research investigated if the game made use of the characteristic features of serious games and educational games on health information in particular, because these all add up to the overall enjoyment and understanding of the game content (Grammenos, 2014).

To start with, the current design of the educational video game *Immune Patrol* does not yet provide accessibility solutions for existing barriers. This suggests that accessibility has not been considered from the start of the game's development, although this is stressed by various researchers and guidelines, including the Game accessibility guidelines (n.d.-k) and Grammenos (2014). Although it is possible to make some changes to the game, many in-game features have not yet been made accessible, and most of these are provided through the

online platform *YouTube* or have to be obtained through other haptic devices, such as screen readers (Mangiron & Zhang, 2016). As a result, troubles occur within all three information channels.

These missing accessibility considerations become very clear since none of the four basic accessibility settings, stressed in the article by Dealessandri (2022) and the Game accessibility guidelines (n.d.-k), are currently available. First of all, the game does not offer color blindness settings (Grammenos et al., 2009) to overcome visual barriers regarding vision deficiencies. Secondly, the size of in-game text cannot be changed to overcome temporal barriers, such as the use of a small screen, or permanent visual barriers, such as low vision (Game accessibility guidelines, n.d.-b-f). Thirdly, mouse and keyboard are the only offered (haptic) devices to use in the game and game menu, although it is better to include various device choices (Game accessibility guidelines, n.d.-i). Despite the fact that control remapping could somewhat reduce this limiting tactile barrier (Game accessibility guidelines, n.d.-a), this option is also absent. In this case, a helpful accessibility tool is the available auto-saving feature, which the game does provide (Edwards, 2018a). Fourthly, because the game does not offer in-game videos, subtitle presentation can only be discussed for the online platform *YouTube*, which already offers some accessibility features to overcome visual and aural barriers, such as the addition and adaptation of interlingual, intralingual subtitles and SDH (Google, 2023b-c-d). These subtitles are necessary, because the game currently offers six playable languages, creating linguistic barriers for the video content, although it aims to add more in the future (WHO, 2023). Moreover, these interlingual subtitles have not been edited by the game creators, as they are automatically generated (Google, 2023d), therefore containing grammar and spelling errors, which may negatively impact comprehension (Smith et al., 2017; Song et al., 2019). Thus, we must keep in mind that the automatically generated subtitles may lack quality and are best edited by game developers, or they ought to add their own subtitle files. Moreover, regarding aural barriers, *YouTube* also supports the use of a soundtrack for AD (Google, 2023a), although this is currently unavailable for *Immune Patrol*. Besides, it must be noted that this feature is not widely known, and video creators have to manually add it (VocalEyes, 2020). As a result, if *Immune Patrol* were to provide these videos in-game, it would have to offer all previously mentioned features by itself as well. If the developers want to keep the videos on *YouTube*, they may have to add a section that explicitly refers to all available

accessibility measures on *YouTube,* so that the audience knows that they have to consult these tools through *YouTube*.

Linguistic and textual barriers regarding in-game text may be more difficult to overcome since the game sometimes uses very complex sentences, with more than one or two main ideas. This is mainly the case in actual game modes, whereas the game's sources (e.g., the encyclopedia) are overall presented in a clear and short way (Plain Language Campaign, n.d.).

Furthermore, accessibility for visual-verbal and visual-nonverbal in-game content can only be overcome by using a screen reader which supports image description (Vandenbroucke et al., 2022). However, the presence of the game character Lieutenant Juliet poses an opportunity to add voice-overs that immerse the player and does not take away the gaming experience (Game accessibility guidelines, n.d.-h). Lastly, for verbal in-game content specifically, the game creates a clear contrast between background and foreground color, but this feature is lost in some parts due to the use of different shades of the same color.

Apart from the accessibility analysis, it became clear that *Immune Patrol* does make use of many characteristic features of serious video games and games on healthcare in particular. It offers virtual laboratories and virtual patients (National Research Council, 2011). Furthermore, it efficiently combines visual and aural information (Mayer, 2005) through animated videos on *YouTube* and it applies the combination of written text and images when explaining in-game tasks and scientific information. This output through the visual and aural channel via *YouTube* videos creates a multisensory experience (Edwards, 2018b) which can have a positive effect on learning and the gaming experience itself (Barak & Dori, 2011). However, this multisensory experience is largely absent in the game itself, since information transmission through the aural channel does not happen in-game.

In conclusion, all of these findings add up to the overall absence of a user settings menu or a so-called inclusive palette that allows players to make accessibility adaptations to the game and, as such, the absence of accessibility in the three information channels (Grammenos, 2014). Although the game clearly makes use of motivational features characteristic of healthcare games and lays emphasis on a multisensory experience and multimedia learning

(Edwards, 2018b; Mayer, 2005), it is not yet designed in such a way that it makes this information accessible to all its users. However, the game does offer opportunities to add various accessibility features in the future, which have been discussed in this dissertation, and the WHO aims to do so (WHO, 2023).

A number of recommendations can be formulated for research on and the analysis of future educational video games. First of all, as mentioned by Larreina-Morales (2023), there still is no standard framework for analyzing accessibility in video games and serious games in particular. This creates inconsistency and makes it hard for researchers to decide which guidelines to follow (Larreina-Morales, 2023). Therefore, it is helpful to create more comprehensive and standard guidelines that specifically focus on serious video games. A second important consideration is to do more research on the testing of accessibility in different (educational) video games through a combination of accessibility guidelines and user opinions, as users play a key role in game development (Game accessibility guidelines, n.d.-k; Larreina-Morales, 2023). Lastly, since health education video games contain very characteristic elements, such as virtual laboratories and virtual patients (National Research Council, 2011), it would be interesting to test in practice how these elements are received by users who face barriers within the game's different information channels.

Despite the pervasive presence of video games in today's society, their accessibility remains limited, thereby excluding certain individuals (Torrente et al., 2014; Yuan et al., 2010). Various barriers still impede many users from accessing and enjoying (educational) video games (Yuan et al., 2010). Nonetheless, this research has shown that plenty of strategies exist to enhance their accessibility and that there are many possibilities for both practical applications and scholarly inquiries.

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