What's the impact of biofeedback in survival horror games?

Bachelor of Science

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Abstract

Keeping the players always scared in a horror game isn't an easy task. Some players will be more impacted by a huge and noisy monster, while others by a sneaking and silent creature sneaking behind the player to surprise him.

The use of biofeedback, which is a method measuring biological inputs of the subject and giving back feedback based on the measured reactions, can use information about how the player feels about the experience, and it provides a lot of information to the game developers during test sessions about how they can adapt their experience to make the player more scared. With the affordable cost of the biofeedback tools today, it is interesting to see that an experiment could adapt dynamically using the measured inputs about the player's fear.

In this topic, the development of biofeedback in survival-horror games is analyzed and the impact that the player's scare could have on a horror experience is measured. To do so, testers were recruited to play a horror experience in which their pulse was used as a gameplay input and where the information about how feared they felt was interpreted by their pulse and various questionnaires.

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1 State of the art

1.1 Definition and biology of fear

The definition of fear according to the Cambridge Dictionary is "A feeling of great worry or anxiety caused by the knowledge of danger".

Yet, there's no consensus in the scientific study of fear, but some studies argue that there isn't a single brain structure for processing fear. These studies tell that fear is caused by sets of stimuli that lead to sets of behavioral responses (Lindquist, 2015).

Some theories say that there's not a single fear type and that there are different types of states that we include in fear, like anxiety and panic, where fear is conceptualized as a transient state due to the confrontation with a stimulus, like a predator, anxiety is related to the prediction of a threat, and panic is when the brain switches to a survival mood without reflection involved in it (LeDoux, 2012). The studies show that there's a physical distinction between how these different types of fear are processed in the brain. Each of these situations will occur to different kinds of adaptive responses (Adlophs, 2013). But there are also separate neural systems for the types of stimuli that will trigger fear to a human or an animal, like the fear of pain, fear of predatory or aggressive behavior, it's mainly because each of these stimuli will be processed to a distinct sensory channel, like the hearing, the sight, the smell and so on.

The neurobiology of fear is still in its infancy. There exist a lot of different structures to process fear, but studies have shown that the amygdala plays a considerable role and is highly connected with the structures that process fear (Adlophs, 2013). The amygdala receives most of the fear inputs and associates the inputs with the different types of behavioral responses that can occur. It plays a key role in the recognition, the expression, and the experience of fear. But the amygdala also has a role in a wide range of positive or negative stimuli, like for example sexual stimuli or a very enjoyable situation.

Fear is considered a dynamic emotion because there's not a fixed action pattern to react to the diverse stimuli that occur in fear, but a wide range of behaviors. The different reactions depend on the context of the stimuli, for

example, the type of threat, the distance or time left until the encounter of the threat, and the time since the threat was encountered (Blanchard, 1989). These contexts will result in different types of behavioral responses, like for example freezing, hiding, fleeing, screaming, or a defensive attack (Adlophs, 2013). All of these types of responses depend a lot on the subject, like its constitution, its genetics, or its education. Not every human will have the same behavior in front of the same kind of threat. One specific stimulus that is different from the previous ones is unpredictability if there's a temporal uncertainty about the threat if the stimulus is new and the knowledge that one doesn't know much about the stimulus. It can be seen a lot in social reactions between humans, like if someone sees an untrustworthy face if one gets his personal space invaded (Bach, 2008).

1.2 Fear in history

The horror genre was already present in preliterate societies where hunters told tales at the end of the day about terrifying situations they survived, for various possible reasons, for example, to prevent children from putting themselves in danger by going to certain locations (Weaver, 1996). Most of these situations were voluntarily exaggerated and were the premises of ancient mythology. Horror was also used as a virility test to strengthen young boys that had to go hunting for their tribes, for them to be less scared in dangerous situations. When hunting wasn't necessary in the ancient civilization, fear was still a feeling used to strengthen men. In the Greek/Roman civilization, fear was used in entertainment shows, where humans were fighting each other, or wild animals in arenas. At this moment, it was still an advantage to be strong and fearless, because humans still had to use their force to fight in wars. In modern days, this wasn't the case anymore, because, for war, people only have to use machinery and push buttons. But the tradition of men having to be fearless stayed.

1.3 Fear in movies and games

1.3.1 Fear in movies

The horror genre as we know today is only around 200 years old. It started with "Gothic Literature" which is a fiction having a prevailing atmosphere of

mystery and terror, like for example Frankenstein (1818) or Dracula (1897). This genre had a lot of influence on today's horror genre and its evolution (Ward, 1995).

With the appearance of the cinema and movies in the 1890s, also appeared the first silent horror movies. One of the supposed very first movies of horror called Le Squelette Joyeux created by the Lumière Brothers showing a simple skeleton dancing was created only to impress the audience. The very first narrative horror movie Le Manoir du Diable was showing a lot of supernatural creatures like bats, ghosts, witches that still are today popular in the horror genre (Solomon, 2020).

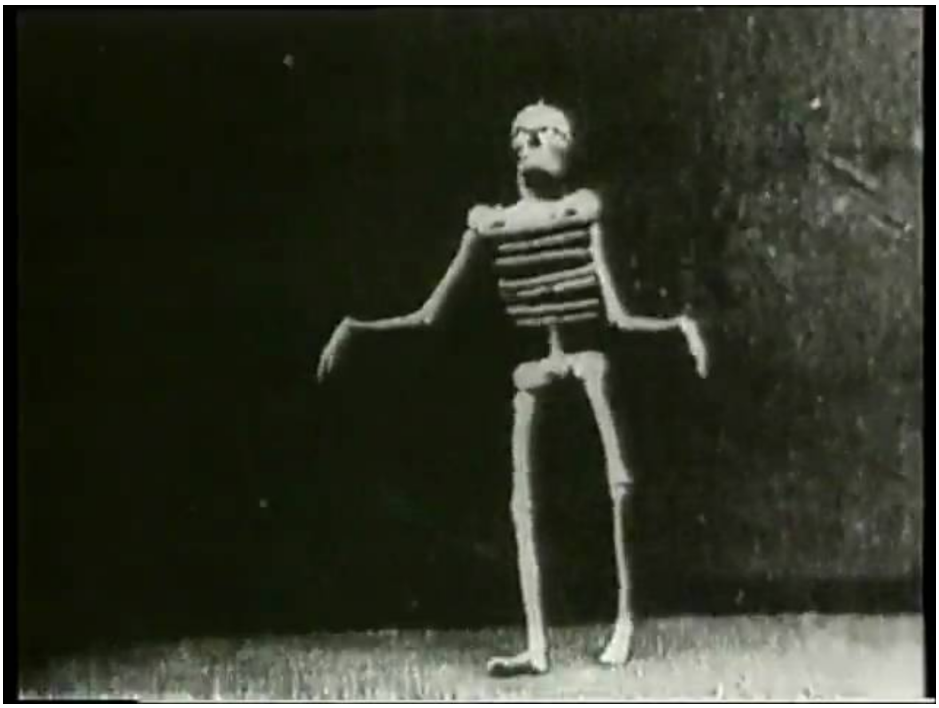

Fig 1: Le Squelette Joyeux (1897)

The first world war then traumatized the entire world and had a huge impact on the horror genre in the movies (Bakker, 2005). In the 1920s a plurality of silent movies came out about veterans forever transformed psychologically and walking in the no man's land, struggling to distinguish the

reality or their imagination (Poole, 2018), like in the 1919's film J'accuse in the "March of the Dead" hallucination sequence, where the French corpses come out of their graves and going back to their homes. At this time, the horror films did not rely anymore on the theater to build movies. Filmmakers reached more immediately resonant terrors.

The late 1920s was the end of the silent era. Sound began to appear in the movies, and it was a complete revolution, because it added a new dimension to the horror, with not only the dialogues but especially the sound effects (Poole, 2018). Producers continued their practice to look at the backwards works to find inspirations, and that's why some of the most popular movies at the time, like Frankenstein or Dracula, saw the day. The horror genre was very popular at this time, because it mainly allowed people to escape the "Great Depression" reality. 80 million people attend the cinema weekly (Towlson, 2016). At this time, there was especially a fascination for "Mad scientists", which reflects the fear of new technologies and the consequences of genetic selection that grew especially when Hitler came to power in Germany, like with the adaptation of Marry Shelley's book Frankenstein (Skal, 1998).

In the 1940s, the horror movies started to decline in quality and popularity, due to the fact that the narratives in horror movies appeared predictable and redundant (Bellemare, 2014). There were also a lot of censors at this time which made it difficult for the filmmakers to adapt their work, especially with the ones about mad scientists that could have a lot of considered "blasphemous" parts (Bellemare, 2014) which already was the case before with the 1931's Frankenstein Movie, where the sentence pronounced by Dr Frankenstein "In the name of God, now l know what it feels like to BE God!" had to be removed. At the end of the war, audiences wanted stories directly connected to their lives due to the fact that the trauma caused by it made them less scared from the same old monsters and stories. New creatures started to see the day in a more plausible way, like the creature in The Beast From 20,000 Fathoms (1953) which was a carnivorous dinosaur frozen in the arctic ice for millennia. It was also the first time that images of supposed "Aliens" were popularized, which added a new popular subject to the horror genre, which is the case with the movie Invasion of the Body Snatchers (1956) where aliens look like human beings and want to take control of every existing human, which also played with the political mistrust. The horror

genre started to get less budget and a lot of famous actors didn't want to be part of these movies because of it. The horror genre began to be very popular to teens, which weren't very interested in character development but more in action, high sensations or suspense. It was also the time when films were recategorized as free speech under the First Amendment in the United States, which gave more artistic freedom to filmmakers to violate the law of nature (Green, 2009).

In the 1960s, horror movies reflect an era of rapid changes due to the post-war stability (Lev, 2003). At this time, horror movies served as a caution about the dangers of abandoning traditional values, like Rosemary's Baby (1968) which explores themes like patriarchal control, questioning of traditional gender roles, or the rejection of organized religion. The end of the censorship allowed filmmakers to add more sex and violence in movies, which were considered taboo. It was also the end of spooky monsters, people wanted horror that was more related to reality, more believable and sophisticated.

The 1970s was the age of depression, it was the beginning of the loneliness and selfishness in the United States, also known as the "me" decade (Hamilton, 2006). But as seen through history, when society goes bad, the horror movies get good. At this time, the religion had no more power to censor movies but had still the ability to write bad articles about some of them, which was an opportunity for filmmakers to get free publicity for their movies, like for The Exorcist (1973) which was criticized for its depiction of exorcism and its portrayal of the Catholic Church, which created a buzz around the movie (Chambers, 2021).

The 1980s was the time when there was no more limit to the visual effects. Animatronics, liquid latex and a lot of different technologies allow filmmakers to have no more limit to give life to their imagination like in A Nightmare on Elm Street (1984) where some new techniques were used in the gory death scenes (Shimabukuro, 2015), or in the Alien (1979) Movie. People were also more demanding in tangible material than in a good plot, because the main audience at this time was between 15 and 24 years old. Horror movies were considered as a rite of passage, they began to be gore and to challenge the viewer to watch despite their repulsion. But the cumulative effect of repulsive images desensitized the public, so each new movie had to

go further than the previous one in the gore (Mac Kerricher, 2018) which led to a rise in censorship and the implementation of rating systems for movies.

Fig 2: Alien (1979) Xenomorph

In the 1990s, murders started to be depicted, and their psychological reasons explained, like in The Silence of the Lambs (1991). But at the end of the decade, the Blair witch project popularized the found footage subgenre of horror by being a surprising hit earning millions at the box office with a budget of only $60'000, making it one of the most successful independent movies in history. It inspired a lot of movies, like Paranormal Activity (2007) or REC (2007) (Grant, 2022).

In the 2000s, torture porn became popular with the Saw franchise (Lockwood, 2009). At this time, Asian horror movies also began to appear on the scene which refreshed the horror movie industry like The Ring (2002) which was a remake of the Japanese movie Ring (1998). Some horror movies were also inspired by video games, like the adaptation of Silent Hill in the cinema, but also on movies like REC (2007) that used the Resident Evil franchise as

a reference (Simpson, 2021).

Today, a lot of horror movies are seeing the day, but movies don't provide the interaction that a player can have in a horror movie, which has a real impact on how scared the people would be. It's still interesting to see that the geopolitical situation and various events had an impact on the horror genre.

1.3.2 Fear in games

Before the 90s, survival horror wasn't a genre on its own. At first, it mainly used popular IPs in the horror genre as the basis to create video games. At this time, like in the beginning of horror in movies, there were many "Monsters", games without the goal to trigger fear, like in the Castlevania franchise. Even if the real genesis of the survival horror genre can be traced to the Atari 2600 with the game Haunted House and many other survival horror games during the 80s, it's only in the 90s that the survival horror genre was considered as its own with Clock Tower (1995) but especially with Alone in the Dark (1992) which are considered as the very first influences. (Bycer, 2021).

Alone in the Dark was conceptualized by Frederic Raynal who worked at Infogrames at the time. The game combined puzzle solving in an adventure game with the player having to deal with threats (Bycer, 2021). Guns were hard to use and had limited ammo, so the player had to fight with his fists. The game also had invincible enemies that the player had to avoid or be killed. It was released in the golden era of adventure games, which made it a great success and inspired a lot of modern games.

While Alone in the Dark and Clock Tower were considered as the very first modern survival horror, another game that had a greater impact, Resident Evil (1996) developed by Capcom. Where Alone in the Dark was more focused on close range combat, Resident Evil wasn't. There were a lot of different firearms with which the player could fight enemies, and the close range weapons were considered as the weakest weapons (Bycer, 2021). Unlike Alone in the Dark, the puzzles in the game and the exploration were more focused on action gameplay. At this time, the technology allowed it to

make enemies much scarier. The game created a lot of iconic moments of horror and featured what is considered as the first jumpscare of the series when the dog enemy breaks through the window. The Resident Evil series became the standard of horror design multiple times over the years and had a huge impact on the game industry.

Fig 3: Resident Evil 1 Dog jumpscare

After Resident Evil 1, Capcom immediately worked on Resident Evil 2 which had a complicated development. The game was a sprawling epic compared to the confined first game. The game was another hit. Capcom also created Dino Crisis, a survival horror game with dinosaurs, that was far more action oriented and which settled up the groundwork for Resident Evil 3: Nemesis (Bolt, 2018).

During the same decade, the first Silent Hill (1999) brought a different experience than the Silent Hill series. The game had a far more cerebral take on the genre, the game was more about atmosphere and thoughtful tension than jump scares. The main difference between Silent Hill and its two predecessors is that the player had a direct control of the camera 3D (Bycer, 2021). The hero was a regular man without any combat training, unlike in

the Resident Evil series. Another intelligent design feature the game added is the radio which gave the player an indication that a danger was near, not giving the direction, which added a source of tension. Silent Hill stood out from the other horror games with the focus on the location, which is the town of Silent Hill that is the center of the story and the characters that are in the second plan.

Fig 4: Silent Hill (1999)

The game is less focused on combat than Resident Evil (Bycer, 2021). Each location was a puzzle to solve with enemies to fight. One of the main difference between Silent Hill and Resident Evil is that the player could decide to avoid some combats by switching down its radio, turning down his light and walking carefully avoiding the enemies in the dark but which came with downsides like the inability to know if there were enemies in the room and the inability to read the map.

An interesting design and hardware decision was the fog that envelops the town of Silent Hill. It was meant to hide areas that weren't fully loaded, but it ended up being an important signature of the Silent Hill mythos, because

of the way it generates fear of the unknown in wide spaces (Bolt, 2018). With this was added the crackle of your radio that occurred when an enemy was near, without indicating what type of enemy was there, which increased the player's fear.

For their part, Capcom continued with Resident Evil 3: Nemesis (1998) on the PS1 and Code Veronica (2000) on the Dreamcast. The latter, besides having a jump in visual quality, the fans and the journalists criticized the lack of innovation, the game using the same structure, mechanics and camera angles as its predecessor (Bolt, 2018).

In parallel, Konami released Silent Hill 2, a serious adult game with a thought-provoking narrative and a good set of characters and location, creating a mysterious and disturbing experience, which showed that games didn't have to follow the Capcom route to be good (Bolt, 2018).

Silent Hill presented lore or backstory beyond just the main characters, the world worked with rules and the enemies represented something about the background of the protagonist, like in Silent Hill 2,"Pyramid Head" which represents the protagonist's need for punishment and frustration about his wife's death. Silent Hill and Resident Evil represent the two popular forms of horror that other developers have been modeling their games after for years.

Fig 5: Silent Hill 2 (2002) Pyramid Head

The early 2000s saw a bunch of successful survival-horror games, but a lot of games started to slowly become action-oriented to hit a wider range of players, which was the case with Silent Hill 3 (2003), that still had psychological horror moments but an upped gun combat and the ability to choose the difficulty of the puzzles you have to solve. This was the start of the slow decline of the Silent Hill series as a horror series, which could be seen with the release of the next games.

The same decline happened to the Resident Evil series, with Resident Evil 4 (2005). The game revolutionized the survival-horror genre, seemingly for the better, which would be in part responsible for the decline of the horror genre at this time. Resident Evil 4 still is one of the best games of its generation. It popularized the third-person camera and had plenty of memorable moments. But the global tone of the game changed to make it a more action title than a horror title (Fahs, 2022). After that game, Capcom didn't get the message of what made their first survival-horror games so popular, and the series slowly declined with their next games.

After a long period of lack of horror game's great success, Visceral Games released Dead Space (2008), a gory sci-fi horror game. It mainly influenced the survival-horror genre with its sound design, which built an effective tension and jumpscares (Bolt, 2018). Dead Space 2 (2011), like a lot of survival-horror games previously, began to add more action in its game. But unlike the previously seen games, the game remained in touch with its scary side, which showed that you could do action horror and still retain the scare. But the series sadly failed with its third episode Dead Space 3 (2013) to keep its horrific side shifting more in an action-oriented game, and EA felt the game didn't match sales expectation, completely abandoning the possibility to see a sequel, especially by closing Visceral games a few years after (Fahs, 2022).

At the end of the PS3 area and the beginning of the PS4 one, indie games started to have a much higher impact on the horror genre, with examples like Slenderman (2012) and Amnesia: The Dark Descent (2010), or Outlast (2013). Those were games in which you are defenseless against the horrific enemies you encounter, and where you basically have to run and hide (Fahs, 2022). Outlast exploited this gameplay well, making a very terrifying experience, but the style became very fast redundant.

In 2014, Creative Assembly made an impressive adaptation of the Alien franchise by releasing Alien Isolation. The game was very well received, especially for the Alien's well-developed artificial intelligence, which inspired a lot of games (Thompson, 2017).

In 2017, Capcom came back with Resident Evil 7. The game abandoned his third person view to a first person view. It also came out with the Playstation VR compatibility. It was the first time that a very successful survival-horror was compatible with VR. It showed how the horror genre can benefit a lot from VR headsets (Pallavicini, 2018).

1.3.3 Virtual Reality and fear

Virtual reality, according to the Cambridge Dictionary, is *"a computer system that creates an environment that looks real on the screen and in which the person operating the computer can take part"*.

The very first idea of virtual reality was presented by Ivan Sutherland in 1965, which was to create an artificial world that includes interactive graphics, sound, smell, test and force-feedback. He constructed what's considered as the first Head Mounted Display with appropriate head tracking. After that, different researchers contributed by developing new tools, like for example the GROPE (1967) which created the first prototype of a force-feedback. Virtual reality was also used by the US Air force, which developed an advanced flight simulator, or by NASA which created virtual exploration of artificial environments. Virtual reality is still today not only used in games and there's still numerous projects that are developed with this technology, and imagined in the future, like in training and education (Gervautz, 1999).

To understand the importance of a VR headset, here are the contribution of the five human senses to feel immersed (Heilig, 1992):

Sight	70%
Hearing	20%
Smell	5%
Touch	4%
Taste	1%

Fig 6: Senses contribution

Human vision provides the most information passed through our brain, followed by hearing. Smell and taste are almost not considered yet, but touch can sometimes play a significant role, especially when manipulating objects.

To provide the best immersion, there are several points that need to be considered, the field of view, the visual acuity, the temporal resolution, the luminance and color and the depth perception (Gervautz, 1999). For the field of view (FOV), it's important to respect the human one. A human has a FOV of 180° and a vertical one of 150°. The visual acuity corresponds to the sharpness of the sight. The human eye has a different acuity depending on the distance from the line of sight. The area with the highest acuity covers a region of 2° around the line of sight, and the sharpness of viewing deteriorates beyond the central area. The temporal resolution refers to the refresh rate of the images. With a too low refresh rate, the human eye will perceive some flickering. The luminance and the color are also important, the human eye can detect a variety of colors. And finally, the depth perception that helps to evaluate the distance. There also exists two main sources of simulator sickness which must be taken into consideration, which are system latency and frame rate variations.

The minimum an immersive VR headset needs is position and orientation. Some other body parts can be tracked to add more immersion (Gervautz, 1999). The most important properties of the trackers, to avoid sickness and provide a better immersion are the update rate, that corresponds to how many measurements are made every second, the higher, the better; the latency, which corresponds to the amount of time between the user's real action and the effect on the experience, the lower, the better; the accuracy, which is the degree of error in the measured position and orientation, the smaller, the better; the resolution, which is corresponds to the ability to detect the

smallest changes, smaller values meaning better performance; and finally, the range, that corresponds to the volume within the tracker can measure the position and orientation with its specified accuracy and resolution. Some other aspects also have to be considered, like for example the weight and the size of the device and there exists a diverse kind of trackers depending on the headset, each providing advantages and disadvantages.

Today, the VR market size is valuated at $12.15 billion in 2022 and is expected to grow considerably (The Business Research Company, 2023). It's mainly used in gaming and entertainment, healthcare, automotive, architecture and education. Some enterprises have shifted to virtual platforms during the COVID-19 pandemic. The Meta (Oculus) headsets are dominating the XR shipment market of 2021 and 2022. The gaming and entertainment sector is expected to grow to $44.5 billion in 2027 and lead the VR market.

1.4 Biofeedback systems

1.4.1 Brief history of the Biofeedback

The biofeedback technique was used for thousands of years, mainly in meditation practices like yoga. The term was introduced in 1969 at the first meeting of the Biofeedback Research Society (El Saddik, 2019). Clinical biofeedback was created in 1975, which is when an individual can learn to control specific physiological functions with the help of a therapist, by changing the thoughts and perceptions that produce them. The biofeedback technique is recognized as a complementary medicine, mainly for physical and mental health illnesses. The Ubiquitous Biofeedback, created in 2014, is another biofeedback technique that utilizes software tools which provide continuous and long term management of physiological processes, which helps the user not to attend clinical sessions to benefit from biofeedback techniques.

1.4.2 Biofeedback Systems

The global Biofeedback Instrument Market size was valued at $169.78 million in 2021 and is expected to reach $253.88 million by 2027. The main biofeedback tools used today are used to measure brainwaves, heart rate, muscle tone and sweat glands. They are mostly used in home use, hospital or clinic

(The Express Wire, 2022).

2 Experience creation methodology

2.1 Existing experiences

2.1.1 The Valve biofeedback experience

Valve worked on such a project in 2011. They've used biofeedback to enhance the gaming experience in their games. They first defined emotion and rationalized it by translating it to a vector in which the magnitude corresponds to the arousal and the direction to the valence, and then, they went through all the advantages and disadvantages of every biofeedback tool (Ambinder, 2011). They used biofeedback to improve the experience of their games, like by modifying the AI Director in Left 4 Dead 2 (2009), adding a physiological input to Alien Swarm (2010) and using eye movements as active controls in Portal 2 (2011).

In the Left 4 Dead 2 game, the player gets a different experience each time he plays. To manage this, the game has an AI Director which modifies enemy spawns, health, weapon placements, boss appearances, ... etc (Ambinder, 2011). The AI Director manages it by estimating an arousal level. They decided to replace the estimated arousal level by the actual arousal given by a pulse sensor to know if it could create a more enjoyable experience. The results of this experience were that the measured arousal produces greater enjoyment than the estimated arousal, that physiological signals are viable inputs, and that there was still more work needed to quantify enjoyment.

In Alien Swarm, a top-down, team-based action shooter, Valve created a mod with time-based constraint in which the players had to kill 100 enemies in 240 seconds using biofeedback. The timer was indexed to arousal, when the players were highly aroused, the timer speeded up and when the players were relaxed, the timer reverted to the baseline. The players had to keep calm to be able to kill the 100 enemies (Ambinder, 2011). They saw problems with this experiment, like the fact that the clarity of relationship between arousal and in-game events isn't always clear.

In Portal 2, which is a puzzle-based FPS, Valve decided to see if it could be enjoyable for the players to use their eyes to aim, since the eyes move faster than the wrist. They used an eye tracker to measure the eye's position (Ambinder, 2011). The result of the experience is that using eyes as a controller is viable, but that they are more suited to action-oriented games.

2.1.2 Nevermind: a game using biofeedback

Nevermind, a game released in 2015 is a horror third person game that implemented a lot of biofeedback tools in their game. The player embodies a therapist that has to enter the minds of clients who suffer from psychological distress to discover the cause of their problems (Nevermind Website, 2015). The player has to navigate to the client's horrifying subconscious and to solve puzzles that will give information about their distress.

Nevermind can be played as a traditional game, but the biofeedback system provides a different experience. The game supports a variety of inputs, it mainly uses heart rate data to get indication of fear, stress or tension that the player feels, but it can also use other inputs. The game can analyze the facial expression of the players using the Affectiva technology that gives more precise information about the emotion that the player feels (negative or positive) (Nevermind Website, 2015). An eye tracking device can also be used as an input, and it unlocks unique gameplay features. By capturing the level of player stress, the game increases the game's difficulty the more stressed the player is by making environments become hostile to the player, obstructing his/her view, movement or visibility, the goal being for the player to manage stress.

2.1.3 Other Researches

There exist several other experiences that linked horror games with biofeedback.

One consisted of using a Heart Rate monitor to enhance the Horror experience, by increasing the difficulty of the game the more the player is scared. To do so, they developed a VR horror game experience in the Unity 5 game

engine using the HTC Vive VR headset. The experience consisted of the player being in a confined space in a Manor of the Victorian age and having to survive for five minutes (Houzangbe, 2018). Around the player are placed some objects that randomly make some noise. A creature is attracted by the sounds and comes at a certain interval of time, so the player has to stop the sounds the objects in the room are making. The more scared the player is, the more frequently the creature will come, and the player has to use a flashlight to make it disappear. To estimate if the participant is scared, its Heart Rate was first recorded for 2 min and 30 seconds listening to relaxing music. They managed to have up to 32 participants, and they first had to sign a form and pass an examination questionnaire to get information on their profile, like their genre, age, experiences in gaming, relation with horror games... etc. The testers had to do two kinds of experiments, one with the biofeedback and the other without it. The result was that the majority of the participants preferred the experience with the biofeedback gameplay feature. The main goal of this experiment was to help players to control their fear with the biofeedback mechanic, but the problem was that the players could not really know if they were calming down or not, there wasn't a clear feedback for them to know it, so the player felt a bit less engaged to try to scale down their scare.

Another horror experience similar to the previous one, a VR Experience developed with the Unity 5 Game engine, implemented a "Horror Manager" that collects as an Input all the data that the player provides and outputs a horror feature. In the experiment, the Player is an investigator that has to search for clues in a mysterious house (de Lima, 2020). The game uses traditional horror elements such as darkness, apparitions or unknown voices or sounds. Their goal was mainly to measure the accuracy of their "Horror Manager" to see if it can be used in real time. They realized that it works to find a precise effective horror element when the game starts, but the game can become predictable over time.

2.2 The experiment

When you compare all the diverse experiences, being scared is often seen as a condition to lose or making it harder. You can see that every player isn't necessarily scared at the same level with the same inputs.

Most of the independent researches were using games that were especially created for the experience from scratch, while the Valve experiences used edited versions of already existing games from the studio. Using an already existing game would be a complicated task to make the biofeedback tool interact with the game experience.

With the entire situation analyzed, it was decided to do an experiment from scratch. The project will be a VR horror game, with the tester's pulse having an impact on the experience. The goal is to trigger fear following the player's own fear with some horror elements and see what impact it has on them. The experiment must have an easy-to-understand gameplay loop and few basic controls.

2.3 Constraints and ideas

Before developing the experiment, it was important to look at the various constraints of creating such an experience and to write the several ideas for the project.

One of the first constraints was the fact that it was important to gather the most possible information about the player scare and let it have a sufficient impact on the player. To do so, it was decided that there was no way for the players to lose the game and stop the experiment. Instead, they were punished by a jumpscare. It was also important to note that the experiment must be easy to understand by the testers, the controls had to be the simplest possible for the tester not to feel lost.

The idea of the experience was mainly to test different things, to test different biofeedback interactions with the rules changing during the game. An inversion of the fear impact on the experience was already an idea to place during the experience to see if it had an impact on the player's fear or the player's behavior. Another idea was not only to create a negative aspect if the player is scared, but also a positive one. The idea was to create a more oppressive ambience, but also to make the main character move faster.

2.4 Unity Engine

The project was developed on the Unity Engine. Unity is one of the most popular game engines today, especially in the indie game development spheres (Schardon, 2023). The engine supports 3D and 2D graphics, each type coming with its own specialized set of tools. A lot of popular games were created with Unity, such as Subnautica (2018), Cuphead (2017), Pokémon Go (2016), Fall Guys (2020) or Genshin Impact (2020).

The Unity Engine was especially chosen because it's very easy to use, there are various tools available, and you can easily integrate VR to your projects.

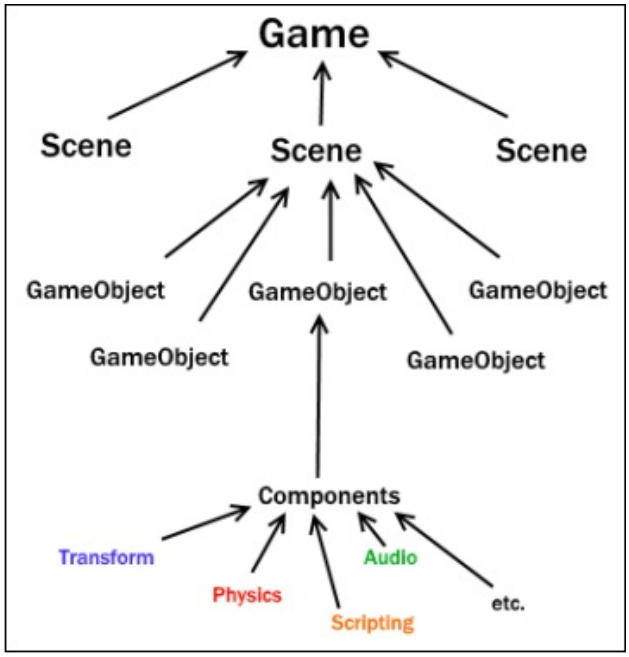

Fig 7: Unity Structure

Using Unity, your Game is divided into multiple Scenes which are composed of multiple GameObjects that contain multiple components, such as transforms, audio components, materials, models, scripting elements... etc. The engine provides an interface where you can load the various scenes and see the elements contained in each of them (Unity Technologies, 2023). When

working on a game, an important element to use are "Prefabs" which usually corresponds to a reusable element, such as a Prop, an NPC or anything that will keep the general same composition and be placed multiple times in your scene or in the entire game with only few value changes (like position, status... etc.).

Scripting is one of the most used elements of the various Unity projects. Scripts are components where you write your game flow, where you create interaction between your objects, the various inputs gathered, arrange the various events in the gameplay to happen when they should, and so on. Even if the Unity engine is built with native C/C++, the scripts are written in C#. There are various Unity libraries that provide the most often used functions, such as Start() (which loads once at the start) and Update() (which loops every frame). Various Unity or external libraries can be imported in your scripts, like.NET libraries.

There are a lot of external packages that can be implemented on your Unity projects, such as the official Oculus Integration package that provides multiple tools for creating games with Oculus headsets. The engine also supports a multiplicity of assets formats.

2.5 VR Headset

The first VR headset used was the HTC Vive Cosmos. The Vive Headsets are very popular on the VR market, especially for being more powerful than the other headsets. The headset has a resolution of 1440x1700 per eye, a field of view of 110 degrees, and a refresh rate of 90 Hz (HTC Corporation, 2023). The main problem with it was that there was an error with it and the computer couldn't display any games on the device. And the device was also very big, heavy and had a lot of cables which made it uncomfortable. The decision was to use the Oculus Quest 2 instead.

The Oculus Quest 2 has a lower resolution than the HTC Vive Cosmos (1 832 x 1 920) and a 95 degrees field of view, but it is much lighter, more comfortable, can be connected to the computer without any cable, and it doesn't have the glitch that the HTC Vive Cosmos had (Meta, 2022). The refresh rate can also go up to 120 Hz. That's the reason why the oculus was

used for this experiment.

2.6 Biofeedback

2.6.1 Tools to measure fear

At first, the idea was to measure the brain waves to measure the player's fear. The brain waves are an electrical activity in the brain with five different kinds of waves, each corresponding to an emotional state. The problem was that Electroencephalography is a very complex subject, the patterns are unique for every individual and the large amount of data from a single EEG makes the interpretation difficult (Abhang, 2016). Another problem is that the tools to measure brain waves are very expensive and the availability of tools for such projects is very low, so it may be too early to use it as a reference.

The second idea was to use skin conductance, which has its importance on the measure of fear. The skin conductance or electrodermal activity is when an internal or external stimuli makes the skin temporarily more conductive. It's mainly triggered by someone's arousal. But the idea was quickly aborted, because its implementation was too complicated for such a project.

It was at the end chosen to gather the pulse to measure the player's fear (Shu, 2020). The method comes with its own problems, like making the difference between fear, enjoyment or frustration, which is why it is important for the players to answer questions before and after the experience to estimate what really triggered their pulse to increase or decrease.

2.6.2 Arduino

The idea was to use a pulsometer and integrate it to the project. Arduino is an open-source electronics platform based on easy-to-use hardware and software. Arduino boards are able to read various inputs and turn it to an output to then link it to the Arduino software (Arduino, 2023). Arduino is a very good platform for fast prototyping, aimed at students, hobbyists or even professionals without a background in electronics and programming. It

comes with its own IDE, and the language can be expanded through C++ libraries.

2.6.3 Arduino Hardware

There are several Arduino kits. In this project, the Arduino UNO R3 was used.

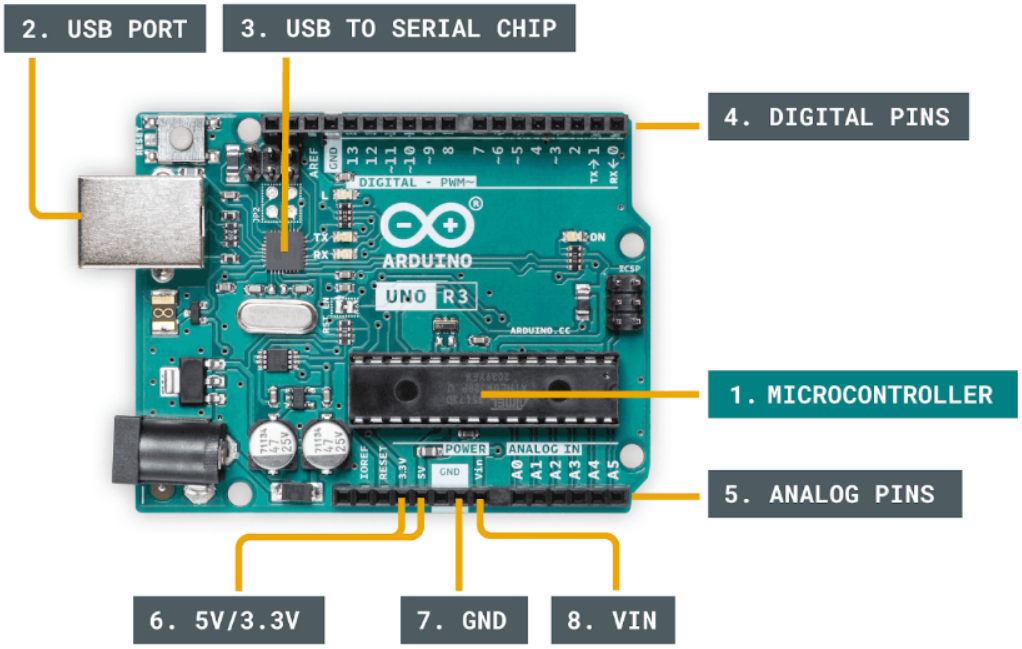

Fig 8: Arduino Chipset Structure

1. **Microcontroller:** The Microcontroller is where all programs are loaded
2. **USB port:** Connects the board to the PC
3. **USB to Serial chip:** Translates input and output data between the computer and the board
4. **Digital pins:** Pins using digital logic (0,1)
5. **Analog pins:** Pins reading values in a 10 bit resolution
6. **5V/3.3V pins:** Pins used to power components

7. **GND:** Used to complete a circuit where the electrical level is at 0 volt

8. **VIN:** Used to connect external power supplies

Arduino boards are mostly designed to run a single program, while an actuator is used to change a physical state, like turning a light on (Arduino, 2023). In Arduino programs, it's common to have a sensor that actuates something if it meets a certain condition. Some serial communication protocols can also be used to send data between the Arduino and the computer. Those are usually used to upload a program to the Arduino, but it can also be used to upload read information by a sensor directly to the computer, to be then used by a program with a loop function loaded on the microcontroller. Programs usually read a sensor, then do an action, and then wait an amount of time before going back to the start. Usually, external tools will be connected to the Arduino and create an electric circuit and receive electrical signals. It can receive digital signals, which represents two binary states (0 or 1), but it can also read an Analog Signal which can have a 10 bit resolution. Those external tools can be of two different types, Sensors and Actuators. A sensor senses its environment, like by changing the state if a button is pressed or measuring the temperature.

2.6.4 Arduino Software

The Arduino API comes with several functions to control the Arduino board and computations, variables such as int, boolean or array, and the general structure of the C/C++ language, using the same control structure (if, else, while), the same arithmetic operators, and the same comparison operators (Arduino, 2023). A basic Arduino program requires the void setup() function that executes only once when the Arduino is powered on, and the void loop() function that loops until the program is stopped. The program has to be written in a sketch that has the .ino extension, in which libraries can be added. Once the code is written, it has to be compiled, first to check errors and then to convert it to a binary file for the Arduino, and then send it to the board. The serial monitor can then be used to view the data sent from your board to your computer.

2.6.5 Pulse Sensor

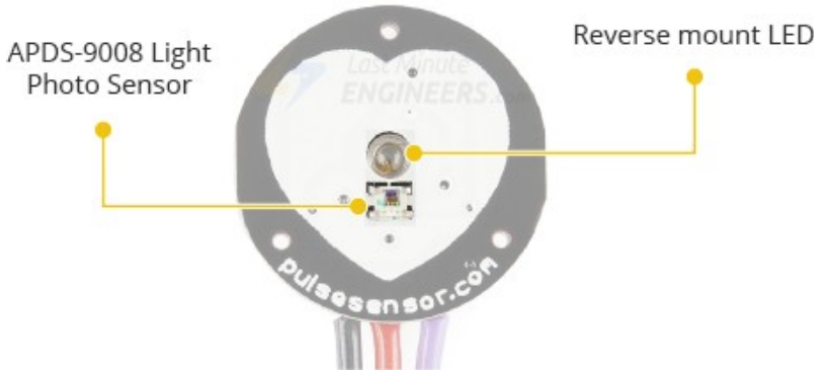

Fig 9: Pulse Sensor

The Pulse sensor used for this project measures your heartbeat is composed of a Photo Sensor and a LED. The pulse sensor measures the pulse by shining a green light with the LED on the finger and by measuring then the amount of reflected light using the Photo Sensor (LastMinuteEngineers.com, 2022). This technique is called Photoplethysmogram.

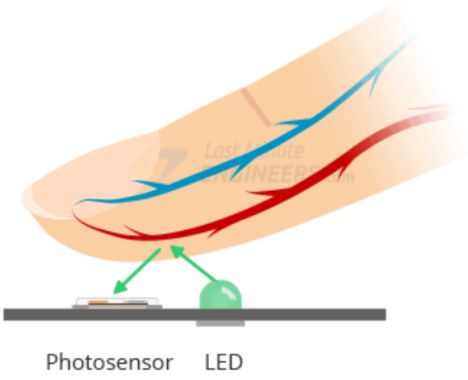

Fig 10: Photoplethysmogram

The oxygenated hemoglobin absorbs the green light. The redder the blood is, the more green light is absorbed. The amount of reflected light changes with each heartbeat as the blood is pumped through the finger. The pulse

sensor comes with 3 cables. Two that correspond to the electric current needed for the sensor that connects to the VIN and the GND, and the third one that outputs the signal of the pulse sensor.

2.7 Hardware and material

CPU	Intel(R) Core(TM) i7-10700KF CPU @ 3.80GHz
GPU	NVIDIA GeForce RTX 3080
RAM	32 GB
Headset	Meta Quest 2 128 GB
Arduino Board	Arduino Uno Rev3 SMD
Pulsometer	Arduino SEN0203
Arduino IDE Version	1.8.19
.NET Version	4.8.9032.0
Windows version	Windows 11 22621.963
Unity Engine Version	2021.3.2f1

Fig 11: Hardware and Software

The test was passed in a 10 (m2) room on a desk with a low luminosity.

3 Experience development

3.1 Design

3.1.1 Constraints

Before designing the experiment, it was important to note some new constraints that came with the choice of tools and the methodology.

With the Arduino board and the pulsometer connected to it, it was impossible to imagine the player standing during the experiment, the testers had to sit in the front of the desk and not move their left hand. To do so, it was important to give the player some camera control. It was decided to give the player the availability to move the camera with a jump of 45 degree in their left or right view, avoiding a constant camera movement so as not

to trigger motion sickness.

Another constraint was that the testers were only using one hand to control their character, because of the pulsometer being connected to the second. It was important to make the player available to control its character entirely with one hand. To do so, it was decided to use the stick to move the camera, the triggers to move forwards, and the grip to move backwards. To make it easier for the player to move around easily, the players can aim with the controller the direction where they would like to move. There were only the 2 buttons and the stick button left for a new possible interaction.

One constraint mentioned before was the fact that it was mostly important to gather the most data possible during the experience. Designing a game, with the availability to lose and stop or restart the game, would have an impact on the quality of the gathered information. That's why it was decided to "punish" the players instead of making them lose to let the experience continue.

Another constraint to create the game was the lack of assets available for the experience. The game had to be designed with the available data on various websites or on the Unity Assets Store, which was a considerable constraint. The most limited resource was the models.

3.1.2 Concept

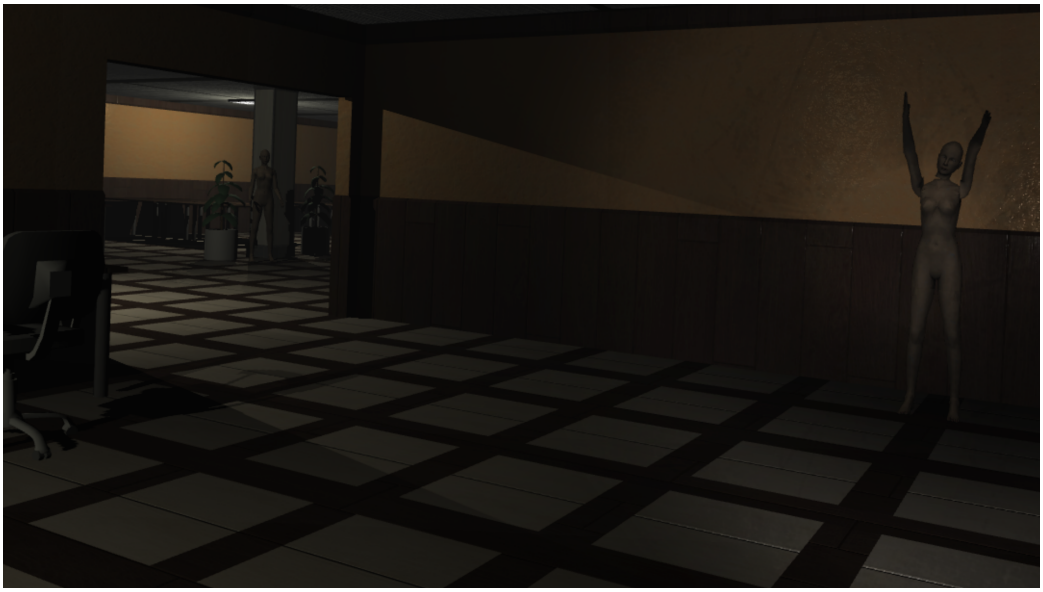

Fig 12: Experience Image 1

With all the constraints and various elements, the full concept of the game was developed. The player has to patrol in an office and find the creepy moving mannequins before they get crazy and punish the player, while some creepy noises and elements happen through the experience.

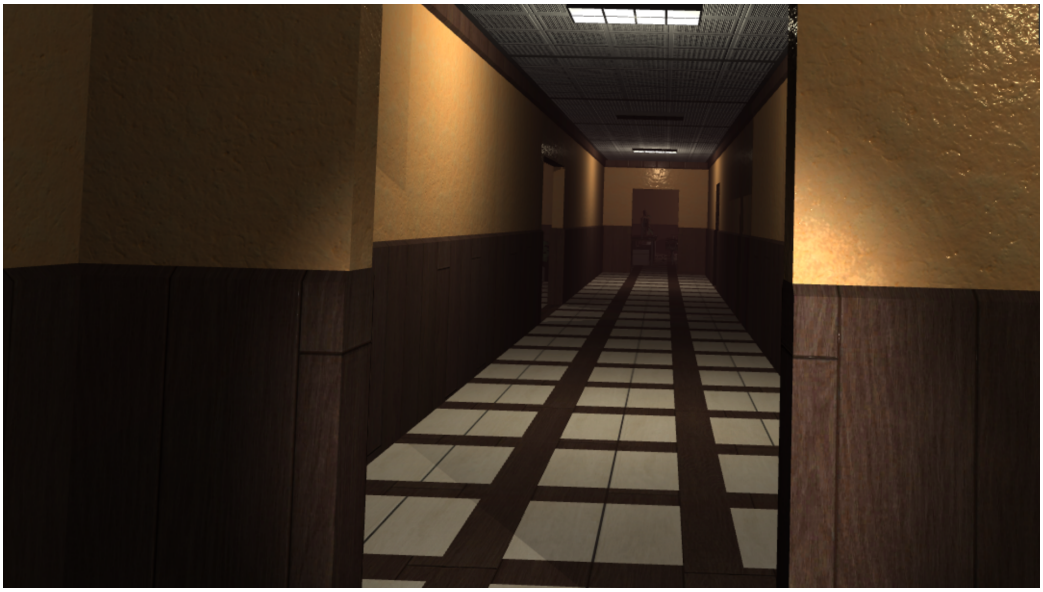

Fig 13: Experience Image 2

The gameplay uses some basic VR movements, moving forward, backwards, turning the view with the stick or with head movements. The character also has a flashlight which corresponds to its hand position and that aims where the players aim with their hand, and also has a flash which has to be used to deactivate the mannequins. The flash is triggered by pressing the buttons near the stick or by pressing on the stick, and it also has a cooldown to be used again, so the testers can't abuse using it. During the game, one mannequin is activated, the player has to find it in less than 40 seconds, otherwise the mannequins jumpscares the player. When the player runs out of time or hits an activated mannequin, the latter gets deactivated, and a new mannequin gets activated somewhere on the map. The mannequins are dispatched on a small circular map which correspond visually to an office, with desks and computers, a cafeteria, an open space, and various rooms that the player has to patrol. During the entire experience, various elements come to create an evolution. Some creepy sounds can be heard at a certain time, and the lights turn off after 110 seconds.

Fig 14: Experience Image 3

During the game, the tester's pulse has a direct impact on the experience. The pulse has an impact on the ambience sound, on the color of the fog (gray or red) and on the player speed. For the first 150 seconds, the more scared the player is, the more the ambience music gets oppressive, the fog becomes red, and the player goes fast. After 150 seconds, the situation reverses. The less scared the player is, the more oppressive the ambience gets.

3.1.3 Design elements

The map has a total of seven rooms connected to each other. The entire map is a loop, to make it easier for the player to patrol and to understand.

During this experience, a lot of game design clichés elements such as jumpscares or ambient noises were used. These elements are still very effective to build a scary ambience and the entire experience doesn't have to be really coherent, the main goal being to build a scary ambience. The use of a flashlight in a horror game is also very common, but still effective, especially for a 5 minutes experience.

A quick tutorial was also necessary for the testers to get the controls and the main goal of the experience. Their objective was quickly presented to them without telling them everything they'll encounter during the game to keep the scare of the unknown.

3.2 Development

3.2.1 VR Headset implementation

To implement the Oculus Quest 2 VR Headset to the Unity project, there exists an official package dedicated to the implementation of every kind of Oculus Headsets on Unity projects, which can be downloaded on the Unity Asset Store. This API comes with a lot of useful tools to test and develop VR games with the Oculus headsets.

A problem encountered during the development, was the fact that the project could not be read on the Oculus Quest headset. In the Oculus documentation, it's specified that the project has to be built with the android platform. It was also told to select in the XR Plug-in management both "Windows, Mac, Linux" and Android. By doing so, and loading the game, the game wasn't displaying on the Oculus Quest 2 for debugging. There was a conflict between the android and the windows XR build. On the Oculus Quest 2, the supported games are built with an android version and are loaded on the headset, but the current project had to be a PC project, because the latter has much higher performances and because the pulse sensor is connected to it. The project was finally built for PC and the headset was able to load the experience.

The Oculus Package provides an already set up player controller, called the OVRPlayerController which is very useful to use to avoid starting from scratch to create the player movements.

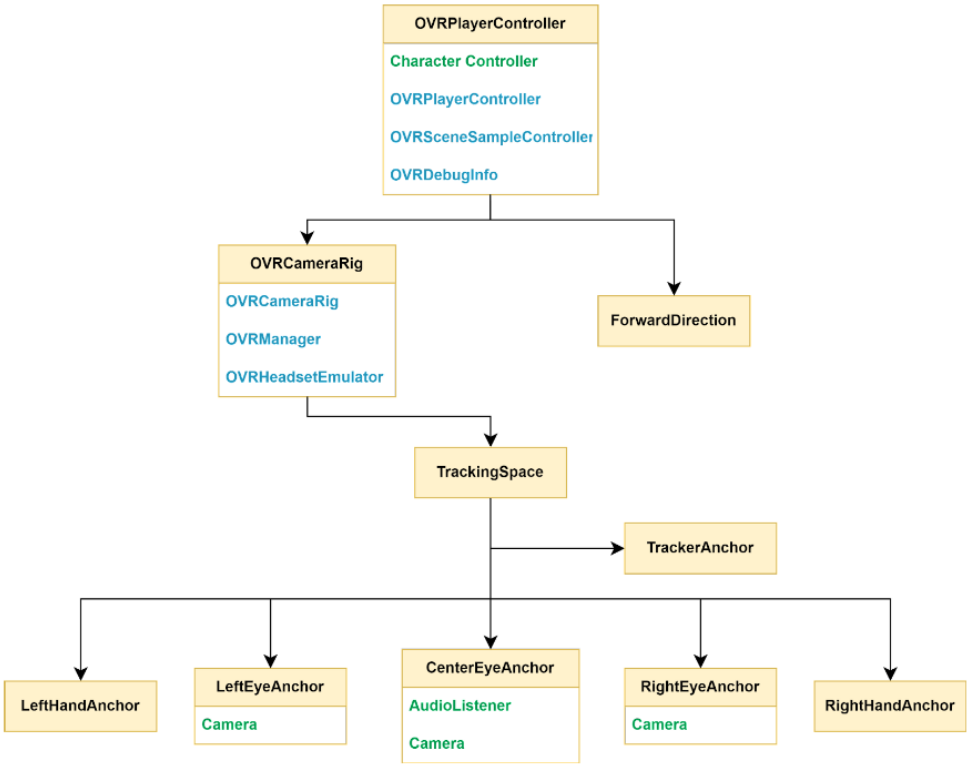

Fig 15: OVRPlayerController Structure

The OVRPlayerController script provides basic movements in a virtual environment, the CameraRig script links the headsets head trackers to the cameras for each eye, the OVRHeadsetEmulator script stimulates the movement of the player in the Unity Editor.

The OVRPlayerController script wasn't compatible with the specific controls of the experience, it was needed to create a new player controller and edit the controls manually to make them correspond to the needed controls. While usually in the various games, the players can see their hands to ease them, it was decided to put a flashlight instead of the player's right hand, which corresponds to the main gameplay element of the game.

3.2.2 Connecting the biofeedback tool

To measure the pulse with the pulse sensor and the Arduino, a basic code was first implemented to gather the information about the pulsometer and send them to Unity. It was then chosen to use the PulseSensorPlayground.h header that provides a lot of useful tools and facilitates the pulse sensor reading and sending the various information about the tester's pulse.

```
#include <PluseSensorPlayground.h>

const int PULSE_INPUT = 0;
const int LED13 = 13;
const int THRESHOLD = 550;

PulseSensorPlayground pulseSensor

void setup() {
  // put your setup code here, to run once:
  Serial.begin(9600);
  pulseSensor.analogInput(PULSE_INPUT);
  pulseSensor.blinkOnPulse(LED13);
  pulseSensor.setThreshold(THRESHOLD);
}

void loop() {
  int calculatedBPMs = pluseSensor.getBeatsPerMinute();
  if (pulseSensor.sawStartOfBeat()) {
    Serial.println(calculatedBPMs);
  }
  delay(20);
}
```

Fig 16: Arduino Code

The PULSE_INPUT used in the pulseSensor.analogInput function corresponds to which analog pin, the pulse sensor sends information to gather, the pulseSensor.blinkOnPulse blinks a lead on the Arduino board each time a pulse is detected, the threshold determines which signal has to be considered as a pulse and which hasn't. The Serial.begin function opens a serial port and sets the data rate in bits per second for the serial communication

and the Serial.println function prints data to the serial port. The Serial.write function would've been more accurate to send and gather data at the needed format instead of transforming the data to strings (Arduino, 2023).

After compiling the code, the code is uploaded to the Arduino and the data of the pulsometer are collected and can be tracked using the serial monitor of the Arduino IDE.

The current code is implemented on the chipset, which constantly makes it loop and send the pulse. To gather the various information in the Unity Project, it was needed to use the Windows communication protocol. The communication protocols allow two or more entities to transmit information to each other using in this case the Universal asynchronous receiver-transmitter (UART) device where format and transmission speed are configurable (Microsoft, 2023). The Serial.println() function sends data through the usb port. Windows considers it as a serial port and refers to it by the name COM with the specified speed of communication.

To collect the ECG data in a script, it was needed to add the System.IO.Ports namespace from the C# .NET framework. To do so, it's first needed to edit, in the Unity Project, the API Compatibility Level in the Configuration section of the Player's Settings and set it to .NET Framework instead of .NET Standard 2.1. It would then be possible to add the Library and access to the functions needed.

One of the main problems using this Method is the fact that the ReadLine() functions stops the entire simulation to wait to receive the next information from the data stream. It was needed to use the System.Threading namespace of the .NET framework, to dedicate a thread to read the Arduino data and so avoid this problem.

3.2.3 Setting up the biofeedback tool

Setting up the biofeedback interaction for the experience was especially important for the heartbeat to have the best interaction with the experience.

At the start of the experience, the tester's average heart rate is calcu-

lated. To do so, the experience starts with a 2m30 introduction, where the testers are immersed in a spatial relaxing environment, with some relaxing music. The instruction given to the player was not to move and try to relax. The pulse is only measured after 60 seconds, to give some time to the player and heartbeat to adapt to this situation. At the end of the introduction, the tester's medium heart rate is calculated to be used as the minimal player's pulse during the experience, which corresponds to the player not being scared. The maximum tester's pulse is calculated as well, which corresponds to the tester's minimum pulse +30 bpm and corresponds to the player being very scared. The tester's heart rate is constantly displayed to the test's instructor for him to notice if any problem is detected during the measurement, as well as the medium heartbeat calculated at the end of the introduction.

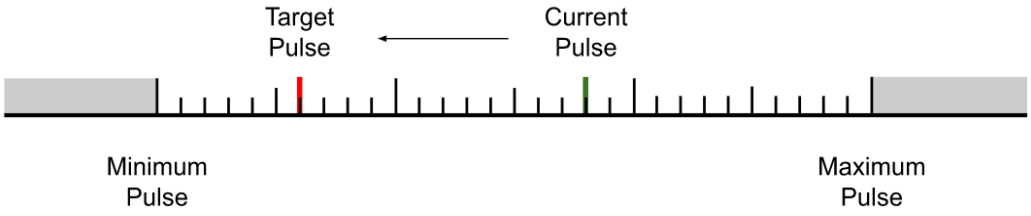

Fig 17: Scare system

During the experience, the minimum and maximum pulse value will be used as a base to estimate the tester's scare level, the minimum corresponding to a 0% scare level and the maximum 100%. The scare percentage is calculated every second using the tester's pulse measured by the ECG. To avoid sudden changes in the environment, audio and in the character's speed, the values slowly increase or decrease at a constant percentage speed to reach the calculated scare percentage. This also significantly reduces the measurements' imprecision of the ECG tool that happen during the various tests. After 2m30, the scare system changes. The minimum value is considered as a 100% scare level and the maximum as 0%. The scare level has an impact on various elements. It increases the volume of a stressing audio source, it lerps between a gray and red fog color, and it lerps between the minimum and maximum character's speed, as well as the footsteps sound's pitch.

3.2.4 Collecting data

During the game, various data elements are saved such as the player's pulse information, as well as the various events that happen during the experience.

A "pulse struct" containing the pulse (int) and the time (float), as well as an "event struct" containing the event type (string) and the time (float) are used to keep the information and 3 lists, the introduction's pulse list, the game's pulse list and the game event's list are used to store them. During the introduction, every second, a new pulse struct is created containing the information about the player's heart rate and stored to the introduction's pulse list, and during the game, the same process is done for the game's pulse. An event struct is only added to its corresponding list when an event is triggered, such as elements in the background, the mannequins jumpscaring the player or the player deactivating a mannequin. At the end of the experience, the values stored in the various lists are then saved as json, as well as the average pulse calculated during the introduction.

3.3 Hypothesis

- Hypothesis 1: The various recurrent and random events will have an impact on the tester's pulse.
- Hypothesis 2: The switch of state at the middle of the experiment will create a difference depending on how the tester was scared or not during the introduction.
- Hypothesis 3: The various interviews will be very useful to correlate the tester's fear and their pulse.

4 Tests

4.1 The experiment

4.1.1 Procedure

The participants were guided to the experiment room. Some questions were asked to detail their profile: Their genre, their age, how they felt at the mo-

ment, their sport frequency, their gaming frequency, their experience in VR, their experience in the horror genre and how they felt about the experience. It was also asked if they had heart rate problems and if they did know the risk of VR and horror experiences and consent to participate. After agreeing the VR mask was put on their face and adjusted, the pulsometer was put on their left index or middle finger, and it was indicated to them that they had to put their left hand down and not to move it.

It was then told to them that they had to try to relax during 2min30 and that they had nothing to do and that the following of the experiment was going to be clarified after the 2min30. After asking if they were ready to start, the introduction started, in which a relaxing music was played. The heart rate is measured after 60 seconds to give them some time to relax and eventually give indications of how to behave if they were moving too much.

After the introduction, the testers were familiarized with the controls and their main objective in a quick tutorial. The tutorial is composed of a room, a corridor and a room with 4 mannequins, 3 non-active and 1 active. There is no timer for the mannequins, the testers can take as much time as they like to familiarize with the controls. The experience starts when the second mannequin of the tutorial is deactivated.

When the game starts, the goal is to find on the map where the mannequin is active. If they don't find it in time, which corresponds to 40 seconds, the game punishes them with a jumpscare. This part lasts 300 seconds During the experiment, there are several scary elements that occur. After 50 seconds, a creepy music plays for 20 seconds, at 110 seconds, the lights of the map switch off, at 120 seconds, a creepy voice is heard in the environment and at 180 seconds a creepy distorted crying sound plays until the end. During this time of the experiment, the tester's pulse base calculated during the introduction is used as the minimum pulse input, and the maximum pulse is the minimum pulse + 30 bpm. During the first 150 seconds, the more stressed the tester, the more the experiment gets oppressive and scary, and during the last 150 seconds, the situation is inverted.

After the experiment, the pulse sensor and the VR headset are removed. The testers have to answer questions, on a scale of 0/10 how they felt scared, what scared them most, what they thought about the experiment and what

they liked and disliked. The experience is at this moment ended, and it's explained and shown to them the impact of their pulse on the experiment.

4.1.2 Participants

A total of 14 participants aged between 18 and 45 years experienced the experiment, 9 considering themselves as males and 7 as females. Most of the testers didn't have a lot of experience in Virtual Reality games or with horror experiments in general. 7 of the participants are not playing video games or rarely, 2 participants consider themselves as occasional gamers, 3 participants as regular and 2 of the participants as hardcore gamers. 3 of the 14 participants didn't play the entire experience because they were too scared and decided to stop, 2 non gamers and 1 regular gamer.

4.2 Results

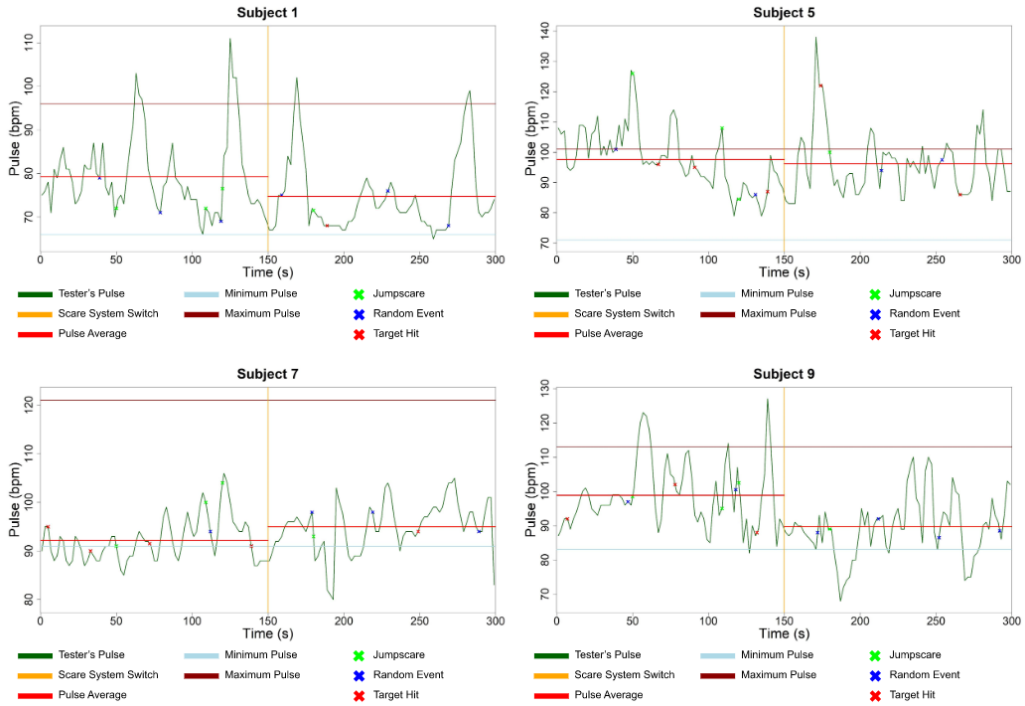

Fig 18: Test Results

To evaluate the player's fear during the experience, the tester's heart rate variations and various events that occurred during the entire experience were analyzed. The correlation between the measured heart rate and the tester's questionnaire and various questions asked was measured.

The results show that the first jumpscare is very effective on the player scare. All testers related that it was the moment they felt the pick of their fear during the entire experience. The jumpscares loses their efficiency during the experiment after becoming almost irrelevant. This effect can be related to the decreased impact of the fear of the unknown, which is one of the best generator of fear. Testers generally related that they quickly understood what the real danger was.

The various random events during the experiment had mixed effects. Some related them being effective, other related not even bothering about them, and the Subject 5 even related feeling reassured by them. One tester was so scared by the first random element that he decided to stop the experiment even before a jumpscare occurred. The results of the random events are pretty hard to see, because the jumpscares often interfere with them. It's complicated to evaluate if the fear is generated by the events, by the jumpscares or both.

The impact of the switch of the scare system state at the middle of the experiment is difficult to measure. At the start of the experiment, most of tester's fear is high and goes down, at the middle of the experiment. The subjects related that it was mostly due to the fear of the unknown, and that their fear lowered with the time. The Subject 7 related that he felt more and more oppressed with the time, which can be seen in the graph.

The interviews, passed before and after the experience, helped a lot to link the various results with what really happened to them. Some related that at the middle of the experiment, they were very little concerned by the fear than to accomplish their objectives, which can be seen in most graphs. The Subject 5 even explained the increase of his heartbeat at the end was due to frustration due to the character moving slowly instead of fear.

4.3 Limitations

4.3.1 Pulsometer

One of the first limitations was the precision of the pulsometer. The used pulsometer is very good to start with electronics, but very limited when it has to measure the precise tester's pulse. During some tests, it happened that the player's started moving their left hand, which had a considerable impact on the imperfection of the measured pulse. The pulse had to be carefully watched during the experiment and every problem had to be noticed.

4.3.2 The experience

The experience was another limitation to gather the best possible information about the fear generated through biofeedback.

During most of the interviews after passing the experiment was the fact that the testers were very scared at the start of the experience, but after understanding the main gameplay loop, they were much less scared and stressed. The only moment the tester got an intensive stress impact is during the jumpscares, which has a length of 1 second, and the scare of the unknown is then dissipating. Some testers said that it would have been much more stressful if the mannequins were moving, if they felt chased by something.

4.3.3 Dissipation of the fear of the unknown

The various testers related that most of the fear generated at the start was due to their fear of the unknown. Most of the testers explained that their fear scaled down after they understood the main gameplay loop, which corresponds to the gathered information. What would have been interesting during the entire experiment is to see an evolution in the main gameplay loop.

4.3.4 The tester's profile

By analyzing the player's results and their profiles, it was also very interesting to notice that some people were more sensitive to some fear elements

and not to others. Some people noticed being scared about the creepy mannequins movements, some related being reassured by the various random audio elements in the background and some told even being stressed during the introduction, when they were supposed to relax.

5 Conclusion

In this paper, the impact of biofeedback was tested in an experience where the tester's pulse representing the tester's fear was used as an input to change the experience. Various experiences and games are using a similar approach, but most of them punishes the player for being scared, and their fear system doesn't evolve, where here, the player's fear only have an impact on the environment and the player's speed, and the fear system changes during the experience. The hypothesis were that the switch in the fear system at the middle of the experiment would generate a difference depending on how the tester scared was during the introduction, that the interviews would be useful to correlate the tester's fear and their pulse, and that the various scary elements of the experience would have an impact on the player's pulse.

The developed experience demonstrated that despite the imperfections in precision of the pulse sensor, the pulse is still very effective to measure the player's stress, that the effectiveness of the various scare elements differ from one person to another, but that a jumpscare almost always is effective until it gets predicted. It was also noticed, that this kind of experience is not the best to make fear have a that high impact on the gameplay and to measure the variety of a fear system. The testers related quickly understanding the main gameplay loop, being then less scared, and only have a stress pick during the firsts jumpscares, which is due to the dissipation of the fear of the unknown. A more effective test would've been to place a direct threat to the player, like a monster chasing the players.

The experience of this paper had a lot of problems that can be solved with other types of similar experiences. The creation of an experience, where the testers would be chased by a monster instead of frequent jumpscare, would be interesting to do. What could be interesting would be to still variate the player speed, but instead of changing it at half of the experience, changing it

at the start of every chase with the main ennemy. It could also be interesting to use a wireless and effective pulse sensor, as well as an eye tracker or even a facial expression tracker, to increase the effectiveness of the experience and maybe use these new inputs for other purposes.

The use of biofeedback in games can increase a lot game experiences if well-used. With the cheaper cost of biofeedback tools, it wouldn't be surprising to see more games using such systems for their games. The human body transmit a lot of information that could be exploited by games, and there still is a lot to explore.

5.1 Acknowledgment

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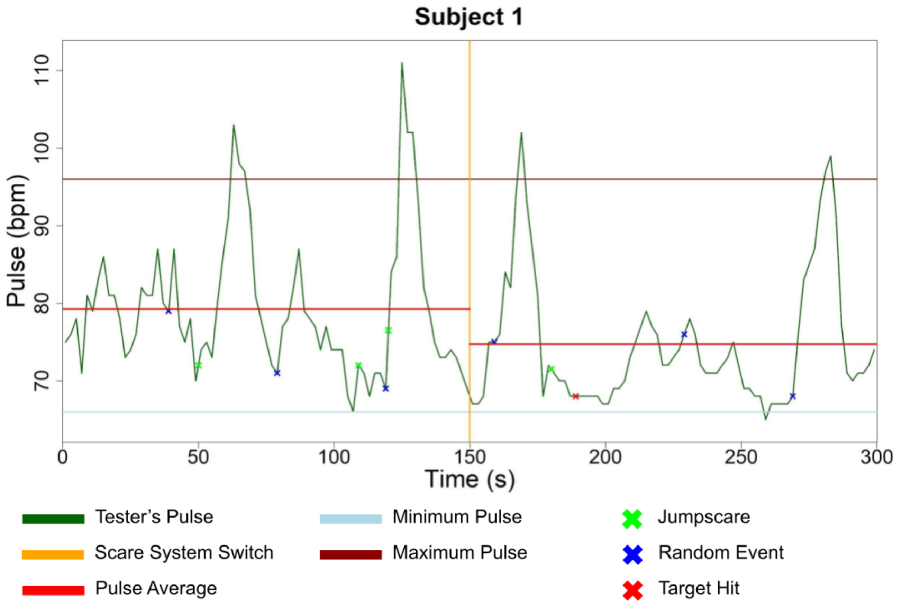
Figures

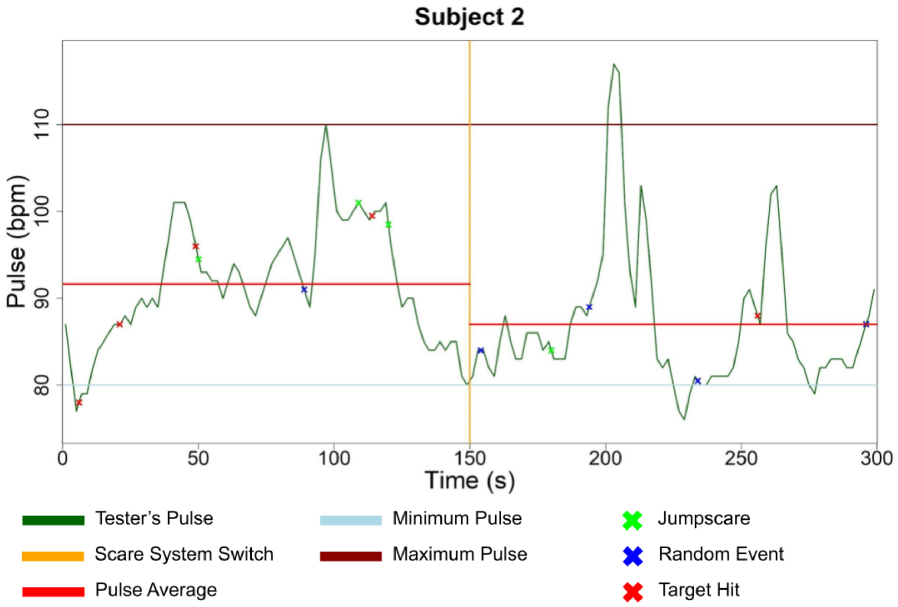
- Figure 17: Scare system, product by the author
- Figure 18: Test Results, product by the author

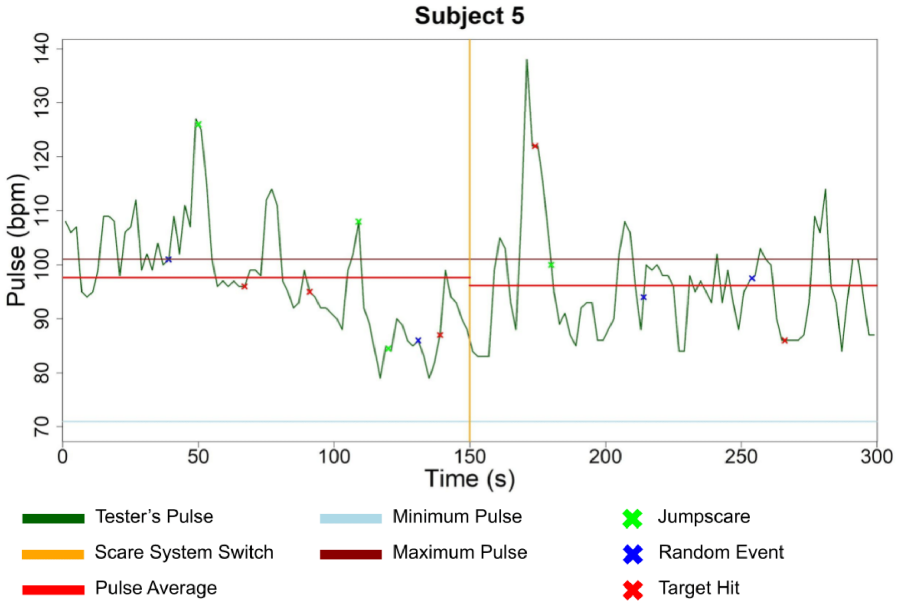
Appendix

I. Test Results

I. Test Results



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Pulse (bpm)
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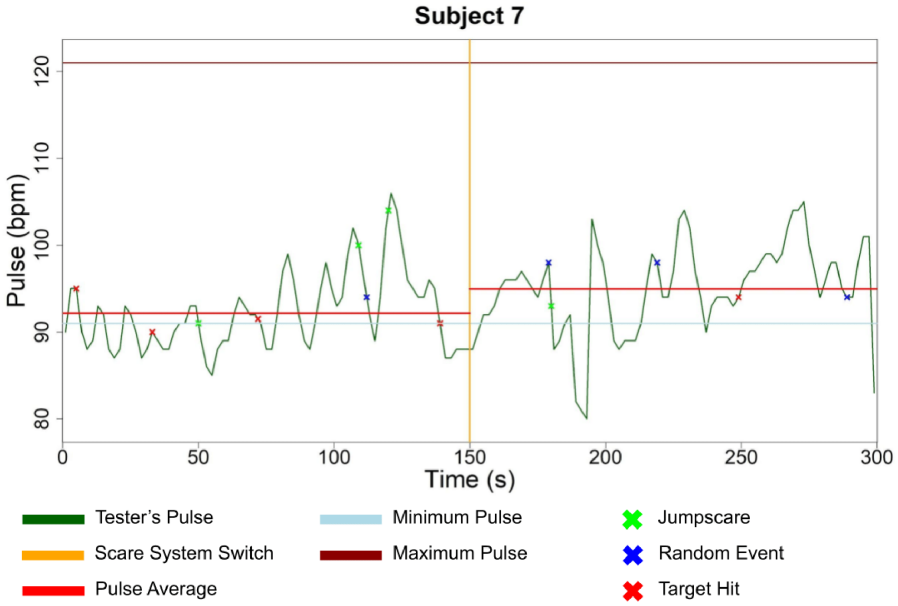
90
100
110
120
130
140
0
50
100
150
200
250
300
Time (s)
Tester's Pulse
Scare System Switch
Pulse Average
Minimum Pulse
Maximum Pulse
Jumpscare
Random Event
Target Hit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Pulse (bpm)
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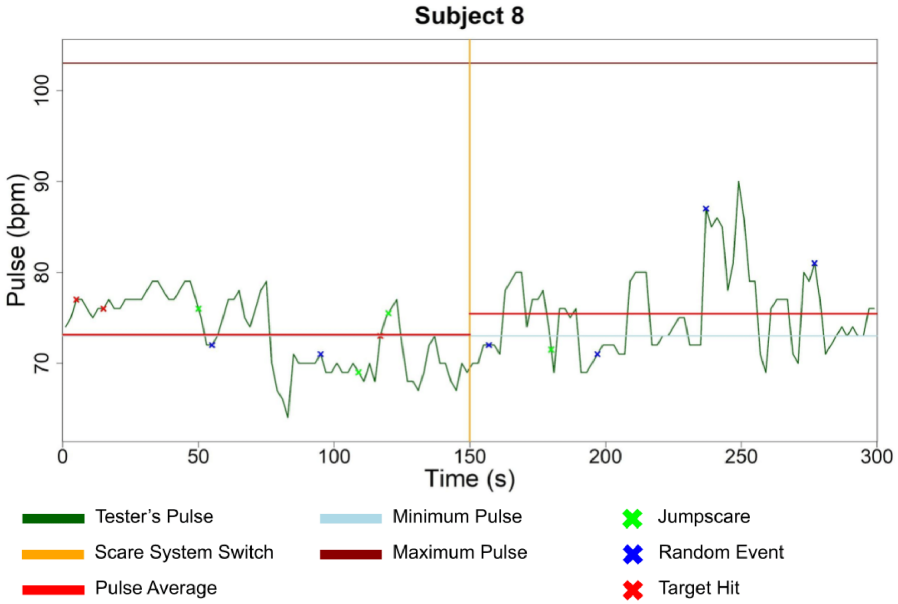
90
100
110
120
0
50
100
150
200
250
300
Time (s)
Tester's Pulse
Scare System Switch
Pulse Average
Minimum Pulse
Maximum Pulse
Jumpscare
Random Event
Target Hit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Pulse (bpm)
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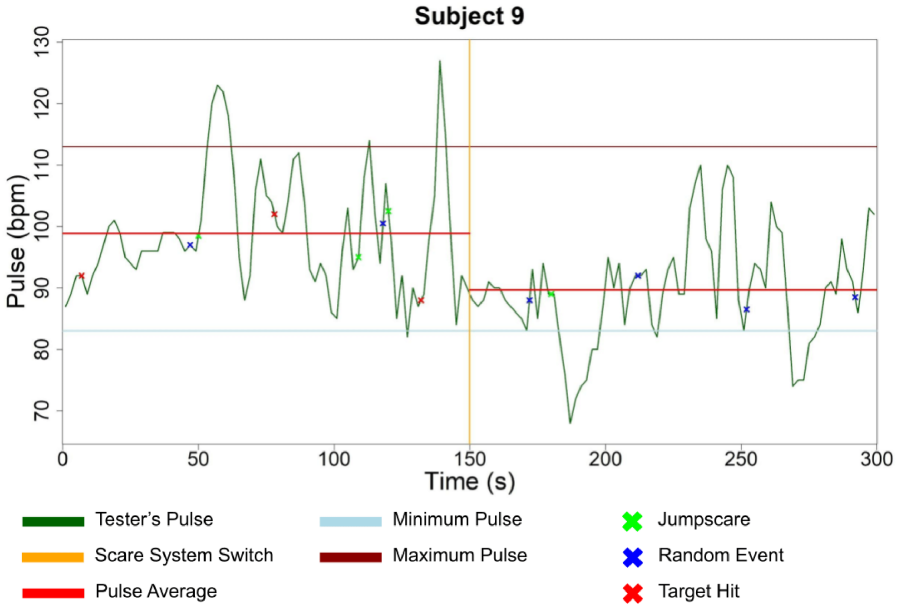
80
90
100
0
50
100
150
200
250
300
Time (s)
Tester's Pulse
Scare System Switch
Pulse Average
Minimum Pulse
Maximum Pulse
Jumpscare
Random Event
Target Hit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110
120
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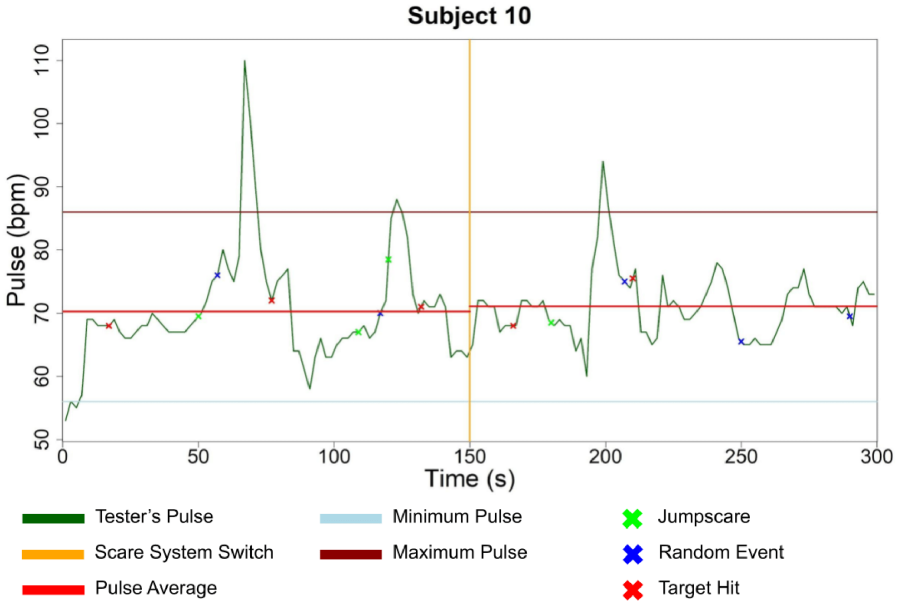
0
50
100
150
200
250
300
Time (s)
Tester's Pulse
Scare System Switch
Pulse Average
Minimum Pulse
Maximum Pulse
Jumpscare
Random Event
Target Hit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80
90
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0
50
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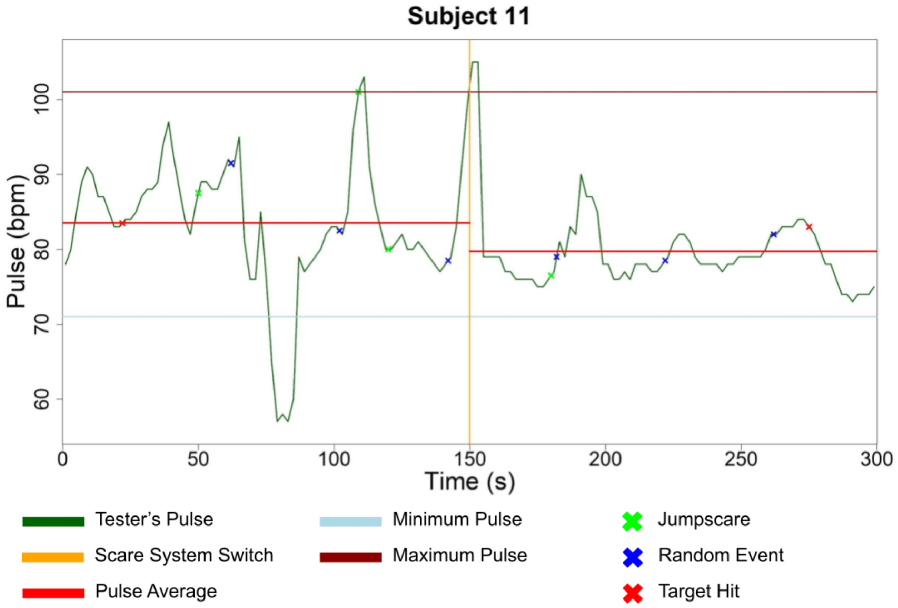
200
250
300
Time (s)
Tester's Pulse
Scare System Switch
Pulse Average
Minimum Pulse
Maximum Pulse
Jumpscare
Random Event
Target Hit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Pulse (bpm)
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80
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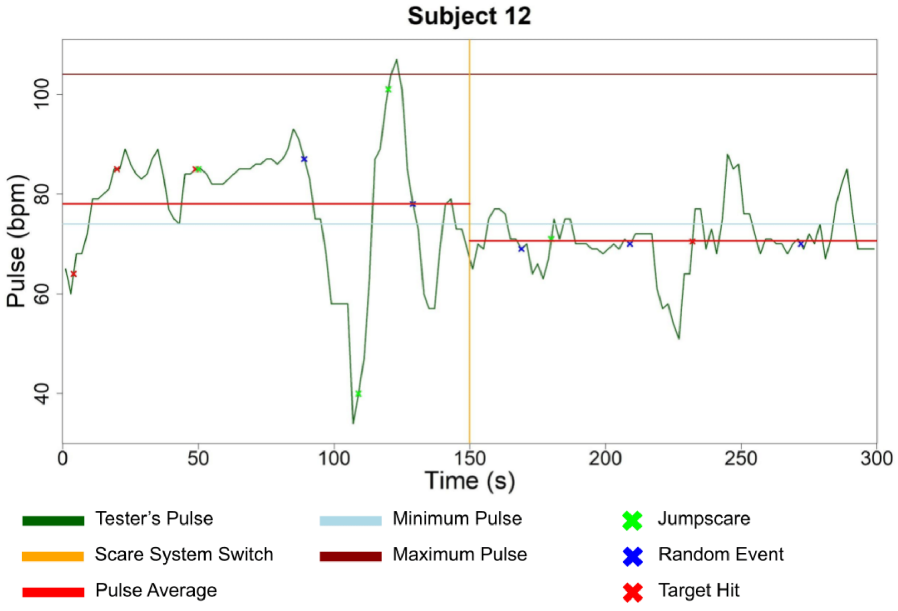
100
0
50
100
150
200
250
300
Time (s)
Tester's Pulse
Scare System Switch
Pulse Average
Minimum Pulse
Maximum Pulse
Jumpscare
Random Event
Target Hit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Pulse (bpm)
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0
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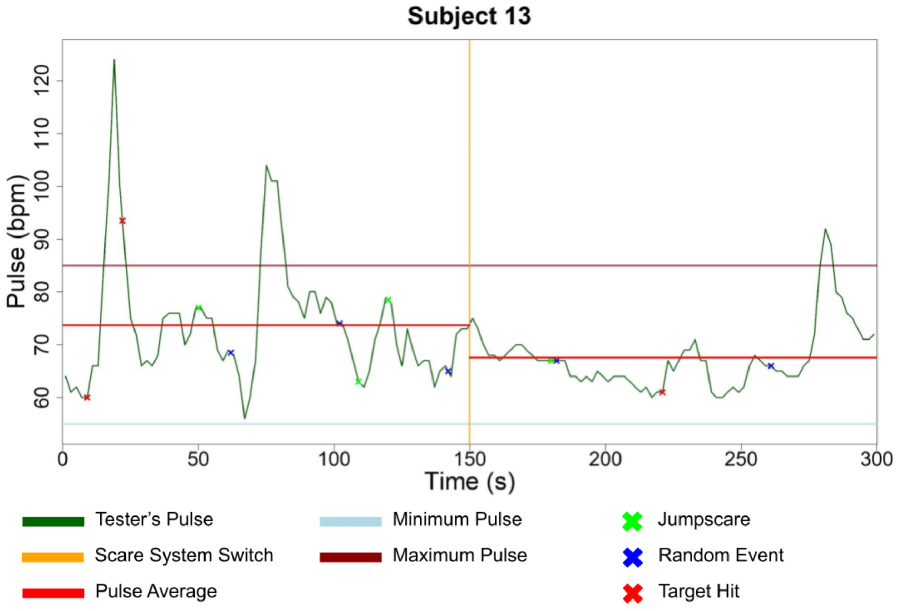
100
150
200
250
300
Time (s)
Tester's Pulse
Scare System Switch
Pulse Average
Minimum Pulse
Maximum Pulse
Jumpscare
Random Event
Target Hit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Pulse (bpm)
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80
90
100
110
120
0
50
100
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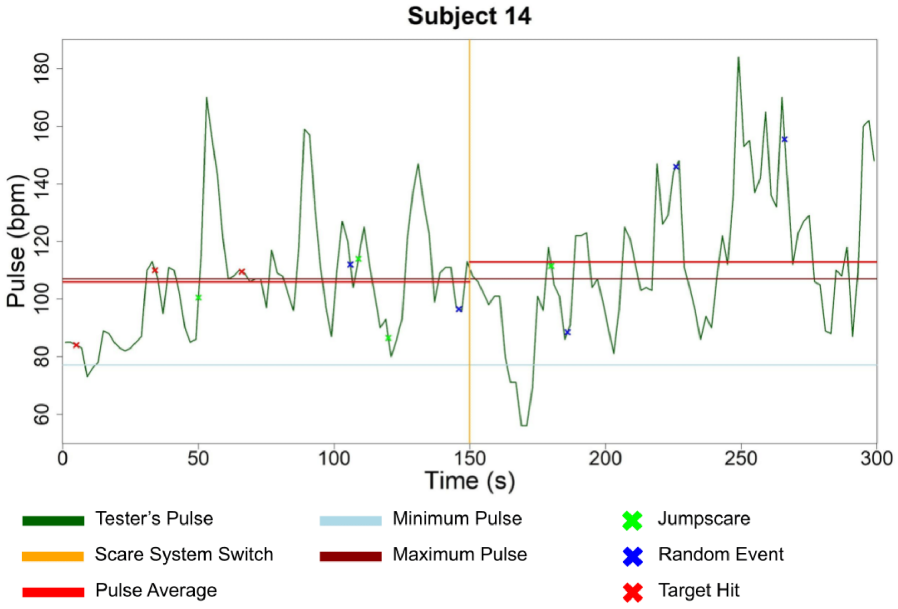
200
250
300
Time (s)
Tester's Pulse
Scare System Switch
Pulse Average
Minimum Pulse
Maximum Pulse
Jumpscare
Random Event
Target Hit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Pulse (bpm)
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100
120
140
160
180
0
50
100
150
200
250
300
Time (s)
Tester's Pulse
Scare System Switch
Pulse Average
Minimum Pulse
Maximum Pulse
Jumpscare
Random Event
Target Hit