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Hardware Solutions for Biofeedback and Game Interactions

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HARDWARE SOLUTIONS FOR BIOFEEDBACK AND GAME INTERACTIONS

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Introduction

- Video game developers aspire to create more personal and intimate games for players.
- However, static standard input devices such as a keyboard and mouse vary the experiences that each player has.
- A third dynamic input device to monitor stress levels of players might improve a game's ability to create a more personalized experience.
- The third input would monitor a player's heart rate.
- The program would assume a player's stress level and dynamically craft a unique experience in the game, thus crafting an intimate experience for a player.

Static inputs

- Unfortunately the input devices for gaming have remained rather static since gaming genesis.
- For home console devices or personal computers: the choice of input has mostly been either a controller with buttons or the mouse and keyboard.
- Only within the past couple of years have companies such as Microsoft, Sony, and Nintendo experimented with their home consoles with some more dynamic inputs.
- However, no such inputs have engaged with a player's personality or preference. With a non-invasive heart rate monitor, games will be able to learn player reactions and create games dynamically and personally for the user.

Why invest into video games? ESRB

- The Entertainment Software Rating Board (ESRB) is a non-profit body that assigns and standardizes content ratings for video games, so parents may make more informed choices before purchasing a videogame for their child [9].
- According to the ESRB Video Game Statistics posted in 2010, the average age of a gamer is 34 years old [10]. More importantly, 67% of US households play video games [10].

Why invest into video games? Steam/Microsoft

- Steam is an online retail distribution for video games.
- They release their unique users playing statistics of their last 48 hours for the public use [11]: As of August 26th, 2013, Steam peaked with over 5 million unique users playing videogames [11].
- Microsoft released their fiscal statement for the year 2011.
- Microsoft sold about 13.7 million Xbox 360 units, and had about 35 million users playing online for the year.

Defining the hardware solution

- Finding the correct hardware solution for biofeedback interactions is a precarious balance of ease of implementation, affordability to the end user, amount of useful data for the program, and how invasive the hardware is to the end player.
- Invasiveness is how much privacy a player has to give up in order to enhance their gaming experience.
- Since a player and their privacy needs are important to developers, each method of is individually judged for how invasive it is to a player.
- Affordability is a reflection of the cost of the hardware for a player and the developer, so it is important to develop hardware as cost efficient as possible, though players may be willing to spend more money if the hardware offered yields outstanding results for gameplay.
- Finally, the hardware will have to supply useful data for the entire game play-through.

Defining the hardware solution

- It is possible that some hardware solutions provide data only partially of the time, so the developer adjusts the software to allow for no incoming data.
- A few possible hardware solutions may be defined as the following:
  - Heart rate monitor
  - Electroencephalography (EEG)
  - Eye tracking
  - Face detections
  - Perspiration detection

Heart rate

- A heart rate monitor is one of the least invasive forms of obtaining biofeedback from a player.
- Two ways of measuring the heart rate is either through the subject's finger or wrist. If measured through the wrist, a player wears some variation of an electret microphone [2].
- The microphone listens for a pulse.
- The microphone attaches to the wrist of a player, leaving the fingers of a player free to use.
- A potential problem is that the microphone hugs the wrist of a player and if the microphone is rubbed, this may produce unwanted noise.
- Developers may purchase a high quality microphone that reduces unwanted noise, but that increases the cost of the product for a player.

Heart rate

- Another way to record the heart rate of a player is to mount a LED light and photo-resistor to the finger of a player.
- The LED light penetrates the finger in such a way that the photo-resistor records the light, and determine how much blood volume is in a player's finger [4] [6].
- If done correctly, this method may be more reliable than the microphone since it is more difficult to introduce unwanted noise for the photo-resistor to record.
- However, attaching a LED and a photo-resistor to a player's digit proves to be bulky and completely removes a digit to use on the keyboard or mouse.
- Respectively, both approaches to record a heart rate prove to be inexpensive and provide enough feedback to the developer.

EEG

- The brain offers a wealth of information that, if developers could access, would help generate dynamic games and offer a more personal experience.
- An Electroencephalography (EEG) offers the most information for the developer but presents some obstacles for the developer and a player [3].
- Out of all the options, the EEG proves to be not only costly, but the EEG sensors need to be placed on a player's head so they can read electrical signals from the brain.
- Each time a player wants to engage in a game activity, a player needs to mount the sensors.
- Then after the play-through a player will have to dismount each individual sensor.
- The attachment of the sensors to a player's head consume a lot of time and may not be a favorable scenario for a player.
- Though there are limitations, using EEG results in a great amount of useful data for the developer to utilize.

Eye tracking and face detection

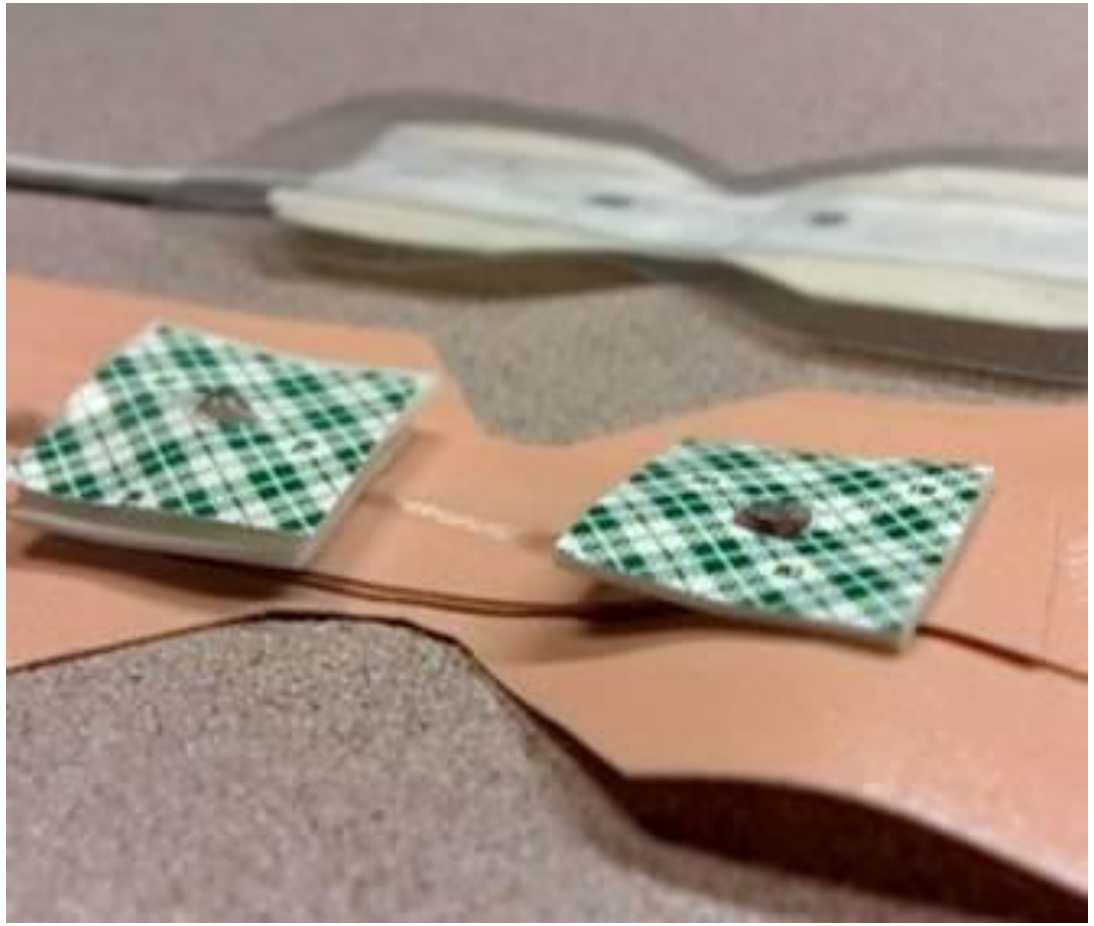
- Eye tracking and face detection are two methods which utilizes a player's camera. Cameras are relatively inexpensive but are still not the cheapest solutions for biofeedback.
- Eye tracking relies on a player's rapid eye movement to judge a player's anxiety [3]. Increased eye movement may mean a player is in a heightened state of stress and anxiety [3].

Eye tracking and face detection

- On the other hand, face detection is looking for physical moods of a player. Determining face states means that there can be multiple states [3].
- A face may depict anger, stress, sadness, happiness, etc.
- Since face detection can include many more states, the game software would be extremely flexible as opposed to surveying a heart rate.
- Though both face detection and eye tracking are only useful when a player's eyes are focused on the computer monitor.
- The software adds complexity and assume that a player may not always be looking towards the computer monitor.

The heart rate solution

- For the purpose of this study, biofeedback is a result of the heart rate.
- The hardware is a LED and a photo-resistor monitoring the blood flow of the subject's finger [4].
- This solution was chosen because the ease of implementation and the amount of useful data that is generated from the hardware.
- Also, this implementation of recording the heart rate has less of a chance to produce a lot less noise in a controlled environment.
- The hardware inputs into an automation I/O device [5] that allows easier software development.



Heart rate apparatus with photoresistor and LED.
Picture by National Instruments [4].

The complete system

BIOFEEDBACK IMPLEMENTATION IN A VIDEO GAME ENVIRONMENT

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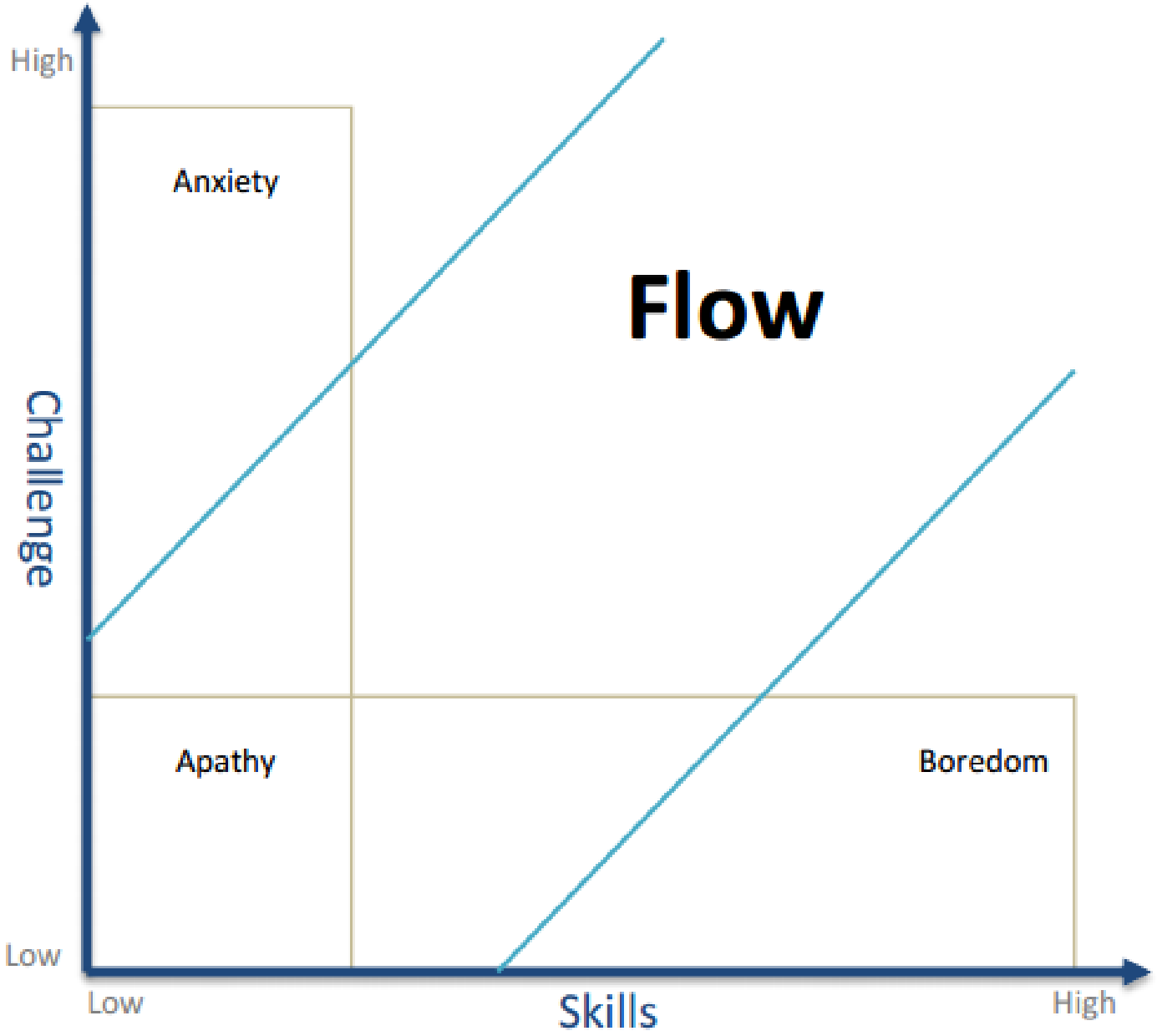
Achieve a game with “Flow”

- One of a game developer’s main goals is to create a game that fully emerges, engages and challenges a player enough to make the game enjoyable [1].
- According to the Flow Theory researched by Mihaly Csikszentmihalyi in the early 1980’s [2], video games need to maintain a constant balance between levels of difficult
- “Flow” is described as when the balance of challenge and skill of a player is achieved [2].
- In this project’s case, the challenge/anxiety is derived from fear, and the skill/boredom is a product of how frightened a player is.
- A possible challenge with obtaining perfect “Flow” is that each individual player has a different “Flow”.
- A certain game event may appeal to one player’s fear, but to another player, the event does not have an influence[2].



Mihály Csíkszentmihályi's Flow representation when Challenge and Skills are balanced. Picture provided by [1].

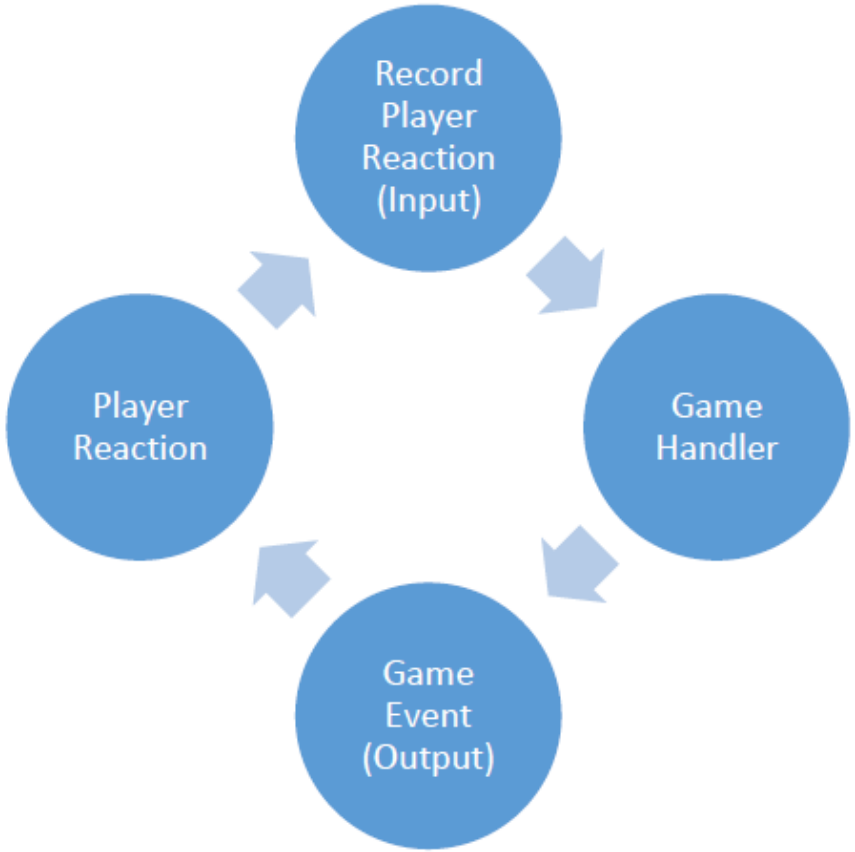
Dynamic inputs

- A possible obstacle with horror titles is the limited number of players who would be willing to play the game, with a predisposition of how frightening it might be.
- For this reason, a game may be desaturated with a few horror scenes removed so it can appeal to a larger audience. Research could allow more intimate gaming experiences by allowing a player to be in a level with which they are comfortable.
- Depending on a player's choice, the game dynamically tracks a player's stress levels and generate events instantaneously.
- This third dynamic input device would improve the development of a game that is personalized to a player and his interests.

Previous Work

- VALVe, a game development company out of Bellevue, Washington, tested biofeedback among players and games [3].
- VALVe used the same psychological approach to a player using the "Flow" model.
- Their test cases attempted to use quite of few different types of inputs such as eye tracking, heart rate, Electroencephalography, as well as a couple of other inputs.
- Their results provided a base and inspiration for this research paper. VALVe concluded that it is possible to playtest with these apparatuses, but this paper will dive deeper into the heart rate aspect of play testing.
- This paper studies how events are dynamically generated for a player's preference, as well as validating how well the biofeedback model works.

Game Events Model



A version of VALVe's flow chart

- This paper is going to use a similar flow model to what VALVe used to read and react to the biofeedback of a player [3].
- This model makes sure that the next game events is based off of the previous reaction of a player [3].

Hardware

- National Instruments supplies the specifications and instructions for a heart rate monitor.
- This monitor can be built using common items from an electronics store [4].The LED is powered by a voltage source and the LED is faced in such a way that the light pierces the subject's fingertip where the light is received into a photo resistor.
- The photo resistor outputs a value to an automation I/O device [5] which interprets the data for the game program.
- The device should be placed on a player's thumb. A disadvantage to this model is that the device is bulky and eliminates the thumb digit, so a player is not allowed to use the thumb digit on the keyboard.
- A workaround to this solution is to use a more slimming device that would work more like a glove, so all digits can still be used, or use an electro microphone to record the pulse of a player's wrist.

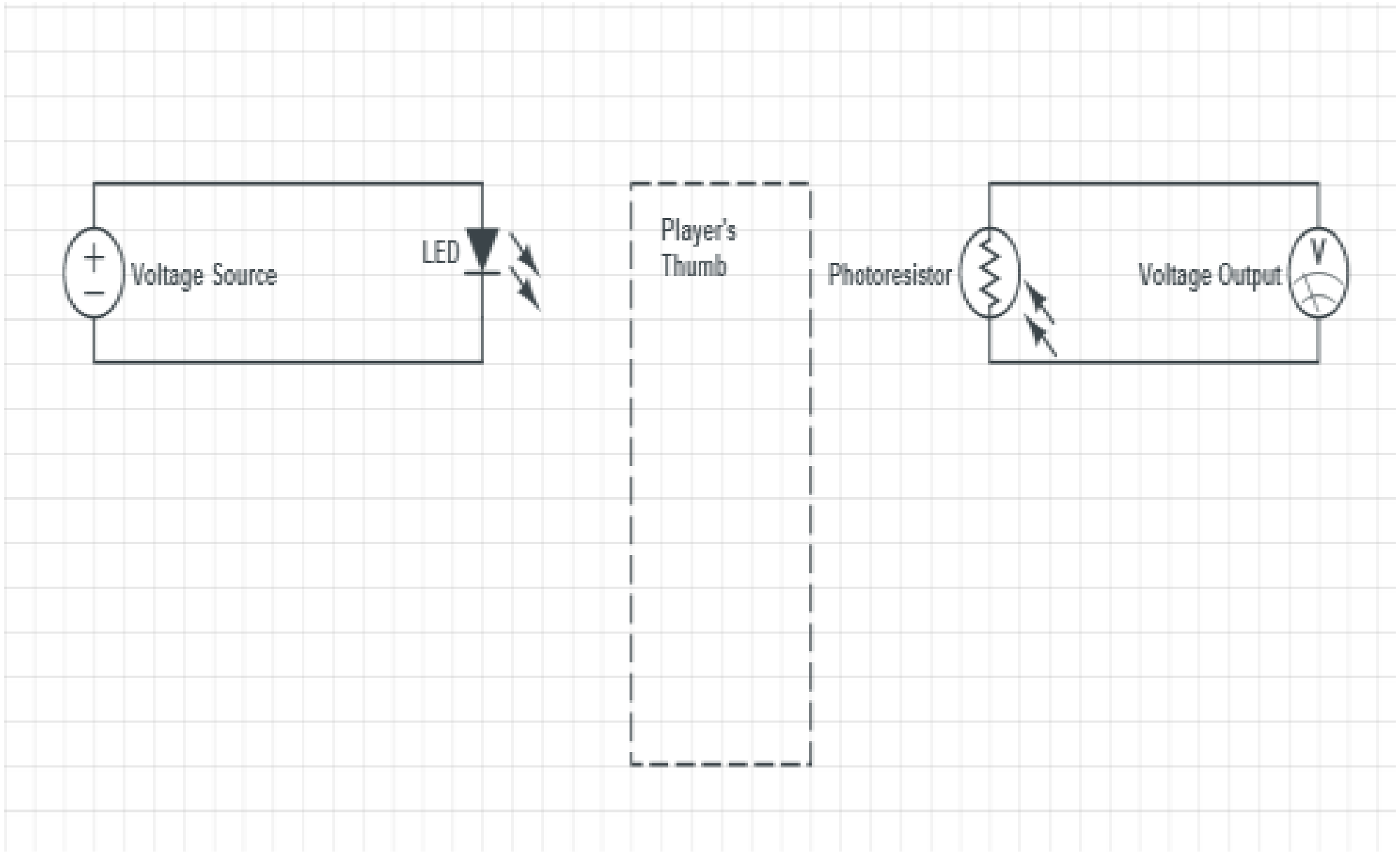


Diagram of the Heart rate Monitor [17].

Software and Hardware

- The photo resistor reads a different voltage level based on the amount of blood flowing through the finger in this experiment's device [6].
- The software and hardware will determine when a player is anxious.
  - In this project's case: When the heart rate jumps across a relative threshold.
- Once an event is triggered, the game notes if the player was stressed or not.
- The next game event that is generated is based on how the player reacted to the previous event.

Software and Hardware

- In this current model it's extremely easy to swap out a new type of biofeedback hardware device without having to rework the current game program.
- All the developer would have to do is design a new hardware feature, update the current software handler, so the hardware may be able to define an anxious state and a relaxed state.
- Some possible hardware that could replace our current heart rate monitor:
  - Electroencephalography(brain activity)
  - Skin perspiration (Skin conductivity)
  - Facial tracking (Both face and Eye tracking)

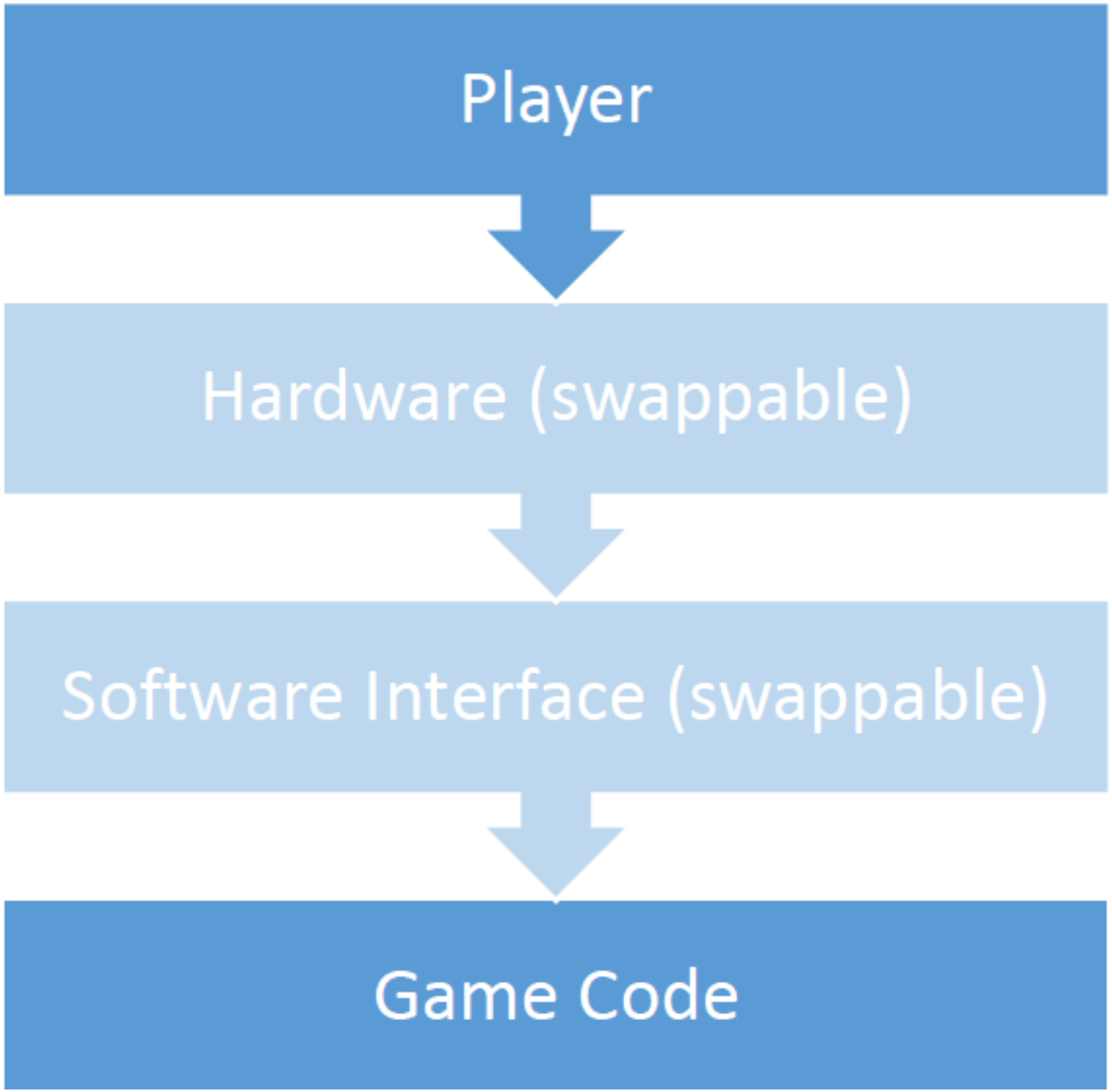


Figure 3: Model of Game implementation

Software

- This experiment uses VALVe's Source Development Kit (SDK) for the game [13].
- VALVe's SDK is a powerful set of tools completely backed by a powerful game engine that has been constantly modified and improved since 2004 [13].
- VALVe has successfully released twelve games since the debut of the Source engine.
- Many of those titles have received numerous awards for their gameplay, mechanics, and storyline.
- One of the reasons for such highly awarded games is because VALVe is backed by such a powerful toolset like the SDK.
- The SDK offers robust tools such as a map editor and model poser, and the game engine itself.
- This project focuses on using VALVe's map editor and source engine for the implementation of this project.

Software

- The map editor, also known has “Hammer Editor”, is a tool environment that allows the developer to forge the environment or “map” that a player interacts with.
- Hammer also handles the logic for the world, meaning it handles the creation of game events.
- In this project’s case, the map listens to what events are stressing a player and has to implement those events later on in the level.
- The Source Engine is modified to allow Hammer to have an event listener for when a player is stressed.

The Game

- The game stage that the test subjects play through is a linear map, linear meaning a player's follow a path with little to no deviation or choice from a planned path from the developer.
- The game generates and host events that are aimed to scare and heighten a player's heart rate.
- This game follows a similar model to a critically acclaimed horror game called, "Amnesia: The Dark Descent" developed by Frictional Games [14].
- Amnesia's gameplay is based around a player being defenseless against perusing monsters.
- The only way to 'defeat' monsters is to quickly make a decision of where to run and hide to evade opponents.
- If caught, the monsters kills the player and the game is over.

Game Events

- Most generated events and encounters in Amnesia are based around two premises.
- First, a planned chase scene: a player is able to see the monster, but the monster is not yet aware of a player.
- This scenario allows for a player to plan his route and possible actions before he initiates the chase scene.
- This type of event also allows for anticipation and anxiety to build before the chase scene is initiated.
- The second type of events are 'jump' events.
- This type of event is where a player doesn't expect a chase scene and is required to make a quick decision to survive the event.
- A 'jump' event results in a 'jump' in anxiety or heart rate. The game events are based on either event or a combination of these two type of events.

Implementation

- When testing hardware, software, and a player all together, the test is done in a controlled environment.
- Test subjects are introduced to the device as well as taught how to play the game and the overall experience to expect from the game.
- This teaching is done in a brightly lit room to ensure a player can be as relaxed as possible.
- Once a player has an understanding to how the game will work and has the heart rate monitor properly fitted the test may start.

Implementation

- Right before a player begins the game, room lights are turned off and only a moderator will remain in the room with a player.
- The moderator's job is to assist in any problems or issues that may arise, but is not allowed to give possible hints that could relax a player's heart rate.
- The moderator is also supposed to keep a careful log of how a player reacts with the game.
- This log is used for further analysis the player's visual stress level vs. the recorded data during the game.

Implementation

- During the game a player's heart rate is recorded.
- The respected times in which a player interacts with events are noted and are placed in a graph after a player's play through.
- The graphs are documented and placed in a folder with the notes from the moderator.
- This way it's easy to analyze the feedback data after the test.
- Once the test is concluded, a player is asked a series of questions from the moderator to confirm which events the subject felt 'scared' at and if that corresponds to the data from the graph.

Results

- In order to judge if events were generated correctly, the moderator in the room constructed a graph of the subject's heart rate of the play-through.
- If the heart rate elevates across a certain threshold during a game event, then the next event that is generated should be similar to the previous event.
- The moderator needed to confirm that the subject was actually 'frightened' during certain game events, so the moderator needed to confirm in a form of inquiry to a player.
- The moderator may ask a player something similar to, "Did you feel frightened during 'this event'?"
- 'This event' refers to the event that scared a player according to the graph.

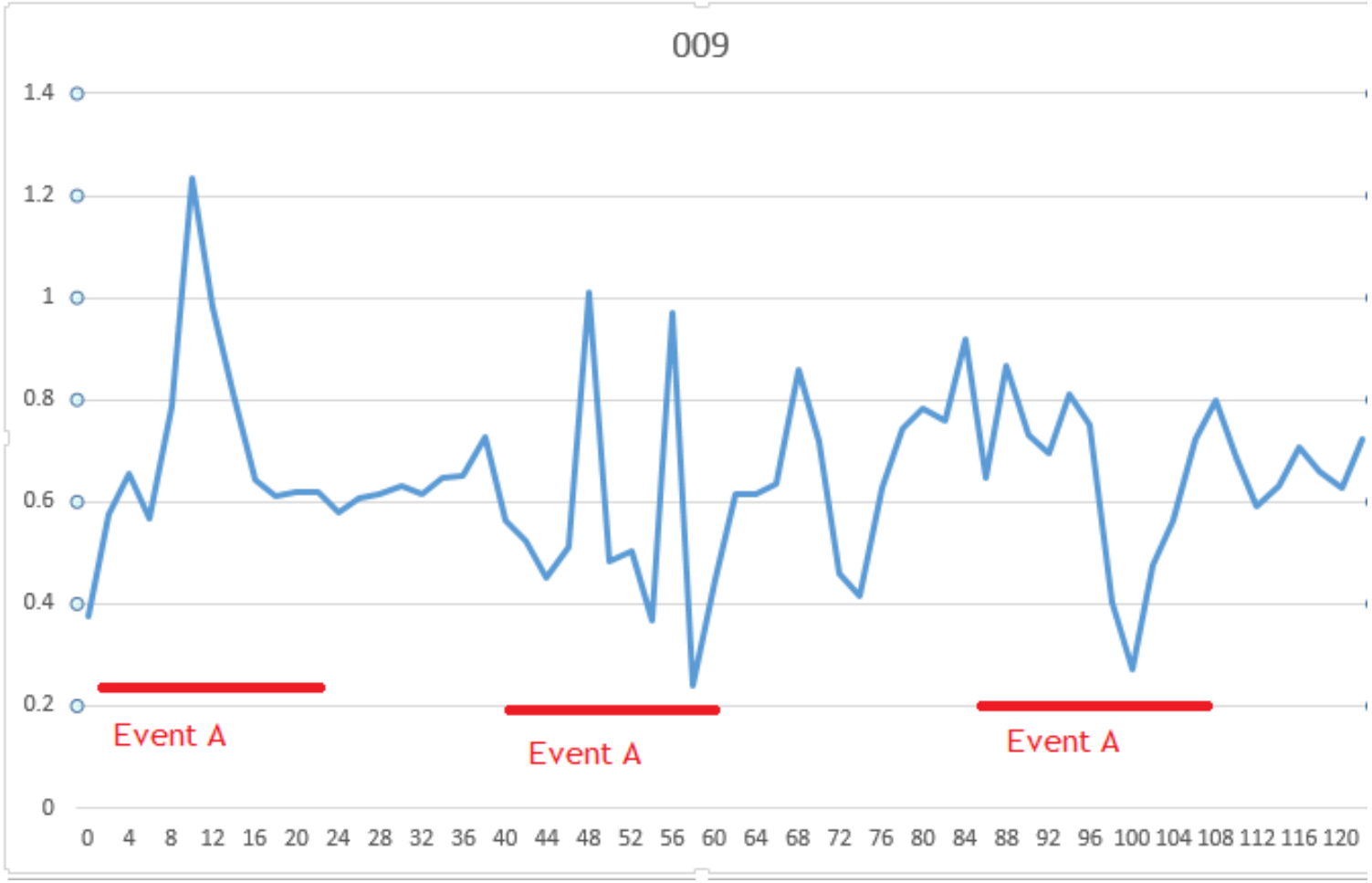
Results

- To make sure that a player does not give false information, the moderator confirms with his notes of the play-through if a player demonstrated signs of stress at key game events.
- It is up to the judgment of the moderator to determine if the game event was generated correctly or not.
- Even if a player is not scared at all during the game.
- The game handler still can generator successful events by attempting to generate new events to scare a player.

Results

- 11 subjects were tested. 16 out of 20 game events were dynamically generated correctly or 80% of the game events were generated correctly.
- For one of the participants, all the game events that generated completely failed. One possibility may be because the participant was wearing nail polish and obstructed the sensor from the heart rate monitor.
- Since this test was a small set of tests subjects, this is not fully conclusive data, but these results do highly suggest that biofeedback is plausible and may work if implemented into a full game experience.
- Each of the game events were generated by a player's preference at the current game time, so the game was tailored to the individual player's experience.

Results


009
1.4
1.2
1
0.8
0.6
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0
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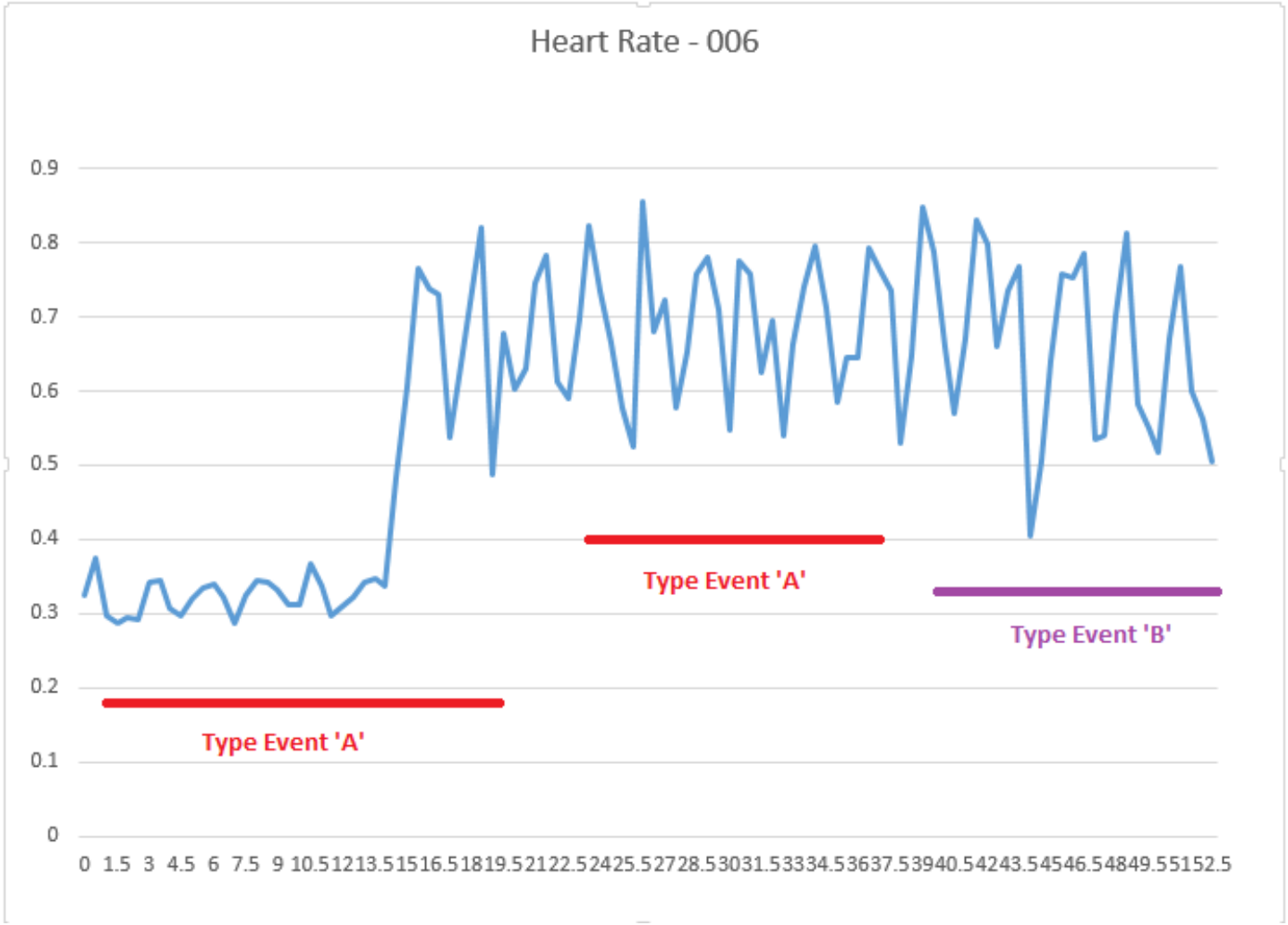
Event A
Event A
Event A

Results


Heart Rate - 006
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0 1.5 3 4.5 6 7.5 9 10.5 12 13.5 15 16.5 18 19.5 21 22.5 24 25.5 27 28.5 30 31.5 33 34.5 36 37.5 39 40.5 42 43.5 45 46.5 48 49.5 51 52.5
Type Event 'A'
Type Event 'A'
Type Event 'B'

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Thank you

- Questions and Comments.