Daydream

A Virtual Reality Mind-Tour

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1 Introduction

The inner workings of the brain is largely still a mystery to humans. It's only in recent years that computer science began to explore the idea of a brain-computer interface (BCI). Many of these non-invasive BCIs use EEG technology to measure a brain's Alpha and Beta waves to determine more general states of mind such as “relaxed” or “focused”. How exactly developers should be utilizing this technology is still not concrete. There are obvious areas of applications, such as for prosthetics, but the majority of people cannot benefit from BCI technology. Daydream aims to find commonplace applicability of BCIs through a virtual reality medium.

Virtual reality itself is a fairly new innovation that still faces issues with effectiveness. One of the biggest concerns with virtual reality is how to take in input from the user. Typically, the user must either hold a controller or another foreign object to control their actions. These external inputs detract from the intention of virtual reality; immersing oneself into a completely different world. A brain-computer interface in combination with a virtual reality environment would allow for a hand-free, completely immersive experience. Daydream's main goal is to demonstrate the practical nature of this form of interaction and the potential for it to be a viable form of input for virtual reality. With the only input being the users own thoughts and emotions the experience is taken to an entirely new horizon of interaction where nothing exists but the person's mind and their fantasy world.

Since the concept phase, the focus of the project has shifted from developing a BCI video game to gaining a greater understanding of the potential power of BCI for virtual reality. This has led to changes in the devices used, detailed below, and the type of game to be produced. The method of delivery is still in the form of a video game as it demonstrates and encapsulates behavior in an interactive and visually-stimulating way. Daydream sets the player in on a thought-driven journey to take pictures using their brain to act as a camera. The game move players through a scene, allowing them to look around with head tracking. Entities will be arranged along the scenery at varying distances, either farther away or closer to the player. The player then has to focus their mind, for an amount of time equivalent to how far away the entity is, to zoom in their camera. When the player is satisfied with their camera position, they can snap a photo of the entity and be given a score based on how well their shot turned out. A tutorial for the game will also be available for first-time players. Daydream delves into many areas of interest, such as the practicality of having to quickly focus in, and the feasibility of having a user focus for an extended period of time. Confirming that the players are able to accurately control their actions would be an optimistic indicator of future applications of BCI and virtual reality.

The devices chosen are the NeuroSky Mindwave Mobile, for the BCI component, and Google Cardboard, for the virtual reality environment. The Mindwave offers two mental state readings, an eye blink tracker, and access to raw EEG data. The functionality of the Mindwave is simple yet captures a large enough range of brainwaves to use for a video game. The Google Cardboard has drawbacks in its magnet trigger mechanism but is affordable and an excellent environment to test out the interaction between BCI and virtual reality. Instead of having a desktop application as detailed in the concept portion of the project, the game will be made into a mobile application for Android using Unity.

The concepts used in this project come with the challenge of being on the leading edge of technology. BCI in particular is a brand new form of interaction, bringing a unique dynamic to the game. Regardless, the innovative notions of BCI and virtual reality hold great promise for the future. These forms of interaction can accommodate a large number of users from as game enthusiasts, to people who practice meditation, to people with impaired fine motor skills, and those with ADHD and anxiety disorders. Because of the breadth of potential users, the options for marketing the product are flexible and adaptable.

This paper covers the requirements, use cases, requirements traceability matrix, initial snapshots, a glossary, a list of references, and the contributions of the team members. The requirements specification details both the functional and nonfunctional requirements for the game. The use case section contains descriptions of the use cases, detailed use cases, and a use case diagram. The traceability matrix shows the relationship between the use cases and the functional requirements. Initial snapshots display some early prototypes with descriptions. The list of references section presents references that are applicable to our domain and used to aid us in our project. The contributions section describes the duties of each member. The table of contents details where each of these sections can be found.

2 Requirements

2.1 Functional

R.01	[1]	Daydream shall allow the user to start the game.
R.02	[1]	Daydream shall allow the user to stop the game at any time.
R.03	[1]	Daydream shall allow the user to exit the game at any time.
R.04	[1]	Daydream shall allow the users to view the pictures that they have taken.
R.05	[1]	Daydream shall allow the users to pause the game at any time.
R.06	[1]	Daydream shall allow the users to restart the game.
R.07	[1]	Daydream shall render the game's environment, textures, and models.
R.08	[1]	Daydream shall update the scene with its most current state.
R.09	[1]	Daydream shall support head tracking for camera movement in the game.
R.10	[1]	Daydream shall detect physical button input.
R.11	[1]	Daydream shall calibrate BCI input device for proper use of various users.
R.12	[1]	Daydream shall detect varying levels of brainwave activity.
R.13	[1]	Daydream shall determine and detect a "Focused" state of brainwave activity.
R.14	[1]	Daydream shall determine and detect an "Unfocused" state of brainwave activity.
R.15	[1]	Daydream shall allow the user to save a snapshot of the current gameplay view as an image file.
R.16	[1]	Daydream shall implement a scoring mechanism.
R.17	[1]	Daydream shall include a tutorial to instruct users on how to play the game.
R.18	[2]	Daydream shall detect user eye movement.
R.19	[2]	Daydream shall provide audio feedback in correlation to brain wave activity.
R.20	[2]	Daydream shall support multiple entity recognition.
R.21	[2]	Daydream shall allow the user to choose multiple levels.
R.22	[2]	Daydream shall allow night and day environments with different visibility settings.
R.23	[2]	Daydream shall allow the player to use items that interact with entities.
R.24	[3]	Daydream shall support haptic feedback.
R.25	[3]	Daydream shall provide a mode for augmented reality.
R.26	[3]	Daydream shall support a multiplayer mode.
R.27	[3]	Daydream shall provide online leaderboards.
R.28	[3]	Daydream shall offer level customization to the user.

2.2 Non-Functional

T.01	Daydream shall be written in Unity.
T.02	Daydream shall be implemented through OpenGL.
T.03	Daydream shall render in real-time.

T.04	Daydream shall run at 30 FPS.
T.05	Daydream shall utilize Mindwave.
T.06	Daydream shall utilize Google Cardboard.

3 Use Cases

3.1 Use Case Diagram

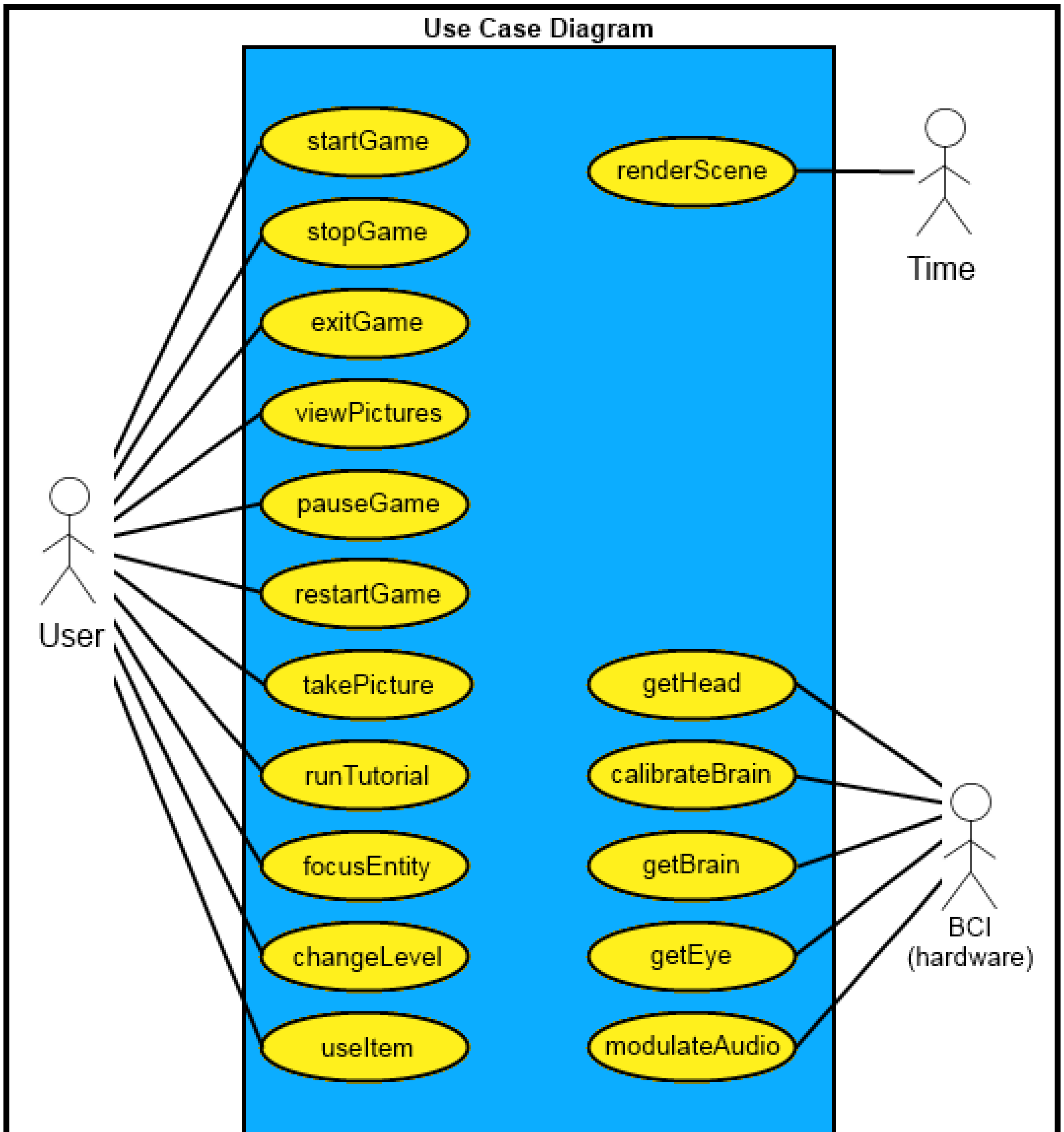

Figure 1

3.2 Detailed Use Cases

Use Case Descriptions		
UC.01	startGame	The user selects the "start" option from the main menu. The game will then begin for the user.
UC.02	stopGame	The user brings up a pause menu and selections the option to stop their game. The user will then be taken out the game and brought back to the main menu.
UC.03	exitGame	The user selects the "exit" option from the main menu. The game will be ended and the user will be brought back to their device interface.
UC.04	viewPictures	The user selects the "View Pictures" option from the main menu. The user can then look through an album of pictures taken in the game, being able to focus in on a picture to view it in full.
UC.05	pauseGame	The user may interrupt their game with a trigger input during a transition scene. The game will suspend the game and bring up a pause menu.
UC.06	restartGame	The user restarts the game by pushing the restart button during main gameplay. The game returns to main title screen.
UC.07	renderScene	Daydream steps the game and updates the location of all entities depending on each entity's physics. Daydream then renders the current frame.
UC.08	getHead	Daydream reads in input from head tracking device. Daydream then adjusts user's in-game view in relation to input.
UC.09	takePicture	The user takes a snapshot of the current view by pushing the take picture button. Daydream saves the snapshot as an image file. Daydream also calculates a score based on a scoring algorithm that takes into account distance from entity, size of entity, and the user's brain wave activity level.
UC.10	calibrateBrain	Daydream calibrates the brain wave input device by running the input device's default calibration program.
UC.11	getBrain	Daydream reads in input from brain wave input device. Daydream then adjusts user's in-game brain wave activity in relation to input.
UC.12	runTutorial	The user may play a tutorial to understand how to play the game.
UC.13	getEye	Reads the user's eye movements and slightly shifts the in-game view.
UC.14	modulateAudio	Adjusts audio volume levels based upon the user's current brain wave activity level. More focus would equate to a louder volume.
UC.15	focusEntity	Allows the system to determine which entity, if there are multiple entities on screen simultaneously, is the focus of the picture being taken.

UC.16	changeLevel	The user may select from multiple levels, and may adjust the time of day between day and night to set different levels of ambient lighting.
UC.17	useItem	The user may use items to interact with the in-game entities. Different items shall have different effects upon use.

3.3 Detailed Use Case Templates

Use case: takePicture	
User Case ID	UC.09
Actor	User
Precondition(s)	1. Brain Wave Activity input device is calibrated. 2. User has selected a level. 3. User currently in a level.
Flow of Events	1. Daydream provides audio feedback in the form of a camera shutter sound effect. 2. Daydream provides visual feedback by mimicking the closing of camera aperture in user's view. 3. Daydream takes a current snapshot of the game view and saves view as an image file. 3.1 Daydream removes the prompt overlay. 4. Daydream increments the counter for number of pictures taken and updates value in HUD.
Postcondition(s)	1. Current view saved as an image file.

Use case: runTutorial	
Use Case ID	UC.12
Actor	User
Precondition(s)	1. The user is at the main menu.
Flow of Events	1. The use case starts when the user selects the "Play Tutorial" option on the main menu. 1.1 Daydream starts the tutorial game. 2. Daydream prompts the user to look around. 3. The user looks around at their surroundings. 3.1 Daydream removes the prompt overlay. 4. Daydream displays an entity. 5. While the user is not in a focused state. 5.1 Daydream regularly prompts the user to focus. 5.2 Daydream adjusts the zoom to the current focus condition. 6. While the user is in a focused state. 6.1 Daydream prompts the user to press the trigger to take a picture. 6.2 Daydream adjusts the zoom to the current focus condition. 6.3 If the user takes a photograph with a satisfactory score.

	6.3.1 Daydream informs the user of scoring and notifies the user the tutorial is over. 6.3.2 The use case ends. 6.4 If the user does not take a photograph with a satisfactory score. 6.4.1 Daydream informs the user of scoring. 6.4.2 Daydream allows the user to try again.
Postcondition(s)	1. The user returns to the main menu. 2. The user has an understanding of the game mechanics.

Use case: changeLevel	
User Case ID	UC.16
Actor	User
Precondition(s)	1. User is at the main menu.
Flow of Events	1. The use case starts when the user selects the “Start Level” option on the main menu. 2. The user may select a level from a list to play. 2.1 Daydream prompts the user for a time of day for the level. 3. The user may select a day or night setting for the level. 4. The user selects the “Play” button. 4.1 Daydream loads the selected level and adjusts light according to the specified time of day. 5. The user is brought to the level and may play the game.
Postcondition(s)	1. The user may play the level to completion or quit at any time.

4 Requirement Traceability Matrix

Requirements	Use Cases	UC.01	UC.02	UC.03	UC.04	UC.05	UC.06	UC.07	UC.08	UC.09	UC.10	UC.11	UC.12	UC.13	UC.14	UC.15	UC.16	UC.17
	R.01	X																
	R.02		X															
	R.03			X														
	R.04				X													
	R.05					X												
	R.06						X											
	R.07							X										
	R.08							X										
	R.09								X									
	R.10									X								
	R.11										X							
	R.12											X						
	R.13											X						
	R.14											X						
	R.15									X								
	R.16									X								
	R.17												X					
	R.18													X				
	R.19														X			
	R.20															X		
	R.21																X	
	R.22																X	
	R.23																	X

5 Snapshots

Figure 1: Display of mockup title screen. Title screen will hold for a couple seconds, then will start to take in input. Game starts when a certain level of brain activity is read. Original image used in title screen taken from < http://wallalay.com/clouds-30-382768-desktop-background.html >

Figure 2: Display of main menu. User can choose to select a stage, run the tutorial, or to exit the application. Original image used in title screen taken from < http://wallalay.com/clouds-30-382768-desktop-background.html >

Figure 3: Display of level select if implemented. User selects a stage to proceed to. Original image used in title screen taken from < http://wallalay.com/clouds-30-382768-desktop-background.html >, < http://simonemccallum.files.wordpress.com/2012/06/unicorn_and_rainbow.jpg >, < http://www.wired.com/wp-content/uploads/blogs/insights/wp-content/uploads/2012/11/clouds_660.jpg >, < http://www.cse.unr.edu/~dascalus/ >

Figure 4: Display of a well zoomed entity to take a picture. Entity is centered well is in good view in for the user to take a picture. Such a picture would net the most points. Original image taken from: < http://abstract.desktopnexus.com/wallpaper/358514/ >

Figure 5: Example of an entity zoomed in too far. This is what happens when the user focuses too much on an entity that is relatively closer. Such a picture would not score many points. Original image taken from: < http://abstract.desktopnexus.com/wallpaper/358514/ >

Figure 6: Example of an entity zoomed out too far. This is what happens when the user focuses too little on an entity that is relatively far away. Such a picture would not score many points. Original image taken from: < http://abstract.desktopnexus.com/wallpaper/358514/ >

6 Glossary

Alpha Waves	A type of brainwave that registers the state of physical and mental relaxation. It is associated with deep relaxation and ranges between 7.5-14Hz.
Augmented Reality	A live view of real-world locations and objects, with digital overlays generated via computer.
Beta Waves	A type of brainwave that is emitted during and alert or agitated state. It is associated with waking life and ranges between 14.40Hz.
Brain Wave Activity	A measure of the amount of synchronized electrical pulses generated from neurons communicating with each other.
Brain-Computer Interface (BCI)	A communication between a computer system and the brain.
Calibration	Optimizing of device by adjusting and standardizing input readings in respect to user's latent input range.
Electroencephalography (EEG)	A test to detect electrical brain activity using a contact point called an electrode. EEG data is expressed using waves.
Focused State	A state in which brain wave activity is above a certain threshold.
FPS	Frames Per Second.
Google Cardboard	A low-cost, do-it-yourself eyepiece that integrates with Android smartphones to provide a mobile virtual reality experience.
NeuroSky Mindwave	A simple BCI device that measures EEG signals for the purpose of development, entertainment, and education.
Non-invasive BCIs	A brain-computer interface that does not break the skin but rather sits on top of the head.
Unfocused State	A state in which brain wave activity is below a certain threshold.
Unity	A cross-platform video game creation system that includes a game engine and an IDE.
Virtual Reality	A world that a user may experience which is entirely virtual, though means of electronic devices such as a computer or smartphone.

7 References

Folgieri, R., & Zichella, M. (2012). A BCI-based application in music: Conscious playing of single notes by brainwaves. *Comput. Entertain., 10*(3), 1-10. doi: 10.1145/2381876.2381877

This paper details the possible application of BCI instruments to play musical notes. The detail this paper takes into the effects of a combined paradigm of audio, gesture, and visual stimuli on the user is especially important for the considerations our team will take on this project.

J, M., & rvinen. (2013). *Beyond Five Senses: Non-Sensory Output in Brain-Computer Interface (BCI) Research*. Paper presented at the Proceedings of International Conference on Making Sense of Converging Media, Tampere, Finland.

This paper proposes a research review on the topic of non-sensory output in BCI. This paper proposes alternative outputs rather than visual or audio stimulus and notes the advantages of implementing additional output. The paper also does well in illustrating the limitations imposed by both HCI and BCI input and output.

Kapeller, C., Hinterm, C., ller, & Guger, C. (2012). *Augmented control of an avatar using an SSVEP based BCI*. Paper presented at the Proceedings of the 3rd Augmented Human International Conference, Megève, France.

This paper focuses on the use of BCI instruments to control an avatar in the popular video game, World of Warcraft. This paper details the process for appropriating working BCI control onto a video game and will greatly influence the considerations our team will take on this project.

Yoh, M.-S., Kwon, J., & Kim, S. (2010). *NeuroWander: a BCI game in the form of interactive fairy tale*. Paper presented at the Proceedings of the 12th ACM international conference adjunct papers on Ubiquitous computing - Adjunct, Copenhagen, Denmark.

This paper focuses on the use of a specific BCI device, the NeuroSky Mindset, in the implementation of an interactive version of a fairy tale. The NeuroSky functions very much like the Mind Wave device we plan to implement. The NeuroSky's use of an "attention" and "meditation" state will be especially valuable as our team uses a "focused" and "unfocused" state to accomplish the same task and similar roles.

8 Contributions

Sarah Koh contributed to the following:
- Introduction
- Functional requirements
- Use case descriptions
- Detailed use case
- Glossary

Jan Chris (JC) Orolfo contributed to the following:
- Naming project Daydream
- Setting up weekly team meetings
- Functional Requirements
- Non Functional Requirements
- Use Case Description
- Glossary of Terms
- Initial Snapshots
- List of References

Matt Fredrickson contributed to the following:
- use case descriptions
- detailed use case template
- glossary
- cover page
- created the use case diagram
- created the traceability matrix
- compiled all information into the SRS from individual members