



EEG-Based Dynamic Difficulty Adjustment



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The Premise:

Sometimes, puzzles or games can feel too difficult. In other cases, they are far too easy. Either way, users end up feeling disengaged, bored, and frustrated.

This project explores how difficulty can dynamically adjust to tailor-fit the user, creating an engaging and immersive experience.

Methodology:

Before beginning development, I analyzed similar existing works. Given the EEG headset available to me (Emotiv Epoc X), I found that the most realistic approach would be to use decreasing beta/gamma waves and increasing alpha waves as an indicator that the user was losing focus.

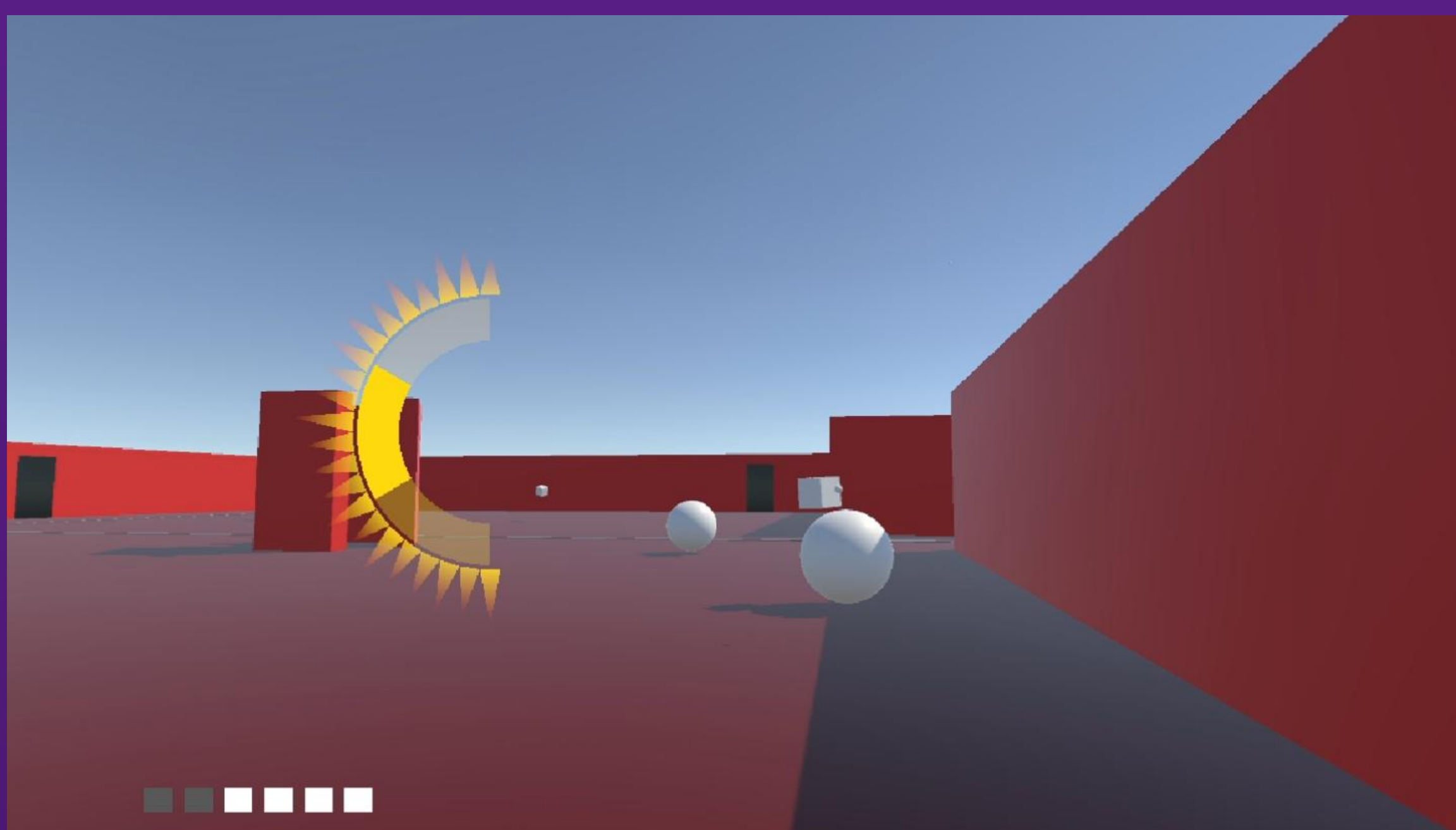
Using Open Sound Control (OSC), I read this input into Unity as a single focus variable. Then, depending on smoothed and normalized focus readings over time, several parameters of the game would be changed dynamically.

Project Contact Information:

This was a remote project, done under the supervision of Dr. Myungin Lee:
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```
Command Prompt - python n x Windows PowerShell
03fa6abaf2e8be/branch:refs/tags/v1.16.2/build:Release/compiler:MSVC-19.0.24245.0/link:SHARED
Stream name: Epoc X \\?\HID#VID_1234&PID_ED02&MI_01#7&3971dce0&0&0000#{4d1e55b2-f16f-11cf-88cb-001111000030}, Device path: \\?\HID#VID_1234&PID_ED02&MI_01#7&3971dce0&0&0000#{4d1e55b2-f16f-11cf-88cb-001111000030}
Stream for device with path \\?\HID#VID_1234&PID_ED02&MI_01#7&3971dce0&0&0000#{4d1e55b2-f16f-11cf-88cb-001111000030} initialized.
Complex signal shape: (2, 14, 768, 5)
Sent full-freq power: 186.52465066499187
Sent gamma power: 143.85732447441976
Sent alpha power: 55.69606410669743
Sent beta power: 210.29768565613475
Sent theta power: 367.37241216735305
Complex signal shape: (2, 14, 768, 5)
Sent full-freq power: 1.8774796800476288
Sent gamma power: 1.9970033450463376
Sent alpha power: 1.9245913708067142
Sent beta power: 1.840160668806396
Sent theta power: 1.8922252929674728
Complex signal shape: (2, 14, 768, 5)
Sent full-freq power: 1.706933205305992
Sent gamma power: 1.9616060701673363
Sent alpha power: 2.1687104416924456
Sent beta power: 1.5533011965886434
Sent theta power: 1.807417128537993
Complex signal shape: (2, 14, 768, 5)
Sent full-freq power: 1.6046972336238823
Sent gamma power: 2.1778981765237386
Sent alpha power: 2.3044981957221067
Sent beta power: 1.6281831991276037
Sent theta power: 1.8042584759374336
Complex signal shape: (2, 14, 768, 5)
```

A few Python scripts oversee reading input (your brainwaves) from the EEG headset. Every channel is measured, but only three are used and sent to the game. C# was then used to normalize and smooth the sent “focus” variable.



The user in this example has been completing the puzzle elements of the game very easily. This has caused them to lose focus, so the game has added a stamina nerf. This makes it harder for the player to move around as quickly, meaning they must pay more attention to the enemies shooting at them.

Novelty:

Previous works that have used Dynamic Difficulty Adjustment (DDA) before have a pattern of heavily leaning into the awe factor of EEG. This project instead focuses on integrating DDA into a complete experience, where it enhances gameplay rather than defining it.

The game is a simple First-Person Shooter (FPS) combined with puzzle elements. As the player’s focus changes, gameplay responds through effects such as increased damage output or faster stamina drain. Visual effects are exaggerated to reinforce these changes and increase immersion.

Future Work:

I consider this a work in progress. The textures are still quite basic and not yet indicative of an immersive experience.

There also remains the possibility to implement a Machine Learning (ML) model using this game. By having many participants play the game, enough data can be collected to eventually create a system that predicts when the user might eventually lose focus.

Each of these elements have been explored individually, but not at the same time. There remains the possibility to create an experience that is both scientifically meaningful and genuinely engaging.

Acknowledgements:

Thank you Dr. Lee and IMD staff for your guidance throughout this process, as well as for teaching me how to conduct thorough research and effectively use EEG technology.
I would also like to thank Dr. Holtz and Dr. Merck for their responsiveness and continued support during my time in Science and Global Change.

