INTERTWINED

Virtual And Physical Prototyping
Politecnico Di Milano

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Executive Summary

Intertwined is a Virtual Reality experience that is driven by biofeedback and in which users get to learn and become aware of cognitive distortions, a phenomena that makes people see life through a negative lense of exageration and despair. The experience takes place in an abstract natural environment to reinforce the notion that everyone belongs to the same ecosystem and that no one is ever alone in facing these psychological difficulties.

This report demonstrates the process adopted by the team conducting the study that led to the final prototype of the Intertwined VR experience

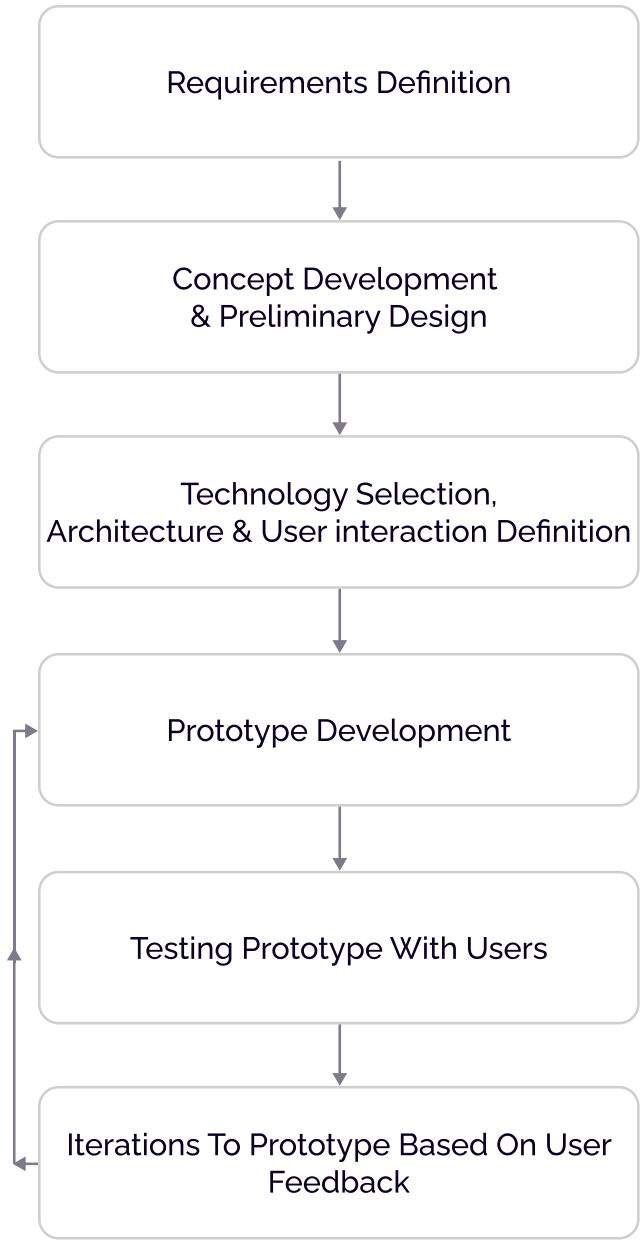
Introduction

At one point or another in life, every person had to face the problems that come with the subjectivity of perception. These obstacles are manifested in a psychological phenomena called cognitive distortions that push people to think that situations are more negative and dangerous than they actually are.

To raise awareness to the topic, the team conducting the study proposes a virtual reality experience that utilizes biofeedback (gathered from users as they are participating in the experience) to modify the virtual environment in real time to further increase the immersivity of the experience.

Given that older people are more likely to be aware of the subjective aspect of perception, the team decided that it would be more impactful to focus on younger generations that might not be aware of the problem. The target users for this experience would be young adults between the ages of eighteen and twenty-three years old.

This report will begin with showcasing the state of the art of the technology, showcase the main concept articulated and proceed to explain the devlopment of the virtyal reality experience. The scheme below illustrates the methodology that was adopted to guide this study and to create the final prototype.



Main Concept

Research shows that the vast majority of people have had to overcome cognitive distortions in their daily lives. In total, there are more than fifteen types of cognitive distortions. In the publication titled "Measuring Cognitive Errors: Initial Development of the Cognitive Distortions Scale (CDS)', Psychologists Roger Covin, David J. A. Dozois, Avital Ogniewicz, and Pamela M. Seeds present an experiment that suggests that the three most common cognitive distortions are: Mind Reading, Catastrophizing, and All-Or-Nothing Thinking. These three distortions would be the ones used as educational examples in the proposed virtual reality experience. Given that these phenomena trigger negative feelings such as stress and anxiety, the next step was to understand how they would affect the physiological state of a person. Studies show that the heart and respiratory rate drastically increase when a person is in an agitated state of anxiety. For these reasons, the team investigated how to properly trigger a slight state of anxiety in users in order to get a change in the physiological response that will be measured throughout the experience. The most effective method would be to get users to implicitely think of intimate stories that affected them on a personal level and ensure that they are really engaged with the experience. Getting people to think of personal situations in which they were affected by cognitive distortions would allow them to learn about the concept through an embodied learning approach.

Based on the findings from the inital desk research conducted, the team drafted the following proposoal:

A virtual reality experience that makes users ponder over previous personal experiences in which they were affected by cognitive distortions without explicitly mentioning the cognitive distortions at first. Remembering these situations will trigger a change in the physiological state of the users. This change will be detected by sensors and will modify the virtual environment in real time, suggesting to users the impact the phenomena could have on their lives. The biofeedback detected will also be used to generate a customized natural element (tree). Users would then navigate a setting (forest) that is made uf of other trees and they will be able to read personal stories of other people affected by cognitive distortions. The takeaway message of the experience would be that everyone deals with this problem and that users are not alone in facing this. The Natural setting in which the experience is set is a metaphor for a supportive community and suggests to users that they are not alone but rather connected to a wider ecosystem that is there to help and support them. After the experience is over, the tree generated would be added to the virtual environment and users would have the choice to anonymously contribute with a personal story, fortifying the sense of connectedness with others.
The User Interaction flow attached below would serve as the structure of the virtual reality experience (Scheme I). This concept was then proposed to and approved by Psychologist Monica Clerici.

State Of The Art

STATE OF THE ART

A research on existing projects that utilizes biofeedback for human biometrics monitoring and environment control has been conducted in order to gain a base knowledge what are the main implications of utilizing such techniques during a VR experience.

STRATA a project by The Mill (imgNum), “responds to your physiological and neurological data to generate procedural audio and visuals”.
This has been followed as a main source of inspiration for the model of interaction.

Screenshot of Strata

Technology

TECHNOLOGY EMPLOYED

- Head Mounted Display (Oculus Quest 2)
- VR Controller (Oculus Quest 2)
- Pulse Sensor for heart rate monitoring (UC-E6)
- Piezoelectric Respiration Sensor (PZT) (Plux Biosignals)
- Bitalino

Research has shown that monitoring heartbeat rate during immersive experience can give a precise estimation of the level of stress connected to anxiety.

Combining respiratory rate with heartbeat rate can also validate both measurements at the same time as they are interconnected.

For maximizing the reliability of aquisition, the Piezoelectric Respiration sensor has been positioned on the nipple line instead of on abdominal position since users are prone to switch from diaphragmatic breathing to thoracic when conscious of the monitoring.

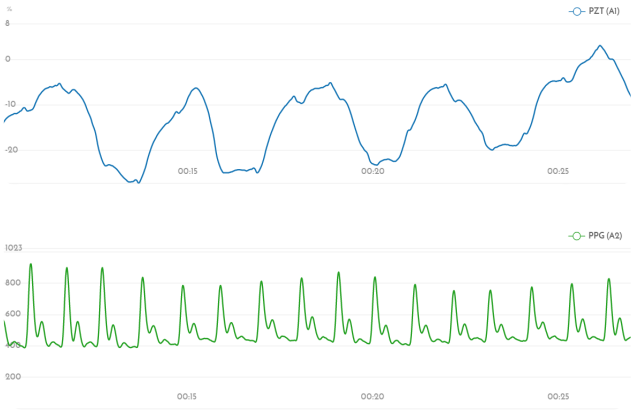
breathing during episodes of self-awarenes over breathing control.

The Pulse Sensor is positioned on the fingers of the right hand. In order to reduce artifacts during the aquisition of data, all hand interactions happen by the mean of the left controller.

User wearing the Respiratory Sensor (PZT) and Pulse Sensor (PPG) of the Bitalino

DATA COLLECTION

To test the viability of the Respiration Sensor (PZT) and Pulse Sensor (PPG) for our purpose, preliminary tests were made recording data using the Brain Answer app to record both bio signals in our environment. This was useful to understand the ranges and threshold needed by the script in the unity project. Multiple recording has been done to validate the parameters with different people and different positions.



Brain Answer app, sample of data collected

The Biofeedback data coming from the Bitalino Board was connected to Unity through the “PLUX Unity API” which provided a user interface to connect the board to the unity scene and collect data.

DATA PROCESSING

Since the Bitalino board returned only the instant values of the sensors to Unity, and it was needed to detect the emotional involvement of the user during the experience, two unity scripts were written to be able to collect the heart rate and respiration rate by detecting the number of beat or breath per minute as the pseudocode schemes below illustrate.

Pulse Sensor (PPG)

Min and max values updated every 200 samples

↓

Threshold updated

$$BPM_{threshold} = \frac{M_{avg} + m_{avg}}{2} + \frac{M_{avg} - m_{avg}}{4}$$

↓

If a (value > Threshold) and not too close to previous beat

↓

Beats count ++

Respiration Sensor (PPG)

The first and last value of 100 samples is stored

↓

If (last - first > threshold)
Trend = 1

If (last - first < -threshold)
Trend = -1

↓

If (oldTrend = 0 or 1, and Trend = -1)

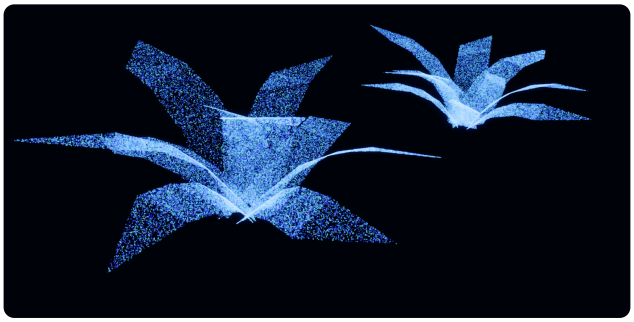
↓

Breath count ++
oldTrend = Trend

Development

PRELIMINARY PROTOTYPE

The first step after the concept definition was to explore the appearance and the feeling of the environment. The first prototype explored a natural particle environment to represent an abstract scenery, this was decided in order to make the experience introspective and not too literal.
Small floral plants were used as the main objects, but the scale of the elements was too small and did not make people feel immersed as elements were always beneath the person. It was needed to look into elements that would cover the environment from top to bottom and for that future prototypes would include trees.

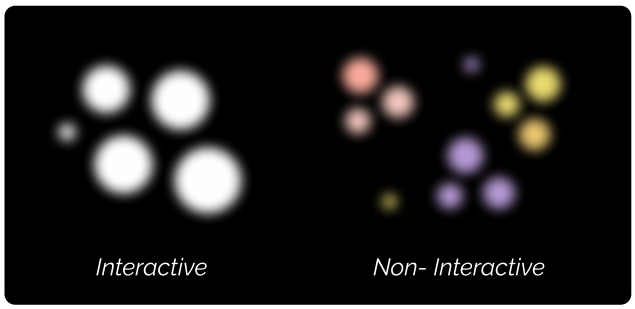


Preliminary environment

USER INTERFACE

Given that users are not familiar with virtual reality controllers, all triggers in the experience happen by natural interaction.
Actively-interactive elements in the environment are highlighted by using a white color and bigger particles. This gives the user a clear feedback for the possible interactions and prevents false affordances that would result in a decrease in the level of dominance.

A user interacting with the controller



Representation of the difference between interactable objects (left) and non-interactable objects (right)

MID-FIDELITY

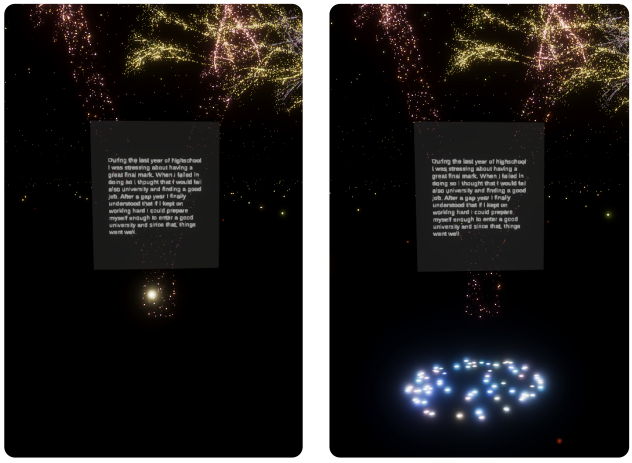
The middle step of the development found mainly the implementation of the individual features such as modifying the environment with biometrics data from the sensors and the dialogue system for the narration of the experience. At this stage the team wanted to have a solid working base in order to refine and polish the interactions and visuals of the environments.

Users that tried this version found interesting the possibility to visualize their own biometrics in an external virtual environment as a way to enhance the perceptions of your feeling. This was also a good way to validate the concept and its implementation through the technology selected, giving the green light to move on with a higher fidelity prototype.

ITERATIONS

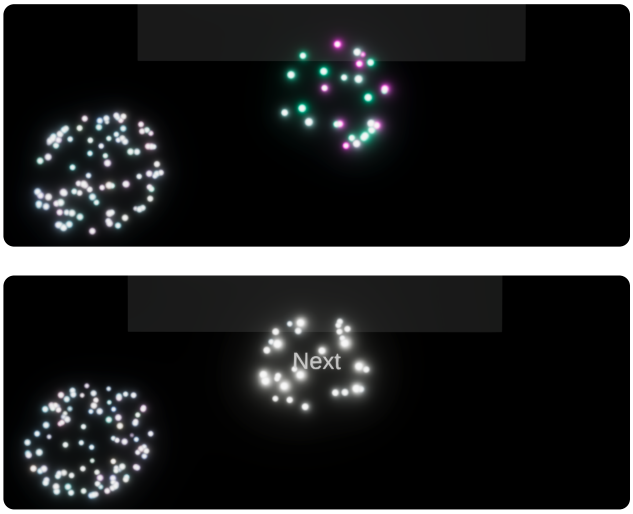
The Mid-Fidelity prototype was then informally tested on 3 users to gather some qualitative data and to highlight some problems or uncomfortable aspects of the experience that the team might have overlooked. The main findings of these tests were:

. Increase the affordances for the interactions with the trees because it was not clear to users that they could interact with the elements - feedforward was needed.



Tree stories interaction without and with the feedforward particle plate

Increase the affordances for the interactions with the colors because participants did not create the link between the particles around their controler and the button they had to interact with - the visual elements had to be revised



Next button interaction before and after the affordance improvements

HIGH-FIDELITY PROTOTYPE & USER TESTING

Based on the findings of the previous test, the team made the changes needed and proceeded to fully develop all the components of the virtual reality experience. This prototype had higher dimensions of fidelity in terms of interactivity, depth, breadth, visual refinement and data model. To assess the impact of the designed experience, a final session of user testing in which five target users (aged between twenty-one and twenty-three years old) participated was implimented to gather some qualitative and quantitative feedback. The System Usability Scale has been used to measure the usability of the experience while qualitative questions focused more on understanding if users really felt touched by the experience and if they learned anything from it. The questions that were asked in the end of the experience were:

1. Did you feel immersed in the experience?
2. Did you make the connection between what was happening to your body and the virtual environment?
3. What did you feel when you were wandering around the natural environment?

The results of the testing session were fairly positive: the average SUS score of the five participants was eighty-nine, indicating that the level of usability reached in the final prototype was decent.
Some of the answeres gathered in the end survey were:

“By the fifth scenario or so I was super engaged with the environment and I remembered a bad situation and it made me really nervous and I could tell that the sphere around me was changing according to that” - Matteo
“\When I was in the forest reading the text between the trees I felt a warm feeling I really enjoyed it and I had no idea that cognitive distortions were a thing!”- Yuginq Su

A user testing the experience

Conclusion

The results of the user testing conducted with the final high-fidelity prototype testify to the high levels of usability and immersion provided by the virtual reality experience. This also attests to the validity of the methodology that was used to guide this study up until the synthesis and testing of the high-fidelity prototype. Users with higher involvements have shown higher values in respiration and heartbeat rate during the self-reflection phases.

Intertwined is an experience that will introduce young adults to the concept of cognitive distortions and will show them that they are not alone in dealing with the problem of the subjectivity of perception. The experience will combine the processing of biofeedback and the method of embodied learning to create an environment of self-reflection that is both responsive and immersive. The moral of the virtual reality experience is delivery through a natural environment that is a metaphore for a supportive and empathetic entourage of people that users have in their life.

Acknowledgments

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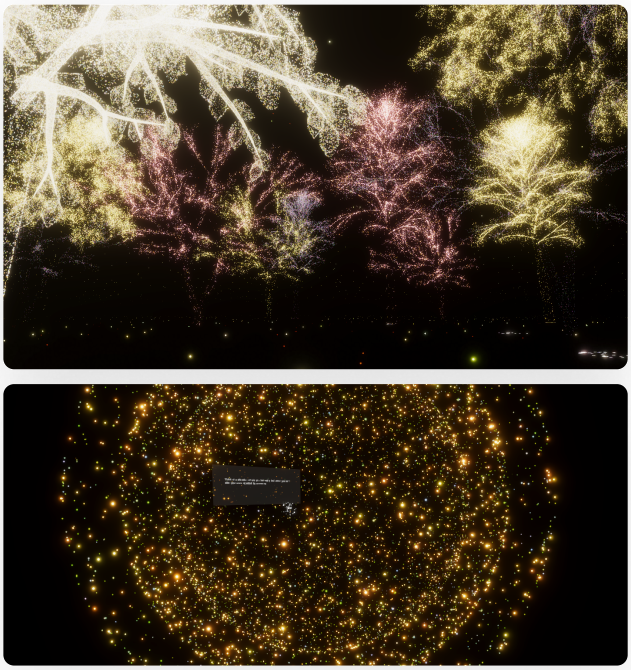

The forest scenery (top)
The first phase viewed from the outside (bottom)

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