# Deep Reality: An Underwater VR experience to promote relaxation by unconscious HR, EDA and brain activity biofeedback

Judith Amores
MIT Media Lab
amores@mit.edu

Anna Fusté
MIT Media Lab
annafuste0@gmail.com

Robert Richer
FAU
robert.richer@fau.de

Pattie Maes
MIT Media Lab
pattie@mit.edu

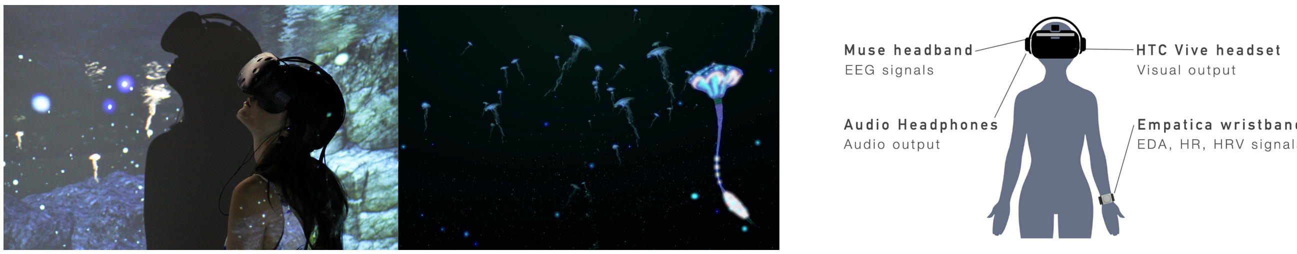


**Figure 1: User experiencing *Deep Reality*. The system monitors real-time physiological data and dynamically changes the movement of the underwater creatures, flickering and lighting based on a slower heartbeat biofeedback to increase relaxation.**

## ABSTRACT

*Deep Reality* is an interactive Virtual Reality (VR) experience that aims to decrease heart and respiration rate by subtle, almost imperceptible light flickering, sound pulsations and slow movements of 3D underwater creatures. Our goal is to improve relaxation by unconsciously influencing the body signals of the user by passively displaying audio-visual cues that are synchronized with a slower frequency of the user's heart and breathing rate, as well as lighting changes of the environment that reflect its brain wave activity associated to relaxation. We monitor in real-time brain activity using the Muse flexible EEG headband and electrodermal activity (EDA) using an Empatica E4 wristband and dynamically adapt the virtual experience.

## CCS CONCEPTS

• **Human-centered computing** → **Virtual reality**; *User centered design*; • **Applied computing** → *Consumer health*;

## KEYWORDS

virtual reality, biofeedback, relaxation

**ACM Reference format:**
Judith Amores, Anna Fusté, Robert Richer, and Pattie Maes. 2019. Deep Reality: An Underwater VR experience to promote relaxation by unconscious HR, EDA and brain activity biofeedback. In *Proceedings of SIGGRAPH '19 Virtual, Augmented, and Mixed Reality, Los Angeles, CA, USA, July 28 - August 01, 2019,* 2 pages.
https://doi.org/10.1145/3306449.3328818


*SIGGRAPH '19 Virtual, Augmented, and Mixed Reality, July 28 - August 01, 2019, Los Angeles, CA, USA*

ACM ISBN 978-1-4503-6320-4/19/07.
https://doi.org/10.1145/3306449.3328818

## 1 INTRODUCTION AND BACKGROUND

Virtual Reality (VR) has been used as an alternative method to improve relaxation and has been extensively used in health care research and therapy. The content in the Virtual Reality Therapy (VRT) can be digitally controlled by the therapist, without the associated risks or costs of a real-world environment [Hoffman 2004]. Researchers have used VRT to treat Post Traumatic Stress Disorder (PTSD) [Difede and Hoffman 2002], phobias and different levels of anxiety [Meyerbröker and Emmelkamp 2010]. Other examples include the fear of height, closed spaces [Botella et al. 2000], social phobia [Gebara et al. 2016], or fear of flying [da Costa et al. 2008]. VR has been also used for cognitive training and attention [Cho et al. 2002], mindfulness and concentration [Amores et al. 2016], as well as promoting relaxation when combined with olfactory wearables [Amores et al. 2018].

*Deep Reality* was motivated by previous research that aims to subtly influence behavior [Adams et al. 2015], such as the work by [Costa et al. 2016], that uses vibrotactile stimuli to influence heart rate and reduce anxiety. Other researchers have looked into subtle light changes to influence breathing for promoting calmness and focus [Ghandeharioun and Picard 2017] and regulating feelings by changing voice self-perception [Costa et al. 2018].

In our work, we used audio-visual cues to relax the user by providing very subtle, almost imperceptible audio-visual feedback.

## 2 SYSTEM OVERVIEW

### 2.1 Software

We acquire continuous, wireless, real-time physiological data using Empatica E4 Wristband and Muse EEG. The values are streamed and processed in an Android Application that we have developed. The Android app collects data from these sensors and streams packages via OSC to a specific IP and port. This data is collected in Unity and processed to change the virtual environment accordingly.

We monitor alpha brain wave activity and heart rate to show in real-time a 80% delayed feedback in the underwater creatures, lighting and sound. We created the scenario in the game engine Unity 3D. The Virtual Reality environment consists of a set of 3D models floating in water. A flocking system controls a school of creatures procedurally generated and procedurally animated using vertex shaders. A set of particle systems were designed in order to simulate particles and certain creatures submerged in water. Glowing shaders were designed in order to give a more contrasted look to the piece. The bioluminescent shaders establish a relationship between the underwater environment and outer space as they make the background resemble the universe.

## 2.2 Hardware

This project was developed for the HTC Vive (tethered). We used Empatica E4 Wristband and a modified Muse 2016 EEG without the hard casing and using 2 hydro-gel electrodes instead of the rubber ear channels for better contact. The subject needs to stick two ECG electrodes to the neck for ground and power. We used noise cancelling headphones for a fully immersive experience.

## 2.3 User Experience and Visuals

The bioluminescence of the underwater creatures changes very subtly for every heartbeat. The overall relaxation of the user changes the lighting of the creatures and makes the scene darker as the user gets more relaxed. The color selection was inspired by color psychology; we experimented dynamic color changes depending on EDA and inspired by the Bouba/kiki effect [Ramachandran and Hubbard 2001] we also changed the shapes of the jellyfishes depending on the breathing rate and relaxation.

The brightness variability, active movement of elements and sound in the environment are synchronized with the heart rate of the user. The movement of animals, such as jellyfishes, is synchronized the user's heart rate signal with a delay to decrease their heart rate and improve relaxation. We explored with different settings on the Virtual Reality space to affect the biofeedback loop.

The bioluminescence and biofluorescence colours of the environment were tuned to adapt to the user's brain activity. High focus would increase blue hues (cold colors) in the environment and would increase saturation and brightness while high relaxation levels would increase warm colors and decrease brightness. After some testing we found that very saturated colors were not preferred for the user's experience, therefore color changes were not considered for the final application and instead we only used brightness changes. Similarly, we experimented with different timings between the user's heart rate and the representation as a audio beats or visual changes in the jellyfishes (movement, shape and flickering).

The shape and animation of the jellyfishes was originally designed to resemble a heart and to beat with every heart beat of the user. We found that this effect was creating the opposite effect of relaxation and we decided to reduce the speed of the animation to half the speed of the user's heart rate. After several testing, we finally established a frequency that was relaxing with an 80% delay (e.g; if the user's heart rate was 90bpm, the jellyfishes will beat at 18bpm - 80% delay). The subtle flickering of the jellyfishes inner light was set at half the beat (45bpm, 50% delay). Finally, we tested with the electrodermal activity signal as biofeedback but the reaction time was too slow to be consciously perceived, we therefore would like to conduct further studies to see if this could be benefitial for relaxation purposes.

## ACKNOWLEDGMENTS

The authors would like to thank the Council for the Arts at MIT for funding part of this project.

## REFERENCES

Alexander T Adams, Jean Costa, Malte F Jung, and Tanzeem Choudhury. 2015. Mindless computing: designing technologies to subtly influence behavior. In *Proceedings of the 2015 ACM International Joint Conference on Pervasive and Ubiquitous Computing*. ACM, 719–730.

Judith Amores, Xavier Benavides, and Pattie Maes. 2016. Psychicvr: Increasing mindfulness by using virtual reality and brain computer interfaces. In *Proceedings of the 2016 CHI Conference Extended Abstracts on Human Factors in Computing Systems*. ACM, 2–2.

Judith Amores, Robert Richer, Nan Zhao, Pattie Maes, and Bjoern M Eskofier. 2018. Promoting relaxation using virtual reality, olfactory interfaces and wearable EEG. In *2018 IEEE 15th International Conference on Wearable and Implantable Body Sensor Networks (BSN)*. IEEE, 98–101.

Cristina Botella, Rosa M. BaÃśos, Helena Villa, Conxa PerpiÃśÃą, and Azucena GarcÃŋa-Palacios. 2000. Virtual reality in the treatment of claustrophobic fear: A controlled, multiple-baseline design. *Behavior Therapy* 31, 3 (2000), 583 – 595. https://doi.org/10.1016/S0005-7894(00)80032-5

Baek-Hwan Cho, Jeonghun Ku, Dong Pyo Jang, Saebyul Kim, Yong Hee Lee, In Young Kim, Jang Han Lee, and Sun I Kim. 2002. The effect of virtual reality cognitive training for attention enhancement. *CyberPsychology & Behavior* 5, 2 (2002), 129–137.

Jean Costa, Alexander T Adams, Malte F Jung, François Guimbretière, and Tanzeem Choudhury. 2016. EmotionCheck: leveraging bodily signals and false feedback to regulate our emotions. In *Proceedings of the 2016 ACM International Joint Conference on Pervasive and Ubiquitous Computing*. ACM, 758–769.

Jean Costa, Malte F Jung, Mary Czerwinski, François Guimbretière, Trinh Le, and Tanzeem Choudhury. 2018. Regulating Feelings During Interpersonal Conflicts by Changing Voice Self-perception. In *Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems*. ACM, 631.

Rafael T da Costa, Aline Sardinha, and Antonio E Nardi. 2008. Virtual reality exposure in the treatment of fear of flying. *Aviation, space, and environmental medicine* 79, 9 (2008), 899–903.

Joann Difede and Hunter G Hoffman. 2002. Virtual reality exposure therapy for World Trade Center post-traumatic stress disorder: A case report. *Cyberpsychology & Behavior* 5, 6 (2002), 529–535.

Cristiane M Gebara, Tito P de Barros-Neto, Leticia Gertsenchtein, and Francisco Lotufo-Neto. 2016. Virtual reality exposure using three-dimensional images for the treatment of social phobia. *Revista Brasileira de Psiquiatria* 38, 1 (2016), 24–29.

Asma Ghandeharioun and Rosalind Picard. 2017. BrightBeat: Effortlessly Influencing Breathing for Cultivating Calmness and Focus. In *Proceedings of the 2017 CHI Conference Extended Abstracts on Human Factors in Computing Systems*. ACM, 1624–1631.

Hunter G Hoffman. 2004. Virtual-reality therapy. *SCIENTIFIC AMERICAN-AMERICAN EDITION-* 291 (2004), 58–65.

Katharina Meyerbröker and Paul MG Emmelkamp. 2010. Virtual reality exposure therapy in anxiety disorders: a systematic review of process-and-outcome studies. *Depression and anxiety* 27, 10 (2010), 933–944.

Vilayanur S Ramachandran and Edward M Hubbard. 2001. Synaesthesia–a window into perception, thought and language. *Journal of consciousness studies* 8, 12 (2001), 3–34.